A collection of
papers
mainly concerning

THE GEOLOGICAL HISTORY OF TASMANIA WITH SPECIAL REFERENCE
TO EVENTS DURING THE PALAEOZOIC ERA

submitted to
the University of Tasmania
for the degree of

Doctor of Science

by Maxwell R. Banks
CONTRIBUTIONS TO THE GEOLOGICAL HISTORY OF TASMANIA

ABSTRACT

Rocks of the Parmeener Super-group (Late Carboniferous to Late Triassic) of Tasmania rest with angular unconformity or nonconformity on a basement of folded Precambrian to Early Devonian sedimentary rocks and Late Devonian to Early Carboniferous granitic rocks.

Within the basement, geanticlines of Precambrian rocks are overlain by a Middle and early Late Cambrian "eugeosynclinal" association associated with ultramafic rocks and a silicic volcanic "arc." After Late Cambrian movements, especially around the Tyennan Geanticline, local marine silts formed and were followed by widespread alluvial fan deposits derived from the recently uplifted geanticlines. The alluvial fan deposits initiated shallow, stable shelf deposition of shelly sediments in central and western Tasmania which continued into the Late Ordovician. Subsequently an alternation of sandstone and siltstone deposition under less stable conditions continued into the Early Devonian.

From Early Ordovician to Early Devonian unstable shelf deposits of turbidite type were formed and are now found in north-eastern Tasmania.

Earlier rocks were folded during the several phases of the Tabberabberan Orogeny in Early and Middle Devonian time. Subsequently granitic batholiths and some ore bodies were emplaced.

Deposition of the Parmeener Super-group in the "Tasmania Basin" began in the Late Carboniferous as an extensive ice sheet covering a basement with a relief of several hundred metres began to melt. After this initial glacial episode, deposition of the Parmeener Super-group may be considered as an alternation of shallow marine and
continental, largely fluviatile, deposition. Silt was the common sediment formed in the sea but sands, rare gravels and calcareous rocks were also deposited. The marine sediments are fossiliferous, in places richly so. The marine sediments are characterised throughout by the presence of megaclasts which can be demonstrated to be dropstones, and of glacial origin in at least some cases. The fossils are numerous but not so taxonomically diverse as in contemporaneous rocks elsewhere in Australia. This also suggests a cooler sea than elsewhere. Coal occurs at two main levels in the Permian part of the Super-group and suggests a humid (and probably cool) climate. From Late Permian to Late Triassic inclusive, Tasmania was the site of extensive fluvial plains supporting vegetation initially glossopterid but subsequently filicalean, corystospermacean and then cycadalean. The climate was probably humid during this interval except for a short period early in the Triassic when red beds and abundant clay pellet conglomerates suggest at least temporary dessication. The clay-pellet conglomerates contain tetrapod bones in many places, the tetrapods suggesting a land connection with South Africa, India and southern China.

At some time after deposition the beds of the Parmeener Super-group were folded into a broad syncline with minor local folds. Dolerite intrusions during the Jurassic and faulting during the Tertiary, especially the Early Tertiary, disrupted the Parmeener Super-group. Pleistocene glaciation in central and western Tasmania has stripped rocks of the Parmeener Super-group from older rocks and super-imposed Pleistocene glacial features on a Late Carboniferous glacial surface.
INTRODUCTION

I submit the papers herewith for consideration for award of the degree of Doctor of Science of the University of Tasmania.

The papers are original works either by myself alone or in conjunction with others. Where others are involved, approximate assignment of responsibility is shown in the statement of contents in each volume. Acknowledgement of help received is made in each paper as appropriate. None of this material has been previously submitted for this or any other degree.

The papers, with few exceptions, attempt elucidation of the geological history of Tasmania. The major thrust has been towards establishment of the history of the area during the Late Palaeozoic and Early Mesozoic. Papers in this field are grouped in Volume 1. A considerable, but secondary, interest has been directed to obtaining a better understanding of the more complex history of Tasmania during the Early and Middle Palaeozoic. This interest is represented by papers in Volume 2. An ancillary interest has been in post-Triassic, especially Cainozoic history with particular reference to Pleistocene glacial history. Papers on post-Triassic history as well as a few summary papers on the geology of Tasmania are included in Volume 3.

I wish to acknowledge the assistance and support of my wife in many ways and on many occasions during preparation of the papers.

Maxwell R. Banks

SUMMARY OF PUBLICATIONS
in order of publication.


(senior author)  
1962.

(senior author)  
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1965.

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1967.

1962.

1971.

(junior author - mainly description of Tasmanian species and fauna)  
1971.

1962.

21. with others - Correlation chart for the Triassic System in Australia. I Simposio int. sobre Estratigrafia y Paleont. de Gondwana, Mar de Plata, Argentina, 478-480, 1 table.  
(co-ordinating author)  
1969.

PERMIAN, TRIASSIC, AND JURASSIC ROCKS IN TASMANIA

by

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Abstract.
Introduction.

Permian System:
- Structural Relationships, Distribution, Thickness;
- Stratigraphy;
- Mineralogy;
- Lithology;
- Sedimentary Structures;
- Facies Variations;
- Glaciation and Eustatism;
- Summary.

Triassic System:
- Structural Relations;
- Distribution and Thickness;
- Stratigraphy;
  - Knocklofty Sandstone and Shale;
  - "Felspathic" Sandstone;
- Summary.

Jurassic Dolerite.

General Summary.

List of Illustrations.
Locality Index.

Bibliography.

Sediments of the orthoquartzite-limestone suite were deposited in an autogeosyncline during the Permian Period under frigid to cold temperature conditions in lacustrine to epinertic biostromal environments. These sediments rest unconformably on Lower and Middle Palaeozoic rocks and are followed disconformably by Triassic sediments. Several pulses in the glaciation are noted, one probably of Sakmarian the other probably of Upper Artinskian age. Vulcanism is lacking and the Hunter-Bowen Orogeny is represented by change in sedimentation and disconformity. Lacustrine sediments of Triassic age were deposited under similar tectonic conditions to those of the Permian but the climate varied from that of the high pressure belt to that of the cloudy tropics. Vulcanism began in the upper part of the Lower Triassic and highly felspathic tuffs resulted. This continued to the Upper Triassic and perhaps the Lower Jurassic. Coal was formed during the formation of the tuffs. Deposition of 4,000 feet of sediment in the autogeosyncline was terminated by the intrusion of a tholeiitic dolerite in the Lower Jurassic Epoch.
SYMPOSIUM SUR LE GONDWANA

RÉSUMÉ


INTRODUCTION

When this school was invited to contribute to a symposium on the Gondwana Systems, we surveyed briefly the literature available in the light of some of the impressions we had been gathering in the last few years and found that there was a great deal of work yet to be done in Tasmania on the subject. A detailed survey of the literature was commenced but this proved a large task and could not have been finished in time for the symposium. It was decided, therefore, to summarise ideas on the Gondwana System in Tasmania before the survey was completed so that, while it is felt that the ideas expressed in this contribution are substantially correct, further reading and work in progress at the present time may cause alteration to some of our ideas and will certainly necessitate changes in nomenclature of some of the formations. This paper should, therefore, be regarded as an interim report and not a final statement.

Previous summaries of the Permian and Triassic Systems in Tasmania are numerous. Johnston (1888) made the first comprehensive summary and reviewed most of the literature to that date. The next comprehensive summary appeared in 1922 in the Coal Resources Bulletin of the Tasmanian Geological Survey, and another summary was published by the Geological Survey in 1938. Voisey in the same year made a survey of the Permian rocks throughout Tasmania depending partly for some of his sequences on Lewis, whose summary of the stratigraphy of the Hobart area was published posthumously in 1946. Since that year several regional studies have been made and they were partly summarised by Hills and Carey in the Handbook for Tasmania issued by the Australian and New Zealand Association for the Advancement of Science for the Hobart Meeting in 1949.

I wish to acknowledge with many thanks much helpful discussion with Professor S.-W. Carey. Miss E.-M. Smith has helped in the preparation of the paper in several ways and I have used unpublished observations lately made by G.-E.-A. Hale, T.-H. Rodger and R.-P. Mather, for which I wish to tender thanks. Miss J. Batt, of the French Department, assisted considerably with the Résumé.

PERMIAN SYSTEM

A flatly dipping group of “Permian” formations unconformably overlies rocks ranging in age from Pre-Cambrian to Lower or Middle Devonian and are themselves overlain unconformably by non-marine “Triassic” rocks. Although the Permian rocks are in many places richly fossiliferous, the fossils have not been studied sufficiently to make accurate, detailed correlations with
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SHOWING DISTRIBUTION OF THE
PERMIAN SEDIMENTS, THICKNESSES AND CLASTIC RATIOS
areas outside Tasmania possible, and because of the complex faulting and widespread injection of dolerite, correlations within Tasmania are still in considerable doubt.

The accompanying map (fig. 1) shows the areas where Permian rocks outcrop in Tasmania. Marine sediments are recorded from almost every area and indicate that during at least part of Permian time Tasmania was covered by the sea. At others, however, the sea withdrew leaving parts of the present island above the sea, and based on the present distribution of coal and oil shales, the shore line can at some times be drawn with considerable accuracy. Until correlations within the State are established, however, no continuous shorelines can be drawn.

Thicknesses of the system vary greatly. The greatest thickness is probably in the southeast and in the Hobart area the thickness is about 2,500 feet (762 m.) according to recent measurements. A similar thickness is recorded by Voisey (1938, p. 320) in the Preolenna area but of this over 1,200 feet (366 m.) are tillites, or other sediments produced indirectly through glaciation. This basal glacial formation shows greater variations in thickness than the other formations as is shown by Voisey (1938, pp. 310-333) and in the accompanying table, T. 2, taken from Voisey's paper. These variations in thickness may be due to the original irregularities in the surface of deposition. In all, measurements of only thirteen reasonably complete sections are available so that any attempt to construct isopach maps would be premature. However, despite the lack of information, and taking into account such variations as are known to occur, it would appear that the zone of greatest thicknesses lies in the belt from the north-west coast to the south-east coast around Hobart and Bruny Island.

Stratigraphy.

In view of the difficulties of correlation within the State, the following discussion will centre mainly about the formations of the Hobart area where the Permian is comparatively well-known, and brief comparisons will be made with other areas. Two tables are included, one showing the succession in the Hobart area, and taken largely from Hills and Carey (1949, pp. 30-32), the other showing the succession of the Permian in other parts of the state and taken from a paper by Voisey (1938, p. 329).

"Basal Glacial" Formation.

This formation does not outcrop in the immediate vicinity of Hobart but is found in the valley of the Weld River about forty miles (64 km.) to the west. There tillites are the basal beds of the system and unconformably overlie quartzites, probably of Lower Cambrian age. The tillites contain boulders of red granite, grey quartzite, quartz, slate and mica schist. The tillite is followed by a conglomerate, 300 feet (92 m.) thick, containing boulders of quartzite and this in turn is followed by fossiliferous marine mudstones.

Glacially derived sedimentary rocks are common at the base of the system in many parts of Tasmania. Particularly interesting are the tillites, conglomerates, sandstones and mudstones of the Wynyard area which, according to David, show several intra-formational gavements with glacial striae. These indicate that the glacier responsible for their formation was moving from the south-west. Boulders of red granite, conglomerate, limestone, quartzite and graptolitic slate have been found. Erratics of an impure limestone containing Noloconchidium tasmaniensis have been found and suggest derivation from within Tasmania as the genus is known only from Tasmania and Victoria and the species is close to that described from the Florence Quartzite (see Gill and Banks, 1950, pp. 263-9) which outcrops in many parts of western Tasmania. On Maria Island the basal tillite contains boulders of slate, sandstone and granite, and Lewis regards the tillite as a land moraine. Conglomeratic mudstones are associated there with the tillite. Similar rocks are known from the Mersey and Lilydale areas.

Granton Limestone and Marl.

This formation is probably about 800 feet (244 m.) thick, but no complete sections have yet
been found. The lower parts of the formation are mudstones and sandstones with occasional thin beds of limestone, which are followed by about 350 feet (105 m.) of limestones with calcareous mudstones and shales. Within this limestone member there is a rhythmic alternation of limestone and calcareous shales, the limestone beds being up to thirty inches (75 cm.) thick and the shales being up to eight inches (20 cm.) in thickness. The topmost beds are sandstones and mudstones which pass up into the overlying formation. Throughout the Granton Limestone erratics are present although not common.

Mineralogy: Angular fragments of quartz are common in the limestones and occur also in the sandstones and mudstones. Felspars are present in small proportions and are usually angular, micas are not common but occur on the bedding planes in small quantities. No heavy minerals have yet been separated from the limestones or associated sandstone and mudstone. Much of the calcite is of organic origin. Dolomite is not known from the formation. Nodules of pyrite occur sporadically throughout the formation. The limestone is usually foetid.

Lithology: The associated sandstones are normal quartzose types with only small amounts of felspar and the mudstones are largely siliceous siltstones or shales. The limestones are of several types. Of particular interest are the biohermal limestones composed largely of the unbroken zoaria of *Fenestella* spp. and *Stenopora* spp. and other bryozoa; in many cases the complete zoaria being preserved in the original living position. Another interesting type is the coquina limestone which occurs on several horizons in the Hobart area and is even better displayed by approximately contemporaneous limestones at Maria Island. These show articulated shells of *Eurydesma* spp. preserved unbroken and showing no sign of post-mortem transport. At other times it seems that fairly strong currents must have affected the sea floor on which the limestone was being deposited as, despite the richness of both columnals and calyx plates, articulated crinoids are not yet known from the limestone. Oolitic limestones are unknown from this or any other horizon in the Tasmanian Permian and this may be due to the cold climatic conditions at the time. The limestone of the Granton Formation and from Maria Island is usually blue-grey.

Palaeontology: Despite the large number of species in the Granton Limestone, very few of them are of any value in correlations with regions outside Tasmania. One exception is *Eurydesma cordatum* var. *saccatum* which occurs only in the Lower Marine Series of New South Wales and in Tasmania has been recorded from the Granton Limestone and the equivalent limestones on Maria Island. *Stenopora johnstoni* has a similar distribution to *E. cordatum* var. *saccatum* in Tasmania and is restricted to the lower part of the Lower Marine Series in N. S. W. *Taeniothaeus subquadratus* occurs in Tasmania in the Granton Limestone or the Grange Mudstone and in other parts of Eastern Australia is found in the lower parts of the marine Permian sequence as pointed out by Hill (1950, p. 6). Other bryozoa, such as *Proloretetora ampla*, *Polypora woodsi*, and *Fenestella granulifera*, are shown by Crockford (1951, pp. 105-122) to be restricted to the Upper Marine Series in N. S. W. but in Tasmania they are found in the Granton Limestone as well as some being recorded from the Grange Mudstone.

In most areas of the Permian in Tasmania there is a zone low in the sequence which is comparatively rich in *Eurydesma* spp. and as a working hypothesis these may be correlated with one another and with the Lower Marine Series of N. S. W. In Voisey's Lower Latrobe Stage a band of *Eurydesma cordatum* limestone is reported which contains foraminifera. These have been identified by Crespin (1947) as an assemblage dominated by *Calcitornella stephensi* which suggests correlation with the Allandale Stage of the Lower Marine Series.

Conditions of Deposition: The Granton Limestone was formed probably in a shallow sea on a slowly sinking floor. It is probable that the Granton Limestone and its facies variants are widely spread in Tasmania and that it marked a period of eustatic high sea level. Glaciers were present on a distant land surface during its deposition. The land surface from which the Granton Limestone derived its constituents was probably low.
Porters’ Hill Mudstone.

This formation consists of about fifty feet (15 m.) of brownish shales occurring between the Granton Limestone beneath and the Grange Mudstone above. No detailed studies have yet been made of its mineralogy but it is apparently a siliceous shale containing abundant small erratics distributed in thin bands within the formation. A distinct shaly bedding is developed and causes the rock to weather in flakes. The fossils recorded from the formation are few and are imperfect fragments of *Gangamopteris* sp. and many ostracodes, *Cythere tasmanica*, which indicate a marine environment of deposition, as they are found in the underlying Granton Limestone. This formation may record a fall in sea level in the change from the limestone of the underlying rocks to the shales and the presence of *Gangamopteris* probably indicates that the shore line was closer than during the deposition of the Granton Limestone.

Grange Mudstone.

This formation consists of about three hundred feet (92 m.) of mudstone, marl, and limestone lying between the Porter’s Hill Mudstone beneath and Woodbridge Glacial Formation above. Angular grains of quartz are associated with some felspar, which may, however have been introduced by the dolerite magma. Calcite is common and in some bands is the dominant mineral. Close to the dolerite contacts cale-silicate minerals are developed but further away the metamorphism is detectable in the form of chalcedonic bands and lenses in the mudstone. Erratics are found commonly in the Grange Mudstone and in many cases are seen to have indented the underlying strata. The erratics include grey granites, limestone, quartzite and dark grey to black hornfels, and some of them reach diameters of almost a foot. Their glacial origin is well displayed not only because of the discrepancy between the size of the boulders and the grainsize of the mudstones, but by the indentations in the bedding planes beneath the boulders and the faceting shown by many of the boulders. No striated boulders have yet been found.

The rocks in this formation are mostly yellow to brown, laminated mudstones very rich in fossils, and on analysis they are found to contain calcium carbonate. Thin bands of sandstone of a quartzose type are also present. More common are bands of a blue-grey massive limestone with a rich fauna, and these resemble the Granton Limestone.

Despite the richness of the fauna, only a few species have been described or determined. The laminations are found to be partly due to bands extremely rich in bryozoa, particularly *Fenestella* spp. and laminar species of *Stenopora*. These laminae alternate with others crowded with the articulated valves of various strophomenacea, particularly species of *Strophalosia*. One of these, *Wyndhamia dalwoodensis*, is particularly characteristic of the formation and occurs also in the Branxton Stage of the Upper Marine Series, where it is associated with many fenestellids which include *Polypora woodsii*, also known from the Grange Mudstone. This is the only correlation which can be suggested at the moment.

The bedding is in many places flaggy with the laminations superimposed on the flaggy bedding. There is a rhythmic alternation based mainly on colour with the yellow and brown bands alternating.

The Grange Mudstone was apparently deposited in a shallow sea with a slowly sinking floor under cold climatic conditions. The presence of icebergs floating over the surface of the sea is suggested by the erratics. The land surface from which the sediment of the mudstone was derived seems to have been low, as generally only fine grained material was available for deposition.

Woodbridge Glacial Formation.

Four hundred feet (122 m.), approximately, of sandstones and mudstones overlie the Grange Mudstone, and in this higher formation there are many erratics, in places forming beds several feet thick. Erratics up to six feet (1.8 m.) in diameter are known. These erratics led to the recognition of this formation as partly of glacial origin and to mark this important horizon of glaciation the name Woodbridge Glacial Formation was proposed.
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SHOWING DISTRIBUTION OF THE TRAASSIC SEDIMENTS, THICKNESSES
The main mineral in the formation is quartz which often shows very angular outlines; rounded grains are exceptional. Felspars are also present but form usually less than ten percent of the rock. Both orthoclase and plagioclase are represented, and are usually fresh and angular. Heavy minerals are now known as the result of analyses during 1951. They include melanite garnet, cassiterite, rutile, zircon, and tourmaline mostly in angular or euhedral grains. These may well have been derived from the Pre-Cambrian and Lower Palaeozoic rocks of western Tasmania. Thus a garnet, similar to the melanite in the Woodbridge Glacial Formation, is found in a garnetiferous hornblende schist from the western part of the State.

Further evidence that the sediments could well have been derived from a terrain including western Tasmania is provided by the erratics from the formation. In the Hobart district boulders of fine and coarse quartz hornfels, granites, both red and grey, porphyries and schists are found. Prider (1948, p. 134) reports large boulders of red granite and of a conglomerate very like the West Coast Range Conglomerate from the Woodbridge Glacial Formation from Marlborough, and recently a boulder of fossiliferous Florence Quartzite was discovered in the formation at Eaglehawk Neck. Both the conglomerate and the quartzite are common rocks in the western part of the State.

The main part of the formation is composed of a rhythmic alternation of sandstones and siltstones which are grey on fresh faces but weather yellow and brown. This alternation is relieved occasionally by narrow beds of erratics or more rarely by limestone bands. These bands of erratics occur sporadically throughout the formation and are well exposed on the shore platforms south of Hobart. In addition erratics occur irregularly through the sandstone and siltstone beds. The formation is very widespread and it has been recognised from Maria Island west to the Central Highlands and south to South Cape.

Fossils are not so common in this formation as in the lower ones. However, many species have been reported and characteristically occur in thin lenses of very limited dimensions, often only a foot or two in diameter. These apparently represent concentrations of the fossils by currents after their death. In some places, however, there are bands and lenses composed of a single species. Thus Plycomphalina strzeleckiana occurs in large numbers in thin bands in the sandstone at Eaglehawk Neck and in the same locality concentrations of complete calices of an unknown species of crinoid occur so that currents in that area were apparently not strong at the time. On Bruny Island a band of limestone has been reported composed almost entirely of large zoaria of Stenopora crinita, one of them measuring more than three feet (92 cm.) in diameter. A band very rich in fossils commonly occurs about fifty feet (15 m.) below the top of the formation and is a useful mapping horizon. A feature of the Woodbridge Glacial Formation is the large number of fossil trees found at different horizons. These have usually been silicified with perfect preservation of the structure. Many are remarkably complete and include the roots. Their presence in a marine formation indicates that they floated into the sea before becoming waterlogged and sinking. Taken in conjunction with the coarser nature of the sediments and the presence of bands of erratics, they indicate shallower water than the preceding formations and the closer proximity of the land surface.

The Woodbridge Glacial Formation was apparently deposited under cooler and shallower-water conditions than the older formations. The land surface was closer than during the earlier part of the period, and was probably low with a cover of vegetation.

Ferntree Mudstone.

In the immediate vicinity of Hobart the topmost beds of the Permian group are mudstones of the Ferntree Mudstone. This formation is about three hundred feet (92 m.) thick and overlies the Woodbridge Glacial Formation. The base of the formation is a prominent band of sandstone, the Risdon Sandstone, about twenty to thirty feet (6-9 m.) thick, which is followed in the Hobart area by a rhythmic alternation of siltstones and claystones (or shales). Fairbridge (1949, p. 118) reports, however, that near Bothwell there are a number of bands lithologically like the Risdon Sandstone.
The Risdon Sandstone consists of quartz and felspar, the latter forming up to fifty percent of the rock as reported by Prider from Marlborough (1918, p. 134). The quartz in addition to the colourless variety normally present in the Permian is represented by a variety with a bluish tinge. It occurs in large rounded grains or in fine angular fragments. The felspar is usually an acid plagioclase, but orthoclase and microcline are also recorded. These minerals are usually quite fresh. The Risdon Sandstone usually contains also fragments of various rock types most of them angular and these, with the slight clayey matrix of the sandstone, would suggest a sub-greywacke, but the variations from the quartzose sandstone are probably not due to changes in the tectonic environment but are a reflection of the glaciation which was apparently waning though still present in the distance. Fine sub-greywacke conglomerates are also present in the Bothwell area. Fossils are rare in the Risdon Sandstone.

The main minerals in the Ferntree Mudstone are those of its basal member with the exception that the bluish quartz is lacking. Heavy minerals similar to those from the underlying formation have been separated from the mudstone. The formation is highly siliceous, and although it is grey or mottled grey and white on the unweathered surfaces, rapidly becomes white or cream on exposure to weathering. Shaly bedding is commonly developed in the finer bands and the rock has been indurated to such an extent that it could well be referred to as an argillite. Erratics are scattered sporadically throughout the formation and may reach a diameter of a foot (30 cm.). It is noticeable in sections that the constituent grains are angular to sub-angular. Fossils are extremely rare in the formation and are mostly marine types although a few fragments of plants are known. No fossils of any correlative value are yet known from the formation.

The Ferntree Mudstone was probably formed in a very shallow sea, where conditions for marine life were not favourable but where the carbonaceous matter which is responsible for the colour of the mudstone could accumulate. The presence of glaciers in the distance is suggested by the occasional erratics, and from the nature of the sediments it would appear that the land surface supplying the deposits was probably low, with only gentle relief. The Ferntree Mudstone tends to become slightly coarser again towards the top and this may be a reflection of a more rugged land surface due to epeirogenic movement.

Cygnet Coal Measures.

Such an epeirogenic movement could well explain the presence of fresh water sandstone in the Cygnet Coal Measures which overlie the Ferntree Mudstone in the Cygnet area about twenty miles (32 km.) south-east of Hobart. Near Cygnet these coal measures are the topmost beds of the Permian sequence and are overlain disconformably by the basal beds of the Triassic. The Cygnet Coal Measures consist of about two hundred feet (60 m.) of carbonaceous shales, coal seams and laminated, ripple-marked sandstone. Four feet (1.2 m.) of coal are reported from the area the associated rocks contain plant fossils including *Gangamopteris spatulata*, *G. obliqua*, *Glossopteris browniana* var. *praecursor*, and *Versebraria australis*. An approximate correlation with the Upper Coal Measures of New South Wales has been suggested.

Mineralogy.

Some of the mineral constituents in the Permian sediments are worthy of note. Little has been done in the past in the way of systematic examination of the minerals but Prider (1918, p. 133) remarks on the felspar in the Bronte facies and in the Risdon Sandstone. Quartz and felspar are the most important clastic minerals with small amounts of mica and a few heavy minerals; clay minerals are present in small amount but have not yet been identified further. The quartz has not been studied to determine its provenance but two types have been noted; the commoner type is a clear, colourless variety while some of that in the Risdon Sandstone has a bluish tinge. Most of the quartz is angular to sub-angular, both in the coarse-grained rocks and in the limestone. This is due probably to the influence of ice in transportation. The commonest felspar is an acid pla-
Lithology.

Gioclase, but microcline and orthoclase are also present. In unweathered rocks the felspar is quite fresh and is usually angular. The amount in the rocks varies between wide limits, as Prider (1948, p. 134) records a sandstone with 50% felspar from Marlborough, while sandstones on the same and different horizons in the south-east usually contain less than 10% and often less than 5%. In contrast to the overlying Triassic rocks, the Permian is poor in muscovite, which is usually associated with rocks thought to have been deposited close to the shore-line and is common in shales associated with the Cygnet Coal Measures. Until recently no work has been done on the heavy minerals but during 1951 two honours students of this school have devoted some attention to this topic and they report the presence of cassiterite, melanite, rutile, zircon and tourmaline. Taken generally it would appear that the Permian sediments are derived from a low lying terrain with little relief and composed of acid plutonics, metamorphics and Lower Palaeozoic sediments. The angularity and freshness of many of the minerals noted above reflect the glaciation affecting the areas close to Tasmania at the time (and suggest further that deposition was comparatively rapid with little movement by waves and currents to produce rounding).

Calcite is the main mineral of chemical deposition. Dolomite has not been recorded from the Tasmanian Permian and this probably means that it is not present as the limestones have received much attention in the past. Such a lack would be in accord with the generally accepted view that dolomitisation is associated with a warm climate. Nodules of pyrite occur in the Granton Limestone.

Sedimentary rocks in the Hobart area are fairly typical of Permian rocks throughout the State but some rock types are not represented. The commonest types are conglomerates, sandstones, siltstones and claystones, with limestones developed very well in some places. The sandstones are generally poorly sorted and in this respect contrast with the Triassic sandstones. The colour of the Permian clastic rocks is generally grey to white, with a few of a yellowish tint, while the Ferntree Mudstone is typically mottled, grey and white.

Limestones showing similar variations to those present in the Granton Limestone are found in other parts of the State and the *Eurydesma* coquina limestone of Maria Island is famous. Noteworthy is the lack of oolitic limestone, probably because of the cool conditions.

Carbonaceous sediments are well-known in the Permian of Tasmania and include the *Tasmanites punctatus* Shale, an oil shale, other types of oil shales and, in addition, normal bituminous coals, such as are developed in the Cygnet Coal Measures. In a number of sections coal occurs low in the sequence associated with fresh-water sediments intercalated between marine beds. These seams have, in the past, been correlated with one another and collectively with the Lower Coal Measures of New South Wales. Such correlations may be valid but it is much more probable that the seams occur on several separate horizons, representing swampy facies of marine sediments elsewhere in Tasmania. The coal seams of the Mersey valley have been correlated for many years with the *Tasmanites punctatus* Shale, a marine bed containing among other fossils an assemblage of foraminifera dominated by *Ammodiscus multilocinctus*, an assemblage characteristic of the lower part of the Upper Marine Series in N. S. W. Glendonites have been noted from this shale, and their presence would indicate deposition under very cold conditions in a barred or semi-barred basin.

The lithology of all the marine sediments is influenced by the glaciation of the nearby land surface and this glacial impress tends to make the sediments more poorly sorted and of wider range of composition than would otherwise be the case. Because of this the Risdon Sandstone in places should be considered a sub-greywacke. One feature in which the Tasmanian sequence differs markedly from that of New South Wales is the lack of vulcanism. Only one occurrence of tuff has been recorded (see Montgomery, 1891, p. 23), a thin bed on Maria Island, which from the description is not obviously a tuff. No lava flows are known.
Fig. 3

TASMANIA
SHOWING DISTRIBUTION OF THE Dolerites
Sedimentary Structures.

A feature in which the Permian record differs markedly from that of the Triassic is the abundance of sedimentary structures. Bedding is largely flaggy or massive, but also with examples of shaly bedding and lamination, while the influence of currents as recorded in the sediment is lacking generally. Current bedding has been observed in the western and north-western parts of the state at Eden and Preolenna, and in the Cygnet Coal Measures in the south-east. Studies of this subject are not sufficiently advanced in Tasmania to show how these observations fit into the general picture. Slump structures, such a feature of the Triassic, have not been observed in the Permian.

Facies Variations.

Because of the lack of significant knowledge of fossils it is difficult to establish the presence of facies changes but they are suspected on general grounds. By using the method advocated by Sloss et al. (1949, pp. 100-2), the elastic ratios may be estimated for the complete sequence in a number of places and it will be seen from the accompanying map (fig.) that the variation is somewhat systematic. At Maria Island the elastic ratio is 2 : 1 while further north at Seymour it has become 1 : 1. Further north at Grey the ratio has increased to 6 : 1 but a few miles further west at Harefield it has decreased to 3 : 1 but increases further to the north. At Lilydale the elastic ratio is about 200 : 1 but further to the west at Beaconsfield the ratio has decreased but rises again to the west where at Latrobe the ratio is several hundred to one. South and west of Maria Island the ratio again increases and at Hobart is about 6 : 1 and at Marlborough for the exposed section is about 25 : 1. Further west still the ratio increases fairly rapidly apparently and in the Preolenna area there is little if any limestone. From these figures it would appear that the limestone of the Maria Island and Seymour areas are replaced to the north, west, and south by sandstones and mudstones, so that facies variations in those directions are indicated. There is also a strong suggestion that the increasing elastic ratios represent increasing closeness to the shore-lines during the period. Recently it has been noted that the sandstone-shale ratio increases south from Hobart.

The other sediments of interest from the viewpoint of facies change are the coal and Tasmanites punctatus Zone. It was demonstrated during the last century that the coal and Tasmanites Zone in the Mersey area were contemporaneous, so that during the deposition of the coal the shoreline can be more or less accurately located in those areas.

Throughout the western part of the island the carbonaceous and associated fresh water sediments represent a notable proportion of the Permian sequence while in the south-east they are less important and in areas such as Marlborough, through the Midlands to Beaconsfield no fresh-water intercalations in the marine sequence are known. Oil shale is noted near Karoola, probably indicating the proximity of the old shore line while coal is known low in the Permian sequence from Mangana, Harefield and at Grey. No coal from horizons low in the sequence is known to the south of Grey but generally south and east of Hobart coal seams and carbonaceous shales occur near the top of the sequence, but the original distribution may have been much wider as Carey (1947, p. 32) reports coal from Dilston associated with rocks like the Ferntree Mudstone. It is possible that much of these coal measures would be removed by pre-Triassic erosion. The thickness of the seams of coal themselves is never great and at most are less than two feet (0.6 m.). The total thickness of coal is also usually very small, the greatest thickness being at Preolenna, where there is less than six feet (2 m.). The distribution of the Permian fresh-water sediments suggests that the western and north-eastern parts of the State were low-lying swampy areas during most of the period with fairly frequent marine inundations, and that during the latter part of the period such swampy conditions spread over most of the State.

Glaciation and Eustatism.

One feature of the Tasmanian Permian is the continuity of glaciation through most of the for-
mations. On the accompanying diagram (fig. 4) is shown the intensity of glaciation of the land surface near Tasmania. This is based largely on observations on the Hobart area and the intensity inferred from the number and size of erratics is plotted against the thickness of the different formations. The graph can only provide a very general idea of the glaciation as it is very subjective and the thickness of the formations is not necessarily related to the time taken for their deposition. From the graph it will be particularly noted that erratics are present in all formations except perhaps the Cygnet Coal Measures, and that the intensity of glaciation reached maxima during the deposition of the “Basal Glacial” Formation and the Woodbridge Glacial Formation. Beds of erratics are known in both formations as well as more widely dispersed erratics. In each case it is evident from the sections that there were many pulses in the glaciation and it was not a single major event. Erratics are present in smaller numbers in the Granton Limestone, the Porter’s Hill Mudstone, the Grange Mudstone and the Fernstree Mudstone.

![Diagram](image)

Fig. 4. Diagram showing the approximate relationship of the depth at which Permian sediments near Hobart were deposited, to the intensity of Glaciation.

(a) Graph showing intensity of glaciation plotted against cumulative thickness of Permian sediments.

(b) Graph showing depth of water during deposition of Permian sediments.

It is likely that the intensity of glaciation influenced the type of sediment through eustatic changes affecting the depth of water in the sea and the distance of any place of deposition from the shoreline. Such a control on the type of sediment is inferred for the formations below the Ferntree Mudstone as in most cases decrease in intensity of glaciation is reflected not only by decrease in the number of erratics but also in the type of sediment and the types of fossils which indicate changes in depth. The inferred changes in depth of the sea through the Permian in the Hobart area are plotted on a second diagram (fig. 4 b) for comparison with the glaciation diagram; these depths are inferred from the grainsize of the sediments and the associated fossils, and such inferences are subject to change as our knowledge increases. It will be seen that there is a reciprocal relation between intensity of glaciation and inferred depth until the Ferntree Mudstone is reached, but during the deposition of the Ferntree Mudstone depth is thought to have decreased and the glaciation is thought to have decreased in intensity. If the inferences are correct, there are several pos-
sible explanations. In any case, the sea floor began to rise and this may have been due to either isostatic adjustment after the load of ice was removed from the neighbouring land surface or to epeirogenic movement associated with the Hunter-Bowen orogeny in New South Wales. Perhaps both factors were operative with the epeirogenic movement becoming dominant during the time of deposition of the Cygnet Coal Measures. At that time it appears that the land surface was becoming more rugged as sandstones again became important in the sequence. As upward movement continued, sedimentation ceased in Tasmania and erosion of the lately deposited and semi-consolidated mud began.

Summary.

To summarise briefly, the Permian sediments are mostly members of the orthoquartzite-limestone suite of Pettijohn (1949) and lack of vulcanism is a feature. In terms of Dapples, et. al. (1948, p. 1943) the association could be interpreted as the result of deposition on a stable to middly-unstable shelf with the source areas being stable to middly epeirogenic. Environments vary from lacustrine or fluvial through transitional to epineritic over much of the State and perhaps an epineritic biosstral environment at Maria Island (terminology as in Krumbein et. al. (1949, pp. 1876-7). Perfect agreement with the classification is not shown, as some of the structures are not developed, but this may be due to the glaciation. It is difficult to place the area of deposition in one of Marshall Kay's (1947, pp. 1289-93) categories but perhaps the Permian of Tasmania was deposited in an autoge-syncline with the surrounding craton subjected to glaciation. The glaciation had at least two main pulses in Tasmania, each of them multiple, and the surrounding land surface was being glaciated during most of the period. During the latter part of the period the Hunter-Bowen orogeny influenced Tasmania indirectly through the elevation of the land surface with the development of lacustrine sediments and the commencement of erosion which is marked by a disconformity with the overlying Triassic rocks. Correlation of the Granton Limestone with part of the Lower Marine Series of New South Wales seems justified as also does the correlation of the Grange Mudstone and Woodbridge Glacial Formation with part of the Upper Marine Series on the evidence of fossils. There is not yet sufficient fossil evidence available to correlate the Tasmanian succession confidently with the international time scale and the correlations suggested in the stratigraphic table are indirect through the sequence in New South Wales.

TRIASSIC SYSTEM

Overlying the Permian formations of the eastern and south-eastern areas are a group of formations of Triassic to perhaps Lower Jurassic age. The relationship of this group to the underlying "Permian" Group was shown by Nye (1921, pp. 47, 55-57, and 1924, p. 22) to be disconformably as he discovered boulders of Permian rocks (probably Ferntree Mudstone) in the basal beds of the Triassic in the Stonor area at Bellerive and Sorell, and of fossiliferous Permian mudstone in higher beds in the York Plains area. Other evidence adduced for this interval of erosion has been the complete break in flora from one dominated by Glossopteris to one dominated by Thinnfeldia and Cladophlebis (see Hills and Carey, 1949, pp. 32, et. seq.). In 1951 further evidence was discovered in the Brock Bay area where cliff sections along the Huon River show the boundary between the Ferntree Mudstone and the Knocklofty Formation to be an irregular one with evidence of erosion well displayed. In addition, in this same section the sandstone contains boulders of the Ferntree Mudstone. Thus it is well established that there is a disconformity, representing a considerable erosional break, between the Permian and Triassic Systems in Tasmania. The period of sedimentation following this disconformity was terminated apparently by intrusions of dolerite, probably of Jurassic age. The Triasso-Jurassic rocks are in a number of places overlain unconformably by Tertiary sediments or basalt.
**Distribution and Thickness.**

The accompanying map (fig. 2) shows the distribution of the rocks of this group. It will be seen that they are much more restricted than the Permian rocks. The most northerly known occurrence is at Hadspen whence the boundary passes south west to just west of Lake St. Clair from which it passes almost due south to the coast. Eastward from Hadspen the boundary passes to the coast just north of St. Marys. While the western boundary may be somewhere near the true western margin of deposition, this is doubtful, as the thickness in the Butler's Gorge area is probably of the order of 1,500 feet (460 m.) and it is likely that the northern margin of the basin originally lay much further north as the thickness in the St. Marys area is about 1,250 feet (380 m.). Due to complex faulting and dolerite intrusions thicknesses have not yet been satisfactorily established. In many places the thickness must be more than 1500 feet and may be more than 2,000 feet (610 m.).

**Stratigraphy.**

Knocklofty Sandstone and Shale.

This formation includes those rocks lying between the base of the system and the base of the "Felspathic" Sandstone. It includes the Springs Sandstone and Ross Sandstone of previous authors.

Mineralogy: Both the sandstone and shales consist essentially of quartz. In the sandstones the quartz often has a sparkling appearance. Prider (1948, p. 135) has shown that the sparkle is due to the development of crystal faces by the enlargement of the originally rounded grains through the addition of quartz in optical continuity with the original mineral. Quartz from the Springs Sandstone Member at Grove shows undulose extinction, indicating probable derivation from a terrain including acid plutonic rocks. Felspars may be present in quantities up to 10 % of the rock. Prider records both plagioclase and microcline from this formation in the Bronte-Tarraleah area, and at Grove the felspars include acid plagioclase, either albite or oligoclase, with microcline and some microperthite so that derivation from a terrain including acid plutonic rocks is suggested.

A mineral noted many years ago in the Knocklofty Sandstone and Shale and equivalent formations is muscovite. This is so common in some places that it imparts to the bedding planes a distinctive silvery lustre, and assists in the development of fissility producing flaggy and shaly bedding. There are small quantities of biotite present. Whether this muscovite is derived from acid plutonic rocks or from mica schists is not yet known. Small black flakes of graphite with a metallic lustre are associated with the muscovite on the bedding planes. Two hypotheses may be offered to explain the presence of the graphite. On the one hand, it may have been derived by the metamorphism of carbonaceous fragments in the sandstone and shale but this seems unlikely, as the depth of burial of the Triassic sediments has never been great. On the other hand, the graphite may have been derived from the graphite schists such as are known to occur in the Pre-Cambrian of the Slate and could well outcrop in the Central or South-Western Highlands. The association with muscovite suggests this latter hypothesis.

Heavy minerals from this formation were first noticed by Prider (1948, p. 138) in sandy clays beneath Big Marsh. There, a little ilmenite is associated with unworn zircon and colourless garnet. In the south-eastern area the commonest of these minerals is a pink to red melanite garnet, found at Risdon, Claremont and Dover, in each case forming distinctly red bands or patches. This could well have been derived from the Pre-Cambrian garnetiferous hornblende schist which outcrops in western Tasmania. Magnetite, tourmaline, rutile and zircon are also known from the same areas in the south-east.

Cementing material is usually argillaceous, frequently with some haematite or limonite to produce the yellow, red or brown colour of the sandstones and shales. Calcite has been noted (Prider, 1948, p. 137) from this formation on the Nive River where it forms a "Fontainebleau" Sandstone. Two minerals of considerable interest and some economic importance are halite and
epsomite which occur in sandstone in a number of places. Salt pans are known in many places in
the lower Midlands and apparently derive their salt from the sandstone with which they are closely
associated. Two distinct saliferous bands are reported by Reid (in Hills et. al. 1922, pp. 112-3)
near Buckland. The lower bed contains epsomite and is followed 20 feet (6 m.) higher by a bed
rich in halite. Similar beds are known close to Richmond, near Ross and recently an epsomite
band has been identified at Police Point on the Huon River. These minerals suggest a high rate
of evaporation during part of the time of deposition of the Knocklofty Formation.

Lithology: Fine conglomerates are commonly developed near the base of the Triassic group.
These are mainly quartz conglomerates containing fine to coarse boulders set in a predominant
matrix of sandstone. The well-waterworn boulders include both reef quartz and quartzite with
few other rock types. In several places the conglomerates contain boulders of the Fern tree Mud-
stone. These conglomeratic bands vary in stratigraphic position, for although they are all low in
the sequence, they may occur at the base or lying above normal sandstones up to fifty feet above
the base. Higher in the sequence there are prominent beds of "clay-pellet" or intraformational
conglomerate. The pellets may be rounded, angular or twisted and up to about six inches long.
These indicate periodic exposure of the lake floor to the air and suggest deposition in very shallow
water.

Sandstones of the quartz sandstone type are well developed. These are essentially quartz
with small quantities of felspar, mica and heavy minerals. Fontainebleau sandstone is reported
from one locality. The sandstones are well-sorted as shown by recent mechanical analyses. With
these sandstones are associated red, brown, purple and green shales. Judging from observations
on hand specimens these shales are really siliceous siltstones with shaly bedding, on which micas
and graphite are well developed. Few claystones are found in this formation.

Sedimentary Structures: Bedding varies from laminations in some of the shales to shaly, flaggy
and massive in the sandstone members. Rhythmic alternations of sandstone and shale characte-
rise the Knocklofty Formation, complete rhythm being about 50 feet (15 m.) thick. Minor rhythms
are superimposed on this major one. Current bedding is common in the coarsergrained sediments.
The normal type, sigmoidal in section is commonest and the bedding frequently shows truncation.
Also found in a few places is a symmetrical type which can be developed perpendicular to the current
in restricted channels. Both Fairbridge (1949, pp. 119-20) and Prid (1948, p. 139) record current
bedding, at Waddamana and Tarraleah respectively, indicating currents flowing from the north-
west. In the area south east of Hobart, observations indicate currents from many directions.
Near Police Point unilateral rolling strata have been found in the Knocklofty Formation while
current ripple marks are common in the shales.

Slump structures in the sandstones have been reported by Fairbridge from the Waddamana
area where they indicate that the lake floor sloped to the south-east. Near Hamilton and south-
east of Hobart similar structures are found and indicate floors of deposition sloping to the south-east,
est, and north-east. Taken in conjunction with the current bedding these structures would indi-
cate that the sediments were derived from a land surface lying to the north-west and south-west,
but were deposited in a series of small lakes in a low-lying area.

Palaeontology: Fossil animals from this formation are restricted to a few vertebrates. Two
fossil fish, Acrolepis hamilloni and A. tasmanicus, have been described from the Springs Sandstone
Member, and more fish have been discovered but not described. The same formation has yielded
two labyrinthodont humeri, thought to belong to the Captorhinidae, of Lower Triassic affinities.

Plants are somewhat commoner, particularly in the shale bands of the Knocklofty Formation.
Phyllotheca australis, Thinnefalia odontopterodes, Cladophlebis, sp., and Phoenicopsis elongatus are
all found in the formation but there are also many others as yet undescribed.

From the above remarks it will be seen that there is little good evidence available to date the
formation. The plant species all have a long time range, the fish require revision and the labyrinh-
thodont remains are too poorly known to provide a sound basis for fixing the age.
Environment of Deposition: From the facts that have been recorded above, it is inferred that the Knocklofty Sandstone and Shale was deposited in a lake (or series of lakes) bounded on the west by the Pre-Cambrian rocks of Western Tasmania. The lake was shallow and probably periodically dried up to form a series of mud or sand flats. The climate probably varied from rather moist to hot and dry, when the saline deposits were formed. The floor was sinking slowly as shown by the good sorting and the current bedding and from the minerals present it would appear that the terrain from which the sediments were derived contained acid plutonic rocks, quartzites, quartz veins, dynamically metamorphosed rocks and Permian sediments and for the most part was not very rugged.

“Felspathic” Sandstone.

This formation overlies the Knocklofty Formation and is followed unconformably by Tertiary lacustrine sediments or basalt. The New Town, Langloh and Cornwall Coal Measures lie within this formation. The thickness varies from about 400 feet to 800 feet (120 m. to 240 m.).

Mineralogy: Quartz, which played such an important role in the formation of the underlying rocks, is relatively unimportant in this formation. It is generally angular, wedge-shaped, or cuspatel (Lewis and Voisey, 1938, pp. 34-37) while Nye (1921, p. 45) records some showing crystal boundaries. Inclusions of apatite and tourmaline in the quartz were also noted by Nye.

Felspars, on the other hand, are very abundant in this formation and according to Nye (loc. cit., pp. 44-45) may form up to 80 % of the rock. Both orthoclase and plagioclase are recorded by Nye, and Voisey (Lewis and Voisey, 1928, pp. 35-37) describes labradorite and perhaps andesine in this formation from New Town.

Muscovite is not nearly so common as in lower formations, but biotite is noted by several authors and may have been the primary mineral from which much of the chlorite in the sandstone was derived. In some places crystals of biotite have been seen. Chlorite is common and the green to blue colour of the sandstones is largely due to the presence of this mineral.

Calcite of several colours occurs in the sandstone and associated with the coal seams in the form of veins or bands. In the sandstone the calcite is interstitial, concretionary or occurs as alteration product of the plagioclase. Siderite is rare and to date dolomite has not been recorded. Gypsum (selenite), occurs associated with carbonaceous remains at Plenty.

The clay minerals are much more common at this level than in the Knocklofty Formation. They act as cement for the coarser grains or form separate beds of Claystone. Limonite and haematite both occur but are not common. Associated with the coal and some of the mudstones are pyrite and marcasite, and the coal in some analyses shows up to 0.63 % sulphur from these minerals. Nothing is known yet of the heavy minerals of this formation.

Lithology: Conglomerates are known in the “Felspathic” Sandstone. Of particular interest is that reported by Nye (1921, p. 47) just above an “unconformity”, which contains water worn boulders of quartz, quartzite, acid igneous rocks and a rock with “lower marine Permo-Carboniferous fossils”. This forms a thin band near the top of the formation. Intraformational clay-pellet conglomerates are very common.

Quartz sandstones, such as are described under the heading of the Knocklofty Formation, occur throughout the “Felspathic” Sandstone but usually only in thin beds which are well exposed on the surface and occur in bore cores. Such a sandstone member may have been the basis of reports of an Upper Siliceous Sandstone formation but this has been shown to be absent in most places and, at most, very thin in others. Less work has been done on the so-called felspathic sandstone than on the underlying rocks but from the few descriptions available it would appear that they are arkoses with a variable proportion of felspar, usually quartz and biotite but with less muscovite than the Knocklofty Sandstones and Shales. The green to blue colour is attributable to the chlorite they contain and on weathering the iron in the rock is oxidised and the colour becomes a light buff. Up to 80 % of felspar has been noted in the rock. The mode of origin of this arkose is still debatable. It is possible that it was derived by the stripping of a terrain of intermediate to basic rocks of consi-
derable relief and was deposited rapidly to preserve the large amount of felspar present. As far as is known no such source rocks were available and in addition the arkose shows current bedding quite commonly, and so was apparently deposited on a slowly sinking floor and subject to the action of strong currents. An alternative hypothesis, and a more attractive one, is that they are really tuffs, or largely of tuffaceous origin. This idea was proposed by Lewis and Voisey (1938) who adduced the irregular shape of many of the particles and the presence of small fragments of volcanic rock to support their idea. Lewis also suggested that some boulders found by Twelvetrees in the coal-bearing strata at South Cape Bay were volcanic bombs. Thus there are strong suggestions that the arkoses are tuffs and water-sorted tuffs and, again following Lewis (loc. cit., p. 38), they may well represent the early volcanic activity associated with the dolerite intrusions. The intrusions themselves are later as is shown by the fact that in many places the “Felspathic” Sandstone has been intruded by dolerite. There are difficulties in the hypothesis of a volcanic origin as considerable quantities of quartz are recorded from the arkose and some of it contains inclusions of apatite and tourmaline. It seems unlikely that so much quartz and particularly the type mentioned above could be derived from a doleritic magma.

Associated with the “Felspathic” Sandstone are shales and fine-grained rocks, including both claystones and siltstones, which are commonly grey to black in colour due to the presence of carbonaceous matter.

Most Tasmanian coal belongs in this formation and varies in rank from sub-bituminous to anthracitic, the latter being due to the baking of the coal by dolerite intrusions. Up to eight seams are present in any one district and the thickest seams approach 18 feet (5 m.). This coal is widely distributed from under the Western Tiers to the east coast and from Hadspen in the north to South Cape.

Sedimentary Structures; Bedding varies from laminations in some of the argillaceous rocks to massive in the sandstones themselves. Current bedding is commonly recorded from the sandstone members but observations on the direction have not been reported.

Concretions are very common in this formation and have been known for many years. They reach very large sizes and Nye (1921, p. 46) refers to examples ten feet (3 m.) in length from York Plains. Similar large concretions have been noted at New Town and at Plenty. The concretions are almost cylindrical, being circular to oval in cross-section and up to two feet (0.6 m.) in diameter. Other concretions are discoidal but are much smaller, being only two or three inches (5-18 cms.) in diameter. The concretions are composed of felspathic sandstone with a concentration of calcite within the concretion.

Palaeontology: The only fossils reported yet from this formation are plants but they are present in large numbers, and in considerable variety. Lycopods have not yet been recorded but equisetales, ferns, pteridosperms; cycadophytes, and ginkgoales have all been described so that the flora is rich, not only in numbers but also in species. Twenty-seven species have been described and, of these, eighteen also occur in the Ipswich Series of Queensland, as shown by Jones and de Jersey (1947).

Typical species are listed below:

Equisetales.

Phyllotheca australis;

Neocalamites carrerei.

Filicales.

Cladophlebis australis, C. johnstoni, C. tasmanica.

Pteridospermae.

Thinnfeldia odontopteroides, T. acula, T. lancifolia, T. feistmanteli; Johnstownia coriacea, J. dentata, J. tribolita;

Sphenopteris morrisiana;
Cycadales.

*Doratophyllum tenison-woodsi*.

Bennetitales.

*Pterophyllum strahani*; *P. risdonensis*.

Taeniopterids.

*Taeniopteris carruthersi*; *T. morrisiana*.

*Linguifolium lillieanum*.

Ginkgoales.

*Ginkgo digitata*;

*Czekanowskia tenuifolia*;

*Phoenicopsis elongatus*.

Caytoniales:

*Sagenopteris moribunda*.

The Tasmanian arkoses are apparently very similar lithologically to those of Victoria, but the floras are very different and the two formations are apparently not contemporaneous. The Tasmanian flora has more affinity with that of the Wianamatta Shale of New South Wales, and an even closer one with that of the Ipswich Series of Queensland. Zones representative of the different stages in Queensland are identifiable in Tasmania although their position within the "Felspathic" Sandstone has not been established.

Thus *Cladophlebis johnstoni* is restricted in Queensland to the Tivoli and Kholo Stages of the Ipswich Series, *Johnstonia dentata* to the basal portion of the Tivoli Stage, *J. Coriacea* to the higher parts of the Ipswich Series and *J. tribolitae* to the Tivoli Stage. *Linguifolium lillieanum* occurs in the Tivoli Stage only, and *Neocalamites carrerei* commences in the Tivoli Stage as also does *Thinfolia fectmanteli* and *Ginkgoites bidens*. Others, such as *Taeniopteris carruthersi*, begin in the Cooneana Stage and continue into the Blackstone Stage. *Phoenicopsis elongatus*, which is very common in shales associated with the coal seams in Tasmania, occurs in Queensland only in the Blackstone Stage. *Phyllotheca australis* occurs only in the Blackstone Stage of the Ipswich Series, but in Tasmania is apparently longer in range.

It appears likely, therefore, that the "Felspathic" Sandstone is approximately equivalent in age to the Ipswich Series but its boundaries have not yet been determined and may well be wider than those of the Ipswich Series. Jones and de Jersey (1947) consider that the Ipswich Series is Lower to Upper Triassic so that the "Felspathic" Sandstone has approximately the same age, and may even extend into the Jurassic.

Environment of Deposition: Apparently climatic conditions changed considerably after the deposition of the Knocklofty Formation. The abundant plants and the coal seams in the "Felspathic" Sandstone suggest that the climate had changed from an arid or monsoonal climate in the Lower Triassic to a climate with abundant rainfall and lacking the dry periods. Deposition would appear to have occurred in a lake or, more probably, a series of lakes, usually shallow and occasionally becoming swampy, with a slowly sinking floor. The area surrounding the lake was probably part of a low-lying terrain but with volcanoes dotted over it and erupting periodically.

**Summary.**

The Triassic rocks of Tasmania are members of the orthoquartzite suite with the addition of volcanic sediments of intermediate to basic composition, all formed under lacustrine-swampy and perhaps fluvial conditions on a slowly sinking floor. The area of deposition was apparently surrounded by slowly rising areas which, however, never attained any great height but remained part
of a low-lying terrain. The western margin of the lake was probably the belt of Pre-Cambrian rocks running from Port Davey to Cradle Mountain and Ulverstone, but none of the other margins can yet be suggested. The period began with an arid or monsoonal climate which later changed to one with a high rainfall and no arid spells. Deposition is thought to have occurred in an auto-

geosyncline.

**JURASSIC DOLERITE**

The period of almost continuous sedimentation during the Permian, Triassic and perhaps part of the Jurassic time was closed by the intrusion of some thousands of cubic miles of doleritic magma and the possible extrusion of flows and tufts at the surface. The rock consists essentially of plagioclase, and pyroxenes. The plagioclase varies from bytownite or labradorite in the core of the grains to oligoclase as thin marginal zones. The pyroxenes are pigeonite, which is the common one, augite, and both bronzite and hypersthene. Edwards (1942, pp. 451-480, 579-610) has described the dolerite in some detail and has shown the relationship of the pyroxenes to the differentiation processes. Olivine is present in small quantities but does not seem to be a normal constituent of the rock. Quartz and alkali felspar are present in small amounts forming micrographic intergrowth. Amphiboles, biotite, chlorite, and calcite are also occasionally present. Ilmenite occurs intergrown with magnetite and small amounts of pyrite and less chalcopyrite are also known. Apatite is rare.

The magma, when intruded, was of uniform composition and on cooling crystallised to a tholeiite and some slightly more acid pegmatitic segregations which occur sporadically through the dolerite masses. Differentiation occurred in situ with some interesting mineralogical effects described by Edwards (op. cit.). The rock varies in grainsize from very fine, close to contacts with the sedimentary rocks, to coarse in the central parts of the intrusions and to pegmatic in the segregations. The chilled margins may be micro-porphyritic and may contain olivine. Such chilled margins can be seen on both the base and the top of sills and the chilled top in places forms marked flats many square miles in area with occasional outliers of the intruded rock as low hills on the flat. The margins of the dykes are also chilled.

The dolerite intruded commonly as sills, some of them probably 1,600 feet (480 m.) in thickness and extending for many miles. Certain stratigraphic horizons seem to have been more favourable for intrusion than others. Such are the unconformity surface at the base of the Permian, the Grange Mudstone, the Woodbridge Glacial Formation, the top of the Ferntree Mudstone, the Knocklofty Sandstone and Shale and finally the “Felspathic” Sandstone. Of these the Grange Mudstone and the Knocklofty Sandstone and Shale proved most incompetent and in these formations the intrusions were most irregular. The sills were fed by dykes, passing through the Lower Palaeozoic rocks beneath the Permian, where the dykes were generally much wider, some of them being over a mile in width. The intrusions were not, however, regular and in many places the sills become shelving bodies, or the dykes give rise to sills on one side only, causing extensive displacement of the strata. Thus the dykes arose very commonly along fault planes which are now recognisable by the chilled margin of the dolerite, the metamorphism of the sediments and the drag dip on the bedding planes of the sedimentary rocks. Laccolithic intrusions have been recognised locally and there are suggestions in places of lopolithic masses. A structure, which may prove very confusing in mapping and structural work, is the common occurrence of rafts of sandstone or mudstone in the dolerite apparently torn from the sides of the intrusions. Some of these rafts are many feet thick and hundreds of yards in diameter.

The contact metamorphic effects of the dolerite magma, which according to Edwards (1942, p. 458) was intruded at a temperature of 1,000°C, were remarkably slight. The mudstones and sandstones were hornfelsed with the formation of quartz hornfels, the coal was baked to produce restricted areas of anthracite, and only with the somewhat calcareous Grange Mudstone were any notable effects produced. In two or three localities near Hobart, these marls have been metamor-
phosed to form calc-silicate hornfels. It has been suggested that the reason for the general lack of metamorphism is the lack of much water in the dolerite magma.

Hills and Carey (1949, p. 34) have suggested that the intrusion occurred as a single, although highly complex, intrusion of magma. The age of the dolerite has not yet been determined very accurately. It is younger than the Triassic to (?) Lower Jurassic sedimentation and older than the alkaline syenites which in turn preceded the probably lower Tertiary faulting. As this epoch of faulting broke and tilted a mature surface on which the dolerite had been lateritised and bauxitised, the dolerite probably was much older than the faulting. Edwards remarks on the similarity of the Tasmanian dolerite to the Karoo dolerite of South Africa and the dolerite of the Antarctic continent. The Karoo dolerite is considered by du Toit to be Lower Jurassic and there is no evidence which prevents us regarding the Tasmanian dolerite as being of similar age.

**General Summary**

After the (?) Middle Devonian epoch of folding and intrusion Tasmania apparently became a land surface. Erosion reduced the original surface, which was probably mountainous, to a low-lying surface which was further planated by a continental ice-sheet in the Upper Carboniferous Epoch. On this planated surface the ice-sheet deposited morainal material as it retreated and these sediments represent the initial deposition of the Permian-Triassic Periods. The ice retreated to a land surface, probably lying to the west of Tasmania, and with the retreat of the ice the area was associated with the Tertiary faulting. As this epoch of faulting broke and tilted a mature surface on which the dolerite had been lateritised and bauxitised, the dolerite probably was much older than the faulting. Edwards remarks on the similarity of the Tasmanian dolerite to the Karoo dolerite of South Africa and the dolerite of the Antarctic continent. The Karoo dolerite is considered by du Toit to be Lower Jurassic and there is no evidence which prevents us regarding the Tasmanian dolerite as being of similar age.

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bably monsoonal, the dry period providing the necessary heat for evaporation of the lakes, and the formation of saliferous beds as well as the heat and oxidation necessary for the development of the red to purple colour in many of the sediments. The wet season would provide enough moisture to refill the lakes and to support the vegetation of which we have fossil evidence. Tasmania may then have lain in the high pressure belt marginal to the tropics. Plants of several different divisions are present and we have evidence also of the existence of labyrinthodonts, although little is known about them.

Late in the Lower Triassic Epoch probably, these conditions were replaced by conditions more conducive to abundant plant growth and preservation. The climate became more pluvial probably, although it remained warm to even hot, and Tasmania may well have lain in the expanded tropical zone. The sediments were deposited in shallow lakes or in swamps surrounded probably by a low-lying, hilly land surface. It seems likely that volcanoes formed on this surface as the sub-stratum began to warm up preparatory to the dolerite intrusions. The plants in the arkoses and associated finer-grained sediments indicate a close time relationship with the Ipswich Series of Queensland which Jones and de Jersey (1947) consider to range from the upper part of the Lower Triassic to the Upper Triassic so that the "Felspathic" Sandstone probably covers the same time range approximately but may be somewhat younger in places.

In Tasmania the deposition of about 4,000 feet (1,200 m.) of sediment in an autogeosyncline under gradually ameliorating climatic conditions was closed by the intrusion into the newly deposited sediments of great masses of tholeiitic dolerite which may be regarded as Upper Triassic or more probably Lower Jurassic. The succession of climatic events is similar to that deduced by du Toit (1948, pp. 124-5) for the same period in South Africa and by Teichert (1950, pp. 206-208) for the mainland of Australia.

**LIST OF ILLUSTRATIONS**

- Figure 1. Map of Tasmania showing the distribution of the Permian sediments, thicknesses and elastic ratios.
- Figure 2. Map of Tasmania showing distribution of the Triassic sediments and thicknesses.
- Figure 3. Map of Tasmania showing the distribution of the dolerite.
- Figure 4. Diagram showing the approximate relationship of the depth at which Permian sediments near Hobart were deposited, to the intensity of Glaciation.

**Table 1. Stratigraphic Summary of the Permian, Triassic and Jurassic Systems in Tasmania.**

**Table 2. Table showing Permian Succession in Different Localities in Tasmania, after Voisey (1938), Prider (1948) and Hills and Carey (1949).**

**Locality index**

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**Legend**
- SANDSTONE
- MUDSTONE
- CONGLOMERATE
- TILLITE
- LIMESTONE
- SHALE
- COAL
- OIL SHALE

**PERMIAN SEQUENCES IN TASMANIA**

**Table 2**

- **2500 FT**
- **2000 FT**
- **1500 FT**
- **1000 FT**
- **500 FT**
- **0 FT**

**Syndrome of Gondwana**
M. R. BANKS

RECENT ADDITIONS TO THE KNOWLEDGE OF THE PERMIAN SYSTEM IN TASMANIA

Sobretiro de la

Comisión de Gondwana

págs. 151-177, 4 figs., 1 tabla

MEXICO, D. F.
1958
RECENT ADDITIONS TO THE KNOWLEDGE OF THE PERMIAN SYSTEM IN TASMANIA

M. R. BANKS *

ABSTRACT

Late in the Carboniferous or early in the Permian deposition of sediments began on a surface with a relief of a few hundred feet composed of rocks of Precambrian to Middle Devonian age. Ice-smoothed surfaces underly the Permian in several places and tillite is the basal rock in some areas. In other areas, however, conglomerates, sandstones and even oil-shale form the basal beds. Low in the sequence are Eurydesma-rich limestones or siltstones with Calcitornella and above these are fresh-water beds, containing coal in some places, and interbedded with marine beds in others. A little higher are richly fossiliferous siltstones or limestones, the Berriedale Limestone and its correlates, with Lyroporella, Taeniothaerus subquadatus and Pteroblastus. This is followed by the Woodbridge Glacial Formation, then the Risdon Sandstone, which is glauconitic in eastern Tasmania, the Ferntree Mudstone and finally the Cygnet Coal Measures. The lower limestone is correlated with the Callytharra Limestone (Lower Artinskian) in Western Australia, the Rutherford Formation in New South Wales and the Dilly Stage in Queensland. The Berriedale Limestone can be correlated with the Branxton Sub-group (Upper Artinskian) of New South Wales and the Cattle Creek and/or Ingelara Stages in Queensland. Correlation with Western Australia is not yet possible.

There is a distinct Westralian element in the dominantly Eastern Australian fauna with the bryozoa Lyroporella and Strebitriya and the echinoderms Pteroblastus, Calciceolispongia and Jimbacrinus. This element is not known to extend higher than the Berriedale Limestone.

The only evidence of vulcanism in Tasmania during the Permian consists of a number of beds of meta-bentonite in the Berriedale Limestone.

INTRODUCTION

Compilation of information in connection with the writer's paper in the Gondwana Symposium (Banks, 1952) emphasized the areas of ignorance of the Permian System in Tasmania. Since the publication of the earlier paper many geologists have made contributions to the problem so that some exact information now covers a few of the areas of ignorance. The main contributor

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has been K. G. Brill, of the University of St. Louis, Missouri, who was Visiting Professor of Geology at the University of Tasmania under the Fulbright Scheme in 1953. Other contributors have been B. F. Glenister, K. R. Walker, A. T. Wells, J. Loveday, D. Ll. Scott, M. L. Yaxley, J. MacKellar and especially G. E. Hale. Palaeontological contributions have been made by Dr. I. A. Browne, of the University of Sydney, and Miss E. M. Smith. The writer has generally acted as co-ordinator but has measured stratigraphic sections in several parts of the state and begun to gather biostratigraphic information. The author wishes to acknowledge the constructive criticism and advice of Professor S. W. Carey during the work.

During the writing of this paper the author has had access to the collections and library of the British Museum of Natural History and wishes to acknowledge this with gratitude.

THE SECTION IN THE VICINITY OF HOBART

Although sections which include the whole of the Permian System as developed in Tasmania occur and have been measured in several places, details of these have not yet been published and they are somewhat atypical. For these reasons this discussion will start by treating sections in the Hobart area or the central and south-eastern parts of the island. It is in this area that the Permian seems thickest and although three sections will be taken together as constituting the type, correlation between them is reasonably sound. Taken together they constitute a useful standard, variations from which can be considered later.

The closest place to Hobart where basal Permian rocks occur is on the northern side of the Styx Range a couple of miles west of Maydena which is about 40 miles west of Hobart (for all localities see text-figure 1). Here steeply tilted Owen Conglomerate (Ordovician) is overlain unconformably by almost horizontal Permian beds which are locally tillites with interbedded laminated siltstones containing Stenopora and other fossils. These tillitic beds are a couple of hundred feet thick and are followed by a dark grey, carbonaceous siltstone containing pyrite nodules, calcareous concretion, and glendonites as well as fenestellids, Chaenomys, Gangamopteris and silicified wood.

This glendonitic siltstone is several hundred feet thick and near the bridge over the Styx River ellipsoidal concretions are found, some small sub-rounded erratics occur, and small pelecypods and Gangamopteris are present. In the Florentine Valley some fifteen miles from Maydena on the flanks of the Misery Range the glendonitic siltstone again occurs with pyrite nodules and
Locality map around Hobart.
erratics and contains numerous fossils, including *Stenopora tasmaniensis*, *Fenestella* spp., some of them in living position, *Strophalosia*, *Grantonia* and other spiriferids, *Eurydesma cordatum*, *E. hobartense*, *Chaenomya* and aviculopectinids as well as plant remains. On the Styx Range the glendonitic siltstone formation is overlain by a fossiliferous siltstone with *Stenopora tasmaniensis* and *Keeneia*, a formation consisting of alternating coarse feldspathic sandstone with *Platyschisma ocula* and a *Strophalosia* siltstone, and then by a “tillite” with *Eurydesma cordatum* and *Keeneia platyschismoides*. At the Misery Range locality the glendonitic siltstone is overlain by fossiliferous mudstone and dark grey, fossiliferous, erratic-rich sandstone.

The glendonitic siltstone of the Maydena area resembles in gross and detailed lithological characters the Woody Island Siltstone (see Banks, Hale and Yaxley, 1955) which also contains pyritic nodules, glendonites, erratics and ellipsoidal and calcareous concretions. This correlation is supported by the fossils in the siltstone in the Maydena area and in the overlying rocks, particularly *Stenopora tasmaniensis*, *Eurydesma cordatum* and *Keeneia platyschismoides* which at Woody Island occur in the Woody Island Siltstone or in the overlying formations.

The Maydena succession can then briefly be summarized as a formation of tillite, erratic-rich sandstone and siltstone and laminated siltstone overlain by a formation of glendonitic siltstone which may be correlated with the Woody Island Siltstone.

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The Woody Island section has been described in some detail by Banks, Hale and Yaxley (1955), and will only be summarized here. The lowest formation is the Woody Island Siltstone with its glendonites, pyrite, etc., and *Eurydesma cordatum*. This is followed by the Sunset Bay Sandstone, also glendonitic and pyritic, and containing *E. cordatum*. The next formation is the Satellite Siltstone which is extremely fossiliferous and contains *Stenopora tasmaniensis*, *Streblotrypa marmionensis*, *Calceolispongia* and *Jimbacrinus*. A thin tillitic bed, the D’Entrecasteaux Tillite, succeeds this and in turn is overlain by the Lewis Point Siltstone and Sandstone with *Stenopora prob. tasmaniensis*, *Eurydesma cordatum* and other fossils. The next formation in the sequence is the Alonnah Sandstone with *E. cordatum*, *Strophalosia clarkei* and *Calcitornella stephensi*. The Dreamy Bay Tillitic Sandstone is the next unit and this contains abundant *Stenopora johnstoni* and *S. tasmaniensis*. The next formation, the “Eurydesma Limestone”, contains *E. cordatum*, *Stenopora tasmaniensis*, *S.
The final formation exposed on Woody Island a richly fossiliferous siltstone, the fauna of which includes *E. cordatum* and *Keeneia platyschismoides*. This siltstone is lithologically very like the siltstone in the cliffs above the shoreline at Porters Hill, Hobart, and like the Bundella Mudstone in the Mount Nassau section near Brigewater. The siltstones in the cliffs at Porters Hill overly a limestone with *E. cordatum*, *Keeneia platyschismoides* and *Calcitornella* (Crespin, letter, 28.2.1956, on *Calcitornella*), and the Bundella Mudstone containing *E. cordatum*, *Stenopora tasmaniensis*, *S. johnstoni* and *Keeneia platyschismoides*. Thus, for lithological, stratigraphic and palaeontological reasons, the final formation on Woody Island is correlated with the Bundella Mudstone. The total thickness of Permian formations on Woody Island is 330 feet.

The Bundella Mudstone, at the base of the Mount Nassau section, is at least 140 feet thick and is probably more, as the base is soil and talus-covered. It consists of an alternation of fissile and non-fissile fossiliferous siltstone with four beds of impure sandstone. Most of the bed contain erratics, one of which is 3 feet across. The fossils include *Stenopora johnstoni* and *S. tasmaniensis*, *Eurydesma cordatum* and *Keeneia platyschismoides*. This is followed by a bed of “tillite” 1 1/2 feet thick containing plant fragments including *Gangamopteris*. Erratics up to 3 inches in diameter are very common and are of many rock types. The next formation is 35 feet thick and consists of micaceous quartz sandstone and shaly siltstones. Mud pellets are common, erratics are lacking and cross-bedding and ripple-marks are present. This formation appears to be lacustrine and paludtine in origin. A thin bed of very poorly-sorted arenite overlies the fresh-water beds. It is only 2 inches thick and contains numerous angular to sub-angular fragments of several rock types. A formation consisting of an alternation of non-fissile greywacke and fissile siltstone follows the tillite. This formation is 27 feet thick and contains numerous erratics but the only fossils are worm tubes. There follows another formation, 20 feet thick, of quartz sandstone and shaly carbonaceous siltstone without erratics and with plant fossils like the paludtine or lacustrine formation lower down. Again the fresh-water formation is followed by a thin conglomeratic formation, only 1 1/2 feet thick, with numerous, poorly-sorted, sub-angular to rounded boulders. This is overlain by another formation of alternating fissile and non-fissile siltstone with a bed of greywacke breccia. The unit is 37 feet thick. Some marine fossils occur near the top of the formation. The following formation, a greywacke-type sandstone 8 feet thick, is richly fossiliferous with *Martiniopsis*, *Aviculopecten*, *Strophalosia* and other marine fossils as well as *Glossopteris*. The next formation is the Berriedale Limestone which in this section is about 300 feet thick and
Fig. 2.—Columnar sections.
consists of an alternation of fissile siltstone and massive limestone, the siltstone predominating in the lowermost and uppermost parts and the limestone in the central part of the formation. Erratics are common in both types of sediments (see Brill, 1956), and there are several thin beds of meta-bentonite (Hale and Brill, 1955). The Berriedale Limestone is richly fossiliferous with foraminifera, corals, brachiopods, bryozoan, molluscs, ostracodes and crinoids, as well as plant remains. Fossils significant in correlation include Lyroporella, Polypora internata, P. woodsi, Taeniothaerus subquadratus, Strophalosia jukesi, Eurydesma cordatum and E. cordatum var. succulm and Pterotoblastus.

Following the limestone formation is a formation, 275 feet thick, of sub-greywacke sandstone and siltstone with numerous erratics and a thin band of limestone about 10 feet from the top of the formation. Fossils are common and include numerous spiriferids and pelecypods while Stenopora crinita is found especially in the limestone. This is the so-called Woodbridge Glacial Formation. It is followed by the Risdon Sandstone which here is 10 feet thick and consists of a coarse, feldspathic sandstone with numerous pebbles. Tubicolac casts are common in the Mount Nassau section and other marine fossils occur elsewhere. The Ferntree Mudstone is the final formation in this section and is a mudstone formation 600 feet thick with alternating beds of fissile and non-fissile siltstone with a few marine fossils. Although in the Mount Nassau section the Ferntree Mudstone is overlain by Triassic quartz sandstones, in some other places the Cygnet Coal Measures intervene between the two formation. The Hobart section is shown diagrammatically as text-figure 2 (b).

SECTIONS IN OTHER PARTS OF THE STATE

At Quamby Brook near Deloraine the Permian has been studied by A. T. Wells (1954). Here, the Permian rests on folded Precambrian, Cambrian and Ordovician strata and the basal beds of the Permian are tillites. The tillite is 300 feet thick and is followed by a dark, carbonaceous mudstone, also 300 feet thick and including a bed of tasmanite. Above the mudstone is a limestone with Stenopora tasmaniensis, Eurydesma cordatum and Calcitornella stephensi. This limestone is correlated with the “Eurydesma Limestone” of Woody Island, Porters Hill and Maria Island on account of the abovementioned fossils, the underlying carbonaceous siltstone with the Woody Island Siltstone, and the tillite with the basal beds of the Styx Range (see text-figure 2, (a) and (b). The limestone and associated fossiliferous mudstone are 200 hundred feet thick and are succeeded by a formation dominantly composed of sandstone but with some carbonaceous plant-bearing shales. The sandstone itself contains
carbonaceous fragments. It is 110 feet thick. It appears to be dominantly, if not perhaps entirely, of fresh-water origin. The sandstone is followed by a formation of alternating beds of subgreywacke sandstone and siltstone with marine fossils which closely resembles the Woodbridge Glacial Formation of the Hobart area and this in turn by a formation very like the Risdon Sandstone and then the Ferntree Mudstone. The Risdon and Ferntree totalling 650 feet. The lower part of this section, i.e. up to the fossiliferous mudstones, can be correlated with the Styx Range, Woody Island and Hobart sections, and the three upper units of the Woodbridge, Risdon and Ferntree with the upper units in the Hobart section. The difficulty is in correlation of the fresh-water sandstone in the Quamby Brook section. At first sight it is easy to correlate it with the fresh-water formations below the Berriedale Limestone in the Mount Nassau section, with the added postulate that in the Hobart area there are several marine intercalations during the time of deposition of the fresh-water sandstone at Quamby Brook. This correlation raises the problem of the correlates of the Berriedale Limestone in the Quamby Brook area; there are apparently none. Brill (1956) has shown in his isopach map for the Berriedale that this formation or facies does not extend so far north. It is strange, however, that there is not a fossiliferous mudstone, like the Grange Mudstone, equivalent to the Berriedale in this area. Alternatively, the fresh-water sandstone may be equivalent to all the beds in the Hobart section from the top of the Bundella Mudstone to the base of the Woodbridge or the “Woodbridge” at Quamby Brook may be a near-shore facies of the Berriedale Limestone in the Hobart area. This last alternative is not considered likely, but no evidence is yet available to solve the problem, which requires much more palaeontological data.

The Quamby Brook section is significant for correlation with sections further north and west and there are parallels with sections near Latrobe, Wynyard and Cradle Mountain (see text-figure 3).

In Bore 15, at Native Plain near Latrobe (Reid, 1924), the rocks below the tasmanite are sandy, or pebbly mudstones with a conglomeratic and a sandy bed. Above the tasmanite are mudstones with occasional fossils, then a sand and clay unit before fossiliferous, sandy and pebbly mudstones follow. These latter occupy the stratigraphic position of the limestone and fossiliferous mudstone at Quamby Brook and these are followed at Native Plains by unfossiliferous mudstone. There follows a sandstone, mudstone and a grey sandstone with a seam of coal, equivalent to the fresh-water sandstone in the Quamby section and then a sandy mudstone, possible the Woodbridge. Bore 27 at Native Plains provides a little more data. The tasmanite is followed by mudstone and then fossiliferous and pebbly mudstones, then an unfossiliferous
Fig. 3.—Columnar sections.
mudstone. A coarse white sandstone follows this and is considered here as probably equivalent to the fresh-water sandstone at Quamby Brook as such sandstones in the Permian in Tasmania are quite exceptional and usually found with coal or other fresh-water sediments. The white sandstone is succeeded by pebbly mudstone and fossiliferous mudstone, probably the Woodbridge Glacial Formation. These correlations are tentative, being based on lithological similarity and similarity in succession without any faunal basis.

Considering next two bores in the Latrobe area; in Bore 24, from 12 to 71 feet are sandstone and mudstone, with pebbles, which are perhaps the equivalent of the Ferntree Mudstone; from 71 feet to 262 feet are fossiliferous sandstone, mudstone and conglomerate, perhaps equivalent to the Woodbridge Glacial Formation; from 262 feet to 489 feet, sandstone, mudstone and coal, perhaps equivalent to the fresh-water sandstone in the Quamby Brook section; from 489 feet to 779 feet pebbly mudstones, sandstones and conglomerates with fossils, perhaps equivalent to the fossiliferous limestone and mudstone at Quamby Brook; from 779 feet to 935 feet are mudstones with pebbles and pyrite, equivalent to the dark carbonaceous mudstone at Quamby Brook; from 935 feet to the base at 968 feet are conglomerates and mudstone, probably equivalent to the basal tillite at Quamby Brook.

The last bore to be considered in this area is no. 17 at Spreyton. In this bore, from 40 feet to 138 feet is a micaceous sandstone, and then a fossiliferous mudstone, possibly the Woodbridge Glacial Formation; from 138 feet to 200 feet is sandstone, mudstone, and coal, equivalent probably to the fresh-water formation at Quamby Brook; from 200 feet to 416 feet are fossiliferous mudstones, equivalent possibly to the fossiliferous limestone and mudstone at Quamby Brook; and from 416 feet to the base at 430 feet is a sandy sediment, possibly a shallow-water equivalent of the dark, carbonaceous sediment at Quamby Brook.

Again these correlations are based on similarity in stratigraphic succession without fossil evidence. Unfortunately in nor of the bores with a long section at Latrobe is the tasmanite encountered Only in Bore 22 is the position of the tasmanite known and here it is just above the collar of the bore, and is about 589 feet above the base with pyritic mudstones, sandstones and conglomerates, and 43 feet of fossiliferous mudstones beneath it. Lithological correlations of this bore with others cannot unfortunately be made.

In the past the tasmanite and the coal have been correlated. One of the reasons given for this correlation is that coal and tasmanite do not occur mutually superimposed anywhere in the district (Reid, 1924, p. 43), but while this is usually true, coal occurs above tasmanite in Bore 15, Native Plains. Until the detailed palaeogeography of the area in the Permian is worked out
the significance of the general exclusion of coal from tasmanite areas can be explained in other ways than in terms of the equivalence of coal and tasmanite. The juxtaposition of oil-shale and coal at Nook near Latrobe may, as Reid (1924, p. 43) stated, by due to faulting. The significance of the black carbonaceous shale with characters of both coal and tasmanite at the northern end of the Bott Gorge near Nook may be that the coal and tasmanite area equivalent as stated by Reid (p. 43), but again other explanations are possible. The fossils in the tasmanite include Grantonia hobartense, Cardiomorpha gryphoides, Eurydesma hobartenese, Mourlonia morrisiana, Aviculopecten latrobeensis, Deltopecten subquinquelineatus, D. fittoni, Aviculopecten sprentii, Keeneia twelvetreesi, the foraminifera Ammodiscus multicinctus, Hyperamminoides acicula, Digitina recurvata and Crithionina teichei, and Tasmanites punctatus. Of these fossils only the foraminifera are of stratigraphic value, and they are stated tentatively by Crespin (1947) to indicate an age equivalent to the Maitland Group of New South Wales. This conclusion cannot be challenged at the moment, but some doubt is cast on it by the occurrence of tasmanite at Quamby Brook below the limestone with Stenopora tasmaniensis and Calcitorina stephensi, and the possibility that the tasmanite at Native Plains occurs in the same stratigraphic position as at Quamby Brook. The problem requires detailed mapping of the Mersey tasmanite fields and collection and identification of many fossils.

Passing next to comparison of the sections at Wynyard (Hills et al., 1922) and Quamby Brook, it will be seen that in both places there is a basal glacial formation, followed by mudstones with few fossils and including a bed of tasmanite, then mudstones or limestones with a rich fauna of marine fossils. The fossiliferous formation is followed in both places by a fresh-water sequence and then a sequence of fossiliferous mudstones and sandstone, correlated with the Woodbridge Glacial Formation. Against this correlation is the foraminiferal fauna of the oil-shale at Oonah (Crespin, 1947) which is taken to indicate correlation with the Maitland Group. Perhaps this is an ecological rather than an age indicator.

The section in the Cradle Mountain area (Hills, et al., 1922) commences with a tillite and conglomerate followed by pebbly sandstone and mudstone. This is succeeded by blue-grey unfossiliferous mudstone with a band of pelionite oil shale and then by a richly fossiliferous mudstone. The next unit is a sandstone with carbonaceous shales and coal seams, equivalent perhaps to the fresh-water formation at Quamby Brook; sandstone follows and above this is a fossiliferous sandstone and siltstone formation with a thin bed of limestone near the top, probably the Woodbridge Glacial Formation (E. M. Smith,
Fig. 4.—Columnar sections.
pers. comm.), and this is followed by rocks resembling the Risdon and Ferntree formations.

To the east, at Lilydale, there is a basal tillite, then unfossiliferous mudstone; a limestone with *Eurydesma cordatum* and *Calcitornella stephensi* (Crepin, 1947, then fresh-water sandstones at the top of which occurs a thin bed of oil-shale which Nye (1924) emphasized is not tasmanite. This is succeeded by the Woodbridge and then Ferntree formations (interpretation from Voisey, 1938 (a), and based on personal observation).

At St. Pauls Dome, just east of Avoca, the Permain rests unconformably on the Mathinna Group (Silurian or Devonian) and the basal formation is a conglomerate composed mainly of sub-angular boulders of quartz or quartzite in a matrix composed mainly of quartz (see text-figure 4). This is 15 feet thick. The next unit is composed of alternating beds of pebbly sandstone and sandstone, and is 46 feet thick. The only fossils present are worm casts. Lithologically this is very like the fresh-water sandstone formation in the Quamby Brook section. Above this is a thin bed, only 3 inches thick, of very poorly-sorted impure sandstone like the “tillites” between the Bundella and Barriedale formations in the Hobart section. This is followed by 15 feet of quartz sandstone, some of which contains rounded pebbles, carbonaceous matter, worm casts and silicified wood. This is lithologically like the fresh-water sandstone in the Quamby Brook section, and seems to be the second definite fresh-water interlude in this sequence. The succession is reminiscent of that above the Bundella Mudstone in the Hobart section. This fresh-water formation is followed by a unit, 67 feet thick, composed mainly of sub-greywacke siltstone, with a bed of sub-greywacke sandstone 42 feet above the base and a coarse sub-greywacke sandstone, like the Hobart “tillites” at the top. This unit contains worm cast and marine fossils such as *Martiniopsis subradiata*, but the fossils are not common. The next unit, 50 feet thick, is similar in lithology to the last one but has numerous fossils, mainly *Strophalosia* spp., aviculopectinids and *Stenopora*. This is followed by 30 feet of richly fossiliferous siltstone which is better sorted than the last unit. The fossils include *Cladocnhus*, fenestellids, *Stenopora, Trigonotreta, Martiniopsis subradiata*, and other spiriferids, aviculopectinids, *Mourlonia morrisiana*, and ostracodes. A limestone is the next formation and it is 14 feet thick. There is a basal silicified unit with fenestellids, *Stenopora, Strophalosia, Dielasma, Martintiopsis*, spiriferids and aviculopectinids. The upper part of the formation is unsilicified and contains *Stenopora, fenestellids, Lyroporella, Thamnopora*, spiriferids, *Strophalosia, Mourlonia*, ostracodes, *Pterotoblastus* and crinoids. It is followed by 54 feet of siltstone which contains fenestellids and has some limestone lenses near the top. This may be equivalent to the top part of the Barriedale Limestone at Hobart or to the Woodbridge.
Glacial Formation. The next unit is a poorly-sorted, impure sandstone with numerous boulders, some fossil wood and some glauconite, and is 20 feet thick. is lithologically similar to the Risdon Sandstone of the Hobart section. The final formation is at least 95 feet thick and is a siltstone with rare erratics like the Ferntree Mudstone of Hobart with which it may be correlated. The section is terminated by a dolerite intrusion.

From this section on St. Pauls Dome there is a suggestion that sandstones like those in the fresh-water formation at Quamby Brook underlie the Berriedale Limestone which consequently would be missing or represented by Woodbridge-like rocks at Quamby Brook.

In the Killymoon Bore, just west of St. Marys (Hills, et al., 1922), is a limestone unit underlain by shaly mudstone and some conglomerate. This is underlain by a sandstone with coal, possibly wholly or partly equivalent to the fresh-water sandstone at Quamby Brook. Under this is a unit of sandstone with some shale and conglomerate and at the base is conglomerate. Correlation of these beds is doubtful.

At Rays Hill, just north of St. Marys, the Permian rests unconformably on Mathinna Group rocks and a hypersthene granite. The basal formation is a conglomerate with boulders of the underlying rocks. This is followed by an arkosic sandstone and this by a conglomeratic arkose which contains marine fossils and fragments of leaves and wood. The next unit is a mudstone with some fossils including brachiopods, gastropods, and ostracodes. The mudstone is overlain by a limestone with numerous fossils which include *Lyroporella*, *Streblotrypa* and *Eurydesma cordatum* var. *sacculum*. The presence of *Lyroporella* suggests a correlation with the Berriedale Limestone, a correlation supported to some extent by the presence of *E. cordatum* var. *sacculum*. The limestone is followed by fossiliferous shale and this in turn by glauconitic sandstone, correlated with the Risdon Sandstone.

Just south-east of St. Marys, a bore at Harefield passed through Permian beds. A green sandstone, probably the glauconitic Risdon Sandstone, is directly underlain by a thick formation of limestone and conglomerate. Beneath this is a thin formation of mudstone and then a formation of sandstone, shale and conglomerate with coal. The base is a sandstone resting on slate.

A mile or two further east Permian rocks are exposed in the roadcuttings on Elephant Pass, where the section has been measured by K. G. Brill. The basal formation, which is 16 feet thick, consists mainly of conglomerate and this contains angular to rounded pebbles of Mathinna Group rocks in a feldspathic sandstone matrix which is carbonaceous in places. It rests unconformably on folded Mathinna Group slates. One of the boulders shows grooving but the texture, structure and composition preclude a directly glacial origin and sug-
gest fresh-water conditions. It may be fluvi-glacial but even this is doubtful. The next formation consists mainly of sandstone with two conglomerate beds near the base, some carbonaceous siltstones and some coaly partings. Fragments of fossil plants are present and it is probable that this formation is of fresh-water origin. It is 100 feet thick. This is followed by 137 feet of siltstones and some sandstones with marine fossils and then by 144 feet of limestone with subordinate mudstone. The limestone is richly fossiliferous, and contains *Lyroporella* on two horizons, one 8 feet above the base and the other 44 feet above the base, and in addition it contains *Eurydesma cordatum* var. *sacculum*, *Fenestella*, *Colpora*, *Protoretepora*, *Stenopora*, *Martiniopsis*, spiriferids, *Linoproductus*, *Strrophalosia* and *Dielasma*, *Euryphyllum* and *Plerophyllum*, *aviculopectinids*, *Mourlonia* and crinoid plates. Crespin (letter, 28.2.1956) reported *Calcitornella* from the lower part of it. The limestone is followed by one foot of mudstone and then 3 feet of glauconitic sandstone, equivalent to the Risdon. This is followed by 92 feet of pebbly mudstone and sandstone, probably equivalent to the Ferntree Mudstone. The apparent absence or extreme thinness of Woodbridge-type sediments above the limestone and the comparative thinness of the Ferntree Mudstone is noteworthy (Brill, 1956).

A few miles further down the coast at Seymour a bore passed through Triassic then Permian sediments before penetrating granite. The basal Permian formation is a conglomerate with much granitic detritus and is 55 feet thick. Over this is 50 feet of sandstone, shale and some conglomerate and coal, corresponding perhaps to the second unit in the Elephant Pass section. This is succeeded by 42 feet of finegrained sandstone and then 220 feet of limestone, presumably equivalent to the limestone at St. Marys. The limestone is followed by 20 feet of green pebbly sandstone, probably the correlate of the Risdon, and this in turn is overlain by 80 feet of mudstone with minute fossils. Without more details than are given in the drillers' reports, correlation of this mudstone is impossible.

One of the bores (no. 3) (Hills et al., 1922) sunk during the search for coal at Llandaff near Friendly Beaches passed directly from "Triassic sandstone" onto granite. Whether the lack of Permian is due to non-deposition or to erosion in the earlier part of the Triassic Period is not known. Close to Friendly Beaches Permian rocks are exposed and some sections can be measured. The Permian rests on granite and commences with an arkose, with occasional rounded granitic boulders, which is very hard to distinguish from the granite in the field. The arkose is followed by a coarse-grained, micaceous, quartz sandstone with some pebbles of quartz and quartzite. This contains *Eurydesma cordatum*, *Chaenomya*, spiriferids including *Martiniopsis* and some gasteropods. The sandstone is overlain perhaps by a conglomeratic formation in which some beds
may be true tillites and others of glacio-fluvial origin. One bed shows well-developed imbrication with the long axes of the pebbles dipping east. The structure and association of the bed suggest a beach facing east, rather than a west-flowing stream. The tillite is followed by a thick limestone formation (Peter Limestone, Hill, 1955, figure 3), which is very rich in fossils. These include *Euryphyllum*, *Plerophyllum*, *Stenopora*, spiriferids, aviculopectinids, *Fenestella*, *Martiniopsis*, *Strophalosia*, *Polypora*, *Eurydesma cordatum* and *E. cordatum* var. *sacculum* *Dielasma*, *Protoretepora*, *Lyroparella*, *Taeniothaerus subquadratus*, *Platydictys* and *Stutchburyia*. The presence of *Lyroparella*, *E. cordatum* var. *sacculum* and *Taeniothaerus subquadratus* suggests correlation with Berriedale Limestone. The limestone is followed by a richly fossiliferous shale with many spiriferids including *Martiniopsis*, *Stenopora*, numerous fenestellid colonies, *Strophalosia*, *Chaenomys* and *Myonia carinata*. This shale is, at most, 100 feet thick. It is followed by an almost arkosic sandstone with a few marine fossils and glauconite (Hale and Brill, 1955, p. 234). It is only about 10 feet thick and its stratigraphic position suggests correlation with the Risdon Sandstone. The final formation in the section is a subgreywacke silstone very similar to the Ferntree Mudstone in Hobart with which it can be correlated.

One of the best sections available in Tasmania of beds below the Berriedale Limestone occurs at Darlington on the northern end of Maria Island (see text-figures 2 (c) and 4). Where studied in detail by K. G. Brill, the author, and others, the section does not extend to the base of the System as developed elsewhere in Tasmania although on the east coast of Maria Island the basal unconformity is exposed (see Clemes, 1920). It is stated by Lewis (1937) that the basal formation is a tillite and this may be so on the east coast. However, where the author has seen it in the cliffs on the north and south side of Reidle Bay, the eastern bay separating North from South Maria, it is a coarse-grained sediment but *Johnston* not a tillite as will be detailed a little later. The lowest formation exposed at Darlington is what Johnston (1902) and others have called the "Fratric Zone". It is 24 feet thick and consists of an alternation of erratic-rich sandstones and bryozoal siltstones. It contains *Stenopora johnstoni*, *S. tasmaniensis*, *Eurydesma cordatum*, *Conularia laevigata*, *Camptocrinus* and *Streblotrypa*. This is followed by a formation known as the "Pachydomus Zone" by Johnston (1902).

This is 50 feet thick and consists of several types of limestones in complicated cycles. It contains *Eurydesma cordatum* in large numbers, *Stenopora johnstoni*, *S. tasmaniensis*, *Calceolispongia*, *Streptorhynchus* and *Calcitornella*. *Eurydesma cordatum*, *Stenopora johnstoni*, *S. tasmaniensis* and *Calcitornella* suggest correlation with some part of the Dalwood Group of New South Wales, perhaps especially the Rutherford Formation. *Eurydesma cordatum* var. *sac-
culum is distinctly rare, especially when the hundreds of thousands of *E. cordatum* are considered. The "Eurydesma Zone" is followed by 5 feet of marine "tillite" with *Stenopora johnstoni* and *Eurydesma cordatum*. Over this is 1 foot 6 inches of plant-bearing carbonaceous siltstone, which is probably fresh-water and then 15 feet of sandstone and "tillite" extremely rich in spiriferids. This formation contains *Stenopora johnstoni*, *Eurydesma cordatum*, some *E. cordatum* var. *sacculum*, and numerous other fossils. The next formation, 66 feet thick, consists dominantly of carbonaceous siltstones with thin bands of quartz sandstone. It contains plant fragments, worm casts, petrified wood, *Vertebraria* and *Gangamopteris* or *Glossopteris*. This association of lithological types and fossils probably indicates fresh-water conditions of deposition for most of the formation, but the presence of *Conularia laevigata* near the top of the formation is puzzling. This is succeeded by 2 feet of tough sub-greywacke, mistaken by Montgomery (1898) for a tuff (see Johnston, 1902). The next formation is 115 feet thick and consists of an alternation of limestone and siltstone. This corresponds to Montgomery's "Productus Zone" as productids, mainly *Strophalosia*, are common. Fossils in the formation include *Euryphyllum cainodon*, *Stenopora*, *Fenestella*, *Polypora*, aviculopectinids, *Eurydesma cordatum*, *Neospirifer*, *Martiniopsis* and other spiriferids, *Conularia*, *Cladochonus*, *Pterotoblastus* and crinoids. The next formation is dominantly limestone with subordinate siltstone and meta-bentonite bands (Hale and Brill, 1955). The limestone is light grey to almost pink and very rich in crinoidal fragments. It is 115 feet thick. It is richly fossiliferous, the fossils including *Lyroporella*, *Taeniothaerus subquadratus*, *Pterotoblastus*, *Eurydesma cordatum* var. *sacculum*, *Platyschisma*, *Euryphyllum*, large *Martiniopsis subradiata*, *Stenopora*, *Strophalosia jukesi* and aviculopectinids. The presence of *Lyroporella*, *Pterotoblastus* and *Taeniothaerus subquadratus* indicates correlation with the Berriedale Limestone and the presence of *Eurydesma cordatum* var. *sacculum* in considerable numbers supports this. In Tasmania this variety is much commoner in the Berriedale Limestone and its correlates than lower in the sequence. This crinoidal limestone corresponds to Montgomery's (1898) "Crinoidal Zone" (see Johnston, 1902). It is overlain by 68 feet of highly fossiliferous calcareous siltstone lithologically very like the Grange Mudstone at Hobart. This contains *Cladochonus* and *Thamnopora* as well numerous other fossils. *Cladochonus* also occurs in the "Productus Zone" and Crinoidal Zone". The next formation is lithologically very like the Woodbridge Glacial Formation at Hobart and is 115 feet thick. It consists of sandstones and siltstones with occasional limestone bands or lenses. Fossils are common and include fenestellids, *Stenopora*, *spiriferids* including *Neospirifer*, "Spirifer" *avicula*, *Martiniopsis*, *Strophalosia*, aviculopectinids, *Stutchburia costata*, and *S. compressa*, *Mourlonia morrisiana*, *Myonia carinata* and
Chaenomya. The Woodbridge Glacial Formation is overlain by 45 (?) feet of somewhat glauconitic feldspathic sandstone in which the only fossils locally are plant stems and aviculopectinids. This corresponds in stratigraphic position with the Risdon Sandstone at Hobart and except for the presence of glauconite is lithologically like it. The final formation in this section is about 520 feet thick and consists dominantly of unfossiliferous sub-greywacke siltstone with three coarser bands, 35 feet, 190 feet and 400 feet above the base, which may correspond to some of the Risdon-type sandstones in the Ferntree Mudstone near Waddamana (Fairbridge, 1949). This final formation is lithologically very like the Ferntree Mudstone at Hobart.

At the northern side of Reidle Bay the unconformity at the base of the Permian is exposed in several places. Here the Permian rests on granite and the basal formation consists of an arkosic material with boulders of granite up to 6 feet across and some boulders of quartzite. This arkose is poorly bedded and the boulders are angular. A granitic cliff against which the arkose rests seems to be a remnant of the Permian landscape. The arkose becomes better bedded and the boulders more rounded and smaller the further away from the granitic cliff and the higher in the section one progresses. These beds seem to represent a cliff breccia cemented by arkosic sand and then successive shingle and even sandy beaches. On the southern side of this bay the pre-Permian surface of granite can be seen to have a relief of at least 50 feet and to be quite irregular. The basal formation is a coarse conglomerate with boulders several feet in diameter in a matrix of quartz and feldspar. Although some of the boulders are angular, many are rounded. They are mainly of granite and Mathinna-type quartzite. Again these beds appear to be cliff-base and beach deposits. Some beds of sandstone composed of angular fragments of quartz and feldspar occur in the conglomerates. Several hundred feet above these conglomerates occurs a crinoidal limestone with Lyroporella, Pterotoblastus and Eurydesma cordatum var. sacculum, correlated because of the presence of these fossils with the Berriedale Limestone. This is overlain by Grange-type mudstones, Woodbridge-type sediments and then a sandstone with occasional grains of glauconite which in other respects is very like the Risdon Sandstone. No measurements of this section have yet been made but the whole sequence appears to be thinner than that at Darlington.

THE NATURE OF THE BASAL FORMATION OF THE PERMIAN

In the past there has been a consistent idea that the basal formation in Tasmania is a tillite. The author accepted this idea without criticism in 1952.
Subsequent examination of sections in the East Coastal area has indicated that is not always true. At Wynyard, Quamby Brook and Lilydale the basal rock does seem to be a tillite in the strict sense, and at Wynyard includes varved shales (Banks, Loveday and Scott, 1955). At Wynyard the actual unconformity surface is exposed or can be dug out and as reported by David (1907) shows glacial striations. Some of these grooves seem to indicate ice moving from the north but others seem to show the reverse, and this problem is being attacked now. David (1907) stated that this glacial formation is 1,220 feet thick, but so far no complete section through it has been measured and the figure is thought to be too high due to rolling strata having been treated as having a single dip. Basal tillites are recorded from Point Hibbs, Mount Dundas, Mount Read, Mount Pelion, Mount Anne (Voisey, 1938 a for references) and on the Styx Range. These recorded occurrences need further checking.

The basal formations in the Latrobe and Native Plains area as revealed in bores vary considerably in character and are definitely not tillites in some places (Reid, 1924 for bore logs). At Spreyton, west of Latrobe, one bore (no. 17) penetrated to quartzites including some coarse beds which are probably part of the Owen Conglomerate, and in this bore the basal Permian beds consist of 14 feet of sandy sediment (an aquifer) and then a mudstone with occasional marine fossils. Another bore (no. 32) at Spreyton showed Ordovician limestone overlain by 20 feet of calcareous sandstone, then 100 feet of sandy mudstone. A little east of this at Tarleton (Bore 18) a quartzite (probably Ordovician) is overlain by 6 feet of grey sandstone, 38 feet of fossiliferous mudstone and then pebbly mudstone. Another bore at Tarleton (no. 2) shows the Ordovician limestone succeeded by 18 feet of conglomerate, then 66 feet of conglomerate and sandstone with marine fossils. A bore at the old Racecourse, Latrobe (no. 24) shows 3 feet of conglomerate, 2 feet of mudstone and 28 feet of conglomerate resting on diorite or basalt, and finally, at West Sassafras (Bore 22) 17 feet of conglomerate, 2 feet of mudstone and 91 feet of conglomerate overly a diorite (?) with quartz veins. It must be emphasized that in most cases the rock identifications are those of drilling foremen and are not, therefore, completely reliable, but only in the Tarleton no. 2, the Latrobe no. 24 and the West Sassafras no. 22 bores is it in the least probable that tillite is the basal rock in the Permian System.

A little further south in the Native Plains area, 5 bores reached pre-Permian strata. In Bore 12, Native Plains, a quartzite, probably Ordovician, is followed by 86 feet of pebbly mudstone. Bore 27, east of Merseylea Bridge, is of considerable interest as in it a quartz conglomerate, probably Ordovician, is directly overlain by 3 feet of tasmanite which is followed by mudstone. Near Hogg’s Bridge, Native Plains, in Bore 13, a quartzite, Ordovician (?) is succeeded by
5 feet of water-worn pebbles, 5 feet of mudstone, then 28 feet of pebbly mudstone. In this bore the tasmanite is 105 feet above the base of the Permian. In Bore 14, Native Plains, a quartzite is followed by 8 feet of pebbly mudstone with pebbles of quartzite predominant and then by 6 feet of pebbly mudstone with quartzite boulders still present. The tasmanite is 200 feet approximately above the base of the Permian in this bore. Finally, in Bore 15, Native Plains, a dark slaty mudstone, probably Ordovician in age, is overlain by 9 feet of sandy mudstone, 35 feet of pebbly mudstone and 5 feet of conglomerate with the tasmanite 115 feet above the base. Thus in this area a basal tillite may be present in Bore 12 and Bore 14 but even this is doubtful and the basal formations show considerable lithological diversity. Of especial interest is the variation in height of the tasmanite above the base of the system. If the tasmanite is on one horizon, as seems likely by reason of similarity in associated rocks, it seems to indicate a relief of the pre-Permian surface of at least 200 feet, with progressive overlap from the east. Alternatively it may indicate a progression of the tasmanite magnafacies from west to east with time if the tasmanite represents extremely limited conditions as far as down-dip extent is concerned. To resolve these alternatives detailed palaeontological data, which are not available, are needed.

The basal beds at Avoca, Rays Hill and Elephant Pass are conglomerates which are too well-rounded and sorted to be considered as true fillites, and conglomerates are reported as the basal rocks in the Harefield and Seymour Bores. They may be fluvo-glacial conglomerates but there is no real evidence on this point. At Friendly Beaches an arkose rests on granite, and where the author has seen the unconformity on Maria Island the basal beds are probably cliff-sceee breccias and beach conglomerates. Finally, at Ida Bay, the basal beds are marine sandstones with erratics and are probably of glacial origin but not true tillite.

Evidence available thus suggests that while tillites are present in some places at the base of the System, in other places the beds indicate only indirectly the presence of glaciers, and in the east coast area and at some places near Latrobe there is little if any evidence of glacial contribution to the basal sediments.

The interpretation of these variations in the character of the basal beds in terms of palaeogeography cannot be made until more evidence is available on their age. It is possible that the tillites are older than the conglomerates or other rock types but there is no real evidence of this yet.

The age of the tillites has been a subject of some controversy in the past. At Wynyard the top of the tillite is at most 40 feet below a bed of tasmanite containing foraminifera which Crespin (1947) tentatively correlated with the
lower part of the Maitland Group of New South Wales. There is a possibility that the tasmanite at Wynyard is contemporaneous with the tasmanite at Quamby Brook, which lies beneath a limestone containing Calcitornella and Eurydesma cordatum which can best be correlated with the foraminiferal limestone in the Rutherford Formation of the Dalwood Group of New South Wales. If this possibility is correct, the Wynyard Tillite is pre-Lower Artinskian. In the Quamby Brook area the fossiliferous limestone is underlain by 300 feet of siltstone including the tasmanite and then by the tillite. At Lilydale the tillite also underlies at some depth a limestone with Calcitornella and other foraminifera, indicating correlation with the limestone in the Rutherford Formation of New South Wales (see later). Thus at Quamby Brook and Lilydale the top of the tillite is Lower Artinskian or older and this is possibly also the case with the Wynyard Tillite. The age of the base of the tillite is still conjectural as no fossil evidence can yet be advanced.

THE “EURYDESMA LIMESTONE” AND ITS CORRELATES

In many places in Tasmania Eurydesma-rich limestones occur more or less close to the base of the Permian System and in several places lie some hundreds of feet below much thicker limestone (see text-figures 2, 3 and 4). The Eurydesma limestone occurs at Quamby Brook, Beaconsfield, Lilydale, Maria Island, Woody Island, Porters Hill and Berriedale, the latter two places close to Hobart. Calcitornella stephensi has been recorded from these at Lilydale and Woody Island, found by the author in those from Quamby Brook and Beaconsfield, and Calcitornella confirmed in the Quamby Brook and Woody Island occurrences by Miss Crespin (letter 23.2.1956), who also found it in the Porters Hill and Maria Island occurrences. This leaves unchecked only the occurrence on the Glen Lusk Road at Berriedale (Voisey, 1938 a) but because of its stratigraphic position there is reasonable probability that it is equivalent to the other occurrences. With Calcitornella stephensi at Lilydale occurs Hemi-gordius schlumbergi and Geinitzina triangularis, an association typical of the foraminiferal limestone just above the base of the Rutherford Formation in New South Wales (Crespin, 1947; Osborne, 1949), of the Dilly Stage in Queensland and of the Callytharra Limestone in the Carnarvon Basin in Western Australia (Crespin, 1947).

In the “Eurydesma Limestone” on Maria Island Stenopora tasmaniensis and S. johnstoni occur and these have also been recorded from Woody Island, the limestone at the shoreline, Porters Hill, and from the Bundella Mudstone at Mount Nassau (Crockford, 1952; Banks, Hale and Yaxley, 1955). In New
South Wales *S. johnstoni* occurs only in the Allandale and Rutherford Formations.

A fossil which occurs in or just above these limestone at Woody Island, Porters Hill and Mount Nassau is *Keeneia platyschismoides*, a species which is also found only in the Dalwood Group of New South Wales.

The fossil for which the limestones are known is *Eurydesma cordatum* and in some places, e.g. Maria Island, it is present literally in thousands, forming shell banks. This species is not restricted to these limestone as it ranges from the basal sandstones at Ida Bay up into the Woodbridge Glacial Formation, but it is most common at the level of the "Eurydesma Limestone". In New South Wales its range is also considerable as it occurs in both the Dalwood Group and the Branxton Sub-group, but it is much more common apparently in the Dalwood Group. Associated with this species on Maria Island are rare specimens of *E. cordatum* var. *sacculum* which in New South Wales occurs only in the Dalwood Group. However, in Tasmania it ranges up into the Berriedale Limestone where it is as common as *E. cordatum* itself.

Thus foraminifera, bryozoa, pelecypods and gastropods all indicate correlation of the limestone with the Dalwood Group and more particularly with some part of the Allandale or Rutherford Formations. The foraminifera also suggest correlation with the Dilly Stage in Queensland and the Callytharra Limestone in Western Australia (see table 1).

**THE BERRIEDALE LIMESTONE AND ITS CORRELATES**

The Berriedale Limestone as understood in this paper consists of three divisions in a number of places. In the Mount Nassau section there is a basal siltstone-rich division with beds of limestone becoming more numerous and thicker upwards. The middle division is dominantly limestone with siltstone and meta-bentonite beds, and the upper division is typically a creamy, richly fossiliferous, calcareous siltstone. The formation is sharply demarcated from the underlying and overlying sandstones but it is difficult on our present knowledge to make sharply-defined divisions within the formation because of the gradation from one division to another. In the Porters Hill section the formation consists dominantly of the creamy, fossiliferous, calcareous siltstone but contains intercalated limestone beds. Here, because of its different lithology, it has been called the Grange Mudstone. It is hoped that the evidence for the equivalence of the Berriedale Limstone and the Grange Mundstone will shortly be presented elsewhere.

On Maria Island the three divisions are present as at Hobart, the lowest one having been referred by Montgomery (1898) as the "Productus Zone" (see
### TABLE I
CORRELATION OF TASMANIAN WITH OTHER AUSTRALIAN SECTIONS

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Johnston, 1902), the middle one as the “Crinoidal Zone” and the uppermost one not differentiated. At Friendly Beaches the formation consists of a limestone unit followed by a unit of creamy, calcareous siltstone, and at St. Marys there is a fossiliferous siltstone, then the main limestone and then a shale bed which may represent part of the uppermost division at Hobart. At Avoca there is a fossiliferous siltstone and then a thin limestone which may represent more of the formation than just the limestone division at Hobart. The correlation of the overlying fossiliferous siltstones at Avoca is not yet clear.

In the Mount Nassau and Berriedale sections the Berriedale limestone (middle division) contains numerous fossils, including *Fenestella granulifera*, *Polypora woodsi*, *Lyroporella*, *Taeniothaerus subquadратus*, *Strophalosia jukses*, *Eurydesma cordatum* and *E. cordatum* var. *sacculum*, *Calceolispongia noetlirtgi* and *Pterotoblastus*. *Taeniothaerus subquadratus* occurs in this formation at Glenorchy near Hobart (the type locality for the species). In the Grange Mudstone a common fossil is *Wyndhamia dalwoodensis* and this also occurs in presumably the same formation at Cape Paul Lamanon (Voisey, 1938 a) and near Waddamana (Fairbridge, 1959). The Grange Mudstone also contains *Polypora woodsi* in its type section, at Bronte and near Waddamana.

On the south end of Maria Island the “Crinoidal Zone” contains *Lyroporella*, *Eurydesma cordatum* var. *sacculum*, and *Pterotoblastus*. On the north end of Maria Island the “Productus Zone” contains *Pterotoblastus* and *Fenestella chapmani*, while the “Crinoidal Zone” contains a zone rich in *Taeniothaerus subquadратus* fairly close to the base and then a zone rich in *Lyroporella* a little higher up. *Cladochonus* occurs in the *T. subquadратus* zone and *T. subquadратus* occurs rarely in the *Lyroporella* rich zone. *Eurydesma cordatum* and especially *E. cordatum* var. *sacculum* occur in the “Crinoidal Zone” as also do *Pterotoblastus* and *Calceolispongia*. Higher in this formation in a Grange-type mudstone there is a prominent bed very rich in *Cladochonus* and *Thamnopora*. Near Friendly Beaches the limestone contains *Plerophyllum* and *Euryphyllum*, *Lyroporella*, *Taeniothaerus subquadратus* and *Eurydesma cordatum* var. *sacculum*. In the Elephant Pass section, near St. Marys, the limestone contains both *Euryphyllum* and *Plerophyllum*, *Lyroporella*, *Taeniothaerus subquadратus* and *Eurydesma cordatum* var. *sacculum*. Miss Crespin has recently (letter, 28.2.1956) identified *Frondicularia*, *Calcitornella* and *Trepecilopsis grandis* from the limestone low in the section. At Rays Hill, St. Marys, *Lyroporella* and *E. cordatum* var. *sacculum* have been found and *Lyroporella* occurs in limestone at Fingal. Finally, at Avoca, *Cladochonus* occurs in the fossiliferous siltstone below the limestone and the limestone contains *Thamnopora*, *Lyroporella* and *Pterotoblastus*. The limestones on Maria Island (not the “*Eurydesma Zone*” limestones, however), at Friendly Beaches, St. Marys, Fingal and Avoca are considered to be at least partly equivalent to the
Berriedale Limestone because of the common presence of one or more of the fossils Cladochonus, Thamnopora, Lyroporella, Taeniothaeus subquadraatus and Pterotoblastus which at present appear to be restricted to the limestone or the fossiliferous siltstone beds associated with it. None of these fossils occurs in the lower limestone or in the limestone in the Woodbridge Glacial Formation (for correlation see text figures 2, 3 and 4).

The presence of the foraminifera reported by Crespin in the limestone at St. Marys may indicate correlation of the lower part of the limestone with the Cattle Creek Stage at Springsure, Queensland. Crespin says of the assemblage (letter, 28.2.1956), “Many are identical with species from Cattle Creek, Springsure, Queensland”. Cladochonus and Thamnopora in association occur almost at the top of the Berriedale and in New South Wales occur in the Mulbring Formation, in the Macleay Series, in the Yessabah Limestone and the Drake Series, while in Queensland they occur in the Condamine Block at Warwick, the Biarraville Formation in the Esk Valley, the Yatton Limestone (see Hill, 1955, figure 4) and the Ingelara Beds (Campbell, 1953). Thus they may indicate correlation of the upper part of the Berriedale Limestone with the Mulbring Formation in New South Wales (although the Macleay Series, Drake Series and Yessabah Limestone are considered equivalent to the Lower Marine Dalwood Group by Voisey, 1934; 1936; 1938b, the author wonders whether this correlation is sound; Raggatt and Fletcher, (1937) pointed out that of the 38 species noted from the Drake Series, 34 are Upper Marine species). In Queensland the correlation seems to be either with the Cattle Creek Stage or the Ingelara Stage.

The bryozoa from the Berriedale include Fenestella granulifera and Polypora woodsi (Crockford, 1952). F. granulifera occurs in the “Fenestella Shales” of the Branxton Sub-group in New South Wales, and in the Biarraville Formation (Campbell, 1952) and at Lakes Creek in Queensland, the former of which is regarded (see Hill, 1955) as equivalent to the Ingelara Beds. In Eastern Australia Polypora woodsi has been recorded by Crockford (1952) from the “Fenestella Shales” and Ulladulla Shales of the Maitland Group, and in Queensland from the Dilly Stage and Lakes Creek. Thus the bryozoa suggest correlation with some part of the Branxton Sub-group of New South Wales but correlation with Queensland is not indicated with certainty.

The brachiopods from the Berriedale Limestone include Linoproductus cora var. farleyensis which has been recorded from Grange Mudstone at Waddamana (Fairbridge, 1949). In New South Wales this ranges through the Dalwood Group and occurs also in the Macleay Series. Strophalosia jukesi occurs in the Berriedale Limestone in the Hobart district and is closest to forms of Strophalosia from the Cattle Creek Stage in Queensland (Maxwell, 1954, p. 535). Hill...
(1950, p. 12) referred to *Anidanthus springsurensis* from Ben Lomond, Tasmania, and the author has recently seen the specimen in the British Museum of Natural History. It is in a matrix very like the limestone at Avoca which is only a few miles away and the probability is high that it comes from the Berriedale Limestone equivalent in this locality. This species is found in the Yessabah Limestone, Macleay Series, and the Drake Series in New South Wales, and from beds correlated with the Cattle Creek Stag in Queensland (see Hill, 1950; 1955). Voisey (1938 a) recorded *Wyndhamia dalwoodensis* from the Grange Mudstone in two places and this species was first described from the Branxton Sub-group in New South Wales. Finally, *Taeniothaerus subquadratus* which seems to have a restricted range even within the Berriedale Limestone occurs in New South Wales in the Emu Creek and Drake Series and in Queensland in the Dilly and Cattle Creek faunas on their equivalents (see Hill, 1950; 1952, and 1955). The association of *Anidanthus, Linoproductus* and *Taeniothaerus* suggests a Cattle Creek correlation rather than one with the Dilly (Hill, 1952, p. 42).

There are numerous pelecypods in the Berriedale Limestone but they are of doubtful value for interstate correlation. *Eurydesma cordatum* and *E. cordatum var. sacculum* both occur in almost equal numbers but neither is common. *Eurydesma cordatum* apparently ranges in New South Wales from the Dalwood Group into the Branxton Sub-group and *E. cordatum var. sacculum* in New South Wales is regarded as a Dalwood Group index fossil. This fœm together with *Linoproductus cora var. farleyensis* and *Calcitornella* suggest that the Berriedale may range down into the top of the Dalwood Group but more work is needed on this problem before this can be definitely stated. *Aviculopecten mitchelli* is known from the Berriedale Limestone and from the Woodbridge Glacial Formation where in occurs with *Deltoplecten leniusculus*. Both of these species were, until recently, regarded as index fossils for the Dalwood Group, but have recently been found on the coast of New South Wales in beds correlated with the lower part of the Branxton Sub-group (see Fletcher, in Hill, 1955).

Summarizing the evidence for correlation with other Eastern Australian Permian sections, it seems that the Berriedale Limestone is equivalent to at least part of the Branxton Sub-group and may extend a bit lower than this while it may be equivalent to the Cattle Creek and Ingelara Stages in Queensland, the base being approximately of Cattle Creek age and the top of Ingelara age.

When the problem of correlation with Western Australia is considered more difficulties arise. The foraminifera from St. Marys indicate correlation with the Callytharra Limestone (Teichert, 1952, p. 122) and at first sight this is supported by the presence of *Lyroporella, Pterotoblastus* and *Aviculopecten sub-
*Quinquelineatus*, the last of which is used by Thomas and Dickings (1954) as an index fossil for this formation and its correlates. However, the *Lyroporella* is a different species from that described by Crockford (1952), and *A. subquinquelineatus* is not restricted in Eastern Australia, where it is known in the Maitland and Dalwood Groups. If the identification of *Fenestella chapmani* from the “Productus Zone” on Maria Island is correct, this is another species suggesting correlation with the Callytharra Limestone (Crockford, 1952). According to Teichert’s (1952) fossil lists, *Cladochonus* and *Thamnopora* occur together only in the Bulgadoo Shale and the only horizon on which *Taeniothaerus subquadratus* and *Calceolispongia* occur together is in the Wandagee Formation. It seems best, in view of the conflicting evidence, to leave correlation with Western Australian sections until the Western Australian elements of the Tasmanian fauna are studied in detail (table 1).

**CORRELATION OF THE WOODBRIDGE GLACIAL FORMATION**

Within the state this formation is a distinctive lithological unit and so far no really diagnostic fossils are know. The only fossil used to date for inter state correlation is *Stenopora crinita* which is recorded by Crockford (1952) from Eaglehawk Neck and Fitzgerald but is in fact much more widespread. In New South Wales this occurs in the Muree and Mulbring Formation near the top of the Maitland Group.

**CORRELATION OF THE RISDON SANDSTONE WITHIN THE STATE**

Both the Woodbridge and Ferntree Formations, between which the Risdon Sandstone occurs, are of a distinctive lithology and so also is the Risdon Sandstone itself. Until recently, however, the identification of the Risdon Sandstone in the north-eastern part of the state was impossible. Then Brill (see Hale and Brill, 1955) identified glauconite in a sandstone at St. Marys and subsequently in smaller quantities in a sandstone, recognizable as the Risdon by its lithology and stratigraphic position, at Friendly Beaches. Subsequently glauconite has been recognized in Risdon Sandstone as far south as the southern half of Maria Island and as far west as Avoca. The proportion of glauconite in the Risdon Sandstone decreases both to the west and to the south of St. Marys. The sandstone on the southern half of Maria Island is typical of the Risdon except for the presence of 1-2% of glauconite.
THE WESTRALIAN ELEMENT IN THE TASMANIAN PERMIAN FAUNA

One of the surprising features that has emerged from the work done in the last few years has been the discovery of a number of genera of distinctly Western Australian aspect which are not so far known elsewhere in Eastern Australia. The distribution of *Lyroporella* has already been detailed and can be briefly summarized as lying entirely within the Berriedale Limestone in north-eastern, eastern and south-eastern Tasmania. In Tasmania it is apparently limited to a limestone facies and perhaps even to limestones relatively rich in crinoid fragments. *Streblotrypa* has a wider stratigraphic range, being known from the formations below the “Eurydesma Zone” on Maria and Woody Islands up to and into the Berriedale Limestone at Fingal, St. Marys, Maria Island and Hobart. *S. marmionensis* is present in the Satellite Siltstone on Woody Island (Banks, Hale and Yaxley, 1955). The genus seems to occur in both limestones and richly fossiliferous siltstones.

*Calceolispongia* was recorded some years ago as *Dinocrinus noetlingi* from the Berriedale Limestone at Hobart (Sieverts-Doreck, 1942) but is very widespread and the characteristic basal plates are known from the “Erratic Zone” on Maria Island up to the Berriedale Limestone and its equivalents, where they are very common. They have been identified from Hobart, Woody Island, Maria Island and Friendly Beaches. More recently *Jimbacrinus* has been found in the Satellite Siltstone on Woody Island and occurs also on Maria Island, in formations below or just above the “Eurydesma Zone” (Banks, Hale and Yaxley, 1955). Finally, *Pterotoblastus* has been recognized from its radials with long spines in the Berriedale Limestone at Hobart, Maria Island and Avoca. It usually occurs in the richly fossiliferous siltstones associated with the limestone but on Maria Island occurs in the limestone itself.

Thus certain Bryozoa and Echinodermata indicate some faunal connection between Western Australia and Tasmania during part of the Sakmarian and Artinskian Epochs. This connection does not seem to have persisted until the time of deposition of the Woodbridge Glacial Formation as the known faunal relationships of these two phyla as represented in the Woodbridge are entirely with Eastern Australia.

VULCANISM

In the author’s paper (Banks, 1952, p. 72) it was noted that the evidence of vulcanism in the Permian System in Tasmania was lacking or unsatisfactory. Examination of Montgomery’s (1898, p. 23) “tuff” from Maria Island in the
field and in thin section has shown that it is a sub-greywacke, of a type common in the Permian in Tasmania. There is no evidence at all that it is volcanic. Since publication of the earlier paper rocks probably of volcanic origin have been identified by Hale and Brill (1955) in the Berriedale Limestone. In the type section of the limestone three thin beds of meta-bentonite occur and a few miles to the south-east at Glenorchy as many as thirteen have been found. The meta-bentonite beds also occur in the "Crinoidal Limestone" on Maria Island, but have not yet been identified elsewhere. The source of these volcanic ashes is not yet known.

SUMMARY AND CONCLUSIONS

By combining sections from near Maydena, Woody Island and Hobart a composite section covering all but the highest formation in the Permian System in Tasmania can be built up. This extends the previously known section considerably downwards so that the sequence below the Berriedale Limestone can be established. In broad outline this consists of a basal tillitic or conglomeratic formation followed by carbonaceous siltstones which contain glendonites in some places and then fossiliferous sandstones, siltstones and "tillites" including a limestone horizon rich in *Eurydesma cordatum*. Above these is a sequence of marine sub-greywacke siltstone and "tillite" with intercalated fresh-water quartz sandstone and carbonaceous siltstone. Above these comes the Berriedale Limestone with its rich fauna including *Lyroporella, Taeniothaerus sub quadratus* and *Pterotoblastus*.

Comparison of sections in north-western, northern and eastern Tasmania with that at Hobart shows the wide distribution of the *Eurydesma*-rich limestone, and the common occurrence of a fresh-water formation or intercalated marine and fresh-water beds just above it. In the eastern part of Tasmania the fresh-water beds are followed by the Berriedale Limestone but this is absent or represented by other types of sediment at Quamby Brook and in the west and north-west. In many places in eastern Tasmania the Woodbridge Glacial Formation is thin or absent and the Risdon Sandstone is glauconitic.

The basal formation varies somewhat in lithology. In places it is a tillite, in others, or glacial origin, but in some places near Latrobe and in eastern Tasmania there is little, if any, evidence of glacial contribution to the basal sediments. The reasons for this variation are not known.

The *Eurydesma*-rich limestone contains, in addition to *E. cordatum, Stenopitra johnstoni, S. tasmaniensis, Calcitornella stephensi, Hemigordius schlumbergi* and *Geinitzina triangularis*. These fossils indicate correlation of this limestone...
with the Callytharra Limestone of Western Australia, regarded as basal Artinskian by Teichert (1952), with the Rutherford or Allandale Formation of New South Wales, and with the Dilly Stage of Queensland. The Berriedale Limestone contains in various places Calcitornella, Trepeilopsis grandis, Frondicularia, Cladochonus, Thamnopora, Fenestella granulifera, Polypora virga, P. woodsi, Lyroporella, Anidanthus springsurensis, Linoproductus cora var. farleyensis, Strophalosia jukesii, Wyndhamia dalwoodensis, Taeniotaeris subquadratus, Eurydesma cordatum, E. cordatum var. sacculum, Aviculopecten mitchelli, A. subquinqueineatus, Deltopecten leniusculus and Pterotoblastus. On the whole these suggest correlation with the Branxton Sub-group of New South Wales and the Cattle Creek and or Ingelara Stages of Queensland, while some of the species suggest that it may range down and be partly equivalent to the top of the Dalwood Group in New South Wales or the Callytharra Limestone in Western Australia. Teichert and Fletcher (1943) have suggested that the Branxton Sub-group is still Artinskian. These correlations are summarized as table 1.

The Tasmanian Permian fauna is dominantly Eastern Australian in character but contains a few genera unknown elsewhere in Eastern Australia but occurring in Western Australia. These are the bryozoa Streblotrypa and Lyroporella and the echinoderms Pterotoblastus, Calceolispongia and Jimbacrinus. Streblotrypa ranges in Tasmania from below the Eurydesma limestones up into the Berriedale Limestone, while Lyroporella is restricted to the Berriedale. Jimbacrinus is so far known only from below the Eurydesma limestone, Calceolispongia from below the Eurydesma limestone up into the Berriedale, Limestone, and Pterotoblastus only from the Berriedale. Thus no genera of Westralian aspect are known from the Woodbridge Glacial Formation or higher formations.

The only evidence of vulcanism is the occurrence of a number of beds of meta-bentonite in the Berriedale Limestone in the Hobart district and on Maria Island.

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STRATIGRAPHY OF TASMANIAN LIMESTONES

by

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THE STRATIGRAPHY OF TASMANIAN LIMESTONES

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INTRODUCTION.

Limestone occurs in Tasmania on numerous stratigraphic horizons. Precambrian or Lower Cambrian dolomites occur in the north-western, central and south-eastern parts of the State and are commonly thick, and are dealt with in the previous section.

Calcareous rocks are uncommon in the Middle and Upper Cambrian Dundas Group, but they do occur. The thick Gordon Limestone, of Lower Ordovician to probably Lower Silurian age, is very widespread except in the north-eastern part of Tasmania and contains some high-grade limestones as well as some dolomites. The Eldon Group, of Silurian and Lower Devonian age, is known to contain several thin, economically insignificant limestones. Of more importance are the Permian limestones which have a wide distribution in the eastern half of Tasmania, but no high-grade limestones are known from this system. Finally, Cainozoic limestones occur fringing the north-western part of the State, where they occur up to a couple of hundred feet above sea-level, and on the Bass Strait islands.

CAMBRIAN SYSTEM.

Limestones are uncommon in Tasmanian rocks of known Cambrian age, i.e., in the Dundas Group. Taylor (1955, p. 55) noted grey, impure limestones associated with purple slates and tuff bands south of the mouth of the Spero River and remarked on the resemblance of the slates to those in the Dundas district. Until the structure and stratigraphy of the area are better understood it would be better to leave the age of these limestones undecided.

Bradley (1956, p. 94) regarded a limestone east of Lake Dora on the West Coast Range in a quartzose sequence close to the Precambrian as Gordon Limestone in a thrust syncline lying between the thrust-mass of the Dundas Group and the under-thrust mass of Precambrian. The situation at this locality is that the Precambrian quartzites, folded and even overfolded to the south-east, are overlain by west-dipping crenulated chlorite schists and then, less than 100 feet stratigraphically above the contact, by lenses of calcareous material, less than 10 feet thick. The calcareous rocks are followed by quartz chlorite schist, 40 feet thick. The next formation in the sequence is cross-bedded, and a study of the cross-bedded sets indicates that the beds are dipping and facing west. The calcareous rock itself is a dolomitic breccia which has suffered silicification subsequent to brecciation. No fossils could be detected in it. While Bradley's hypothesis cannot be rejected on the available
Fig. 3.—Ordovician Limestones.
LIMESTONES IN TASMANIA

There is no positive evidence for it, no fossils have been found in the dolomite and no independent evidence of thrusting was found in the field.

The schistosity in the beds above the unconformity and the brecciation of the dolomite may equally well be due to slight movement on the unconformity surface if the thin lenses of calcareous rock were originally low in the Dundas Group. The rocks associated with the lenses bear no lithological resemblance to rocks of the Junee Group associated with the Gordon Limestone. Thus, while Bradley's hypothesis is a possible one, the hypothesis that the calcareous lenses are in the lower part of the Dundas Group is as probable, perhaps more so, than Bradley's, and leads to a simpler, more probable structure.

Montgomery (1896) recorded limestone at Penguin but gave no locality. In 1899, Smith noted that the shaft of the old Penguin Mine cut through a hard silicified dolomite and Twelvetrees (1903b, pp. 4-6) regarded it as a "9-feet band of mineralized dolomite." If this is a sedimentary rock, and as no evidence on this point is presented, the possibility of its being gangue material cannot be overlooked, it is associated with lavas, tuffs and breccias lithologically like the Dundas Group correlates occurring just to the south along the strike in the Dial Range.

ORDOVICIAN SYSTEM.

Introduction.

Ordovician limestones are the most important actual and potential sources of lime within Tasmania. Their wide distribution is shown in text-figure 3.

The Ordovician System is represented in Tasmania by the Junee Group which consists, where fully developed, of at least five formations, as shown in text-figure 4.

As pointed out elsewhere (Carey and Banks, 1954), the Junee Group rests unconformably on older rocks in a number of places but the only place where fossils are known to occur in the basal beds of the Jukes Breccia is near Adamsfield, where trilobites, inarticulate brachiopods and gastropods (including *Scaevogyr*a) occur. The age of this assemblage is not yet known with any accuracy, the *Scaevogyr*a indicating an Upper Cambrian or Lower Ordovician age.

The first abundant fossils of which the age is known occur in the Caroline Creek Sandstone which contains *Etheridgaspis, Tasmanocepha*lus, *Asaphellus lewisi, Carolinites bulbosa, Prosopiscus subquadratus*, &c. (Kobayashi, 1940b), at Caroline Creek, near Railton. These indicate a Lower Ordovician age. In the Florentine Valley area the Florentine Valley Mudstone contains *Asaphopsis, Tasmanocephalus, Asaphellus*, and *Carolinites* (Opik, 1951), as well as *Tritoechia lewisi* (Brown, 1948), which indicates an Upper Cambrian age. The first abundant fossils of which the age is known occur in the Caroline Creek Sandstone which contains *Etheridgaspis, Tasmanocepha*lus, *Asaphellus lewisi, Carolinites bulbosa, Prosopiscus subquadratus*, &c. (Kobayashi, 1940b), at Caroline Creek, near Railton. These indicate a Lower Ordovician age. In the Florentine Valley area the Florentine Valley Mudstone contains *Asaphopsis, Tasmanocephalus, Asaphellus* and *Carolinites* (Opik, 1951), as well as *Tritoechia lewisi* (Brown, 1948), which indicates an Upper Canadian age. At Adamsfield the basal beds of the Gordon Limestone contain *Manchuroceras, Suecoceras, Piloceras, Utoceras* and *Allocotoceras* (Teichert and Glenister, 1953), which also are Upper Canadian. The age of the top of the Gordon Limestone is not yet accurately established. In the Florentine Valley the top beds in them. Hill (1955) recorded the corals *Tetradi*um dendroides, *T. tasmaniense, T. conjugatum, ? Lichenaria, ? ramosa, ? Nyctopora, and ? Protarea from the
SUCCESSION IN JUNEE GROUP
(THICKNESSES APPROXIMATE MAXIMA ONLY)

Fig. 4.—Junee Group Succession.
Smelters Quarry, Zeehan, and assigned a Trentonian age to them. These are not, however, the topmost beds as about 700 feet of fossiliferous limestone overlies these and underlies the Crotty Sandstone. The limestone in the Smelters Quarry at Queenstown with corals such as Tetradium tasmaniense, T. conjugatum, T. dendroides, T. syringoporoides, Alveolites sp., Protarnea richmondense and Acidolites was dated by Hill (1955) as Trentonian or Richmondian, but these corals do not occur in the uppermost beds. At Bubbs Hill Plasmaporella, Tetradium, Aulopora, Eofletcheria ida and Nyctopora are present, and Hill (1955) regarded these also as Upper Ordovician. Thus, published evidence suggests that the Gordon Limestone probably ranges into the Richmondian and perhaps higher. At Zeehan and Bubbs Hill where the contact with the overlying Crotty Sandstone is well exposed the contact is seen to be gradational and no evidence of disconformity has yet been found.

Gordon Limestone.

A comprehensive study of the Junee Group and particularly of the Gordon Limestone is in progress and it is hoped the results will be available shortly. It seems undesirable to define the Gordon Limestone out of context so that this definition will be published with that of other formations.

This limestone is typically medium to dark-grey in colour but light-grey, pink, and almost white varieties occur without, as far as is known, any stratigraphic significance. They are compact rocks normally brittle, although some coarse-grained varieties tend to be tougher than others. The fine-grained limestones tend to develop conchoidal fracture, but coarser types usually have an even fracture. The rock is impervious in bulk, but, due to the common presence of solution cavities and passages, allows ready passage of water. Its solubility normally results in the limestone having a subdued topography, often close to local base-level. Where the limestone topography is still above local base-level a karst topography is developed, as at Gunns Plains, Mole Creek-Liena area, Maydena area and Ida Bay.

The limestone is normally of high purity, in many places containing over 90 per cent of calcium carbonate as will be seen in analyses quoted in later chapters. At the Iris Bridge, Florentine Valley, Queenstown and Zeehan, however, there are arenaceous and argillaceous beds in it, but volumetrically these do not seem to be very significant. More significant are beds of dolomitic limestone. It seems probable that the presence of magnesian limestone in this formation was recognised as early as 1886 by Thureau, but its widespread occurrence has been realized only recently. Noakes et al (1954) reported the occurrence of dolomite on some horizons at Beaconsfield and it has been recognized since in the limestone with Maclurites and Girvanella in the Florentine Valley. Sandy-looking patches, typical of dolomitic limestones are widespread and it is probable that as more limestones are tested in the field and sectioned that dolomite will be found to have a wide occurrence in this formation. Silica is a common impurity and takes the form of chert nodules which, at Flowery Gully, are restricted enough stratigraphically for Noakes et al (1954) to refer to a "Chert Zone". The nodules often show a bedding and jointing control. Such chert nodules occur in most major areas of Gordon Limestone. The chert
is medium to dark-grey and as such is readily distinguished from
the light-grey, white or pink chert bodies in the Berriedale Lime-
stone. These nodules are not the only source of silica impurity in
the limestone as there are elongated siliceous rods which may be
sponge spicules (Dallwitz in Noakes et al., 1954), and other forms of
dispersed silica remaining as a residue after acid treatment. Not
infrequently fossils are silicified and beekitized but to a large extent
this is a surficial effect only and silicification frequently does not
extend more than an inch or two below the surface. In quite a few
places spherical or sub-spherical bodies of radiating pyrite and
chalcopyrite up to 1½ inches in diameter occur in the limestone well
away from areas of mineralization, e.g., in the Florentine Valley, so
that they seem to be syngenetic. The limestone usually emits a foetid
odour when struck and in places bituminous and carbonaceous (gra-
phitic) streaks occur in it. In places it contains sufficient iron to
produce reddish and purplish films on joint and cleavage surfaces as
the limestone weathers and while this is particularly well-displayed
at Melrose and Railton, it does occur elsewhere. Terra rossa is not
the normal weathering product of the limestone under Tasmanian
climatic conditions except where the limestone is above local base-
level.

Fossils are common in the Gordon Limestone, but even early
observers noticed that the fossils were frequently restricted to parti-
cular beds in which they are very common so that there are consider-
able thicknesses of limestone with few if any obvious fossils. In
the fossiliferous beds there are frequently a large number of one
species or one order and fewer specimens of other forms. The investi-
gation of the detailed distribution has begun but it is too early yet
for any attempt at generalisation.

The grainsize varies from very fine to coarse, some coralline
fragments at Mole Creek and Ida Bay being over a foot across. Thus
the limestone varies from a calcilutite to a calcirudite but fine and
medium-grained limestone are commoner than the coarser types.
In one case at the Smelters Quarry, Zeehan, it is possible to show
large (6-8 inches long) colonies of Tetradium preserved in living
position and enclosed in a calcilutite matrix. However, at Ida Bay,
the southern end of the Tiger Range in the Florentine area and at
Mole Creek, at least the large coral colonies are preserved as rolled
fragments so that the rocks can adequately be described as coralline
calciurudites.

The limestone is well-bedded with beds varying from laminae in
some calcilitutes to thick beds in the calciurudites. In a few places
the bedding-planes are wavy, due to ripple-marking, but this seems to
be rare. Cross-bedding has been recognized at Bubb's Hill and near
Mole Creek. Stylolites are very common and there is hardly an
outcrop of any extent which does not show them.

The thickness of the limestone varies considerably and as far as
is known reaches a maximum of the order of 5,000 feet thick in the
Florentine Valley area.
Florentine Valley Area.

The area of the thickest development of the Junee Group and the Gordon Limestone is in the Florentine Valley where the limestone is of the order of 5,000 feet thick. The base of the limestone is exposed at Adamsfield in Clarke's workings and in the road cutting on the Australian Newsprint Road just south of Frodsham's Gap. At Adamsfield, as far as the section is known, the limestone overlies white fossiliferous quartzites and the transitional beds contain the cephalopods listed above as well as an assemblage of sponges, trilobites, brachiopods and algae. Near Frodsham's Gap the limestone rests on calcareous siltstones, called the Florentine Valley Mudstone by Etheridge (1904), which contain brachiopods (Brown, 1948), trilobites (Kobayashi, 1940b) and graptolites. Fossils have not yet been found in the basal bed. In the Florentine Valley itself there are many fossiliferous horizons represented. On the main forestry road of the Australian Newsprint Mills about a quarter of a mile from the old Dawson Track an impure, nodular limestone occurs which contains Tritoechia, strophomenids and trilobites. This is presumably not far from the base. Along the Dawson Road a number of horizons have been recognised by Opik (1951) and the author, and are as follows:

- Limestone with ostracodes, brachiopods and trilobites.
- Limestone with *Rhinidictya*, strophomenids and trilobites.
- Limestone with cephalopods and ostracodes.
- Limestone with *Maclurites*.
- Limestone with *Spanadonta*.
- Beds with *Phyllograptus*, ostracodes, trilobites and brachiopods.
- Beds with *Tritoechia*.

The limestone with *Maclurites* also contains numerous *Girvanella* and provides a good marker horizon. The *Maclurites-Girvanella* rich limestone occurs on the Dawson Track, on and close to the main forestry road near Cashions Creek, on Karmbergs Track just north of Wherrets Lookout, on the Adamsfield Track about half a mile east of the bridge over the Florentine River, at Junee Caves with *Orthonybyoceras tasmaniense* and at Pillingers Creek Caves. This horizon is thought by Banks and Johnson (1957) to be Chazyan in age.

Just below the Eldon Group in the Tiger Range, where the Adamsfield Track rises over the southern limit of this range, the limestone is richly fossiliferous and contains *Eofletcheria* spp., *Catenipora*, *Palaeofavosites*, *Favosites*, stromatoporoids, and stauriid corals as well as brachiopods, cephalopods and trilobites in a coralline calcirudite. This is probably still only Upper Ordovician.

Ida Bay.

The quarries of the Australian Commonwealth Carbide Company at Ida Bay are in a limestone lithologically like the Gordon Limestone which is at least partly equivalent to it.

The lowest bed exposed is in a cutting of the old Lune River Timber Tram and as Opik (1951) pointed out they contain *Tetradium*. This *Tetradium* somewhat resembles *T. syringoporoides* which suggests that it may be as old as Blackriveran. Much higher up are
the beds exposed in the cuttings along the Carbide Company Tram. In the quarry closest to the Lune River settlement, *Streptelasma* is common and in the second quarry *Receptaculites* is extremely abundant and large trilobites, strophomenids, *Favosites* and *Streptelasma* occur as well as a cystoid. Along the road to the third quarry, now being worked, there are numerous exposures. The lowest limestone beds contain *Conularia*, *Tetradium* and a halyssid; higher there is a zone with *Girvanella*, and higher still limestone rich in *Tetradium*, a gastropod-rich bed and then after a gap, a richly coralline calcirudite with rare *Receptaculites*. This is followed by a calcarenite of crinoidal elements with some rhychnonellids and fragments of a large species of *Bumastus*, *Scutellum* and *Rhinidictya*. Cephalopods occur in the coral and trilobite beds but are not well-preserved or common. Higher in the section is an algal limestone then another coralline bed followed by a zone rich in *Receptaculites* which may be equivalent to that in the second quarry. Higher still are the coralline beds in the saddle between the Sugarloaf and Cave Hill which contain corals such as *Heliolites* and *Favosites*, gastropods and orthocoen cephalopods. On Cave Hill the highest fossiliferous beds below the Permian are rich in bryozoa and strophomenids and may be Lower Silurian (Opik, 1951). In the westernmost quarry some compound corals and *Hectococeras longinquum* Teichert and Glenister (1953) occur, but fossils are uncommon. However, in the Mystery Creek Caves *Mystertioceras australis* and *Trocholitoceras idaense* are extremely common on one horizon (Teichert and Glenister, 1953). From Ida Bay, Hill (1955) has recorded *Streptelasma* cf. *aeguisulcatum*, *Tryplasma carerioides*, *Lichenaria ramosa*, *Tetradium*, ? *compactum*, *Tetradium* sp., *Billingsaria banksi*, *Eofletcheria ida*, *Coccoperis ramosa* and *Acidolites*, and suggested that beds from oldest Blackriveran to Trentonian age at least were present. The thickness at Ida Bay is of the order of 500 feet. The directly underlying beds are not seen and the overlying beds are Permian. *Trocholitoceras idaense* may indicate the presence of Upper Canadian beds at Ida Bay (Teichert and Glenister, 1953, p. 13) in the westernmost quarry and it is possible that these beds are structurally below those with *Tetradium* on the Lune River Timber Tram.

**Gordon River, Western Tasmania.**

The Gordon River, below the Serpentine River, flows for much of its course through limestone and limestone extends some miles up the Franklin River from its mouth. At Pyramid Island the limestone overlies sandstone, probably the Caroline Creek Sandstone, and it is overlain elsewhere by a sandstone at the base of the Eldon Group (see Carey and Banks, 1954, p. 254, for map). Fossils are numerous but have not been zonally collected with the result that the age of the base of the limestone is unknown. Higher in the sequence a zone rich in *Maclurites* occurs which may be equivalent to that in the Florentine Valley. Johnston (1888) recorded numerous fossils from the limestone in this area, some of which have been determined by Teichert and Glenister (1953) as *Gordonoceras bondi*, *Stromatoceras eximium*, *Ephippiorhchoceras decorum*, *Anaspyroceras* and *Gasconsoceras insperatum*. The presence of the *Gasconsoceras* may indicate that the top of the limestone here is as young as Lower or even Middle Silurian. Another suggestion that the limestone here includes Silurian beds is provided by the record of *Hercophyllum shearsbyi* and *Entelophyllum* (Hill, 1943, p. 58) which may indicate an age as young as Upper Wenlock or Lower Ludlow.
LIMESTONES IN TASMANIA

Bubbs Hill and Head of Nelson River.

At Bubbs Hill, 16 miles from Queenstown beside the Lyell Highway, there are more than 800 feet of limestone dipping gently southwest and capped by a quartzite, probably the Crotty Quartzite. Some of the beds here are somewhat sandy and show cross-bedding and slumping. Algae, corals, bryozoans, brachiopods, gastropods and cephalopods are present. Hill (1942; 1955) has recorded the corals Plasmoporella, Eofletcheria ida and Nyctopora from this area and considered the limestone here as Upper Ordovician, at least in part. The limestone in the road cuts is variable in purity, some beds being markedly impure. The bedding is thick and in places the bedding-planes are wavy. Two species of Tetradium, Aulopora and rugose corals are present in the limestones in the road cuts.

Queenstown Area.

Limestone of this age is common along the valley of the King River but little is known of its characters there.

Bradley (1954, p. 202) gave the thickness of the limestone along the West Coast Range as 700 feet but gave no indication of how this figure was obtained and later indicated considerable variation from this figure. According to Bradley the limestone is transgressive from south to north, but no accurately measured sections or fossils are offered in support of this conclusion. Similarly, he suggested the possibility of the lateral equivalence of the top of the limestone south of Queenstown with the Crotty Quartzite at Queenstown, but again offered no evidence for this view. The occurrence of limestone at Queenstown has been known for some time (Power, 1892; Hill and Edwards, 1941; and Hills, 1927). The beds are steeply-dipping, with fossiliferous blue-grey limestones passing upwards into brown and black shales with trilobites, bryozoa and brachiopods. The limestone contains the corals Tetradium tasmanense, T. conjugatum, T. dendroides, T. syringoporoides, Alveolites, Protarnea cf. richmondensis and Acidolites and the cephalopods Beloitoceras kirttoni and Anaspyroceras anzaas. The corals indicate a Trentonian to Richmondian age for part of the limestone (Hill, 1955). The Tetradium-rich beds are only a few feet below the trilobite shales, but the possibility of strike faults cannot be overlooked. The trilobitic siltstone also occurs as a small ridge beside the railway line just north of the sports ground and contains Ceraurus, lichadids, harpids and other trilobites, as well as Rhinidictya-like bryozoa and rhynchonellids.

At Lake Margaret, Bradley (1954, p. 202) noted a sequence from Owen Conglomerate into the base of the Gordon Limestone which is locally fossiliferous.

Zeehan Area.

The limestone occurs from near Firewood Siding on the Zeehan-Strahan line, north to Zeehan and somewhat beyond. Over most of this area it overlies earlier Ordovician beds but overlaps these north of Zeehan to rest unconformably on Dundas Group or older rocks. At Greaves Siding, near Eden, on the Zeehan-Strahan Railway, the base of the limestone is somewhat argillaceous and arenaceous and contains Favosites, Rhinidictya and Polypora (Gill and Banks, 1950, p. 262). At this locality it is about 2,000 feet thick.
the Oceana Valley, near the Oceana Mine, a light-grey recrystallized limestone was exposed in Fox's Open Cut and contained simple rugose corals, heliolitids, favositids, Aulopora, rhynchonellids, gastropods, and echinoderm fragments. A core from an exploratory drill at the Oceana Mine was sent to Dr. D. Hill, who recorded the following fossils (Hill, 1955): a band with Tryplasma cerioides, ? Lichenaria, Tetradium, T. ? compactum, billingsaria ? banksii, Nyctopora zeehanensis, ? Nyctopora, Lyopora cf. favosa and Eofletcheria contigua, from 47 feet to 102 feet; gastropods from 130 feet to 170 feet; Receptaculites at 682 feet; gastropods from 774 feet to 786 feet; brachiopods from 890 feet to 918 feet; and lower down still Tetradium petaliforme, T. compactum, T. ? tasmaniense, T. dendroides, Lyopora ramosa. Hill considers the higher coral band more likely to be Trentonian than otherwise, and possibly lower Trentonian. The succession in this core is summarised as text-figure 5.

Fossils have been known from the Smelters Quarry, just southwest of the Smelters Works at Zeehan, since Etheridge (1896) recorded Eunema montgomerii, Raphistomina, Hortomota, &c., from this locality. Later, Chapman (1919) noted the presence of Tetradium tasmaniense and since then several workers have added considerably to the list of fossils. The lower part of the limestone is faulted against Amber Slate (Eldon Group) to the west, but the limestone passes gradationally into the Crotty Sandstone on the southern end of the Smelters Hill. The total thickness of limestone revealed in this section is over 900 feet, but there is a distinct possibility of strike faulting producing inaccuracies in this thickness. The lowest bed exposed in the quarry contains numerous Tetradium, while somewhat higher are beds with Rhinitictya, Strophomena, rhynchonellids and asaphids; higher still are beds with numerous pelecypods, a bed with Receptaculites, another bed of Tetradium, and then beyond Austral Creek are impure limestones and brownish and blackish siltstones with numerous fossils, including halysitid, favositid and compound rugose corals, Rhinitictya and other bryozaans, strophomenids, rhynchonellids, nuculid pelecypods, bellerophontids and patelliform gastropods, cephalopods, including Beloitoceras, Kirstoni and Trocholiticoceras and cheirurid, asaphid, iliaenid, harpид and phacopid trilobites. From this locality Hill (1955) has recorded Tetradium dendroides, T. tasmaniense, T. conjugatum, ? Lichenaria ? ramosa, ? Nyctopora and ? Protarae, and considered the most likely age to be Trentonian. Teichert and Glenister (1953) noted Hecatooceras longinquum, H. obliquum. Tasmanoceras zeehanense, Anaspysroceras anzaas, Helicotoma, Raphistoma, Holopea, Hormotoma and Lophospira from this locality and remarked on the resemblance of the fauna to that of the Trentonian of North America while considering that it is possibly as young as Richmondian.

Huskisson River Area.

Limestone occurs in the Huskisson River area (Waterhouse, 1914, pp. 51-2) and is known to be fossiliferous and to underlie the Eldon Group, but the age limits are as yet unknown. It apparently rests unconformably on the Dundas Group.

Heazlewood Area.

At Bells Reward Mine a blue-grey laminated and massive limestone occurs and is overlain by the Eldon Group (Nye, 1923). Favositites grandipora has been recorded from the limestone.
STRATIGRAPHIC COLUMN SHOWING FOSSIL BANDS IN CORE Nº2 OCEANA MINE ZEEHAN

AS DESCRIBED BY DOROTHY HILL — ORDOVICIAN CORALS FROM IDA BAY, QUEENSTOWN & ZEEHAN TASMANIA. (PAP & PROC. ROY. SOC. TAS 1955)

Fig. 5.—Core No. 2 Oceana Mine.
Mackintosh River Area.

At Sophia Flats fossiliferous limestone occurs between a sandstone below and a white sandstone above (Montgomery, 1895). Ward (1908) and earlier workers have recorded fossils from this area and consider the overlying beds to belong to the Eldon Group.

Loongana,

There are numerous outcrops of limestone in the Loongana area and rugose and tabulate corals, gastropods, cephalopods and brachiopods, all of Ordovician aspect, occur on many horizons. The only fossils determined yet from this area is a *Girvanella*, which is associated with a stromatoporoid in cliff sections on the south side of the river about a quarter of a mile above Hells Gates. This may be equivalent to the *Maclurites-Girvanella* horizon in the Florentine Valley (Banks and Johnson, 1957).

Gunns Plains.

Gordon Limestone underlies a considerable area near Gunns Plains. To the west and south Owen Conglomerate occurs, but there is a considerable gap in outcrop between the conglomerate and the limestone and other formations may be present. A conglomerate in the cuttings beside the Gunns Plains Road just north of the entrance to the Gorge has been interpreted by Bradley (1954) and the author as Owen Conglomerate and it dips south beneath the limestone. In the valley east of the post-office a white sandstone lithologically like the Crotty Sandstone is found above the limestone and below Tertiary basalt.

Fossils are common in the limestone but few have been identified. Corals such as *Propora*, colonial stauriaceans and stromatoporoids occur in the vicinity of Gunns Plains Caves while on the hill slope above the caves a rich coral fauna with heliolitids, favositids and *Favistella* as well as *Rhinidictya*, rhyynchonellids and trilobites occurs. The general aspect of these is similar to that of the fauna at the Smelters Quarry, Zeehan, and suggests an Upper Ordovician age. Beside the Gunns Plains-Preston Road about half a mile from the turn-off limestone outcrops and contains *Tetradium*, heliolitids, *Favistella*, *Rhinidictya*, rhyynchonellids, gastropods and asaphid trilobites. Close to where Walloa Creek enters Gunns Plains there are corals, gastropods, brachiopods and pelecypods in the limestone.

Moina Area.

Limestone has been known to occur in the Moina area since as early as 1860 (Gunn) and the distribution is summarized by Reid (1919) and Jennings (later chapter). Under the bridge over the Iris River beds of quartzite occur in the limestone and a stromatoporoid is the only fossil reliably reported.

Mole Creek-Liena Area.

Just west of Chudleigh, reddish sandstones, containing brachiopods such as *Triteochia*, and therefore correlated with the Caroline Creek Sandstone, dip south beneath a flat area presumably underlain
LIMESTONES IN TASMANIA

by limestone. This flat area continues westward to Mole Creek where outcrops of Gordon Limestone occur. These outcrops are very extensive and are found from Caveside north to the Mersey and as far west as Liena where Hill (1942, 1943) recorded Favistella cerioides, Favosites marginatus, Plasmodoporella cf. convexotabulata and Halysites ? chillagoensis which indicate possible ages between Upper Ordovician and Middle Silurian. Hill (1943) regarded the age as probably Upper Ordovician. Fossils are common in the limestones in the Mole Creek area, but again few have been even generically identified. Tetradium, cephalopods and a rich coralline fauna occur in limestones, including coralline calcirudites, in a paddock north of the Mole Creek-Liena Road just east of the turn-off to Mr. Lewis Lee’s property. On the hill-slope west of Mr. Lee’s house limestone is exposed, beginning with a cross-bedded calcarenite, then a lithoidal limestone containing Tryplasma, a richly coralline limestone and then a coralline, crinoidal limestone. Higher up the slope a sandstone lithologically like the Crotty Sandstone outcrops. In the cliffs above the Mersey River at The Den and close to the top of the limestone a richly coralline calcirudite with blocks of compound coral up to two feet in diameter occurs. This contains favositids, heliolitids, halyisitids and Favistella.

Melrose and Railton.

At Melrose, rocks of the Junee Group outcrop extensively. The Gordon Limestone is underlain by slates lithologically very like the Florentine Valley Mudstone and containing brachiopods and trilobites similar to those in this formation at Frodsham’s Gap. The limestone is several hundred feet thick and south of Melrose township contains sponges, ? Receptaculites, corals and brachiopods, including rhynchoellids. South of Melrose it is overlain by a white sandstone which resembles the Crotty Sandstone. At the eastern end of the southern wall of the large western quarry at Eugenana, Maculites is associated with Girvanella and stromatoporoids, an association suggesting correlation with the Macurites-Girvanella horizon in the Florentine Valley. On other horizons nearby corals, bryozoans and brachiopods occur.

At Railton the Gordon Limestone overlies reddish slates a few yards east of Blenkhorn’s Quarry. These slates contain Tritoechia and Tasmanoccephalus stevensi (Twelvetrees, 1909) and are correlated with the Florentine Valley Mudstone. The lowest beds in Blenkhorn’s Quarry contain strophomenids and higher beds cephalopods. These cephalopods, Nybyoceras paucicubiculatum and N. multicubiculatum, are considered by Teichert and Glenister (1953, pp. 10, 13) to be Chazyan or Mohawkian. They occur 300 feet stratigraphically above the base. Teichert and Glenister (1952, p. 734) also recorded Ormoceras and Anaspicroceras from Railton and considered that these indicate a post-Chazyan age. In the Goliath Cement Company’s quarry Macurites occurs as well as ? Receptaculites, a sponge close to Zittelella, brachiopods, bellerophontids and cephalopods. These fossils may indicate a Chazyan or Blackriveran age.

Deloraine Area.

On Stocker’s Plain, west of Quamby Bluff, Gordon Limestone overlies a quartzite with Tritoechia, which may be equivalent to the Caroline Creek Sandstone (Wells, 1954), but there is a big gap in
the section. The limestone contains trilobites, but is not very fossiliferous. Limestone correlated with the Gordon Limestone occurs as an isolated fault-block on Cameron’s property in Golden Valley. No fossils have yet been found in it.

Beaconsfield and Flowery Gully Area.

Limestone outcrops from just north of Winkleigh to Flowery Gully and again just north of the Flowery Gully Road about half a mile from the Tamar Highway near Beaconsfield. The occurrence at Flowery Gully has been mapped in some detail by Noakes, Burton and Randal (1954). Below the limestone is a sequence of sandstone, siltstone and shale, possibly the Caroline Creek Sandstone and the Florentine Valley Mudstone, and above it is a sequence of brown slate, black slate and sandstone, possibly the lowest beds in the Mathinna Group. Basing their hypothesis on a discontinuity in their “Chert Zone” and their “Lower” and “Upper” “Zones,” they have deduced a fault affecting the Gordon Limestone, but not the overlying sediments. They postulated a normal fault followed by erosion before deposition of the Mathinna Group sediments. If this disconformity is substantiated it will be the first known case of such a structure between the Gordon Limestone and the Silurian and Devonian sediments. Noakes, et al. (1954) found the limestone here to be at least 1,700 feet thick. The limestone is divided by them into three zones as under:—

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"Upper Silica Zone" .... 300 feet
"Chert Zone" .......... 500 feet
"Lower Silica Zone" .... 900 feet.
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Fossils are rare in the limestone here but a few do occur. An orthocoenic nautiloid was found by the author in Sulzberger’s Quarry in the “Lower Silica Zone,” some algal fragments were found in the “Chert Zone” near Beams Bros. No. 2 Quarry, and echinoderm fragments in the “Upper Silica Zone” at the B.L.P. Quarry and Beams Bros. No. 1 Quarry. Dallwitz (in Noakes et al., 1954) recorded the presence of very elongated siliceous rods which he considered must be sponge spicules. Dolomite is common on certain horizons and of especial interest is the association noted by Dallwitz of chert nodules and pyrite. The deduction of the presence of algal reefs in the limestone (Noakes et al., 1954, p. 8) from the occurrence of dolomitic masses seems suspect in the absence of actual evidence of reef-building algae or stromatoporoids as fossils in the limestone. The only algae observed by the author were spherical or sub-spherical bodies up to half an inch in diameter. In the absence of identified fossils this limestone is correlated with the Gordon Limestone on lithological grounds only.

Along the eastern side of Cabbage Tree Hill and Blue Tier, near Beaconsfield, there is an extensive development of the Junee Group which has been dealt with by a number of people, but perhaps the most comprehensive work is that of Twelvetrees (1903). In this area a formation of conglomerates and sandstones with at least three beds of conglomerate are overlain by sandstones with thin conglomerate bands. This sandstone contains brachiopods, trilobites, cystoid plates, tubular casts and algae (Licrophycc us tasmanicus). The trilobites and brachiopods are forms typical of the Caroline Creek Sandstone. Over the sandstone formation is a formation of slates 32 feet thick in the Tasmania Mine. At the eastern end of
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3. Nybyoceras paucicubiculatum Teichert and Glenister, near base of Gordon Limestone,  
   Blenkorn’s Quarry, Railton. Longitudinal section. x 1.

4. Tetradium compactum Hill, Gordon Limestone, Smelters Quarry, Zeehan. Surface  
   view. x 1.

5. 6. Maclurites n. sp. Banks and Johnson, Gordon Limestone, Florentine Valley.  
   5. Section of specimen from near Cashions Creek. x 3/3.
   6. Basal surface of specimen from Dawson Road, near Benjamin. x 4/7.

(Photographs by T. S. McMahon, University of Tasmania.)

the gorge of Blyths Creek this slate is overlain by a blue limestone containing fossils of which the only recognisable one is an orthoconic cephalopod. Corals have been recorded from this formation by Gould, but have not been seen by later workers. Twelvetrees (1903) gave the thickness of the limestone as 340 feet in the Tasmania Mine. There is a possibility that there is a second thinner limestone separated from the main limestone by sandstone and slate east (down-dip) of the Tasmania Mine. This may, however, be a structural repetition. The lithology and stratigraphic association of the main limestone indicates that it is the Gordon Limestone, overlying the Florentine Valley Mudstone. In view of structural difficulties the nature of the beds overlying the limestone is not known with
certainty. Just south of Beaconsfield but north of the Flowery Gully Road, is a quarry in this limestone and it is here that the cephalopod was found. The limestone extends as far south as the Salisbury Mine at the southern end of Blue Tier (Twelvetrees, 1903).

Summary.

A limestone formation, the Gordon Limestone, occurs from Eden, Zeehan and Heazlewood on the west to Beaconsfield and Ida Bay on the east, from New River on the south coast to Gunns Plains, Melrose, Railton and Beaconsfield in the north. Just north of Zeehan, near the Huskisson River, at Heazlewood and possibly in other places, the limestone rests on pre-Junee Group rocks without the intervention of any formation lower in the Junee Group. At Mount Zeehan and Eden the limestone seems to rest on Owen Conglomerate while further east at Queenstown, Lake Margaret, on the Gordon River and in the north-west the limestone rests on sandstones on the top of the Owen Conglomerate, the "Tubicolar Sandstone" and the Caroline Creek Sandstone, and no definite slate or mudstone formation is found underlying the limestone until the Florentine Valley, Melrose, Railton and Beaconsfield areas are reached. The limestones at New River seem to rest on Owen Conglomerate, but at Ida Bay neither Owen Conglomerate nor Dundas Group rocks are known, and it is at least possible that the limestone rests on pre-Dundas Group rocks.

The zone of maximum thickness of the limestone seems to be from the Florentine Valley to the Mole Creek area, but insufficient accurate measurements of thickness are available to attempt to draw an isopach map.

The oldest known fossils in the Gordon Limestone are Upper Canadian at Adamsfield. At Ida Bay the base is probably at least as old as Blackriveran and may be as old as Chazyian. The age of the base on the Gordon River and at Queenstown is unknown, but at Zeehan it is at least older than Lower Trentonian, as shown by the corals in the Oceana Core which does not reach the base of the limestone. In the north-west Caroline Creek Sandstone or Florentine Valley Mudstone underlies the limestone and is Upper Canadian in age. There is gradation from these formations into the limestone and 300 feet above the base at Railton Chazyian cephalopods have been reported. Thus, where information is available the base of the limestone is not younger than Lower Trentonian and not older than Upper Canadian.

Less information is available on the age of the top of the limestone. In the Gordon River in Western Tasmania the presence of Hercophyllum shearsbyi, Entelophyllum, Stromatoceras ezinium and Gasconsoceras insperatum indicate the possibility of the top of the limestone reaching into the Silurian. In the Florentine Valley area no definitely Silurian fossils have been found in the top beds of the limestone which are probably Upper Ordovician. The top beds at Ida Bay may be Lower Silurian, the topmost dated beds being probably Richmondian. At Zeehan beds perhaps as young as Richmondian are about 500 feet below the top of the limestone but as yet no definitely Silurian forms have been found. Beds at Bubbs Hill and Liena contain corals which may be Upper Ordovician or Silurian, but no definitely Silurian forms have yet been found. Thus the established evidence suggests a maximum age range from
Upper Canadian to Lower Silurian. There is some possibility, in view of the differences in age of the youngest known fossils in the limestone and of the evidence advanced by Noakes et al. (1954) from Flowery Gully that there is an erosional break between the Gordon Limestone and the Eldon Group. An alternative possibility is that of equivalence of the Crotty Quartzite with parts of the top of the Gordon Limestone, but insufficient fossil evidence is available from either formation to regard this as anything more than speculation to be tested.

**SILURIAN AND DEVONIAN SYSTEMS.**

Although limestones are uncommon in the Eldon Group and its probable correlate, the Mathinna Group, they do occur. Probably the best known one is that a quarter of a mile above the Mines General Office at Queenstown. Here a light-grey, stylolitic limestone is found in black slates. The limestone is apparently lenticular, being less than 100 feet thick and probably not much more than a quarter of a mile along the strike. Fossils are quite abundant and include articulated and disarticulated crinoid columns of large diameter, numerous large and small fragments of colonial corals, including favositids, syringoporids and stauriaceans, brachiopods, including rhynchoronellids, and numerous Tentaculites in some places. The enclosing slates are also rich in Tentaculites and richness in this fossil suggests that the limestone and slates are part of the Amber Slate, one of the diagnostic features of which is richness in Tentaculites. However, Tentaculites has a distinctly longer stratigraphic range and more palaeontological work is necessary before the age of the limestone can be regarded as known.

In 1914 Hills reported on some of the country south of Macquarie Harbour and noted the presence of limestone from the Hibbs River to the southern side of Point Hibbs. The limestones were recorded (ibid., p. 9) as being highly fossiliferous and as being associated with "quartzites, claystones, calcareous claystones, sandstones and quartz conglomerates". Hill (1942) has recorded Heliophyllum chillagoense and Favosites ? bryani from limestone at Point Hibbs and suggested a Lower Devonian age for at least part of it. It is possible that it is a lense or bed in the Bell Shale, but detailed field work needs to be done before this is definitely established.

Beds of white, fine-grained limestone occur in the Mathinna Group in road cuttings just west of Fingal. They are only an inch or so thick and it is uncertain whether they are original sedimentary limestones or later deposits from ground-water.

**PERMIAN SYSTEM.**

**Introduction.**

Limestone occurs in the Permian System on three main horizons, the lowest one being the Darlington Limestone and its correlates, the next and most important one being the Berriedale Limestone and its correlates, and the highest being lenticular limestones in the "Woodbridge Glacial Formation." The distribution of these limestones is shown in text-figure 7.
DISTRIBUTION OF
PERMIAN LIMESTONES

Fig. 1.—Permian Limestones.
THE DARLINGTON LIMESTONE, AND ITS CORRELATES

Keeneia, from which it is named. It contains cliff sections at the north end of Maria Island one mile north of the village of Darling-Erratic Zone, and overlain by erratic-rich sandstone, and is exposed in quarry and thick overlying a sandstone and siltstone formation, called by Johnston (1900) the "Erratic Zone," and overlain by erratic-rich sandstone, and is exposed in quarry and cliff sections at the north end of Maria Island one mile north of the village of Darling-

Details of the section are given below and are summarised as text-figure 8:—Top:

Units 14-24. An alternation of Eurydesma-rich limestones and spiriferid, calcirudite similar to units 12 and 13 respectively; the Eurydesma-rich limestone units are thicker than the succeeding spiriferid calcirudites. In unit 17, Eurydesma cordatum var. succedens was noted and this is the lowest unit in the section in which this variety was seen by the author. In unit 24, the 12 feet thick Eurydesma-rich limestone contains the calyx of a Camptocrinus sp. with the plates separated but still associated, and some specimens of Dielasma.

Unit 13. Medium to coarse-grained, poorly-sorted, spiriferid calcirudite; light-grey, thickly-bedded; composed mainly of broken shell fragments with some rounded and faceted rock fragments up to 15 inches long near the top of the bed; dominantly calcite but some quartz and feldspar; it is shocked when struck with a hammer; fauna includes Stenopora, Grantonia sp., Martinopora sp., Eurydesma cordatum, aviculopectinids and crinoid basals and columnals. The fossils are all fragmentary except for some of the smaller spiriferids; this unit has a markedly irregular lower surface, indicating pene-contemporaneous erosion, probably sub-marine, but the upper surface is fairly flat; the unit is a good local marker because of its light colour and irregular base.

Unit 12. A Eurydesma-rich limestone, generally well-sorted, dark-grey, foetid; the fossils are in a matrix of silty limestone, in many places the shells of Eurydesma are convex upwards; colonies of Stenopora tasmaniensis show imbrication in one part of quarry which is mostly in this unit, the currents producing the imbrication having come from the south-west; although generally fairly well-sorted, the limestone contains a number of erratics which have been rejected by the quarrymen; in addition to large faceted ones there are rounded pebbles up to eight inches long. The fauna includes Stenopora johnstoni (up to two feet long), Stenopora sp., a monticulate, encrusting, laminated form and a medium ramose form, Fenestella sp. and Polypora sp., broken bases and fronds, Grantonia sp., articulated or fragmentary or articulated, Martinopora (? subradiata, Eurydesma cordatum, both small and large individuals, some broken, aviculopectinids, Merismopteria, Mourtonia morrisiana, Calceolispongia, some not completely disaggregated but with the plates still associated and others just isolated columnals and calical plates, Camptocrinus, articulated columnals.

Unit 11. A spiriferid calcirudite with a coarse to medium-grained calcareous siltstone matrix; light-grey; few rounded to sub-angular erratics; thin bedding; fauna includes Stenopora tasmaniensis, stenoporids, fine ramose, medium ramose, and a monticulate, laminate form, Fenestella sp., bases common, Polypora sp., articulated, disarticulated and fragmentary, Martinopora sp., M. subradiata, aviculopectinids, fragmentary, Eurydesma cordatum, Merismopteria, broken, Keeneia sp., very small, almost smooth. Calceolispongia sp., basalts up to 2 cms. across, radials, Camptocrinus sp., articulated and disarticulated columnals.

Unit 10. A Eurydesma-rich limestone, light-grey in colour, and with few rounded and faceted erratics; some mica in matrix; fauna includes Stenopora johnstoni, up to one foot long, fine and medium ramose stenoporids, very common, Fenestella sp., many bases, Polypora sp., Grantonia sp., very fragmentary, Eurydesma cordatum, complete and fragmentary, both convex and concave upwards, aviculopectinids, fragmentary, Keeneia, Camptocrinus articulated columnals, Calceolispongia, disarticulated columnals, basalts, anals.

Unit 9. A spiriferid limestone which varies a little in thickness; erratics up to 10 inches long are common near the top of the bed, faceted and rounded and include quartzite and greywacke breccias; fauna includes Stenopora johnstoni, four to five inches long, S. tasmaniensis, a stenoporid, a bilaminar form with a coarse ramose form arising from the monticules, fenestellids, Grantonia sp., Trigonotreta...
LIMESTONES IN TASMANIA

(7). Martinopsis, aviculopectinids, Eurydesma cordatum, Calceolispongia, columnals, radials and basals, a crinoid with pentagonal columnals.

Unit 8. Medium-grained, well-sorted, light-grey bryozoal silty limestone with very rare erratics; lamination due to numerous bryozoa; top surface irregular; fauna includes Calciornella (?), fenestellids, Stenopora, fine ramose; spiriferids, Grantonia Dielasma, aviculopectinids, Eurydesma, very small.

Unit 7. Medium-grained, well-sorted, medium-grey bryozoal limestone; thickness variable; some erratics present and most of them rounded; fossils include Stenopora johnstoni, up to six inches long; Stenopora, fine and medium ramose forms, badly smashed, fenestellids, Fenestella, Polypora, Grantonia, fragmental, smoothed, Dielasma, Eurydesma cordatum, aviculopectinids, Calceolispongia, basals.

Unit 6. Medium-grained, well-sorted, medium-grey, laminated bryozoal siltstone with some mica parallel to bedding; boundaries irregular; fauna includes Stenopara johnstoni, up to six inches long; Stenopora, fine and medium ramose forms; badly smashed, Fenestella, Polypora, Grantonia, fragmental, smoothed, Dielasma, Eurydesma cordatum, aviculopectinids, Calceolispongia, basals.

Unit 5. Poorly-sorted, Eurydesma- rich limestone with numerous angular to sub-rounded erratics up to eight inches in length; medium-grey in color; many shells convex upwards; fauna includes Stenopora, fine and medium ramose, Fenestella spp., bases overturned, Grantonia spp., Martinopsis, Schuchertella, Eurydesma cordatum, aviculopectinids, Calceolispongia.

Unit 4. Coarse-grained, well-sorted, medium-grey, laminated bryozoal siltstone with limestone lenses at two feet and two feet eight inches above the base; rare small erratics of quartz in groundmass of quartz, feldspar and golden mica; fauna includes Stenopora, Fenestella, Polypora, Grantonia, Martinopsis, Dielasma, very small; Eurydesma cordatum, crinoid columnals.

Unit 3. Medium- to fine-grained, fairly well-sorted, medium-grey Eurydesma-rich limestone; shells convex upwards; erratics common, dominantly rounded, some angular, up to eight inches long; fauna includes Stenopora, Polypora spp., Grantonia, Martinopsis, Eurydesma cordatum, aviculopectinids, Camptocrinus.

Unit 2. Coarse-grained, well-sorted, light-grey, laminated bryozoal siltstone with rare small erratics of quartz and quartzite in a matrix of quartz, feldspar and golden mica; fauna includes Stenopora, Fenestella, Polypora, neospirifer, Grantonia, Eurydesma cordatum, aviculopectinids, Merismopteria, Campicrinus, columnals, Calceolispongia, crinoid columns with columnals alternating in size, pentagonal columnals.

Unit 1. Poorly-sorted medium-grey Eurydesma calcirudite with shells convex upwards and a few rounded erratics up to six inches long; quartz, feldspar and golden mica in the groundmass; fauna includes Stenopora, Polyestella, Polypora, spiriferids, Grantonia, Trigonotreta, Martinopsis, Schuchertella, Dielasma, Eurydesma cordatum, aviculopectinids, Merismopteria, Keeneia, Moultonia marrisiana, Calceolispongia, recognized by one horn on the basal, calices disarticulated but still associated, pentagonal columnals, few brachials.

From the section (figure 8) and the detailed notes on this, it will be seen that the Darlington Limestone as exposed in the northern shore of Maria Island in shore platform, cliff and quarry section, consists of an alteration of Eurydesma calcirudites and bryozoal siltstones near the base and of Eurydesma calcirudite and spiriferid calcirudite higher up. The bryozoal siltstone units in the lower part of the formation become more calcareous higher in the formation and more spiriferids are found in them, so that units 6, 7, 8 and 9 take the place of a bryozoal siltstone in the alternation. These are a bryozoal siltstone with numerous spiriferids near the base and top of the unit, a spiriferid bryozoal limestone, then a bryozoal silty limestone, and finally a spiriferid limestone (unit 9). In the next alternation the bryozoal siltstone unit is represented by a spiriferid calcirudite (unit 11), and in subsequent cycles the succession is Eury-
desma and spiriferid calcirudite. Under this interpretation of units 6, 7, 8 and 9 there are eleven cycles involving a *Eurydesma* calcirudite and with the *Eurydesma* calcirudite member of the cycles generally the thicker of the two.

The Darlington Limestone is correlated with the Callytharra Limestone of Western Australia, the limestone in the Rutherford Formation of the Dalwood Group of New South Wales, and the Dilly Stage of the Bowen Basin in Queensland. Reasons for this correlation are given by the author in another paper (Banks, 1957, in press) where this limestone is referred to as the "*Eurydesma* Limestone."

Richly-fossiliferous mudstones and limestones occur on this horizon as far south at least as Woody Island and as far north-west as Wynyard. On Woody Island the Darlington Limestone is only five feet thick, is underlain by an erratic-rich sandstone, and overlain by a very fossiliferous siltstone. As shown by Banks, Hale and Yaxley (1955), it contains *Eurydesma cordatum*, *Calcitornella stephensi*, *Stenopora johnstoni* and *S. tasmaniensis*, and the overlying siltstone contains *Keeneia platyschismoides*.

In road cuttings just north of the bridge where the Channel Highway crosses the Snug Falls River near Snug, 25 feet of grey siltstone with some sandstone and limestones bands are exposed. The presence of numerous specimens of *Eurydesma cordatum* suggests correlation with the Darlington Limestone, but this needs checking.

A limestone occurs near water-level on the shore-line below Porter Hill, about a mile south of Long Beach, Sandy Bay. As the base is below low-tide mark the thickness is unknown, but several feet are exposed. It is a medium-grey, massive, foetid limestone which contains numerous fossils, including *Stenopora tasmaniensis*, *S. johnstoni*, *Eurydesma cordatum* and *Calcitornella*. Above the limestone are blue-grey fossiliferous mudstones with a few specimens of *Keeneia platyschismoides*. The fossils in the limestone and the overlying mudstones indicate correlation with the Darlington Limestone.

Voisey (1938, p. 316) mentioned a *Eurydesma*-rich limestone on the Glenlusk Road about a mile and a half west of the Berriedale Railway Station. The association of sediments supports Voisey's correlation with the Darlington Limestone. On the eastern slope of Mount Faulkner south of the Collinsvale Road, Carey recently measured a section, including about 10 feet of highly-fossiliferous, medium-grey foetid limestone with numerous specimens of *Eurydesma cordatum*. More recently still, the author identified *Calcitornella* in this limestone, thus supporting correlation with Darlington Limestone.

In northern Tasmania, the presence of a limestone, now correlated with the Darlington Limestone, has been known since 1890 when Stephens recorded the first Permian foraminifera from Australia in a limestone near Karoola. This limestone is only three feet thick, but is richly fossiliferous and contains *Calcitornella stephensi* and *Geinitzina triangularis* (Crespin, 1947), as well as fenestellids, brachiopods and crinoid fragments.

Even earlier, Strzelecki (1845) and McCormick (1847) had remarked on the Permian limestones at Beaconsfield. Voisey (1938) noted that they contained abundant *Eurydesma cordatum* and correlated them with the Darlington Limestone. Recently the author
Identified *Calcitornella* in a specimen (P.L. 725) in the British Museum of Natural History from the Beaconsfield area (marked "Near George Town, Port Dalrymple") and later saw numerous specimens of this foraminifer in samples collected by D. H. Green at Beaconsfield. The thickness of this limestone is 10 feet.

Wells (1957) found a limestone in the Permian sequence in Golden Valley just south of Deloraine. This limestone is rich in *Eurydesma cordatum* and contains *Stenopora tasmaniensis* and *Calcitornella*, again indicating correlation with the Darlington Limestone. At Golden Valley this limestone is about 10 feet thick and it extends southwards under the Western Tiers. Much earlier Johnston (1888) had recorded very fossiliferous mudstones from Cheshunt on the Meander River a few miles west of Golden Valley. A specimen from this locality, now in the British Museum (98222), contains *Eurydesma cordatum* and *Calcitornella stephensi*, the latter being abundant.

Beds definitely of this age occur further north-west in the Latrobe area. In a limestone from Port Sorell in the British Museum (specimen 90284, marked "Port Lowell") *Calcitornella stephensi* occurs with *Stenopora tasmaniensis* and indicates extension of the Darlington Limestone correlates at least this far. The author (Banks, 1957) has advanced reasons for correlating richly fossiliferous beds above the tasmanite and below the coal in the Mersey area with the Darlington Limestone and suggested that the fossiliferous siltstones below the Preolenna Coal Measures (Hills, 1913) are also roughly on this horizon. Correlation of richly fossiliferous beds in the Central Plateau and western Tasmania with the Darlington Limestone is not yet based on adequate fossil evidence.

Although the Darlington Limestone and its correlates are quite widespread, they are rarely thick enough or pure enough to provide economic sources of lime. Erratics are common in them and grains of quartz, feldspar and other rock material are abundant. Despite lack of economic significance this limestone is of prime stratigraphic importance for correlation within the Permian of Tasmania and for interstate correlation.

**The Berriedale Limestone and Its Correlates.**

This limestone has been known since Jukes (1847) noted its occurrence on Mount Wellington, at Glenorchy and on Maria Island. Many people have contributed to knowledge of it, especially faunally, but no one published adequate or detailed stratigraphic sections until Brill (1956) dealt with the cycles of sedimentation in it and variations in thickness and elastic content.

Although the type area should be Berriedale Quarry the Permian section is not so well exposed there as at Mount Nassau and has structural complications so that the Mount Nassau section is being chosen as the type section for defining most of the Permian formations. However, the longest and best exposure of the Berriedale Limestone known in the Hobart district is at Weily’s Quarry, Glenorchy, and the section in this quarry as well as in other quarries in the Hobart area, were described by Brill (1956). In Weily’s Quarry the section begins with a sandstone at least four feet thick, then follows 16 feet 11 inches of mudstone with one limestone bed only eight inches thick. The Berriedale Limestone itself which may be taken as starting with Brill’s Unit 11 (Brill, 1956, p. 140) is 93 feet
LIMESTONES IN TASMANIA

5 inches thick, accepting the top of the Berriedale Limestone as the top of Brill's Unit 64 (ibid., p. 138). Of this thickness 68 feet 2 inches are limestone and 18 feet 10 inches are mudstone or meta-bentonite. The thickest limestone unit is number 12, which is six feet, for although unit 19 is thicker, 7 feet 4 inches, it contains seven thin shale breaks. The thickest mudstone bed (Unit 49) is 5 feet 7 inches thick but most of them are less than a foot thick. Of considerable interest is the occurrence of 13 beds of montmorillonite-rich shale, considered by Hale and Brill (1955) to be meta-bentonite. Another point of interest is the presence of a bed of dolomite (Unit 40).

The limestone in this quarry is richly fossiliferous and the fauna includes Taeniothaerus subquadratus, Trigonotreta stokesii, Aviculopecten squamuliferus, and Stenopora pustulosa.

Beds of limestone, lithologically very similar to the Berriedale occur on the western bank of the Derwent as far south as Porter Hill where they occur interbedded with the Grange Mudstone, especially close to the base of that formation. Further north limestone occurs on the north bank of Sandy Bay Rivulet near the Turnip Fields Road and from mudstone beds from this formation on the Huon Road numerous fossils have been recorded. These include Aviculopecten squamuliferus, Stenopora pustulosa, Fenestella granulifera and Polypora woodsii.

Berriedale Limestone is exposed in the quarries on the Berriedale-Collinsvale Road near Collinsvale and the section is recorded by Brill (1956, p. 133) who showed detailed correlations with the Weily's Quarry section. The limestone in this quarry contains Pterotoblastus, Taeniothaerus subquadratus, Lyroporella and Eurydesma cordatum var. sacculum. Thirty feet of limestone with some mudstone beds are exposed in the quarry but the total thickness of limestone is probably about 150 feet. Here the limestone and calcareous shale sequence is also underlain by a fossiliferous sandstone with erratics. The basal part of the limestone sequence is dominantly mudstone as at Weily's Quarry and the main limestone sequence is followed by Grange-type creamy fossiliferous mudstone as at Weily's Quarry. Above the fossiliferous mudstone is a fossiliferous sandstone, the basal unit of the "Woodbridge Glacial Formation."

The Black Snake Gully Quarries behind Granton contain at least 50 feet of limestone with minor beds of mudstone and meta-bentonite as shown by Brill (1956, p. 133). This limestone is virtually continuous with that at Rathbone's Quarries on the northern slope of Mount Nassau. The total thickness of the calcareous units at Mount Nassau is 300 feet and they overlie eight feet of fossiliferous sandstone with numerous erratics and are overlain by the basal sandstone unit of the "Woodbridge Glacial Formation". The basal part, as at Weily's Quarry, is dominantly mudstone which is between 50 and 100 feet thick, then follows limestone with meta-bentonite, and finally the Grange-type mudstone with numerous Strophalosia. The limestone here also contains Lyroporella, Taeniothaerus subquadratus and Eurydesma cordatum var. sacculum.

At several places in the foothills of Mount Dromedary the Berriedale Limestone is exposed. In one section above Bundella Station, 11 feet of fossiliferous sandstone are followed by 90 feet of bryozoal
mudstone and then 255 feet of Berriedale Limestone which is overlain by the “Woodbridge Glacial Formation.” The limestone is richly fossiliferous and contains several beds of meta-bentonite.

In the valley of the Little Denison River, Ford (1956, p. 149) has recorded the presence of 90 feet of Berriedale Limestone. The limestone overlies shales, conglomerates and well-laminated feldspathic sandstone containing muscovite. These are probably equivalent to all the beds from the Bundella Mudstone to the sandstone just beneath the fossiliferous siltstones which grade up into the limestone at Mount Nassau. The limestone itself is a dense, grey, massive limestone with numerous brachiopods, bryozoa, corals and aviculopectinids and Conularia ? derwentensis. The limestone is impure and foetid and contains erratics of several rock types. Between the limestone and the base of the “Woodbridge Glacial Formation” are calcareous shales.

At Bronte Prider (1948, p. 133) noted the presence of richly-fossiliferous, blue-grey calcareous mudstone which he called “Granton Facies” of his Marlborough Group. Correlation of this facies with the Berriedale Limestone is as yet uncertain.

Minor bands or lenses of limestone occur in the Grange Mudstone near Waddamana and Ross and will be considered later. The next area where there is a definite limestone formation is at Avoca. In this area limestone occurs beneath Ben Lomond, on St. Pauls Dome and in other places. On the north-western slopes of St. Pauls Dome a coarse sub-greywacke sandstone is followed by 80 feet of fossiliferous siltstone with Cladochonus and Terrakea, and over this are 14 feet of limestone, the lower part of which is silicified. The upper, unsilicified part of the limestone contains Lyroporella, Thamnopora and Pterotoblastus. Anidanthus springurensis occurs in this limestone below Ben Lomond (Hill, 1950, p. 12; Banks, 1957).

Limestone with Lyroporella, Streblotrypa and many other fossils occurs near Fingal and has been mentioned by Strzelecki (1845) from this area. Limestone was cut by the Killymoon Bore west of St. Marys and is probably the same limestone. At Rays Hill, just north of St. Marys, a conglomeratic arkose is followed by a fossiliferous mudstone and then by 45 feet of creamy limestone, silicified in part, containing Lyroporella, Streblotrypa and Eurydesma cordatum var. sacculum. Over this is a calcareous mudstone. At Enstone Park, west of Falmouth, this limestone is again exposed (Walker, 1957). The bore at Harefield passed through this limestone which is well-exposed in road cuttings and cliff sections in the Elephant Pass area. This is the Gray Limestone of Voisey (1938, p. 323). The limestone section has recently been measured in detail by K. G. Brill who kindly made his section available for publication (text-figure 9). The limestone sequence is 144 feet thick and contains mudstone intercalations. The thickest individual limestone bed is about six feet thick and the thickest mudstone bed is five feet thick. The limestone, which is creamy to grey in colour, is richly fossiliferous and contains Lyroporella and Eurydesma cordatum var. sacculum, and in the lower part of it Calcitornella occurs.
SECTION OF BERRIEDALE (GRAY) LIMESTONE

ELEPHANT PASS

0 - 10 FEET

LIMESTONE

SHALE, MUDSTONE OR SILTSTONE

SANDSTONE

AFTER K.G. BRILL

Fig. 9.—Berriedale (Gray) Limestone, Elephant Pass.
At Seymour a bore cut 220 feet of limestone which can probably be correlated with the Berriedale Limestone (Banks, 1957). At the southern end of Friendly Beaches a conglomeratic formation is followed by about 340 feet of limestone and fossiliferous calcareous mudstone over which is a fossiliferous siltstone. The limestone contains corals, Lyroporella, Taeniothaerus subquadratus, Eurydesma cordatum var. sacculum and many other fossils.

On the northern end of Maria Island above the Darlington limestone are a number of formations before another limestone formation occurs. Overlying a bed of sub-greywacke two feet thick, Montgomery's "tuff" (1891), is a succession of mudstones and limestones with a total thickness of 300 feet. The lowest part of this, 115 feet thick, is an alternation of siltstone and limestone (= Montgomery's "Productus Zone") and contains Pterotoblastus as well as numerous other fossils. The next part of this, also 115 feet thick is dominantly limestone, with some siltstone and meta-bentonite (Hale and Brill, 1955) and was referred to by Montgomery (1891) as the "Crinoidal Zone" in recognition of the fact that the limestone is dominantly a crinoidal calcirudite. It is dominantly creamy coloured or light-grey, although there are some dark-grey beds. There are some erratics but the main impurities are chert bands and nodules which are quite common. Limestone beds are from less than a foot to 10 feet thick and the shale beds may reach a foot thick. Current scour structures are present in several places. The limestone is richly fossiliferous and contains Cladochonus, Lyroporella, Taeniothaerus subquadratus, Eurydesma cordatum var. sacculum and Pterotoblastus. The "Crinoidal Zone" is overlain by fossiliferous calcareous siltstone which will be considered later. At the northern end of the southern half of Maria Island a crinoidal limestone occurs and contains Lyroporella, Pterotoblastus and Eurydesma cordatum var. sacculum. Its thickness is unknown.

Thus the Berriedale Limestone and its correlates occur in the Hobart district, in the valley of the Little Denison River, in the Avoca area, at Fingal, St. Marys, Seymour, Coles Bay and Maria Island. This distribution is expressed in the isopach map of this formation published by Brill (1956, p. 133) and this map also summarizes the known information on the thickness of the formation. The "O" feet isopach should be moved outwards to include the outcrops at Avoca and the Little Denison River, and the isopachs near Maria Island should also be moved outwards to allow for the 115 feet of limestone at Darlington (shown as 73 feet). However, the north-easterly trend of the zone of maximum thickness seems correct and limestone distribution at the time of formation of the Berriedale is not much more extensive than shown. Voisey (1938), Lewis (1945), Banks (1952) and Hosking and Hueber (1954) have all described the general lithological characters and these need be repeated here only very briefly. The limestone is a light-grey to medium-grey or creamy colour, varying in grain-size from calcilutites to crinoidal calcirudites, and usually containing erratics of variable composition up to a foot across. Smaller particles of clastic origin are also common and lead to a calcium carbonate content which may be as low as 18 per cent (Hosking and Hueber, 1954, p. 11). Brill (1956, p. 134) has shown that the amount of insoluble material decreased gradually from the lower part of a limestone bed up to a point just above the middle of the bed and then increases again, thus suggesting relatively deep water and fluctuation in sea-level or
supply of clastic material. Pyritic nodules occur in several places and the limestone consistently has a foetid odour. In addition to the clastic limestones, biohermal and coquinal limestones occur but no detailed work has been done on the limestone types. The fossils important for intra-state correlation have been listed for each locality so that a general correlation of the limestones mentioned seems likely. Detailed correlations are not yet possible so that exact equivalence of the top and bottom of the limestone in its various outcrops cannot be established. In fact there is some evidence suggesting that the bottom and top of the formation vary in age from place to place.

The Berriedale Limestone is considered to be partly equivalent to the Maitland Group of New South Wales and to the Cattle Creek and/or Ingelara Stages of Queensland. Reasons for these correlations are detailed elsewhere (Banks, 1957).

The Grange Mudstone and its Correlates.

This formation was named from the outcrops in the Grange Quarry where the sediments are mainly highly fossiliferous, creamy, siliceous mudstones. K. G. Brill, who measured the section in the quarry, found siliceous clays, limestone and dolomite in addition to the predominant siliceous mudstone. In addition, a bed of nontronite occurs in the quarry (Hale and Brill, 1955). The thickness of the section at Grange Quarry is 113 feet but this is incomplete as it is cut off to the east by a fault and to the west is overlain by a discordant dolerite intrusion. The siliceous mudstone can be traced around the hill to Porters Hill where the full thickness of about 290 feet is exposed. At Porters Hill 10 feet of dense, fossiliferous sandy mudstone is followed by richly fossiliferous, foetid, thickly-bedded, medium-grey limestone, lithologically like the Berriedale Limestone, and the limestone is succeeded by the richly-fossiliferous siliceous mudstones like those exposed in the Grange Quarry. Higher up there are several beds of Berriedale-type limestone in the mudstones and the Grange Mudstone is seen to be succeeded by the basal sandstone unit of the "Woodbridge Glacial Formation." The fossils in the Grange Mudstone in its type area include *Polypora woodsi*, *Schuchertella* and *Strophalosia*. The Grange Mudstone is considered to be a facies variant of the Berriedale Limestone and the beds above and below it at Mount Nassau and evidence for this will be presented elsewhere.

The Grange Mudstone occurs in the La Perouse area where it has been studied by B. F. Glenister. At Dover, Hale (1953, p. 107) reported highly fossiliferous silicified mudstone which he correlated with the Grange mudstone. A piece of blue-grey limestone resembling the Berriedale Limestone was also found but not in situ. Ford (1954) recorded Grange Mudstone from the hills to the north of Castle Forbes Bay where about 400 feet of hard, creamy-white, fine-grained, siliceous mudstone occurs, and contains some coarser bands. No limestone was recorded from this area. The limestone band at Glaziers Bay referred to by Ford (1954, p. 153) will be considered later. Isolated outcrops of Grange Mudstone occur in the Huonville area (Mather, 1955) but lack limestone.

Along the eastern shore of Pierson's Peninsula, Grange Mudstone outcrops in cliff sections south of Blackmans Bay where it is intruded by dolerite. Several thin beds of limestone occur but their
stratigraphic position is unknown and they are somewhat metamor-
phosed by the dolerite. Over 300 feet of Grange Mudstone occur
on the northern wall of the valley of the Snug River about a mile
above its mouth. Limestone beds occur but are few and thin. On
the flats around Nieka and in cuttings along the Huon Road the
Grange Mudstone occurs, forming the roof of a dolerite sill. Again
a few limestone beds are present but they are not thick. At Mount
Nelson several quarries have been opened in the Grange Mudstone
where it is intimately intruded by dolerite sills which have produced
contact metamorphic effects. Although several relatively pure beds
of limestone were originally present these are now metamorphosed.
The maximum calcium carbonate content is just over 50 per cent and
most beds contain little more than 30 per cent.

The Grange Mudstone outcrops in Myrtle Gully and Macrobies
Gully behind the Cascade Brewery and continues north to beyond
Glenorchy, although broken somewhat by faulting and topography.
Some limestone is exposed in the creek bed just above the Cascade
Brewery and bores put down somewhere nearby pass through 500 feet
(?) of limestone before reaching dolerite. In this area from South
Hobart to and beyond Glenorchy the Grange Mudstone overlies the
Berriedale Limestone. This relationship continues at least as far
north as the foothills of Mount Dromedary with the Grange Mud-
stone tending to become thinner in that direction although there
seem to be some anomalies.

At Grass Tree Hill, near Richmond, Grange Mudstone has been
recorded (Nye, 1921) and it occurs at several places in the Sandford
and South Arm Peninsula as in Pipe Clay Lagoon. The best exposure
is probably that at Cape Deslacs, where K. G. Brill measured 103 feet
doamite, limestone and mudstone correlated with this formation.

At Pawleena, near Sorell, and at Carlton and several other
places in the area between Richmond, Dunalley and Swansea, the
Grange Mudstone is exposed but outcrops are not good and the
amount of limestone small. An exception to this is at Cape Paul
Lamanon, where good sections are exposed of Grange Mudstone.
Here the mudstone contains Strophalosia clarkei, S. typica, Steno-
pora crinita.

At Darlington, on the northern end of Maria Island, the “Crin-
oidal Zone” is overlain by 68 feet of mudstone, lithologically very like
the Grange, calcareous and highly fossiliferous. At least one bed of
limestone, two feet thick, occurs and this contains numerous Clado-
chonus and Thamnopora. It is followed by a sandstone formation
lithologically like the “Woodbridge Glacial Formation.”

The thickness of 340 feet of limestone at Friendly Beaches men-
tioned previously under the heading of the Berriedale Limestone,
includes less than 100 feet of cream-coloured mudstones and lime-
stones at the top which are like the Grange Mudstone. The lime-
stones are present but not common.

Overlying the limestone near Avoca is a thickness (on St. Pauls
Dome) of 54 feet of fenestellid siltstones with some limestone lenses.
These siltstones may be equivalent to the Grange Mudstone or to the
“Woodbridge Glacial Formation” and are followed by a glauconitic
sandstone correlated with the Risdon Sandstone.

Fairbridge (1949) noted the presence of Grange Mudstone in an
inlier at Waddamana. The rock types present include creamy fossili-
ferous mudstones, mudstones with erratics, and sandy mudstones. Of the fossils recorded, *Polypora woodsi*, *Strophalosia clarkei*, *S. gerardi*, *S. jukei*, *Terrakea fragile*, *T. brachythaera* and *Canerina farleyensis* are of particular interest in correlation. A little further south at Marlborough Prider (1948, p. 133) recorded the Grange Facies composed of richly-fossiliferous yellow mudstone with moulds of fenestellids, stenoporids, *Strophalosia*, spiriferids and other fossils.

In the Midlands Nye (1924) and others have reported Grange-type mudstones but no long sections are exposed.

Finally, Jennings (1955), p. 174) reported impure, fossiliferous marls in the bed of the Florentine River, 2 1/2 miles north of the Dawson Settlement and these may be equivalent to the Grange Mudstone.

It will be seen that the Grange Mudstone and rocks correlated with it or similar to it occur from La Perouse in the south to Waddama and Friendly Beaches in the north, and perhaps as far north as Avoca, and from Maria Island in the east to Bronte in the west. While the formation contains some limestone bands in most places, the limestone bands are neither numerous nor thick, and the lime content of the formation as a whole is low. There is some evidence that the Grange Mudstone is equivalent as a whole to the Berriedale Limestone and the formations immediately above and below it, although in places the Grange Mudstone, or, more precisely, the upper part of it, overlies the Berriedale Limestone. Fossils in the Grange Mudstone indicate correlation with some part of the Maitland Group, more especially the Branxton Sub-group, of New South Wales and the Cattle Creek and/or Ingelara Stages of Queensland (Banks, 1957, for fuller discussion).

**The “Woodbridge Glacial Formation” and Its Correlates.**

Although the limestones of the “Woodbridge Glacial Formation” are not economically important, they are mentioned here for the sake of completeness.

In the Mount Nassau section lenses of olive-grey, foetid, fossiliferous limestone up to 18 inches thick occur about 13 feet below the top of the formation. Many years ago Johnston (1888) recorded limestones composed dominantly of *Stenopora crinita* in this formation at One Tree Point, on Bruny Island.

A bed of limestone about six feet thick occurs on Silver Hill, near Glaziers Bay, on the Cygnet Peninsula. It is a medium-grey, foetid, fossiliferous limestone with erratics up to six inches in length of quartzites, slate, hornfels, and grains of quartz and feldspar visible. Fossils include *Stenopora* prob. *crinita*, *Protoretepora*, *Fenestella*, *Polypora*, *Neospirifer*, dielasmids, *Strophalosia*, *Schuchertella*, aviculopectinids, *Mouronia*, *Platyschisma* and ostracodes, *Martinoopsis* and *Eurydesma cordatum*. The stratigraphic position of this limestone is not yet clear. It is underlain by a considerable thickness of sandstone and siltstone with a fauna including very alate spiriferids which in Tasmania occur mainly in the Berriedale Limestone and the “Woodbridge Glacial Formation”. Above the limestone is a siltstone with a few erratics and common fossils, including *Strophalosia*, *Fenestella*, alate spiriferids, and a few *Eurydesma cordatum* var. *sacculum*. Its thickness suggests either the Darlington Limestone or a limestone in the “Woodbridge Glacial Formation.” This criterion
does not, however, exclude the possibility that it is the Berriedale Limestone, as evidence from other areas suggests that the Berriedale Limestone is thinning to the south-east (Brill, 1956). The associated rocks allow no sound correlation to be made. The fossils in it and the associated sediments suggest that it is not the Darlington Limestone and make correlation with the Berriedale Limestone, or more especially, with part of the “Woodbridge Glacial Formation” seems more likely.

FIG. 10.—Characteristic Fossils from Permian Limestones.

Figs. 1, 2.—Stenopora johnstoni Etheridge, Darlington Limestone, Darlington, Maria Island: (1) surface view showing monticules; (2) side view showing colaminar form. Both. × 1.

Fig. 3.—Calcitornella stephensi (Howchin), Darlington Limestone, Beaconsfield; section near base. × 15.

Figs. 4, 5.—Eurydesma cordatum Morris, Darlington Limestone, Darlington, Maria Island: (4) internal view of left valve × ½; (5) external view of left valve. × ½.

Fig. 6.—Lyratoporella. Berriedale Limestone, Darlington, Maria Island, showing calcareous support and part of frond. × 3.

Fig. 7.—Taeniothaerus subquadратus (Morris), Berriedale Limestone, Rathbones Quarry, Mt. Nassau; pedicle valve showing sulcus and position of muscle scar. × ½.

(Photographs by T. S. McMahon, University of Tasmania.)
On Maria Island the "Woodbridge Glacial Formation" contains thin limestone beds on two horizons. A bed two feet thick occurs 68 feet above the base and another, also about two feet thick, 95 feet above the base.

Summary.

The Permian System contains limestone and calcareous beds on three horizons. The lowest is that of the Darlington Limestone which occurs from Port Sorell, Beaconsfield and Lilydale in the north to Woody Island and Snug in the south and from Port Sorell and Collinsvale in the west to Maria Island in the east. It seems to be thickest (50 feet) on the northern end of Maria Island and in most areas is less than 10 feet thick. It can be correlated with the Cally-tharra Limestone in Western Australia, which is considered to be basal Artinskian.

Higher in the sequence are the Berriedale Limestone and the Grange Mudstone, which is frequently calcareous and has limestone bands in it. The Berriedale Limestone occurs from Ben Lomond and St. Marys in the north to the Arve River in the south, and from Marlborough in the west to Maria Island in the east. The Grange Mudstone is found as far north as Ross and Coles Bay; as far south as La Perouse; and from Marlborough in the west to Maria Island in the east. The Berriedale Limestone is thickest at Seymour, 220 feet, and decreases in thickness rapidly to the north and more slowly to the south-west and south. The Grange Mudstone is thickest in the south-east and becomes thinner to the north and west. These two formations are thought to be equivalent to part of the Maitland Group of New South Wales and to the Cattle Creek and/or Ingelara Stages of Queensland, which are considered to be Artinskian.

Finally, there are thin limestone lenses in the "Woodbridge Glacial Formation" in several places in the eastern half of Tasmania, eg., Hobart, Maria Island, and Bruny Island. They are seldom, if ever, more than three feet thick. The "Woodbridge Glacial Formation" has been correlated with the upper part of the Maitland Group of New South Wales and is probably Upper Artinskian.

TERTIARY SYSTEM.

Tertiary limestones have been known in Tasmania since Darwin (1844) remarked on the deposit at Gelston, and Strzelecki (1845) described limestones from Wynyard and Cape Grim. These limestones are friable rocks at most places and are composed of fragments of shell material or of small fossils and most of them are calcarenites. Marine limestones occupy a fringe around the North-West Coast from Temma to Irishtown, cover much of King Island, occur in the Wynyard district and outcrop over much of Flinders Island. In the north-western part of the State they are apparently nowhere thicker than 100 feet, although they reach heights of 250 feet above sea-level. On Flinders Island the limestones are apparently thicker and occur up to 600 feet above sea-level (see later chapter). The distribution is shown in text-figure 11.
DISTRIBUTION OF CAINOZOIC MARINE LIMESTONES

**Fig. 11.**—Cainozoic Limestone.
LIMESTONES IN TASMANIA

Far North-West Coast.

At Temma (Ward, 1911) recorded an occurrence of pink and yellow limestone resting unconformably on Balfour Slate and Sandstone and overlain by basalt which has hardened the limestone. The limestone contains abundant fossils, including polyzoa, brachiopods such as *Magellania garibaldiana* and gastropods such as *Marginella* and *Calliostoma*. The outcrop is about 250 feet above sea-level.

As long ago as 1888, Johnston had recorded bryozoal limestones in the Welcome River Valley where they are overlain by basalt. Later Nye (1941) noted that hard, pink limestones overly unconformably Precambrian dolomite and limestone on the northern, north-western and western sides of the Welcome River Flat, south-south-east of Redpa. The base is about 135 feet above sea-level and the Tertiary limestone is from 50 to 100 feet thick and is overlain by basalt. In a pink limestone three miles south-east of Redpa, Chapman in Nye (1941) recorded *Textularia gibbosa* and *Quinqueloculina*. More recently the author identified *Trybliolepidina* in a friable limestone south-west of Redpa on the western side of the Welcome River Flat (locality A, plate 45). Limestone occurs on A. Wilson's farm east of Marrawah (locality B, plate 45) at about 150 feet above sea-level where it is 12 feet thick (Ward, 1911, p. 40) and contains *Textularia, Cellepora, Lepralia, Schizoporella* (?) and *Magellania garibaldiana*. Nye (1941, p. 14) reported a limestone quarry six to seven miles east of Marrawah where the limestone contained *Pleurotomaria, Cyprea* and *Conus* cf. *complicatus*. Ward (1911) recorded limestone from south of Mount Cameron West and east of Green Point. Later Nye (1941) found white bryozoal limestone on G. Loverock's property a mile west of Marrawah at 250 feet above sea-level (locality C, plate 45). Half a mile further west two small quarries in white bryozoal limestone occur 190 feet above sea-level near J. N. Nicholl's house and in the south-western corner of this property white limestone occurs 200-250 feet above sea-level (locality D, plate 4). White limestone and brown mudstone occur on Saward's property even further south-west (locality E, plate 45). Fossils from two of these localities are listed below (from Chapman, 1941, p. 16):

South-west corner of Nicholl's property (locality D):

*Cellepora coronopus, C. biradiata, Schizellozoon, Linthia, Magellania grandis, M. garibaldiana, Chlamys praecursor, Ostrea, Cyprea, Isurus retroflexus.*

1½ Miles S.S.E. of Green Point (locality E, plate 45):

Immediately below the basalt at Mount Cameron West, a yellow, white and red, friable calcarenite occurs (Gill and Banks, 1956, p. 4) which contains *Carpentaria rotaliformis*, *Cassidulina subglobosa*, *Cibicides*, *Notorotalia*, *Spondylus*, *Pecten* and *Magellania*.

Strzelecki (1845) was the first person to record the presence of bryozoal limestone at Cape Grim, but regarded it as an emerged shell-bed. Johnston (1888, pp. 244, 268) recorded bryozoal limestone capped with basalt in the cliffs south of Cape Grim and reported the following fossils from Cape Grim and the Welcome River flats:

*Cellepora gambierense*, *C. spongiosa*, *C. nummularia*, *C. hemisphaerica*, *Lepralia*, *Eschara*, *Placotrochus deltoideus*, *Lovenia forbesi* and *Magellania grandis*.

At the mouth of the Harcus River and on the Montagu River, limestones are recorded close to sea-level. At the northern end of Britton's Swamp, basalt contains fragments of baked limestone with *Carpentaria*, *Triloculina*, *Sigmoilina* and *Pecten cf. antiaustralis* (Gill and Banks, 1956, p. 6), indicating a Tertiary limestone somewhere in the vicinity. Similarly, a limestone boulder in basalt at Irishtown (see later chapter) indicates the presence of limestone nearby.

**King Island.**

Tertiary limestones are widespread on King Island and have been reported from Cape Wickham, half-way from Wickham to Yellow rock, a little south of Lavinia Point, at Blow-hole Creek (about four miles north of Naracoopa), along the Seal River, between the Pass and Ettrick Rivers, near Porky Lagoon and inland from Fitzmaurice Bay and at “Avondale” in the centre of the island (Baldwin Spencer, 1888; et al.).

At Cape Wickham the limestone apparently rests on granite (Chapman, 1912, p. 39). A bryozoal limestone occurs at Blow-hole Creek, and for three-quarters of a mile to the north below high-water mark and just south of the creek above high-water mark (see later chapter). This is possibly that referred to by Waterhouse (1916, p. 90) as near the northern end of Sea Elephant Bay which is composed of marine shells and shell fragments.

At Seal River, Debenham (1910, p. 567) noted the presence of 20 feet of limestone dipping slightly west. At the base is coarse fragmental material with complete shells and pebbles of schist and quartzite, and this is followed by a very hard, firmly cemented, fine-grained calcarenite containing *Pecten cf. antiaustralis*, *Lima cf. bassi*, *Hipponyx cf. australis*, *Turritella*, *Hemithyris* and *Retepora*. Later Chapman (1912, p. 40) described two types of limestone from this area. One of these is a pale ochre colour, fragmental, friable and is apparently a polyzoal calcarenite with some larger fossils. The other is a harder yellow to pink limestone, close-textured and containing polypoza and echinoid spines. It is apparently cemented by calcareous mud. Fossils are numerous in both types and are listed hereunder:

**Hard Pink Limestone:**

Polyzoal Calcarenite:—

_Lithothamnium, Cibicides lobatulus, C. ungerianus, Mopsea hamiltoni, Leiocidaris cf. australiae, Spirorbis, Heteropora pistaformis, Amphiblestrum ? bursarium, ? Lepralia cf. crassatina, Adeona, Pinna reticosa, Vulsella laevigata, Pecten aldingensis, Chlamys praecursor and Placunanomia sella._

At “Avondale,” in the centre of the island, a cream-coloured bryozoal, shelly, marly limestone overlies a blue-grey, partly recrystallised limestone (Crespin, 1945a). The fauna includes _Gaudyrina crespinae, Frondicularia lorifera, Elphidium parri, Fibularia gregata, Aspidostoma airensts, Chlamys praecursor_, and club-shaped cidaroid spines.

Wynyard Area.

Tertiary beds were first noted in this area by Strzelecki (1845) who referred to them as raised shell-beds. These beds have since received much attention by Australian geologists because of their richly fossiliferous nature, accessibility and striking-looking outcrop. Most of the work on them was done in the last half of the last century and the early years of this one, but there have been isolated papers on them during the last 40 years. The beds have been referred to in many formal and informal ways and in order to clarify the nomenclature the units are here formally defined in accordance with the Australian Code of Stratigraphic Nomenclature (Raggatt _et al._., 1952).

**Table Cape Group.**

The Table Cape Group is here defined as consisting of the Freestone Cove Sandstone below and the Fossil Bluff Calcareous Sandstone above as exposed at Fossil Bluff, near Wynyard. The name is derived from a prominent coastal feature several miles from Fossil Bluff. It is Tertiary in age.

The name was first applied to this unit by Stephens (1870, p. 20), who called it the “Table Cape Beds.” The history of the nomenclature is summarised below:—

_Table Cape Beds: Stephens, 1870; Johnston, 1875; Woods, 1875; Johnston, 1880a, 1880b; Johnston, 1885a, 1885b; Johnston, 1888; Montgomery, 1896; Singleton, 1941; David, 1950; and others._

_Wynyard Stage: Nye and Lewis, 1928, p. 31, not applicable, due to use by Montgomery, 1896 of the name Wynyard formation for the Permian tillite underlying these beds._

_non-Table Cape Conglomerate of Etheridge, 1883, pp. 158-159, 161; Johnston, 1888, pp. 66, 263-4; used for the Permian Wynyard Tillite of Montgomery, 1896._

Stephens (1870) pointed out that this group occurs within a radius of five or six miles from the mouth of the Inglis River and later work by Loftus Hills (1913) showed that it extends well up the Inglis River. It extends as far as the south side of Table Cape where
it is hidden by talus. Lately J. Loveday, C.S.I.R.O. Soils Division, has found the Fossil Bluff Sandstone about one mile east of Doctors Rocks. It overlies the basal Permian formation, the Wynyard Tillite, at Fossil Bluff with some unconformity and is overlain at Fossil Bluff and on the hills to the north by basalt. The character of this contact is not known.

South of Doctors Rocks the lower formation of the group is missing and the Fossil Bluff Sandstone rests on basalt. The group is of the order of 80 feet thick at Fossil Bluff. The most probable age limits are Upper Oligocene to Lower Miocene, as will be shown later.

FREESTONE COVE SANDSTONE.

The Freestone Cove Sandstone is that formation of sandstone up to four feet thick, overlying unconformably the Permian Wynyard Tillite and overlain by the Fossil Bluff Sandstone at Fossil Bluff, near Wynyard. It contains Sherbornina atkinsoni, Planorbulinella, Crassatellites oblonga and many other fossils.

The age is probably Upper Oligocene to Lower Miocene. The name is derived from Freestone Cove, near Wynyard.

This sandstone has in the past been referred to as the "Crassatella Bed," a name applied to it first by Johnston (1877, pp. 84-86) and later by numerous other authors such as Noetling (1910) and David (1950). It seems that it has not been referred to by any other name. Stephens (1870, p. 19) described it as a breccia of coarse sand and broken shells, while Johnston described it as consisting of shells in a matrix composed of ferruginous mud containing rounded pebbles of yellowish quartz and many foraminifera. The presence of the yellowish quartz pebbles is characteristic. Johnston described it as from three to four inches thick to three to four feet thick at Fossil Bluff and it is shown as such on the figure, although in the text describing the figure he gives the thickness as 80 feet. His figure of four feet is the correct one. Noetling (1910, p. 162, and pl. XII.) described the contact of the Freestone Cove Sandstone with the Wynyard Tillite in some detail and showed how the sandstone occurs under ledges of the tillite. He pointed out that some of the fossils in the sandstone are broken and rolled.

Fossils are very abundant in the Freestone Cove Sandstone and over 300 species have been identified. Foraminifera are common and include Sherbornina atkinsoni, Planorbulinella and numerous milolids. Both solitary and colonial corals occur and include Placotrochus deltoideus, P. elongatus and Thamnastraea sera. Polyzoa are represented by Cellepora gambierense, C. nummulina, C. hemisphaerica, C. spongiosa and Salicornaria sinuosa. Brachiopods occur but are uncommon. There are numerous pelecypods but the commonest forms are Crassatellites oblonga, Cucullaea corioensis, Eotrigonia semiundulata, Glycimeris maccoyi and Cucullaea caenozoicus. Gasteropods are also very numerous and include Voluta anticinulata and V. weldi, Cypraea platypygga, C. platyrhyncha, Typhics maccoyi and Murex eyrei. Barnacles occur but are rare. Echinoids are rare but Arachnoides australis does occur. Sharks teeth such as Lamna elegans, Oxyrhina trigonodon and Carcharodon augustidens have been reported from this formation and there is also some decomposed wood.

The lithology and fossils both indicate very shallow water as suggested by Tate and Dennant (1896). The presence of Sherbornina atkinsoni, Planorbulinella, many of the pelecypods and gastero-
pods and *Arachnoides australis* indicates correlation with the Torquay Group (Raggat and Crespin, 1955), more especially with the Jan Juc Formation, and with the Longfordian.

**Fossil Bluff Sandstone.**

The Fossil Bluff Sandstone is that formation about 80 feet thick composed of calcareous sandstone and limestone exposed in the cliffs at Fossil Bluff where it overlies the Freestone Cove Sandstone and underlies a basalt. It is named after Fossil Bluff, the headland immediately north of Wynyard and south of Freestone Cove.

The formation contains *Aturia australis*, *Prosqualodon davidii* and *Wynyardia bassiana* and its age is probably Upper Oligocene or Lower Miocene.

Stephens (1870, p. 19) described this formation as composed of fine-grained whitish sandstone but gave it no name. In 1877 Johnston called this formation the "*Turritella Group*" and described it as 80 feet thick and showed its relationship to the underlying "*Crassatella Bed*" and the overlying basalt in plate XII. The contact between the Freestone Cove Sandstone below and the Fossil Bluff Sandstone is gradational. The Fossil Bluff Sandstone consists of white or grey calcareous sandstone with some hard bands which are really impure limestones. Included in the formation are several beds very rich in *Cellepora gambierense*. This formation extends at least as far as the south side of Table Cape to the north and at least one mile beyond Doctors Rocks to the east. Its southward extension is unknown. The history of the nomenclature of this formation is as under:

*Turritella* Group: Johnston, 1877, pp. 82-84; Johnston, 1888, pp. 244, 260-1.
*Turritella* Sandstone: Noetling, 1910.
*Turritella* Beds: David, 1950, p. 537.
*Turritella* Limestone: Gill and Banks, 1956, p. 11.

It does not seem to have been given any other names.

At Fossil Bluff the Fossil Bluff Sandstone overlies the Freestone Cove Sandstone and is overlain by basalt. However, just south of Doctors Rocks it overlies basalt and is overlain by basalt.

Tate and Dennant (1896) remarked on the poverty of species in the "*Turritella Bed*" as compared with the "*Crassatella Bed*" and stated that all species in the higher formation also occurred in the lower except the echinoderms. They pointed out that there is a reduction in the number of species upwards through the formation and that close to the top it becomes unfossiliferous. Stephens (1870, p. 21) had noted the occurrence of leaf impressions and fragments of lignite in the sandstone some years before Johnston (1888, p. 251) reported the occurrence therein of *Sapotacites oligoneurus* and *Pteris bellii*. The formation has been characterised by the abundance of *Turritella warburtoni* and other species of *Turritella*. Corals are common in some bands especially with *Cellepora gambierense* and other species of *Cellepora*; brachiopods occur but are rare. Both gasteropods and pelecypods are abundant but cephalopods are rare. *Aturia australis* has been recorded from this formation by Glaessner (1955). *Lovenia forbesii* var. *woodsi* occurs, especially in the *Cellepora*-rich bands, and several other echinoids have been reported. The mammals are represented by *Prosqualodon davidii* and *Wynyardia bassiana*. Glaessner (1955, p. 359) considered the formation to be at least partly Upper Oligocene on the evidence of *Aturia* and *Prosqualodon*.
Flinders Island.

Tertiary limestones are widespread on Flinders Island and some other islands of the Furneaux Group on the lower parts of the islands.

Strzelecki (1854) apparently collected fossils from the group as *Cypraea eximia* is recorded by him from a well at Franklin Village, now called The Corners, or Cape Barren Island, at the north-west end of Cape Barren Island. Later Johnston (1879) recorded a shelly limestone which he called the "Turritella Limestone" from Heathy Valley, near the Three Patriachs on Flinders Island and noted the presence of *Glycimeris Cainozoicus* and *Nucula Tenisoni*. This limestone rests on slates and granite.

At Franklin Village, Sandford Bay, on Cape Barren Island, hard and friable, cream-coloured bryozoal limestones occur with a rich fauna (Crespin, 1945, p. 13). The fauna includes the foraminifera *Calcarina verriculata*, *Planorbulinella plana*, *Operculina victoriensis*, *Amphistegina lessonii* and *Gypsina globulus*, corals such as *Mopsea tenisoni*, the bryozoa *Cellaria contigua* and *C. depressa* and the ostracode *Bythocypris tumefacta*.

At Wingaroo a bore passed through limestone from which Singleton and Woods (1934) reported *Milthia* (*Milthoidea*) *grandis flindersiana* between 55 and 80 feet.

In a later chapter the distribution of limestone on Flinders Island is detailed. In many places on the west coast the limestone rests directly on granite as at Trousers Point and Emita, but at others rests on sand. The limestones apparently rise to 600 feet above sea-level at Emita, to 400 feet on the Pratts River and up to 340 feet at Ranga. On the east side of the island the limestone overlies beds of sand, gravel and clay with one or more beds of dense tough limestone which pass laterally into clays with calcareous nodules. Foraminifera from these limestones indicate, according to Crespin, an Upper Pliocene to Pleistocene age.

Geilston.

The presence of travertine at the head of Geilston Bay became known soon after colonisation of the State and this deposit was used as a source of lime in the young colony for many years. The earliest scientific record of it appears to be that by Darwin (1844).

It was described in some detail by Johnston (1888). At the base is a stiff brown clay with plant fossils. This is followed by 10 to 12 feet of travertine with numerous plant fossils, leaves, stems and fruit and then there is six to eight feet of yellow to brown calcareous clay with ferruginous bands and veins and stringers of limestone containing bones and teeth of *Hysiprimnus*. There are then four feet of cherty rock with numerous *Cypris alburyana*. This is overlain by five feet of basalt and then a soil cover. Johnston (1888, p. 285) recorded several species of *Helix*, a *Vitrina* and *Bulimus Gunii* from this deposit.

Johnston (1888) remarked on similar travertine deposits at the top of Burnett Street, Hobart, Risdon Railway Station and in the vicinity of Trinity Hill, but gave no details of these occurrences. Milligan (1847) noted calcareous beds with fossil plants between Elizabeth Street and Knocklofty.
Summary.

In view of the present discussion on the age of the Victorian Tertiary formations it is difficult to arrive at accurate dates for the Tasmanian Tertiary sequences. The presence of *Magellania garibaldiana* at Temma seems to indicate a Balcombian (in the sense of Crespin, 1943) age for that limestone. The oldest beds at Marrawah are those at Mount Cameron West which are regarded by Glaessner as most probably Upper Oligocene or Longfordian (Gill and Banks, 1956). The fauna from A. Wilson's property also contains *M. garibaldiana* and is presumably Balcombian. Chapman (in Nye, 1941) regarded the faunas on Nicholl's property and 1½ miles south-south-east of Green Point as...
Lower Miocene. The fauna at the latter locality shows relationships to that of the Jan Juc Formation and the Balcombian of Gippsland. That from Nicholl’s property shows a relationship to the Balcombian and may extend upwards to the Mitchellian as indicated by *Isurus retroflexus*. The *Lepidocyclina* limestone south of Redpa can be correlated with the Batesfordian and the presence of a Batesfordian fauna at Franklin Village on Cape Barren Island (Crespin, 1945) indicates approximate correlation with the Redpa occurrence. The *Lepidocyclina* limestone is probably lower in the sequence than that at Nicholl’s property on faunal and topographic grounds but its relationship to the locality 1½ miles from Green Point is uncertain. The limestones from Cape Grim with *Magellania grandis* and *Lovenia forbesi* appear to be Balcombian. Chapman (1912) regarded the limestones at Seal River on King Island as Janjukan and their fauna shows relationship also to the Balcombian of Gippsland with forms such as *Lima bassi* indicating an age as young as Mitchellian. The fauna from “Avondale” was regarded by Crespin (1945a) as Longfordian. The fauna of the Freestone Cove Sandstone (“Crossatella Bed”) at Table Cape has long been regarded as similar to that of the Jan Juc Formation, while the presence of *Sherbornina atkinsoni*, *Eotrigonia semiwundulata* and *Arachnoides australis* indicates relationship to the Longfordian of Gippsland (Crespin, 1943). Glaessner (1955) regarded the Fossil Bluff Sandstone (“Turritella Bed”) as Upper Oligocene on the evidence of *Prossqualodon davidi* and *Aturia australis*. At Franklin Village, on Cape Barren Island, Crespin (1945) reported a Batesfordian fauna with *Calcarina verriculata* and *Planorbulimella plana* while *Milthia (Milthoidea) grandis finder-siana* from the Wingaroo No. 1 bore indicates a Pliocene-Pleistocene age (Singleton and Woods, 1934).

Marine transgression began at Table Cape and Marrawah and probably at other points along the North-West Coast in Upper Oligocene time (this assumes an Upper Oligocene age for the Jan Juc Formation and the Longfordian, assumptions now under discussion by several groups of workers: Raggat and Crespin (1955) regarded the Jan Juc Formation as Upper Eocene). The transgression reached heights of about 250 feet above present sea-level on the North-West Coast and perhaps up to 600 feet on Flinders Island. The sea withdrew after the Lower Miocene, perhaps as late as the Mitchellian at Marrawah and King Island, and no further marine sediments are known before those deposited at Wingaroo during the Upper Pliocene or Pleistocene. This sequence of events, uncertain as the actual dates may be, agrees with that proposed by Glaessner (1953) of Upper Oligocene and Lower Miocene transgression followed by Upper Miocene regression and then a re-advance of the sea in the Pliocene Epoch, the Pliocene transgression affecting only the Furneaux Group of islands. The presence of Plio-Pleistocene marine beds at considerable heights above sea-level on Flinders Island may indicate late Cainozoic tectonic activity, an activity also suggested by earth tremors with epicentres in the eastern part of Bass Strait and the north-eastern part of Tasmania (Burke-Gaffney, 1952).

The Table Cape Group represents only the initial transgression and seems to merge upwards into a lacustrine deposit (Tate and Dennant, 1896) or at least estuarine deposits representing the infilling of the original bay by sediments brought down by the ancestral Inglis River. The stratigraphic conclusions are summarised in the form of a correlation table (Table 1).
<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Marrawah</th>
<th>King Island</th>
<th>Wynyard</th>
<th>Launceston</th>
<th>Furneaux Group</th>
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<td>Chlamys praecursor, Fibularia gregula, &amp;c.</td>
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<td>roo with Milthia grandis</td>
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</table>

**TABLE 1**

**CORRELATION OF CAINOZOIC STRATA**
QUATERNARY SYSTEM.

West and North-West Coast.

Calcareous sand dunes and emerged shell-beds have been recorded just north of Macquarie Harbour (Stephens, 1941), just south of Mount Cameron West (Edwards, 1941), just north of Mount Cameron West (Gill and Banks, 1956), on King Island (Debenham, 1910; Chapman, 1912; Waterhouse, 1916; Stephens and Hosking, 1932). Pleistocene and recent fossils have been recorded from an emerged shell-bed recorded by Edwards from south of Mount Cameron West, from the aeolianite just north of Mount Cameron West, and from a dune sand at Surprise Bay, King Island (Chapman, 1912, p. 51).

Pleistocene limestones have been known from the Smithton area for many years but the latest work is that of Gill and Banks (1956) which lists earlier references. Patches of marl occur inter-bedded with peat in the Mowbray Swamp Peat and are only a couple of feet thick. They contain fresh-water gastropods and have been dated by the radiocarbon method as older than 37,600 years. The spring mounds of Mowbray Swamp contain alternations of peat and marl, the latter containing fresh-water snails, calcareous algae and marsupial remains. Radiocarbon analysis shows these to be Upper Pleistocene. At Fentons Quarry, Pulbeena, there are alternations of peat and marl containing gastropods, algae and ostracodes. The highest peat is 13,520 ± 40 years and a marl lower in the sequence is 28,190 ± 1,520 years old. The radiocarbon dates indicate an Upper Pleistocene (early Cary) age.

Similar deposits occur in the northern part of King Island (Stephens and Hosking, 1932).

North-East Coast and Furneaux Group.

Calcareous dune-sands and emerged shell-beds occur on the North-East Coast from Low Head to Eddystone Point (Stephens, 1941; Hosking and Hueber, 1954; and later chapter).

On Flinders Island Johnston (1879) noted elevated shell-beds composed largely of oyster shells at a height of about 30 feet above high-water mark about two miles above the mouth of the Arthur River. He showed this and other shell-beds covered by a rock he called the “Helicidae Sandstone” which is 60 to 70 feet thick and occurs up to 100 feet above sea-level. It varies from a coarse gritty sandstone (calcarenite) to a cherty or arenaceous limestone and occurs on Cape Barren, Badger, Chappell, Green and Kangaroo Islands and in the Kent Group. He considered it to be of dune origin. In addition to fragmental marine shells it contains fresh-water snails.

South, East and South-East Coastal Areas.

Spring deposits occur at Richmond (Hosking and Hueber, 1954; Gould, 1869) and emerged shell-beds are found at the Little Swanport River, Pipeclay Lagoon and Ralphs Bay (Lewis, 1946; Hosking and Hueber, 1954).
Several minor occurrences of limestone and dolomite at Point Hibbs and at the south end of the Sticht Range possibly belong to the Middle and Upper Cambrian Dundas Group. The most extensive and valuable limestone deposits belong to the Gordon Limestone which reaches a thickness of at least 5,000 feet in places and in many areas has a purity greater than 90 per cent. This formation covers a time range from the upper part of the Lower Ordovician to the Upper Ordovician and perhaps even into the Lower Silurian. Limestones of Silurian and Devonian age occur in the Eldon Group at Queenstown and Point Hibbs on several horizons but are apparently not extensive. The Darlington Limestone of Lower Permian age occurs in the eastern and north-eastern part of the State but except on Maria Island where it is 50 feet thick it is not thick enough to work. Higher in the Permian a formation of limestone up to 300 feet thick, the Berriedale Limestone and its equivalents, has been worked in a number of places in eastern Tasmania, but is not as pure as the Gordon Limestone. Thin limestone beds are present in the "Woodbridge Glacial Formation" higher in the Permian but are not of economic significance. Probably late in the Oligocene Epoch a marine transgression commences in north-western Tasmania and at its maximum extended from Temma to Trishtown, covered King Island and much of Flinders Island. In this sea limestones were deposited of Upper Oligocene to Lower (or perhaps Middle) Miocene age. A later transgression in the Upper Pliocene covered part of Flinders Island and limestone was again deposited. Quaternary limestones are mainly aeolianites but swamp deposits, spring deposits and emerged shell-beds also occur.

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PERMIAN
By MAXWELL R. BANKS

ADELAIDE
SOUTH AUSTRALIA
1962
The Permian succession in Tasmania is considered to be

Wynyard Tillite (at the base)
Quamby Group,
Golden Valley Group,
Mersey Group,
Cascades Group,
Malbina Siltstone and Sandstone,
Ferntree Group,
Cygnet Coal Measures (at the top).

WYNYARD TILLITE

Basal tillite occurs in many places west of the meridian of Hobart (Fig. 30b). The thickest development is in the Wynyard area where tillite rests against a striated, scoured and plucked surface showing ice movement up and to the north a quarter of a mile east of Doctors Rock. The succession is folded and faulted and detailed mapping shows a thickness of at least 1900 ft. without top or bottom. There are at least nine tillite units and four varved claystone members interbedded with conglomerate and sandstone (David, 1908; Banks, Loveday and Scott, 1955). Four angular unconformities occur where tillite rests on varved claystone or conglomerate and erratics of tillite and varved claystone occur in some of the higher tillites. Surfaces below three tillites in the succession show striations trending between 20° and 50°. Cross-bedding and ripple marks in the sandstone and conglomerate show predominant currents from the south-western quadrant and a few from the north-west. A slump indicates a floor sloping east. Convolute bedding on a large scale occurs in several of the varved clay members and in some other members. All of the erratics could have been
Fig. 25. Distribution of the Permian System (Banks).
derived from the south or south-west with the exception of a graptolitic slate which is unknown yet in Tasmania (Twelvetrees, 1908b; David, 1908). Striations and scour and pluck on the basement beneath tillite at Mount Sedgwick indicate ice moving from just north of west. Striations on a surface below tillite near Mount King William show ice movement from just north of west. Fluvio-glacial conglomerates are associated with the tillite at Mount Sedgwick, Strahan, Point Hibbs and Maydena. The tillite on the Styx Range near Maydena is inter-bedded with several beds, each a few feet thick, of laminated siltstone and passes up into conglomerate. The matrix of the tillite contains fragmentary stenopids, fenestellids, spiriferids and crinoid plates. Erratics suggest a source near Elliott Bay or Mount Darwin. The tillite reported at Rocky Boat Plains Bay (Twelvetrees, 1915, p. 13) is a Cambrian greywacke conglomerate. Tillite at Woodbridge underlies the Bundella Mudstone at a considerable distance and is prob-

Fig. 26. Permian System in South-Eastern Tasmania (Banks).
GEOLOGY OF TASMANIA

ably Wynyard Tillite. It contains erratics (Hogg, 1902) suggesting a source area in western or north-western Tasmania. The tillite at Karoola, near Lilydale, is associated with graded, poorly-sorted sandstones, and contains erratics. Areas such as Cradle Mountain, Latrobe, Beaconsfield and north-eastern and eastern Tasmania have no basal tillite and were beyond the limit of the ice sheet, were nunataks, or were glaciated and later stripped of tillite by an advancing sea or by normal erosion. Support for this last hypothesis is found north of Eaglehawk Neck where a basal conglomerate containing a cobble of chlorite schist, veined with quartz, probably of western Tasmanian origin, rests on a polished, grooved and striated granite surface. The hypothesis is further supported by the presence of boulders of greywacke breccia (Dundas Group) and flakes of golden mica (Precambrian) in the Darlington Limestone on Maria Island, by the presence of large, faceted and rounded fragments of schist, jasper, dolomite and chlorite rock, all probably of western Tasmanian origin, in the "Erratic Zone" of Johnston at Darlington and by the presence of a striated boulder in the basal conglomerate near St. Marys (Brill, pers. comm.). These

Fig. 27. Permian System in Central and Western Tasmania (Banks).
PERMIAN

Fig. 28.Permian System in North-Western Tasmania (Banks).

Fig. 29. Permian System in North-Eastern and Eastern Tasmania (Banks).
finds confirm the view expressed several years ago by Carey that the eastern parts of Tasmania were covered by ice but that the tillite deposited thereon was removed by later erosion.

An ice centre in western or north-western Tasmania or off the present west coast is indicated by striations and by erratic composition. Most writers have considered the tillite to be terrestrial but Carey and Ahmad (1961) suggested that it was deposited below sea-level from a wet-base glacier. The presence of fragmentary marine fossils in the tillite near Maydena tends to support this hypothesis as also does the inferred environment of the succeeding Quamby Group. The age of the tillite is not certain. It is older than the Upper Sakmarian Darlington Limestone and a little older than the Bakes Oil Shale which has a Sakmarian spore assemblage (Balme, letter 18.6.59). Only one plant stem has been found in the tillite at Wynyard. The marine fossils in the tillite on the Styx Range are fragmentary and poorly preserved. On available evidence the tillite could be Upper Carboniferous or Sakmarian.

QUAMBY GROUP

The Quamby Group includes all the formations between the basal tillite or conglomerate and the Darlington Limestone or its correlates. In northern and western Tasmania it consists of only one formation, the Quamby Mudstone, but near Maydena, and on Woody Island it consists of the Woody Island Siltstone, the Sunset Bay Sandstone, the Satellite Siltstone, the D'Entrecasteaux Pebby Siltstone, the Lewis Pt. Sandstone and Siltstone, the Alonnah Sandstone and the Dreamy Bay Sandstone. The Cape Maurouard Conglomerate and Sandstone (Tillite of Lewis, 1937) and the "Erratic Zone" (Johnston, 1900) represent this group on Maria Island.

The predominant rock type is a medium or dark grey mudstone which is carbonaceous in places. Pebbles and small cobbles are rare and generally are well-rounded. However, erratics up to four feet long occur abundantly at Point Hibbs and up to six feet long at Darlington, Maria Island. Pyritic nodules are present in almost all outcrops and are especially abundant on Woody Island, near Maydena and at Point Hibbs. Glendonites are widespread and, in places, very abundant, especially in siltstone. They have not yet been found in Tasmania above the Quamby Group. Calcareous concretions up to twelve feet long are also common. A common feature is the development of elliptical bodies, four to six feet long, by some form of spheroidal weathering. Bedding is rarely apparent in the siltstone. The siltstone is fossiliferous although fossils are rare in the lower parts of the group. Cross-bedding in some of the sandstone units at Point Hibbs indicates currents flowing from the south-west and oriented colonies of *Stenopora tasmaniensis* at Point Hibbs indicate south-easterly currents and at Woody Island north-easterly. Some of the sandstones are very poorly sorted, e.g. the D'Entrecasteaux "Tillite" (Banks et al., 1955), and are greywackes of turbidity current origin. These greywackes on Woody Island and at Point Hibbs are commonly richly fossiliferous although the fossils are fragmentary as in the Alonnah Sandstone (Banks et al., 1955, p. 225). Near the top of the Quamby Mudstone at Poatina bands of pebbles occur in siltstone.
Fig. 30. (a) Relief of sub-Permian surface; (b) Palaeogeography of the Wynyard Tillite and correlates; (c) Palaeogeography of the Quamby Group; (d) Palaeogeography of the Golden Valley Group (Banks).
These bands show graded bedding and the larger fossils and fossil fragments occur near the base of the beds. Pebble studies on these beds by Wanless and the author suggest that the turbidity currents arose in the area between Lorinna and Cradle Mountain.

An oil shale called "Tasmanite" which is rich in *Tasmanites punctatus* occurs near West Takone, Oonah, Dulverton, Latrobe, Kimberley, Beulah, Chudleigh and Quamby Brook (Fig. 30c, Reid, 1924, pp. 45-46). The oil shale is 50 ft. above the base of the Quamby Group at Oonah and in most parts of the Railton-Latrobe area but only 30 ft. near Chudleigh (Burns, pers. comm.) and 65 ft. at Quamby Brook (Wells, 1957). This oil shale (Bakes Oil Shale, Wells, 1957) is pebbly and pyritic and contains marine fossils as well as *Tasmanites* (Reid, 1924, pp. 35, 46-47). Foraminiferal faunas occur in the oil shale at Oonah (Crespin, 1958, p. 27) and Latrobe (Crespin, 1958, locality 52) but do not yet provide a means of dating. Spore assemblages from Oonah and Dulverton are probably Sakmarian (Balme, letter 18.6.1959). The Bakes Oil Shale is not a facies variant of the Mersey Coal Measures (Banks, 1958b, pp. 157-158; Jennings, 1957, p. 173) as suggested by Selwyn (1855) and later writers.

The higher parts of the group are conglomeratic at Mount Sedgwick and Maria Island. The basal Permian formation around the shores of Reidle Bay (Maria Island), the Cape Mauroard Formation, consists of interbedded arkosic conglomerate and sandstone, with well-rounded boulders of quartzite and granite up to eight feet long in a well-sorted arkosic matrix. This formation abuts against a granite cliff on the northern shore of the bay. The basal formation is similar at Cape Surville. The "Erratic Zone" on the northern shore of Maria Island is an alternation of fossiliferous, erratic-rich sandstone and polyzoal siltstone. This unit abuts against and overlies a few feet of basal conglomerate and is overlapped by Darlington Limestone about two miles east of Fossil Cliffs. Thus it may be inferred that the shoreline passed through eastern Maria Island and close to Cape Surville during deposition in the upper part of the Quamby Group.

Fossils found in this group include *Gangamopteris* and silicified wood, *Calcitornella stephensi* and other foraminifera, *Stenopora johnstoni*, *S. tasmaniensis*, *Streblascopora marmionensis*, other *Stenopora* species, fenestellids, *Strophalosia* and other strophomenids, spiriferids such as *Grantonia* and *Trigonotreta*, *Eurydesma cordatum*, *Chaenomya*, *Notomya*, and other pelecypods, *Keeneia platyschismoides*, *Peruvispira* and a straparolid, worm burrows, ostracodes and crinoids such as *Calceolispongia* and *Jimbacrinus*. The overall aspect of the fauna suggests correlation with part of the Dalwood Group in New South Wales (Table III).

The Quamby Group is overlapped by, or passes laterally into, conglomerate south and east of Cradle Mountain (part of an island at the time), on the eastern part of Maria Island, between Avoca and Upper Blessington (probably near Rossarden), just east of Lilydale and between Woody Island and Ida Bay. The north-eastern part of Tasmania appears to have been land at the time.

Too few complete sections are available and have been measured to allow confident drawing of isopachs. The thickest zone appears to be along an arc
from Point Hibbs, through Maydena to Beaconsfield. From the figures available, it is clear that the Quamby Group is a thin sheet of silt and other rock types. From the distribution of this group, it appears that the silt was deposited between islands or in a gulf between low-lying land areas. Oil shale was deposited in the thinner north-western part of the sheet of silt close to the island around Cradle Mountain and close to the smaller islands postulated at Deloraine and near Latrobe. On the whole the arenite to lutite ratio increases towards eastern and south-eastern Tasmania and indicates a source area there. The abundance of pyrite and carbonaceous matter in the siltstone suggests a reducing environment and the calcareous concretions an alkaline one. The glendonites may indicate cold conditions and this is supported by the presence of erratics which are, however, not common. The depth of deposition is not clear except at Maria Island and Cape Surville where littoral conditions can be inferred. Fossils become commoner in the siltstone towards the top of the group and the fauna is dominated by fenestellids, ramose stenoporids and Strophalosia. The fauna, grainsize and lack of bedding indicate quiet, uniform conditions of deposition with very slow current movement except for the turbidity currents. Turbidity current deposits are more common in the upper part of the group and are rare or absent in the lower part.

GOLDEN VALLEY GROUP

The Golden Valley Group includes all the formations between the top of the Quamby Group and the base of the Mersey Group. As such it includes the Darlington Limestone and Bundella Mudstone in south-eastern Tasmania, the Darlington Limestone and Swifts Jetty Sandstone at Beaconsfield, the Brumby, Billopp and McRae Formations at Poatina, part of the Wallace River Group near Lake St. Clair, and the Campbell Formation near Wynyard. The name is taken from the Golden Valley Formation (Wells, 1957).

A richly fossiliferous limestone occurs at the base of the group in many places, especially in south-eastern Tasmania. The limestone is represented elsewhere by very fossiliferous calcareous siltstone with limestone lenses. It is overlain by pebbly sandstone on Maria Island and at Beaconsfield, Poatina and Mole Creek, but elsewhere fossiliferous siltstone overlies the limestone and becomes less fossiliferous upwards.

The Darlington Limestone at Darlington is an alternation of Eurydesma-calcirudite and polyzoal-siltstone near the base and Eurydesma-calcirudite and spiriferid-calcirudite higher up (Banks, 1957, pp. 57-60). It is a Eurydesma-calcirudite on southern Maria Island, at Collinsvale, Beaconsfield and Deloraine, and mainly so near Cape Surville where some spiriferid calcirudite also occurs. It is best described as foraminiferal limestone near Lilydale; at Port Sorell and Woody Island it is a foraminiferal, polyzoal shelly limestone. Polyzoa predominate at Mount Sedgwick and Point Hibbs. The limestone becomes thinner to the west, north-west and south of Darlington (Fig. 30d) and tends to contain less Eurydesma and more stenoporids and foraminifera away from Maria Island. The grainsize of the limestone and of the higher beds in the Golden Valley Group tends to decrease to the west and north-west and the place of the lime-
stone in the succession is taken by polyzoal siltstone in those directions. An easterly source area is thus suggested with shallower sea to the east.

This group is absent or represented by terrestrial conglomerate near Cradle Mountain and in north-eastern Tasmania. Longshore currents (north-easterly) at Darlington may have produced the observed imbrication of *Stenopora* colonies. Both rounded and faceted pebbles are present in the limestone at Darlington and are as much as three feet long. They include quartz, quartzite, granite, and greywacke breccia. Golden mica, quartz and feldspar occur in the matrix. These suggest stripping of a nearby granitic and metamorphic terrain with a veneer of till. The polyzoal siltstone in the alternations in the "Erratic Zone" at Darlington is replaced in the Darlington Limestone by spiriferid-calcirudite and the erratic-rich or pebbly sandstone in the former by *Eurydesma*-calcirudite in the latter. This suggests progressive shallowing of the sea, and the fauna and lithology of the Golden Valley Group suggests that it is of shallower water origin than the Quamby Group.

Siltstone such as the Bundella Mudstone is the predominant rock above the Darlington Limestone and Brumby Formation except on Maria Island and near Cape Sorell. These siltstones are poorly sorted in most places and contain pebbles and large fragments up to three feet long. Some of these pebbles are glacial erratics (e.g. in the Bundella Mudstone), but others occur in clearly defined bands associated with larger macrofossils than those in the intervening siltstone which have few pebbles (e.g. in the McRae Formation, McKellar, 1957, p. 8); such bands appear to be turbidity current deposits. Polyzoa, both stenoporids and fenestellids, are the commonest fossils in the siltstone just above the Darlington Limestone or the Brumby Formation but higher in the succession fossils become fewer and near the top of the group are almost absent. Sandstone overlies the Darlington Limestone at Beaconsfield, Poatina, and near Mole Creek (Green, 1959, p. 9; McKellar, 1957, p. 8; Banks in Ford, 1960, p. 26) and contains many pebbles which may be ice rafted erratics, but at Poatina are well-rounded and support numerous *Calcitornella* on their upper surface (McKellar, 1957, p. 8). On Maria Island a very pebbly slightly fossiliferous sandstone only five feet thick overlies the Darlington Limestone and underlies the Mersey Group. It contains fragments up to three feet long of granite, quartzite, schist and a Permian polyzoal limestone and many represent a shallow-water, near-shore deposit derived from a terrain of granite and quartzite covered by earlier Permian sediments such as would have been exposed at the time only a mile or two to the east. Near Cape Sorell, the Mersey Group rests directly on the Darlington Limestone.

Fossils are common in the Darlington Limestone and the Brumby Formation. Foraminifera are widespread—*Calcitornella stephensi* occurs at Porter Hill, Woody Island, Karoola, Quamby Brook, Mole Creek, Port Sorell, Beaconsfield, Maria Island and Point Hibbs (Crespin, 1947, 1958, and author); *Geinitzina triangularis* occurs at Sandy Bay and Karoola; *Hemigordius schlumbergi* at Karoola and at the bridge over the Don River on the Roland Highway; *Nodosaria* cf. *permiana* at Karoola; *Hippocrepinella biaperta* at Quamby Brook and *Hyperammina elegans* and *Frondicularia hillae* at the Don River bridge. *Girar-
liarella angulata occurs at Mount Sedgwick, probably in the Golden Valley Group. This assemblage suggests correlation with the Callytharra Formation, Fossil Cliff Formation and Nura Nura Member in Western Australia, the Cattle Creek Formation in Queensland and the Rutherford Formation of the Dalwood Group in New South Wales (Crespin, 1947, 1958; Banks, 1958) (Table III). Stenopora tasmaniensis and S. johnstoni occur on Maria Island, on Woody Island, at Porter Hill and Mount Nassau, at Point Hibbs and at Port Sorell. Fenestrate polyzoans are common. Schuchertella is rare in the group but Strophalosia is common in the siltstones. Dielasmids are rare. Spiriferids are common especially in the limestones and sandstones and include Grantonia, Trigonotreta and Ingelarella. Pelecypods are abundant, especially in the Darlington Limestone, in which millions of Eurydesma cordatum are preserved. Mytilids and pectinaceans (Aviculopecten fittoni, Deltpecten limaeformis) are also present. Gastropods are commonly present, especially a small species of Peruwispira, and Keeneia platyschismoides occurs in several places as well as a small straparolid resembling Parornaphalus ammonitiformis (Etheridge). Calceolispongia and Camptocrinus occur. Conularia is rare. The foraminifera, polyzoa (Crockford, 1951), pelecypods and gastropods all indicate correlation with part of the Dalwood Group of New South Wales, especially the Allandale and Rutherford Formations (Table III).

THE BASAL CONGLOMERATES

The Mersey Group is underlain by basal conglomeratic formations in the Cradle Mountain area and in the north-eastern part of the State (Fig. 31a).

The Barn Bluff Conglomerate is a formation of siliceous conglomerate and breccia more than 350 ft. thick resting unconformably on Precambrian rocks in the valley of Brown River and overlain conformably by Mersey Group sandstone around the walls of Waterfall Valley. It is named after Barn Bluff, and is Lower Permian.

The conglomerate overlaps westward onto the Precambrian at Cradle Mountain (see Jennings, 1959b, p. 74), and from Brown River south to Lake Holmes, and from Lake Rodway eastwards (Burns, 1961c, p. 20), so that the sub-Permian surface had a relief of at least 600 ft. The conglomerate occupies an area trending north-north-east with a high area from Lake Windermere to east of Mount Emmett almost enclosing a meridional basin near Cradle Mountain (Burns, 1961c, p. 20). The maximum grainsize occurs just west of Cradle Mountain where boulders six feet long occur and in general the grainsize decreases to south and east. Imbrication and cross-bedding in some conglomerates in the Brown River Valley suggest currents from the north and east. The dominant rock type is well-sorted, siliceous conglomerate with some sandstone beds, a basal breccia at Little Horn and near Lake Holmes, and rare, laterally impersistent siltstone lenses. Near Lake Holmes basal conglomerate passes northwards (basinward) into siliceous sandstone.

Both the grainsize variation and the pebble composition are in favour of a local source, possibly with some contribution from granites and Ordovician conglomerates to the west or north. The Barn Bluff Conglomerate is probably
non-marine and may represent a large alluvial cone or series of cones splaying out from a high area north and west of Barn Bluff.

Siliceous conglomerates form the basal formation in many but not all areas between Cathedral Mountain and the Gog Range. On Mount Pelion East the basal conglomerate is between 50 and 100 ft. thick and it is of this order of thickness at Howells Bluff (Spry, 1958b; Burns, 1959b; Jennings et al., 1961). It can be traced north from Precambrian rocks near Clumner Bluff onto

**Table III**

<table>
<thead>
<tr>
<th>EPOCHS</th>
<th>WESTERN AUSTRALIA</th>
<th>TASMANIA</th>
<th>NEW SOUTH WALES</th>
<th>QUEENSLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARTARIAN</td>
<td>HARDMAN MEMBER</td>
<td>CYGNET COAL MEASURES</td>
<td>NEWCASTLE COAL M.</td>
<td>TOMAGO COAL M.</td>
</tr>
<tr>
<td>KAZANIAN</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>KUNGURIAN</td>
<td>NOONKAMBAH FORM.</td>
<td>MALBINA FORM MEMBER</td>
<td>MULBRING SUB-GROUP</td>
<td></td>
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<td>ARTINSKIAN</td>
<td>IDWIN RIVER COAL M.</td>
<td>MALBINA FORM</td>
<td>MUREE FORM.</td>
<td></td>
</tr>
<tr>
<td>SAKMARIAN</td>
<td>POOLE HIGH CLIFF SANDSTONE</td>
<td>CASCADAS GROUP</td>
<td>BRANXTON SUB-GROUP</td>
<td>CATHERINE SANDSTONE</td>
</tr>
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<td>NURA NURA FOSSIL CLIFF FORM.</td>
<td>MERSEY GROUP</td>
<td>GRETA COAL MEASURES</td>
<td>INGELARA SHALE</td>
</tr>
<tr>
<td></td>
<td>GRANT FORM.</td>
<td>GOLDEN VALLEY GROUP</td>
<td>FARLEY FORM.</td>
<td>MULBRING SANDSTONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QUAMBY GROUP</td>
<td>RATHERFORD FORM.</td>
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<td></td>
<td>WYNYARD TILLITE</td>
<td>ALLANDALE FORM.</td>
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<td></td>
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<td></td>
<td>LOCHINVAR FORM.</td>
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</tbody>
</table>

The Western Australian column is after McWhae et al. (1958), the New South Wales column after Hanlon and Booker (1955) and the Queensland column slightly amended from Phillips (1958). Although Crockford (1951) regarded the Mulbring and Member E of the Malbina as probably Lower Kungurian on the basis of the early Kungurian extinction of stenoporidae elsewhere, they may well be younger, Upper Kungurian, as suggested for the Mantuan by Maxwell (1954) and for the Lightjack Member by Glenister and Furnish (1961).

Ordovician and Silurian rocks near Mole Creek where it is at most 45 ft. thick. It is overlain by Quamby Mudstone in this area (Ford, 1960, p. 27) but further west is overlain by Golden Valley Group (Spry, 1958b), by Golden Valley Group near Dean Bluff further south (Macleod et al., 1961, p. 17) and by Quamby Mudstone and/or Golden Valley Group near Mount Pelion West. The relationship of the conglomerate to the Wynyard Tillite is not known, but the Quamby and Golden Valley Groups seem to pass north and west into the conglomerate. On Dublin Plain this formation contains a crinoid column (Ford,
PERMIAN

1960, p. 27) and is presumably marine. A littoral environment for this conglomerate is probable.

The conglomerates are Sakmarian and Lower Artinskian as suggested by the relationship to other units at Mole Creek, Mount Pelion West and Barn Bluff. During this time there is evidence for a rise of sea-level, although the sea appears to have become shallower. No off-laps have been detected during this time but overlap of Quamby Group by Golden Valley Group occurs on Maria Island, at Cape Surville and near Dean Bluff and February Plains. All these observations may be explained by postulating filling of the sea more rapidly than the sea-level rose. The floor of the sea sloped down to the west at Maria Island and Cape Surville, and to the east or south-east near Dean Bluff.

Conglomerate forms the basal unit at Mount Arthur, Mount Littlechild, Mount Victoria, Rossarden, Avoca, Fingal, Mathinna, Mangana, Elephant Pass and Seymour. The conglomerates are predominantly well-sorted and composed mainly of pebbles to cobbles of quartzite and reef quartz with some granite in a quartz sand or slightly arkosic matrix.

Heavy detrital minerals in the basal conglomerate have been worked in several places, e.g. gold at Mangana (Twelvetrees, 1907b, p. 10), cassiterite near Rossarden (Conolly, 1953, p. 1201), Rays Hill (Herman, 1914, p. 283), and Brookstead (Reid and Henderson, 1929, p. 13). The larger fragments vary from angular to sub-rounded, most of them being sub-angular or sub-rounded. The matrix is well-sorted sand with sub-angular and angular grains. A grooved boulder occurs in this unit at Elephant Pass. The thickness of the basal conglomerate is 15 ft. at Avoca, 23 ft. at Elephant Pass and 54 ft. at Seymour (see sections Fig. 29) but local variations from four inches to 66 ft. have been suggested by McNeil (1960, p. 29) near St. Marys. At Rossarden, Avoca, Fingal, Elephant Pass and Seymour the conglomerate is overlain by sandstones which contain carbonaceous and coaly partings. Spores from these at Elephant Pass are Lower Artinskian (Balme, letter 18.6.59). As the conglomerate passes gradationally up into the sandstone it is probably not much older, possibly also Lower Artinskian. The conglomerates rest on an uneven surface of Mathinna Beds and granitic rocks and may occupy the valleys in this surface (Reid and Henderson, 1929, pp. 13, 94). Twelvetrees (1907b, p. 10) regarded them as extensive sea-beaches but their texture and structure and the fresh-water origin of the overlying formation suggest stream-gravel origin. Uraniferous, pyritic black shales, some of which are oil shales, occur in the basal part of this formation (part of Aberfoyle Formation of Blissett, 1959) at Castle Carey Creek near Rossarden (Hughes, 1957b, p. 23) and may represent marginal marine deposits of the Quamby Group passing up into terrestrial arkoses.

The successions at Rays Hill, St. Marys and Friendly Beaches, Coles Bay (Fig. 29) are abnormal in that they contain no clearly non-marine beds and no Darlington Limestone or Brumby Formation. Arkosic conglomerates are basal in both places and are probably the result of atmospheric weathering of granite in situ or nearly so. The upper part of the Rays Hill Arkose is pebbly and contains Glossopteris as well as marine fossils and may be a littoral deposit.
It is overlain by pebbly marine mudstone. The arkose at Friendly Beaches is overlain by coarse sandstone with a few large shells, e.g. *Eurydesma cordatum*, and some siliceous pebbles. This is probably also littoral. Above the sandstone is the Isaacs Conglomerate (*Tillite of Banks, 1955*), which contains pebbles, cobbles and boulders of granite, quartz, quartzite, and andalusite hornfels in a sand-grade matrix of quartz and feldspar. Some of the boulders are faceted and a few may be striated. One bed shows imbrication, such as might be produced by an east-facing shingle beach. These two successions, the distribution of basal conglomerate, the superposition of Triassic directly on granite at Llandaff (*Hills et al., 1922*), and the Maria Island succession suggest a peninsula extending from near Rossarden to St. Marys and south to Coles Bay on the east and Maria Island on the west in Upper Sakmarian and Lower Artinskian time (*Figs 30d, 31a*).

**MERSEY GROUP**

The Mersey Group includes the formations of the Faulkner Group (*Banks and Hale, 1957*), the Liffey Group, the top 9 ft. of the McRae Formation and the basal 25 ft. of the Meander Formation (*McKellar, 1957*), the Liffey Sandstone (*Wells, 1957*), the Mersey Coal Measures (*Stephens, 1874*), the Preolelenna Coal Measures, the Relapse Sandstone (*McNeil, 1961*), the Don Valley Black Shale, the "Pelionite Horizon", the upper part of the Aberfoyle Formation (*Blissett, 1957*) and the Mount Elephant Coal Horizon (for names see Smith,
Fig. 32. (a) Isopachs for the Cascades Group; (b) Isopachs for the Malbina Formation; (c) Isopachs for the Ferntree Group; (d) Distribution of the Cygnet Coal Measures (Banks).
The Snug Mudstone (Snug Stage of Lewis, 1946), is probably a marine equivalent of the Mersey Group as may also be some of the Isaacs Conglomerate and the Rays Hill Arkose.

This group is widespread (Fig. 31b) and is thickest near Devonport. The typical rock type is a well-sorted, siliceous, micaceous, cross-beded or ripple-marked sandstone with either no fossils or with worm castings, plant fragments, and coaly partings. With this are well-sorted, siliceous, micaceous, carbonaceous siltstones with small-scale cross-bedding and ripple marking. When fresh these siltstones are dark grey. Pebble bands and conglomerates with siliceous pebbles occur but are not common. Bituminous coal occurs in a number of places and it is noticeable that the better deposits of coal, e.g. Preolenna, Barn Bluff, Mount Pelion area and Devonport area, were marginal to the area of deposition of this group and probably close to the higher land bordering the sedimentary basin. Oil shales and cannel coal occurs in or at the top of this group at Barn Bluff (Pelionite), Preolenna (cannel coal), Nook (Don Valley Black Shale) and near Lilydale (oil shale). These deposits are also marginal. Such a geographic relationship of the coals and oil shales to the basin of deposition has been inferred also in the Permian of New South Wales (Dulhunty, 1944, pp. 36-37).

Poorly-sorted pebbly sandstones and siltstones (e.g. the Geiss Conglomerate, the Byers Sandstone, the Altamont Conglomerate of Banks and Hale, 1957; the "worm-cast sandstone" of McKellar, 1957, in the Flat Top, Creekton and Meander Formations, and grey, rock-fragment sandstone in the McRae Formation) are intercalated between the marine units of the Bundella and McRae Mudstones and the well-sorted sandstones of the Rathbones and Flat Top Formations. They occur within the Mersey Group near Oyster Cove, Hobart, Wyld's Crag, Port Sorell, Avoca, Poatina, on Maria Island and near Cape Suvive. At Hobart and Maria Island these poorly-sorted beds separate marine from non-marine beds and it is postulated that they are littoral deposits wherever they occur. They are carbonaceous, and contain plant fragments but also contain worm-burrows and castings and rare marine fossils. They are discontinuous (McKellar, 1957, p. 8) and may represent beaches where deposition was comparatively rapid. Marine intercalations occur at Hobart, near Wyld's Crag, at Oyster Cove and Maria Island (Fig. 31b).

Thickness variations are shown in Fig. 31b, but insufficient figures are available to allow construction of an accurate isopach map. In general the thickness decreases west, south and east from the Devonport area but local areas of greater thickness occur near Avoca, Elephant Pass, Wyld's Crag and Hobart; the first two areas being marginal to the pre-existing highlands and the Hobart area near the shoreline. It will be seen that the Mersey Group is a thin sheet of predominantly well-sorted siliceous sand which covered both the earlier Permian highland areas and the earlier Permian sea-floor. The occurrence of coal, widespread, well-sorted carbonaceous siltstones and the presence of plant fragments in the well-sorted siliceous sediments suggest non-marine conditions. A wide, sandy coastal plain with some river channels, lakes and swamps might be postulated as the overall environment of deposition. Reduction in relief of the highlands near Cradle Mountain and in the north-east is indicated by upward passage from Barn Bluff Conglomerate and the basal conglomerates into
finer-grained sediments. A shoreline near St. Marys and Coles Bay has already been suggested for this time and one may be postulated between Hobart and Snug, between Oyster Cove and Snug, and between Hobart and Castle Forbes Bay as the stratigraphic position of the Mersey Group is occupied by the Snug Mudstone at Snug, Castle Forbes Bay and probably Cygnet (M in Fig. 31b). The Snug Mudstone is a mottled mudstone with a few pebbles and marine fossils such as spiriferids. At Snug it rests on 15 ft. of poorly sorted sandstone of the Geiss Conglomerate type, and is overlain by Grange Mudstone.

Once during deposition of the Mersey Group the sea transgressed over the coastal plain to Cape Surville, Maria Island, Avoca, Poatina, Port Sorell and Wyld's Crag forming a shallow gulf elongated north-north-westerly (extent shown by symbol M1 in Fig. 31b).

Fossils in the Mersey Group include plants such as Gangamopteris cuneata McCoy, G. angustifolia McCoy, G. cyclopteroidea Feist., Glossopteris plana Dana, Glossopteris browniana Brongt., G. ? ampla Dana, Neoggerathiopsis hislopi Bunbury (see Arber, 1905) and many spores including Marsupiopollenites scutatus Balme and Hennelly, Nuskoisporites rotatus, Pilasporites calcitus, Pitysporites giganteus, Punctatisporites gretensis, Verrucosporites leopardus, V. pseudoreticulatus and Vestigisporites rudis, all the spores named above being restricted to the Greta Coal Measures in New South Wales (Dulhunty and Dulhunty, 1949; Balme and Hennelly, 1955, 1956) but Marsupiopollenites sinuosus also from the Mersey Group is known only in the Newcastle and Tomago Measures in New South Wales. Specimens of coal and carbonaceous shale from this group from Nook, Quamby Bluff, Illamatha, and Elephant Pass have been dated by Balme (letter 18.6.59) as Lower Artinskian or probably Lower Artinskian while specimens of cannel coal and oil shale from this group at Nook, Preolenna and Karoola have been dated as Lower Permian or ? Sakmarian. A doubtful vertebrate has been recorded in the group near Devonport (Johnston, 1902a, pp. 9-10). Broken fenestellid colonies occur in the sandstone at the base of this group at Elephant Pass (McNeil, 1960, p. 34) and a Conularia in the uppermost beds on Maria Island. These occurrences may indicate fossil beaches or marginal lagoons and both are close to the postulated positions of the shoreline at the time. Worm-burrows and castings are common and the occurrences closely resemble those figured by Kuenen (1961, Fig. 3, p. 73).

Available evidence suggests correlation of the Mersey Group with the Greta Coal Measures in New South Wales, the Irwin River Coal Measures in Western Australia, and the Collinsville Coal Measures in Queensland (Balme, 1962, pp. 273, 275) of Lower Artinskian age (Table III).

CASCADES GROUP

The Cascades Group includes the Nassau Siltstone, the Berriedale Limestone and the Grange Mudstone of Banks and Hale (1957), the lower part of the Marlborough Group (Prider, 1948), Formation 5 (possibly excluding Unit 11) of Burns (1959b, pp. 62-65), the lower part of the "Malbina Formation" of Banks and Ahmad (1962), the lower part of the Flowerdale Stage (Voisey,
1938, p. 320), the lower part of the Upper Latrobe Stage (Voisey, 1938, p. 317),
the Meander Formation of McKellar (1957, p. 7) excluding the basal 25 ft.,
part of the "Woodbridge Formation" of Green (1959, p. 9), the Castle Carey
Mudstone and Burnt Gully Limestone (Blissett, 1958), the Binns Gully Mud-
stone, Enstone Park Limestone and lower part of the Lohreys Gully Mudstone
of Walker (1957), the Peter Limestone and overlying siltstone (Banks, 1955b,
p. 89) and the Productus Zone and Crinoidal Zone (Montgomery, 1891c). The
dominant rock types in this group are fossiliferous siltstone, calcareous siltstone
and limestone, but fossiliferous sandstone and metabentonite also occur. The
siltstones contain a few phenoclasts some of which in the Grange Mudstone
reach lengths of a foot and are clearly dropped pebbles. Although many phyla
are represented as fossils in the siltstones the predominant groups are productids
and fenestellids and thin ramose stenoporidae are also common. Both fenestellids
and productids occur fossilized in growth position in many localities. Some of
the siltstones are greenish grey, some medium or dark grey, but some, especially
in the Grange Mudstone, are greyish yellow. Bedding is not well developed
within the siltstones although an appearance of lamination is produced by paral-
lelism of fenestellid fronds. The siltstones alternate with impure limestones.
The limestones are clastic and include lutite, arenite and rudite grades, the
fragments being mainly of shelly material. Fragments of quartz, igneous and
metamorphic rocks are also present and reach small-boulder size. Many of these
larger fragments are faceted and rare ones striated. Some of the larger frag-
ments are demonstrably dropped pebbles. The limestones are impure and
contain much sand-grade quartz and other silicate minerals and some pyrite
(Brill, 1956; Banks and Hale, 1957; Banks, 1957). Thin dolomite beds occur
in several places (Brill, 1956; and Brill in Banks and Hale, 1957, pp. 55, 57).
Metabentonites occur in the Hobart area and on Maria Island (Hale and Brill,
1955). In the western and north-western part of the State the proportion of
limestone in the group is very low and sandstone becomes more significant at
Douglas Creek, Pelion Range, Devonport, Wynyard and Malanna areas (Burns,
1959b, pp. 62-65; Voisey, 1938; Banks and Ahmad, 1962). The sandstones are
pebbly, erratic-bearing and fossiliferous with spiriferids, pelecypods and massive
*Stenopora* colonies, e.g. *S. crinita*, being the predominant fossils. Detailed
analysis of a section of the "Woodbridge Glacial Formation", now Malbina
Formation (Banks and Read, 1962), near Hobart shows that the succession in
western and north-western Tasmania called "Woodbridge Group" by McKellar
(1957) and later authors, is comparable to the Cascades Group plus the Malbina
Formation, not to the latter alone. In addition, Unit 6 of Formation 5 of the
"Woodbridge Group" at Douglas Creek contains a simple rugose coral occurring
elsewhere (in Tasmania) only in the Cascades Group on Maria Island, as well
as *Camptocrinus* not seen in the Hobart section above the Cascades Group. The
beds above the Mersey Group at Firewood Siding contain *Schuchertella* and
*Camptocrinus*, neither of which are known from beds above the Cascades Group.
Although the evidence is as yet far from conclusive and the limits of the Cas-
cades Group in western and north-western Tasmania are not yet clearly estab-
lished, a facies change from limestone and calcareous siltstone in eastern
Tasmania to siltstone, calcareous siltstone and sandstone in western and north-
western Tasmania may be postulated. Such a change would be consistent with the comment of Brill (1956, p. 136) that the amount of non-organic clastic material in the Berriedale Limestone in the Hobart area increases to the west and that the number of beds with glacial erratics increases in the same direction, both suggesting a westerly or north-westerly source. Although recent work by Ford (1956), Burns (1959b), and Blissett (1958) and reinterpretation of the Marlborough and Waddamana sections (Prider, 1948; Fairbridge, 1949) necessitate changes in Brill's (1956, p. 133) isopach map of the Berriedale Limestone, they do not fundamentally alter it and only require that the "0 feet" isopach be drawn further from the zone of maximum thickness. The form of the body of Berriedale Limestone still remains as a thin sheet, the zone of maximum thickness of which trends north-easterly. South and east of Hobart the limestone passes into Grange Mudstone.

The Cascades Group is more widespread than any of the older Permian groups or formations in Tasmania as it extends almost to the north-eastern tip of the island (Fig. 32a). It is a thin sheet of siltstone and calcarenite with other sediments and was deposited in a sea which inundated the coastal plains and low hilly areas of Mersey Group time. Far north-western Tasmania and a high area at Llandaff near Coles Bay may not have been inundated. The zone of maximum thickness trends more or less north-easterly from Hobart (Fig. 32a). The erratics suggest the presence of floating icebergs and some elements of the fauna support the idea of a cool temperate sea (Banks and Hale, 1957, p. 56). Palaeotemperature determinations suggest a sub-tropical to tropical sea (Dorman and Gill, 1959, pp. 91-92) and the presence of thick shelled pelecypods such as *Eurydesma cordatum* might be taken to support this latter idea. However, none of the recognised tropical faunal elements (e.g. coral reefs, or reef-building corals, richthofeniid brachiopods or fusilinids) are known and this lack, together with the erratics and overall faunal aspect, make a cool temperate sea more likely. Alternation in the Nassau Siltstone and Berriedale Limestone of calcarenite and fenestellid-productid siltstone (and the gradational contacts between the rock types) suggest slow cyclic changes in sea-level during deposition (Brill, 1956, pp. 134-135). Competence of the depositing currents varied from greater in the limestone bands with inorganic and organic fragments of arenite grade to lesser in the siltstones and especially in the metabentonites in which are preserved intact some very delicate fossils. Erratics are more common in or near the siltstone bands (Brill, 1956, p. 134) than in the limestone.

Fossils in the Cascades Group include rare leaves (*Glossopteris*), cordaitan or conifer wood, protozoans including the encrusting miliolid *Calcitornella*, sponges, conulariids, simple conical rugose corals, the tabulates *Thamnopora* and *Cladochonus*, polyzoans both stenoporid and fenestellid, brachiopods, especially productids and spiriferids, free-living, fixed, swimming and burrowing pelecypods, gastropods, ostracodes and rare trilobites, blastoids, crinoids and cidaroids. The fauna is dominated by benthonic forms and the assemblage is that of a continental shelf area.

The Berriedale Limestone and Grange Mudstone are probably correlates of the Branxton Sub-group of New South Wales and of part of the Cattle Creek...
and the Ingelara Shales of Queensland (Banks, 1957) and are thus Artinskian in age (Table III).

MALBINA SILTSTONE AND SANDSTONE

This formation, formerly the "Woodbridge Glacial Formation" of the Hobart area, has recently been studied in some detail by Banks and Read (1962).

Five members comprise this formation in the Hobart area and in other areas in south-eastern Tasmania (Banks and Read, 1962; Green, 1961; Brill, 1956, p. 137). The basal member (A) is an alternation of poorly-sorted pebbly sandstone with carbonaceous siltstone. Graded bedding is revealed not only by the matrix but also by the concentration of pebbles and fossils near the base of the sandstone beds and the decrease in size of pebbles and fossils upwards in each bed. As the framework is disrupted, the sandstones are considered to be turbidity current deposits. Fossils are uncommon in the siltstones but some fenestellids occur. The second member (B) is predominantly unfossiliferous siltstone with some poorly-sorted, fossiliferous, graded sandstone bands. Member C is a very pebbly sandstone about five feet thick. Member D consists of unfossiliferous siltstone. The top member E is a very fossiliferous fine-grained sandstone and siltstone with lenses of dark grey, foetid limestone.

This succession has been recognized in the South Arm area by Green (1961) and at Eaglehawk Neck. The "Woodbridge Formation" at Beaconsfield (Green, 1959) probably includes both Cascades Group and Malbina Formation but detailed correlation is not possible. The "Woodbridge Group" at Poatina (McKellar, 1957) includes part of the Cascades Group but the Dabool Formation is very like Member A of the Malbina Formation and the Weston Formation resembles Member E, and it is proposed tentatively to include these in the Malbina Formation. Unit 11, Formation 5, of Burns (1959b, p. 63) appears on examination to be very similar to Member A and Units 1 and 2 of Formation 6 are also probably part of the Malbina Formation. The lower part of the Woodbridge Group (MacLeod et al., 1961, p. 32) in Kia Ora Creek and near Horizontal Hill, Central Highlands, is probably Cascades Group but the upper part (at least 42 ft. thick) is possibly Malbina Formation. Pebbly fossiliferous sandstones exposed in railway cuttings near Firewood Siding are lithologically like Member A (Banks and Ahmad, 1962). In the Marlborough section (Prider, 1948) a pebbly fossiliferous sandstone 13 ft. thick ("richly fossiliferous conglomerate" of Prider) is lithologically like Member A of the Malbina Formation and the overlying siltstone, 40 ft. thick, includes a richly fossiliferous siltstone with limestone lenses near the top like Member E of the Malbina Formation. Unit 3 of the Waddamana succession (Fairbridge, 1949, p. 117) is very like Member A of the Malbina and is followed by about 80 ft. of siltstone and pebbly sandstone and then 30 ft. of fenestellid siltstone like Member E of the Malbina Formation.

The Malbina Formation is less widespread than the Cascades Group (Fig. 31b) as it has not been clearly recognised in north-eastern Tasmania north of Maria Island nor east of Rossarden where the Mistletoe Sandstone may represent
this formation or the overlying Risdon Sandstone. If present at Coles Bay and Elephant Pass it is thin (Brill; 1956, p. 137). A tentative isopach map (Fig. 31b) shows a maximum thickness in south-eastern Tasmania with the trend of maximum thickness north-north-westerly. In the Hobart section the rudite-arenite : lutite ratio is about 1 : 1, is low at Waddamana and Marlborough, is about 1 : 1 at Poatina but is higher further to the west, north-west and north-east and near Mount La Perouse in the south.

Silt was deposited in the Hobart area on a relatively deep sea floor on which grew rare fenestellids. Icebergs contributed a few dropped pebbles mainly of western derivation. From time to time instability in a shallower source area in western, north-western or north-eastern Tasmania where gravel and sand were being deposited and in which heavy shelled spiriferids, pelecypods and gastropods were living, initiated turbidity currents which picked up the sediments and fossils and carried them into south-eastern Tasmania (Banks and Read, 1962). Scours on the base of a conglomerate at Eaglehawk Neck correlated with Member C have a north-easterly trend and fragments of wood in the base trend 330° to 350°.

Fossils are abundant in the sands and pebbly sands near the base and in Member E. Fossils in Member A are predominantly spiriferids, with stenopoids, fenestellids, gastropods and pelecypods and near Hobart these are commonly disarticulated or fragmentary. Pelecypods and spiriferids in sands on Maria Island and near Firewood Siding are complete and articulated and these areas were probably included in the source areas for the turbidity currents which reached Hobart. Fossils in Member E are abundant, complete and in many instances in living position. The fauna is thought to be biocoenotic and is dominated by Strophalosia in some places, Terrakea in others, spiriferids, fenestellids, pelecypods or gastropods in others.

The lower part of the Malbina Formation contains Strophalosia typica and Member E contains Stenopora crinita and Strophalosia ovalis (Banks and Read, 1962). These fossils suggest correlation of Member A with the Branxton Sub-group and the Ingelarra Shale and of Member E with the Mulbring Sub-group and the Mantuan Productus Bed (Table III).

FERNTREE GROUP

This group has been recognized widely in Tasmania either as the Ferntree Mudstone or the Ferntree Group. At the base is a characteristic sandstone, the Risdon Sandstone (Garcia Sandstone of McKellar, 1957), and above this the group consists predominantly of an alternation of fissile and non-fissile siltstone with three thin beds of sandstone or conglomerate in many sections. Erratics are uncommon but do occur. Most fossil groups are also uncommon but include some marine forms. Worm tubes similar to those illustrated by Kuenen (1961, p. 73) are common. Fossil logs and leaves are common in some places, e.g. Bothwell.

Risdon Sandstone is a thin (up to 30 ft.) formation of poorly sorted, pebbly, feldspathic sandstone with rare marine fossils. It consists of several beds at least
in the Hobart and Beaconsfield areas where it has been studied in more detail (McDougall, 1959b, p. 62; Green, 1959, p. 10) than elsewhere. It is glauconitic in north-eastern Tasmania (Brill, 1956, p. 137; Banks, 1957, and Fig. 29 herein) the percentage of glauconite being highest at St. Marys (about 20 per cent.) and decreasing west to Avoca (about 2 per cent.) and south to Maria Island (about 1 per cent.).

Sandstones and pebbly sandstones somewhat similar to the Risdon Sandstone occur on at least two higher horizons in the Ferntree Group at Poatina (McKellar, 1957), Beaconsfield (Green, 1959), near Mole Creek (Ford, 1960) on Barn Bluff, at Waddamana (Fairbridge, 1949), Maria Island, near Hobart (Lewis, 1946; Woolley, 1959) and at Mount La Perouse (Glenister). At least one higher horizon of pebbly sandstone occurs at Bronte (Prider, 1948) and on the Arve River (Ford, 1956).

The Ferntree Mudstone is represented by sandier beds at Mount La Perouse, Firewood Siding, the Du Cane area (MacLeod et al., 1961), at Wynyard (?) and Beaconsfield, especially in the upper part of the group, e.g. Bowens Jetty Sandstone.

The isopach form-line map (Fig. 32c) of this group suggests a zone of maximum thickness trending south from Beaconsfield with thinning to north-east and north-west.

The environment of deposition of this group is not yet clear. It contains a few marine fossils, many worm burrows and plants which presumably drifted into the sea. It is pyritic in a few places especially near the top and a few calcareous concretions occur. The presence of rare, generally small, erratics suggests deposition almost at the limit of icebergs. The facies variations and the distribution of glauconite suggest a floor sloping toward the zone of maximum thickness. There is, however, no indication yet of the depth of the floor. Rocks lithologically and faunally similar to the siltstones of the Ferntree Group occur lower in the succession, e.g. the McRae Mudstone, the top of the Bundella Mudstone, the Jarvis Siltstone, the Fergusson Siltstone, and in every case intervene between very fossiliferous shallow water marine beds and non-marine beds except for the Jarvis Siltstone which has been interpreted as a marine incursion member between non-marine members in a cyclothem. The Ferntree Mudstone similarly lies between normal marine beds and the Cygnet Coal Measures. The simplest hypothesis is that all these mudstones are estuarine deposits or littoral and sub-littoral deposits bordering a low-lying land surface.

Correlation of the Ferntree Group with formations beyond Tasmania is not yet possible.

CYGNET COAL MEASURES

These rocks have been referred to as Cygnet Coal Measures by most authors (see Smith, 1959, pp. 47-48) but the Jackey Shale of McKellar (1957) and the Clog Tom Sandstone of Green (1959) are considered to be the equivalents.

The formation is widely distributed in Tasmania (Fig. 32d) but appears to be discontinuous probably due to pre-Triassic erosion as suggested by Lewis
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(1946). It reaches a maximum thickness of about 330 to 350 ft. in the Mount La Perouse area and on the Pelion Range. The Cygnet Coal Measures contain Permian plants in both areas but the overlying sandstones are unfossiliferous in the Pelion Range area. At Mount La Perouse siltstones with *Dicroidium* and *Cladophlebis* occur 660 ft. above the bed taken as the top of the Cygnet Coal Measures. The base of the Triassic on Mount La Perouse is taken to be the first thickly bedded, cross-bedded, glistening quartz sandstone overlying the uppermost carbonaceous or grey siltstone. Only 40 ft. below this level occurs a carbonaceous shale with *Glossopteris* and *Vertebraria*. The base of the Triassic in the Pelion Range area is similarly placed or placed at the disconformity between coal-bearing sandstones and the coarse basal granule conglomerate of the Gould Formation (MacLeod *et al.*, 1961).

The predominant rock type in the Cygnet Coal Measures is a well-sorted, siliceous, cross-bedded and ripple-marked sandstone but feldspathic and "fontainebleau" sandstones occur on at least one horizon. The sandstones are pebbly in many places. Carbonaceous and siliceous siltstones are common and many are micaceous. Thin uneconomic coal seams are present at Firewood Siding, in the Pelion Range, at Cygnet, on Bruny Island, and in the Mount La Perouse area. Cycles from pebbly sandstone to carbonaceous siltstone and coal recognized at Firewood Siding by Banks and Ahmad (1962) show waning current competence.

Fossils found in the Cygnet Coal Measures include *Gangamopteris angustifolia* M'Coy, *G. cylopteroides* Feist., *Glossopteris angustifolia* Brongn., *G. browniana*, *Schizoneura*, *Vertebraria indica* Royle, and the spore *Lueckisporites fusus* with many others. In New South Wales this spore is found only in the Newcastle and Tomago Measures but also occurs in the Irwin River Coal Measures in Western Australia. Balme (letter 18-6-59) dated samples from Cygnet, the Henty River, Pelion Range, and Sky Farm near Hobart as Kungurian to Upper Permian (see also Balme, 1962, pp. 273, 275, 276).

During deposition of the Cygnet Coal Measures, a sandy plain extended across much of Tasmania except north-eastern and probably far north-western Tasmania. Lakes and swamps occurred within the plain and in some of these, especially those in the north-western and south-eastern parts of the plain, peat accumulated. The vegetation preserved is dominantly pteridospermatous but evidence of equisetales and larger woody gymnosperms is also present. The only animal remains recognized are worm tubes and castings in the, thinly laminated siliceous and carbonaceous siltstones formed in lakes and ponds.

STRUCTURE OF THE PERMIAN SYSTEM

The commonest view on the structure of Permian rocks in Tasmania is that they are horizontal or where dipping have been affected by Jurassic or Cainozoic faulting.

Folds have been recorded in the Tasmanian Permian System by Selwyn (1855), Gould (1861) and Hills (1913, p. 14, plates 2 and 3). In each of these cases it is difficult to assess the effect of later faulting but the dome and basin
Fig. 33. Structure of the Permian System (Banks).
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structure suggested by Fairbridge (1949) in the Hunterston area is supported by later check mapping and the dips are the reverse of those expected as drag dips on the recognized faults (ibid., Figs. 5, 6).

Folds are exposed on the Forestier and Tasman Peninsulas, at Maria Island and Firewood Siding. The Wynyard Tillite at Wynyard shows folding on several scales, and although much of the folding in varved siltstone and other incompetent beds is convolute, larger folds, wavelength several hundred feet, amplitude a few feet, in thick competent sandstone and conglomerate units, may be tectonic.

A plot of all available dips on Permian rocks (Fig. 33) reveals that dips are certainly not uniform in direction even in small areas and comparison with the structural map of Tasmania and detailed maps suggests that many of the dips are unrelated to observed faulting. The overall structure appears to be synclinal. The gentleness of dips in the Tasman Peninsula area suggests compaction over an uneven basement, but dips on the flank of the dome near Geeveston are up to 10° which appears to be too high for a differential compaction origin. The domes at Hunterston are also probably too big and too high in the Permian to be compactional.

The age of the folding is probably epi-Permian. In most places Triassic rocks rest disconformably on the Permian (see Chapter VI). Triassic rocks occur only east of the line from New River Lagoon to Mount Rufus (the line along which the Permian dips fairly steeply east and north-east) and west and south of the north-eastern highlands, and may be considered in general to occupy the axial region of a big synclinal structure. In the St. Marys area at Seymour and near Coles Bay the “Feldspathic Sandstone” rests on Permian or pre-Permian rocks suggesting the presence of a high area there in early Triassic time. Blissett (1959, p. 42) noted that conglomerates in the Feldspathic Sandstone near Aberfoyle contain rounded pebbles of Mathinna quartzites. Such pebbles would become available either from the Permian cover or from the basement from which this had been stripped, if north-eastern Tasmania had been previously rejuvenated but not otherwise. Currents from the north-west affected the Waddamana area (Fairbridge, 1949, p. 120), Tarraleah, Butlers Gorge areas (Pride, 1948, pp. 139, 140), and the Gretna area (Anandalwar, 1960, p. 15) suggest a higher area near Lake St. Clair early in the Triassic. There is thus stratigraphic evidence that the Permian rocks in eastern and north-eastern and in western Tasmania had been uplifted prior to the Triassic. The synclinal downwarp therefore began before the Triassic and may have started as early as Kungurian as the isopach maps of the Malbina Formation and Ferntree Group (Fig. 32b, c) show maximum thickness approximately along the axial zone of the major syncline and the thickest development of Cygnet Coal Measures are close to the upwarped western limb of the syncline as revealed by structure contours on the top of the Mersey Group.

Later further downwarping of this synclinal area and upwarping in north-eastern, north-western and western Tasmania (Fairbridge, 1949, p. 126) combined with Cainozoic rifting, would readily produce the present rock distribution.
Late in the Carboniferous Period or early in the Permian ice covered much of Tasmania (Fig. 30b). The sub-Permian surface had a relief of several thousand feet with particularly low areas near Wynyard and Point Hibbs and high areas near Cradle Mountain, Devonport, Deloraine, Wylds Crag and Ida Bay and a peninsula in eastern Tasmania (Fig. 30a).

The glaciers from an ice centre north-west of Zeehan diverged about a higher area near Cradle Mountain. One tongue occupied a deep valley near Wynyard and a lobe fanned out south of the high area to occupy parts of northern and central Tasmania and to override some parts of the east coast peninsula.

West of Maydena the ice scoured shell beds and dumped the shell fragments in the till on the Styx Range. Thus the base of the ice may well have been below sea-level. Carey and Ahmad (1961) suggested that the Wynyard Tillite was deposited below a “wet-base” glacier. David (1908, p. 278) suggested deposition from “land ice in the form of a piedmont or of an ice-sheet” but that near Wynyard the ice came down very close to, if not actually to, sea-level. The extent of the glaciation and the distribution of erratics of western Tasmanian origin in eastern Tasmania make it seem likely that either a piedmont glacier or an ice-sheet rather than mountain glaciation was involved.

Following retreat of the glaciers the sea covered the till, probably to a considerable depth, eustatic rise of sea-level being much more rapid than isostatic readjustment.

The Quamby Group is underlain by or passes laterally into thin conglomerates and sandstones in a number of places, but most of the group appears to be of deep water, partially barred basin origin. Marine oil shales accumulated close to islands. Shallowing of the sea during deposition of the upper part of the Quamby Group seems to be indicated by the fauna and increasing sandiness in marginal areas. Instability in the source areas is shown by the presence of turbidity current deposits in the higher parts of the group. The Golden Valley Group, of Upper Sakmarian and perhaps Lower Artinskian age, was deposited in a shallower sea than the Quamby Group but the deposits are more extensive along the east coast peninsula and on the flanks of the Cradle Mountain island. This anomaly may be explained if the rate of deposition exceeded the rate of rise of sea-level. The sediments of the Golden Valley Group became finer-grained upwards in most parts of Tasmania probably indicating reduction in relief of the source area. Some instability is indicated by turbidity current deposits. Uplift of source areas in north-western Tasmania early in Artinskian time resulted in the spreading of sand over the shallow silts of the Golden Valley Group onto the east coast peninsula and over the Cradle Mountain area. The sand formed a wide coastal plain containing lakes and swamps and the sea was restricted to a small gulf in southern Tasmania during the deposition of the lower part of the Mersey Group. During deposition of this group the sea rose once to form a long, narrow gulf extending as far north as Port Sorell and then retreated. This inundation resulted in the development of two cyclothems in many parts of Tasmania.
A little later in Lower Artinskian time the sea rose and covered most of Tasmania except perhaps the far north-west. This wide transgression probably resulted from down-warping as an eustatic rise in sea-level would be expected to produce thickest deposition over the old gulf in southern Tasmania and along the axis of Mersey Group inundation but the zone of thickest Cascades Group crosses these at a high angle. During deposition of the Cascades Group marine life became very abundant in the shallow sea over which a few icebergs floated. During the Artinskian tectonic instability increased as shown by the increasing number of turbidites in the upper part of the Grange Mudstone and the lower part of the Malbina Formation. The sea became less extensive and the source areas in north-western and north-eastern Tasmania were uplifted. The zone of thickest deposition of the Malbina Formation trended north-north-westerly. The rapid succession of turbidity currents killed the benthonic fauna and it was only during deposition of the upper part of the formation possibly in Lower Kungurian time that life became abundant again in the Hobart area. The sea spread a little over the east coast peninsula and further instability is recorded in the Risdon Sandstone. The resulting turbidity currents killed the benthonic fauna and it never became properly established again in any part of Tasmania during the Permian. A wide shallow sea covered much of Tasmania and was bordered by low source areas during deposition of the Ferntree Group. The axis of greatest thickness had an almost meridional trend and lay west of that of the Malbina Formation. Late in the Permian, probably in the Tartarian, rejuvenation of the source areas, particularly in western Tasmania, and withdrawal of the sea, resulted in deposition of sands and carbonaceous silts of the Cygnet Coal Measures. The zone of greatest thickness was almost parallel to but west of that of the Ferntree Group.

The thickness of the Permian System and the sheet-like character of many of the members and formations suggest shelf rather than geosynclinal deposition. The average rate of deposition was of the order of 1 ft. in ten thousand years (about 0·003 mm./annum). However, the sediments differ markedly from those on stable shelves in that many of them are poorly-sorted. Some of the poor sorting may be attributed to deposition from drifting icebergs but some is due to tectonic instability.

Uplift and downwarping and movement of zones of maximum thickness have been deduced above and it is probable that the tectonic instability started as early as Lower Artinskian and it may have started during Sakmarian (upper part of Quamby Group). Maximum instability seems to have occurred in Middle or Upper Artinskian time (Malbina Formation) and it is probably significant that this was a time of considerable orogenic movement in New South Wales (part of the Hunter-Bowen Orogeny, Osborne, 1950). Progressive-westward movement of zones of maximum thickness of units in Upper Permian time seems to have occurred and this again is reminiscent of the situation at the time in New South Wales (Voisey, 1959, p. 201) but seems to have started later. Uplift and development of a major synclinal structure with a trend approximately north-north-west threatened occurred late in Permian time.
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GENERAL GEOLOGY

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INTRODUCTION

We may think of the Plateau as consisting of two main, nearly horizontal, layers of rock resting on a basement of older, steeply tilted rocks. The surface layer, a few hundred metres thick, is dolerite about 165 million years old. This was injected into marine and non-marine sedimentary rocks deposited during a span of about 90 million years beginning about 290 million years ago. The part of this sequence originally over the dolerite has been removed by erosion, that beneath the dolerite is preserved as an almost continuous band around the northern base of the Plateau from Travellers Range to Table Mountain. The basement consists of metamorphic, sedimentary and igneous rocks some older than 570 million years, intruded by granite over 480 million years ago and again about 345 million years ago, and folded into a mountain range about 370 million years ago.

THE BASEMENT ROCKS

The basement rocks include Precambrian (older than 570 m.y.) schists, phyllites, slates, quartzites and dolomite (distribution shown on map, fig.6). These are overlain at Quamby Brook and near Connorville by Cambrian rocks including slates, siltstones, greywackes and silicic and mafic volcanic rocks. Granite intruded along the margin of the Tyennan Geanticline during the Cambrian. Ordovician to Lower Silurian (500 to 430 m.y. old) shallow water marine sediments overly the Precambrian and Cambrian rocks. The Precambrian rocks occur both in the core of an uparched (anticlinal) structure near Golden Valley and in the Mersey valley upstream from Western Bluff, where they form part of the core of Tasmania, the Tyennan Geanticline, which must underlie much of the Central Plateau. The rocks of this geanticline were folded at least once before the Cambrian. The Cambrian, Ordovician and Silurian rocks were folded about 370 million years ago, and then granite injected about 345 m.y. ago. The folding produced a high mountain range subsequently eroded presumably by sub-aerial agents and finally by part of an extensive ice sheet which deposited boulder clay as it retreated.
THE PARMEENER SUPERGROUP

Introduction and Definition

The boulder clay is the lowest unit in a succession of rocks of Late Carboniferous (290 m.y.) age at the base to Late Triassic (205 m.y.) age at the top. The succession outcrops around the rim of the Plateau from Travellers Range to Table Mountain and could conveniently be called the Parmeener Supergroup (after Mt. Parmeener, 447.4E.539.00N). The Supergroup includes all the units from the Stockers Tillite at the base to the Brady Formation at the top and in the Plateau region is about 1200m thick. It rests with angular unconformity on older rocks and is capped by an intrusive dolerite sheet in most places. The units in the supergroup progressively overlap older units from the east and from the south towards Cradle Mountain. This overlap suggests that the surface of the basement rocks sloped down to south and east from Cradle Mountain in the Early Permian.

Lower Parmeener Supergroup

Details of the lower part of the Supergroup will be given by Mr. M.J. Clarke and his colleagues. Although the lower part of the supergroup includes some important marine beds, the upper part is entirely non-marine.

Upper Parmeener Supergroup

The upper part of the supergroup begins at the base of the Jackey Shale which is Upper Permian (Balme in Jennings 1963). The siltstones, sandstones and coaly streaks in this unit were deposited under humid, probably cool, conditions in swamps, lakes and river channels on a coastal plain initially, at least, close to the sea.

The subdued outcrops of the Jackey Shale are capped and, in most places, hidden by long ramparts of Ross Sandstone in cliffs up to 100m high. A thin bed of carbonaceous siltstone near the top of the Ross Sandstone contains spores of Early Triassic age (Playford 1965). Deposition of the sandstone on point bars in a migrating, slightly meandering stream system is suggested by the grainsize and the cross-bedding in this unit along the Western Tiers. Near Lake St. Clair alluvial fans of easterly derivation are indicated at this time by gravel beds (Gould Conglomerate, Macleod et al. 1961). Mottled red siltstones in rocks of this age near Hobart show that the climate was monsoonal.
The grainsize decreases and the proportion of siltstone increases upwards into the Cluan Formation. These characters, the scale of cross-bedding, and the types of fossils present suggest that the river system had decreased in gradient and become more meandrine. Spores in siltstones show that club-mosses, horse-tails, ferns and seed ferns grew on this Early Triassic flood plain. In the rivers labyrinthodont amphibians lived, some to die in ponds left as the rivers dried up in the dry season. Their bones, especially their teeth and skull bones, were picked up with flakes of dried up clay by the floods of the wet season and dumped in clay-pellet gravel beds as the floods receded. The same species of labyrinthodont occurs in Early Triassic rocks near Derby in Western Australia (Cosgriff 1965).

Fragments of volcanic rock in the next highest unit, the Tiers Formation, as well as some of the minerals in the sandstones reveal that volcanic activity had started within the watershed of the river system. The presence of abundant plant fossils in some of the siltstones of this formation suggest a more equably humid climate than earlier. Spores from these rocks show that they are Middle Triassic. Close interbedding of sandstone and siltstone allow us to envisage deposition on levee banks and in back swamps on an extensive flood plain.

The highest formation in the Supergroup, the Brady, consists of approximately equal proportions of sandstone and siltstone with some thin coal seams. Fragments in the sandstone show the continued presence of, even increase in, volcanic activity. A flood plain dotted with cinder cones, swamps, ponds and lakes may be envisaged with scouring rushes, ferns and seed-ferns growing in and near the water, large club mosses, cycad palms and maiden hair trees further away. These fossils demonstrate the Late Triassic age of the formation. The abundance of plant fossils and the presence of coal suggest a high effective rainfall.

The Latitude Anomaly

The monsoonal climate postulated for the Early Triassic and the very abundant vegetation in the Late Triassic in Tasmania are difficult to reconcile with the high latitude (about 80°S) inferred for the area from palaeomagnetic studies (Irving 1963).

Structure

Study of the dips of the Supergroup and of the heights of
the contact between the lower and the upper parts of the Super-
group (see fig.7) suggest that it is gently folded. The axis
of a shallow syncline may be inferred south of Warners Lookout
and of a shallow anticline near Projection Bluff. Synclinal
axes have also been inferred just east of Bronte and near the
Ouse River, anticlinal axes under Lake Echo and near Hunterston
(Fairbridge 1949). It seems likely that this folding occurred
before the intrusion of dolerite sheets but it certainly occurred
before the Early Tertiary as the Tertiary non-marine beds are
not folded (Longman 1966 p.26).

**INTRUSION OF DOLE RITE**

The next recorded event in the history of the Plateau was
the injection into the Parmeener Supergroup of vast masses of
molten dolerite. This occurred about 165 million years ago
during the Jurassic Period as the supercontinent of Gondwana
began to break up. The dolerite of the Plateau appears to be
predominantly a single sheet and outcrop appears to be unbroken
around the edge of the Plateau from Travellers Range to south of
Bradys Lookout. At least one feeder for this sheet has been
postulated, a circular pipe rising from within the basement and
penetrating the Parmeener Supergroup under Great Lake. More
details on this rock are given elsewhere in the book by F.L.
Sutherland.

The injection of a sheet several hundred metres thick not
far beneath the earth's surface is likely to have raised the
surface but the form of this new surface cannot yet be recon-
structed.

**AN INTERVAL OF EROSION**

After injection of the dolerite, weathering and erosion
gradually removed its sedimentary cover but remnants of it occur
near the Walls of Jerusalem (Macleod et al. 1961), Great Lake
(Jones et al. 1966) and elsewhere. By about the end of the
Cretaceous Period or early in the Tertiary (65 million years
ago), laterite and bauxite had developed on the dolerite under
tropical or sub-tropical conditions and are preserved beneath
Early Tertiary sediments near Launceston. The Plateau area had
probably become by this time part of an extensive plainland or
a very gently rolling terrain.
7. Structural map of the Central Plateau.

**UPLIFT OF THE PLATEAU**

This terrain was disrupted by many fractures about 65 million years ago as Antarctica moved away from the Australian continent (Griffiths 1971). The Plateau began to rise along north-west or northerly trending lines such as the Bracknell Fault (Longman and Leaman 1971, p.7), and the fault just east of Lake King William (fig.7) leaving fault controlled lowlands to the north-east, the south-east and the south-west. In general the Plateau appears to be a major horst (upfaulted block) trending NW or NNW in the north and almost due north further south. The northern part of the horst is relatively unbroken but to the south the horst is increasingly broken into minor horsts, grabens (downfaulted blocks) and half grabens as the main Derwent "Graben", which borders the Plateau to the south, is approached (figs. 7 and 8).

The whole area seems to have been tilted down to the south-east as the heights of the base of the upper part of the Parmeener Supergroup (fig.7) show. The tilt is about 1 in 130. The age of the tilting is unclear. A basalt dated radiometrically at about 26 million years occupies a valley some tens of metres deep at Skittleball Plains south-west of Great Lake, a valley probably cut by a predecessor of the Ouse, flowing south-east and south to the Derwent. This suggests that the Plateau was already tilted enough to allow such a valley to be cut. Basalt-filled valleys at Maggs Mountain and Mole Creek show the Tiers to have had a relief of at least 1060m when the basalt was erupted (Jennings 1963) and the north-western rim of the Plateau a relief of at least 700m. The age of this basalt is unfortunately not yet known.

Alluvial and lacustrine sediments, some containing fossils of a diverse broad-leafed flora and ancient relatives of the native pines accumulated in the Early Tertiary in the down-faulted areas of the St. Clair-King William Graben, the Derwent "Graben" at Ouse and in the Cressy Trough east of Macrae Hills.
(Prider 1948, Longman 1966, p.19-21, Longman and Leaman 1971). The sediments at the southern end of the St. Clair-King William Graben have structures within them suggesting deposition on a north-west sloping floor onto which streams were flowing from the north-east (Prider 1948, p.145). The flora and sediments in the Cressy Trough suggest a hot, humid climate. Minor developments of fluvial sediments occur beneath basalt at a few places - Tarraleah (Prider 1948) near Hunterston (Fairbridge 1949,p.122) and in isolated patches along the eastern shore of Great Lake (Jones et al. 1966, Sutherland and Hale 1970). These sediments represent the channel and flood plain deposits of pre-basaltic ancestors of the Nive, Ouse and Shannon Rivers.

**VOLCANIC ACTIVITY**

A basalt flow at Skittleball Plains (Sutherland and Hale 1970, p.19) seems to have dammed a wide, flat-floored valley to form a lake in which extensive ash beds and entrail breccias were formed *ibid* pp.19-23 and Sutherland, this book). This lake was about twice as wide as the present Great Lake and extended from Maclanachans Point and Christmas Bay at least as far north as Reynolds Island. It seems likely that this lake was drained by the river, predecessor of the Shannon, which deposited the gravels at Tods Corner now covered by basalt dated as about 21.8 million years old.

The basaltic lava eruptions are dealt with elsewhere in this book (by F.L. Sutherland). The lavas flowed into or down earlier river valleys, some narrow (Prider 1948, p.142), others broad (Fairbridge 1949, p.138). The lava forced the drainage to one side (Ouse, Shannon, upper Nive) or both sides (Lower Nive and Derwent) of the valley (Prider 1948, Fairbridge 1949 pp.138-140). Some fluvial sediments are interbedded with basalt north of Tarraleah and it is interesting to note that one such sand is partly of aeolian origin (Prider 1948, p.145).

**SUBSEQUENT GEOLOGICAL HISTORY**

The events which have affected the Plateau since the outpouring of the lavas are considered in the Geomorphology section.
REFERENCES


"Skittleballs" on Skittleballs Plain near Little Pine Lagoon; tors of scoriaceous tholeiitic basalt.

Photograph by Jack Thwaites.
THIRD INTERNATIONAL GONDWANA SYMPOSIUM
CANBERRA, AUSTRALIA
AUGUST 1973

FIELD TRIP No. 1
UPPER CARBONIFEROUS TO TRIASSIC ROCKS
IN SOUTH-EASTERN AUSTRALIA
August 1 – August 10

Organiser: M. R. Banks
Leaders: South Australia – Dr N. H. Ludbrook
          and Dr V. Gostin
          Victoria – Dr G. A. Thomas
          Tasmania – M. R. Banks and M. J. Clarke
                      assisted by Dr N. Farmer,
                      S. J. Forsyth & A. B. Gulline
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SOUTH AUSTRALIA - ADELAIDE REGION

N.H. Ludbrook

INTRODUCTION

The one-day excursion from Adelaide is designed primarily to show participants the land-forms and sediments produced during and subsequent to glacial action in the early Permian in the area south of Adelaide embracing the southern part of the Mount Lofty Ranges and Fleurieu Peninsula. This area has the distinction of providing easy access within 80 kilometres of Adelaide not only to Precambrian-Cambrian and Cainozoic sedimentary sequences, but also to evidence of two widely-separated glaciations, one in the late Precambrian (Adelaidean) and the other in the early Permian. Almost all of the sequence shown in Tables 1 and 2 will be traversed on the excursion route.

Fig. 1. Geological map of Adelaide Hills and Fleurieu Peninsula, excluding thin Cainozoic cover.
Adelaide Region

Adapted from Sprigg, 1946 and unpublished information of B.P.Thomson.

Fig. 2. Geological map of the environs of Flinders University
Adelaide Region

The region lies at the southern end of the Adelaide Geosyncline in which the record of Adelaidean time in the late Proterozoic is preserved. The oldest (Willouran) series of the Adelaidean is not represented in the southern Mount Lofty Ranges where the Torrensian consisting mostly of sandstones, dolomites and quartzite rests directly on basement rocks of the Barossa Complex. Torrensian sedimentary rocks are followed in sequence by Sturtian (including the Sturt Tillite), Marinoan (on which the Permian glacial pavements occur at Hallett Cove) and Cambrian sediments. Sedimentation in the geosyncline apparently terminated in the Middle Cambrian.

The general structure of the region is that of a broad anticline from which the top has been eroded, exposing the core of Barossa Complex schists and gneisses on the western side of which the Adelaidean is best traversed; on the southeastern side collapse of the geosyncline at the end of the Proterozoic resulted in the development of the Kanmantoo Trough in which the Kanmantoo Group of greywackes, phyllites and other metasediments were deposited. These form the principal bedrock of Fleurieu Peninsula.

The area has been considerably broken up by block faulting which led also to the formation of the St. Vincent Basin with its Adelaide Plains, Noarlunga and Willunga Sub-Basins on the eastern side (fig.1). Some 230 m of Permian sediments occur below the Tertiary sequence in this essentially Cainozoic basin.

THE PERMIAN GLACIATION

The clearest evidence of glacial action is to be seen at Hallett Cove and in Inman Valley where striated pavements have been exposed on removal of the soft glacigenic clays and sands which cover them. Permian sediments are extensive on Fleurieu Peninsula where the Permian relief has been obscured or subdued by erosion during the Mesozoic and by subsequent infilling of the glacial valleys during the Cainozoic. It is, however, difficult to distinguish between original Permian bedded sands and their Tertiary derivatives, and much of what is seen in outcrop may be of Tertiary age.

Prior to the discovery in 1956 of arenaceous foraminifera in subsurface Permian clays on Yorke Peninsula and in the section at Cape Jervis, it was assumed that the Permian deposits of South Australia were entirely fluvio-glacial. It is now known that they are partly marine origin, with the exception of Hallett Cove where the known evidence indicates that deposition took place in an isolated lake.

STOP 1. Flinders University. 35°2'S, 138°34'E.

Flinders University is sited on the Eden Fault Scarp and overlooks the Sturt Gorge to the south. Sturt Tillite is exposed in road cuttings within the University grounds, and its contact with the overlying Tindelpina Member of the Tapley Hill Formation will be seen in the road cutting below the Registry Building.

STOP 2. Hallett Cove. 35°4'S, 138°30'E.

The party will leave the bus at the northern end of the Sandison Reserve and walk south about 1 km to Hallett Cove through the series of striated pave-
TABLE 1. PROTEROZOIC AND PALAEOZOIC SUCCESSION IN THE SOUTHERN MOUNT LOFTY RANGES AND FLEURIEU PENINSULA.

<table>
<thead>
<tr>
<th>Formation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PERMIAN</strong></td>
<td></td>
</tr>
<tr>
<td>Cape Jervis Beds</td>
<td></td>
</tr>
<tr>
<td><strong>Middle to Lower</strong></td>
<td></td>
</tr>
<tr>
<td>Kanmantoo Group</td>
<td></td>
</tr>
<tr>
<td><strong>CAMBRIAN</strong></td>
<td></td>
</tr>
<tr>
<td>Heatherdale Shales</td>
<td></td>
</tr>
<tr>
<td>Fork Tree Limestone</td>
<td></td>
</tr>
<tr>
<td>Sellick Hill Limestone and Wangkonda Fm.</td>
<td></td>
</tr>
<tr>
<td><strong>Lower</strong></td>
<td></td>
</tr>
<tr>
<td>disconformity</td>
<td></td>
</tr>
<tr>
<td>Quartzite = ABC Range Quartzite</td>
<td></td>
</tr>
<tr>
<td>red siltstone</td>
<td></td>
</tr>
<tr>
<td>Seacliff Sandstone Mbr.</td>
<td></td>
</tr>
<tr>
<td><strong>Marinoan</strong></td>
<td></td>
</tr>
<tr>
<td>Reynella Siltstone Mbr.</td>
<td></td>
</tr>
<tr>
<td>siltstone, quartzite, slates</td>
<td></td>
</tr>
<tr>
<td>Marino Arkose</td>
<td></td>
</tr>
<tr>
<td>slate, siltstones, sandstones = Angepena Fm.</td>
<td></td>
</tr>
<tr>
<td><strong>PROTEROZOIC ADELAIDEAN</strong></td>
<td></td>
</tr>
<tr>
<td>Brighton Limestone</td>
<td></td>
</tr>
<tr>
<td>Tapley Hill Formation</td>
<td></td>
</tr>
<tr>
<td>Tindelpina Shale Member</td>
<td></td>
</tr>
<tr>
<td>Sturt Tillite</td>
<td></td>
</tr>
<tr>
<td>disconformity</td>
<td></td>
</tr>
<tr>
<td>Belair Sub-Group</td>
<td></td>
</tr>
<tr>
<td><strong>Torrensian</strong></td>
<td></td>
</tr>
<tr>
<td>Glen Osmond Slate</td>
<td></td>
</tr>
<tr>
<td>Beaumont Dolomite</td>
<td></td>
</tr>
<tr>
<td>phyllites = Saddleworth Formation</td>
<td></td>
</tr>
<tr>
<td>Stoneyfell Quartzite</td>
<td></td>
</tr>
<tr>
<td>Woolshed Flat Shale</td>
<td></td>
</tr>
<tr>
<td>Montacute Dolomite</td>
<td></td>
</tr>
<tr>
<td>Aldgate Sandstone</td>
<td></td>
</tr>
<tr>
<td>unconformity</td>
<td></td>
</tr>
<tr>
<td><strong>Lower Proterozoic</strong></td>
<td></td>
</tr>
<tr>
<td>Barossa Complex</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 2. Cainozoic Stratigraphic Sequence Exposed in Coastal Sections South of Adelaide

<table>
<thead>
<tr>
<th>Period</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RECENT TO PLEISTOCENE</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ngankipari Sand</td>
</tr>
<tr>
<td></td>
<td>Christies Beach Formation</td>
</tr>
<tr>
<td></td>
<td>Taringa Formation</td>
</tr>
<tr>
<td></td>
<td>Ngaltinga Clay { Hindmarsh Clay }</td>
</tr>
<tr>
<td></td>
<td>unconformity</td>
</tr>
<tr>
<td></td>
<td>Seaford Formation</td>
</tr>
<tr>
<td><strong>PLEISTOCENE</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PLIOCENE</strong></td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td>Hallett Cove Sandstone</td>
</tr>
<tr>
<td></td>
<td>unconformity</td>
</tr>
<tr>
<td><strong>MIOCENE</strong></td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td>Port Willunga Beds</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td><strong>OLIGOCENE</strong></td>
<td></td>
</tr>
<tr>
<td><strong>EOCENE</strong></td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td>Blanche Point Marls</td>
</tr>
<tr>
<td></td>
<td>Tortachilla Limestone</td>
</tr>
<tr>
<td></td>
<td>South Maslin Sands</td>
</tr>
<tr>
<td></td>
<td>unconformity</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td>North Maslin Sands</td>
</tr>
</tbody>
</table>

The pavements have been formed on late Proterozoic (Marinoan) massive sandstones and quartzite of the Seacliff Sandstone Member and south of Waterfall Creek on the overlying chocolate slates and quartzites of the Brachina Formation. The formation has a westerly dip of from 20° to 66° and examples of local folding will be seen in Waterfall Creek and in the shore platform, particularly below Black Cliff.

The general direction of striation is NNW and the large erratic on the beach in Hallett Cove are of Victor Harbor granite. On Black Cliff an erratic of Sturt Tillite in the Permian till is a noteworthy feature. The overlying sediments are mostly grey and reddish clays with intercalated sands; striated and faceted erratics are common near the base of the sequence. Some varves are present and load-cast and ripple-marked structures will be seen in a small remnant near the beach in Hallett Cove.

The age of the glaciation was determined by Howchin in 1895 from litho-
Adelaide Region

logical comparison with *Gangamopteris*-bearing beds at Bacchus Marsh in Victoria. It has since been confirmed by the occurrence of foraminifera in equivalent sediments at Cape Jervis and on Yorke Peninsula. Only trace fossils have been found in the Hallett Cove area.

The Permian glacigenes are overlain by the Pliocene Hallett Cove Sandstone and Pleistocene deposits. These will be seen in the Amphitheatre at the cove itself. They were divided by Ward (1966) into a number of formations, two of which, the Ngaltinga Clay and Ochre Cove Formation, are probably equivalent to the Hindmarsh Clay.

Fig. 3. Geological map of the glaciated area, Hallett Cove
Adelaide Region

The area is a proclaimed site of scientific interest; 12 acres covering the striated pavements are already vested in the National Trust of South Australia and an additional 118 acres will be dedicated as a National Park when price negotiations between the owners and the South Australian Government are completed.

STOP 3. Cape Jervis. 35°36'S, 138°51'E.

The route to Cape Jervis will pass through the Noarlunga and Willunga Sub-Basins. Eocene strata on the south bank of the Onkaparinga River will be briefly seen from the top of the hill before the descent into Noarlunga, and about 6 km further south extensive mining of the Middle Eocene North Maslin Sands is in progress on either side of the road.

Leaving the Willunga Basin at Sellick Hill the road traverses an excellent section of Cambrian and late Proterozoic rocks before passing down to the Permian valley occupied by the Myponga River. A bore at Myponga intersected 127 m of Permian sandy beds with pebbles and fragments of various rock types before entering phyllite and quartzite bedrock 329 m below the present ground surface. Apart from the limited section of basement gneisses at Little Gorge where the structure is that of a plunging overturned anticline, most of Fleurieu Peninsula consists of Kanmantoo Group metasediments unconformably overlain by Permian till, sandstone, shale and varve beds.

The section at Cape Jervis (fig. 4) is an isolated remnant, but the best exposed Permian sequence of the region. It is described by Ludbrook and Wilson (Ludbrook, 1967) as:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Lithology</th>
<th>Thickness (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Poor outcrop, grass-covered slopes, probably clay as below, boulders on surface.</td>
<td>7.2</td>
</tr>
<tr>
<td>5</td>
<td>Clay shale - grey-brown, fissile, gritty with scattered boulders, becoming red-grey mottled toward top.</td>
<td>9.0</td>
</tr>
<tr>
<td>4</td>
<td>Sandstone - yellow-white, cross-bedded, with scattered calcareous pebbles.</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Sandstone - gritty sandstone and grit with boulders and thin interbeds of laminated fissile grey clay.</td>
<td>3.9</td>
</tr>
<tr>
<td>2</td>
<td>Till - dark grey boulder till with clay-shale band.</td>
<td>1.5</td>
</tr>
<tr>
<td>1</td>
<td>Till - sandy till with boulders of all sizes, 6.7 principally Kanmantoo greywacke and Victor Harbor Granite. Thin (0.15-0.3 m) limestone bands.</td>
<td>6.7</td>
</tr>
</tbody>
</table>

BASE

Total measured thickness of Cape Jervis Beds unconformably overlying Kanmantoo Group. 29.8
Adelaide Region


STOP 4. Inman Valley - Selwyn's Rock 35°30'S, 138°31'E.

Selwyn's Rock, in the bed of Inman River, is a classical example of a striated surface overlain by clays with large erratic boulders. This rock, discovered by Selwyn in 1859, represents the first discovery of evidence of glacial action in Australia. It is composed of metagreywacke of the Inman Hill Formation of the Kanmantoo Group. The susceptibility of the overlying Cape Jervis Beds to erosion is demonstrated on the southern bank.

STOP 5. Victor Harbor. 35°32'S, 138°35'E.

The stop will be made on the hill overlooking the town of Victor Harbor, sited on the alluvial flats of Inman and Hindmarsh Rivers. From east to west, Granite Island, Seal Island, Wright Island and Rosetta Head are outcrops of Victor Harbor Granite, dated at 490 million years or early Ordovician, intruded during the Delamerian Orogeny which terminated Cambrian sedimentation in the Adelaide Geosyncline. Rosetta Head, composed of granite on the seaward side and Kanmantoo Group schist on the landward, is regarded as a roche moutonée.

SELECTED BIBLIOGRAPHY


Adelaide Region


THE PERMIAN IN VICTORIA
HEATHCOTE AND BACCHUS MARSH DISTRICTS

G.A. Thomas
University of Melbourne

INTRODUCTION

Late Palaeozoic glacigene rocks were first recognized in Victoria by A.R. C. Selwyn in 1861 when he suggested a glacial origin for rocks in the Bacchus Marsh and Heathcote districts. Since then a succession of workers have studied them including Scott (1937), Scott in Jacobson and Scott (1937), Bowen (1959) and recently Crowell and Frakes (1971). Valuable reviews by Kenley (1952) and Spencer Jones (1969) provide reference to other workers. Various significant contributions are quoted in this guide.

Outcrops now regarded as Permian extend intermittently in a wide belt across Victoria (fig. 5). Only the major localities are shown. Numerous other minor occurrences are known from outcrops and from old mine workings. Subsurface bore intersections have been recognized from as far apart as the Netherby Bore in the Murray Basin and the Duck Bay Bore near Lakes Entrance. Most occurrences are discrete, thin and often loosely consolidated, and are thought to be the remnants of an originally wide sheet of deposits. Preservation appears to be predominantly in down faulted areas or where covered by younger rocks. Harris and Thomas (1948) suggested that sets of great meridional faults have contributed in the preservation of the Permian rocks. Some support for such control is indicated by recent recognition of more extensive Permian deposits in the Loddon Valley (P. Macumber, pers. comm.). The Permian deposits of the Bacchus Marsh area are partially located in a small east-west trending graben though some lie beyond. Those of the Heathcote-Derrinal area lie within a small north-south trending graben.

All workers have been impressed by the glacigene character of much of the sediments, but fluvial and lacustrine rocks have also been recognized. The earliest workers adduced an aquatic or even marine origin for the glacigene sediments but all later workers until recently considered them to be of terrestrial origin. Two marine horizons (discussed below) were reported in Garratt (1969) and Thomas (1969) and the possibility exists of more extensive marine influence. The marine beds provide evidence of age. The glacigene sediments are not older than Sakmarian and the post-glacial beds are of Artinskian to possibly Kazanian age. Plant fossils have long been known. Species of *Gan-gamopteris* were first recognized at Bald Hill by F. M'Coy in 1847. The Permian palynological evidence is reviewed by Douglas (1969b).

Of the two areas to be visited, the Heathcote-Derrinal area exemplifies much of the Victorian Permian and the Bacchus Marsh area has the thickest succession and best exposures.

HEATHCOTE - DERRINAL DISTRICT

Here glacial deposits occur in a comparatively extensive area of approximately 40 km north-south by 10 km east-west dimensions. They are bounded by meridional faults. The terrain is fairly flat and good exposures are limited. Glacigene sediments are evidenced by widespread erratics. Fairly good exposures are found in the upper parts of the valleys of Meadows Valley, Wild Duck and Mt. Ida Creeks. Bowen (1959) has given the fullest description. D.E. Thomas
PERMIAN IN VICTORIA

- Principal Permian Outcrops
- Permian rocks in bores
- Jerilderie (AOG Bore)
- Netherby Bore No. 1
- Echuca
- Wangaratta
- Bendigo
- Derrinal Heathcote
- Maryborough
- Bacchus Marsh
- Coleraine
- Melbourne
- Duck Bay Bore
- Lakes Entrance

Figure 5.
GEOLOGICAL MAP of Bacchus Marsh Area

(Adapted from Singleton, 1973, in "A Regional Guide to Victorian Geology.")

PERMIAN
- Tillite, Conglomerate, Diamictite, Sandstone, Mudstone.

PRE-PERMIAN
- Mainly Ordovician sandstone, shale, slate, and Devonian Adamellite

POST-TRIASSIC
- Tertiary terrestrial sediments, and volcanic rocks, Pleistocene sands and gravels.

1. Permian fossils
2. Permian fossils
3. Triassic fossils

A-E. Localities in text.  Fault  Road

Figure 6.
The Permian in Victoria

had earlier mapped their boundary in 1940.

Correlation between isolated exposures is difficult but Bowen estimated about 75 m thickness with at least 5 tillites interbedded with outwash conglomerate, sandstone and siltstone. The dip is gentle except near faults and relationships with the underlying folded older Palaeozoic rocks are strongly unconformable. Pavements are uncommon. An equivocal pavement on basement occurs at Dunn's Rock. The higher tillites contain numerous boulders: granites, schists, sandstones, conglomerate and quartz, many being exotic. The largest is the Stranger, a coarse pink granite, near Derrinal. Till fabric studies by Bowen in the Meadows Valley area showed trends of 020° and 050°. Crowell and Frakes (1971) recorded boulder pavements in a diamictite in a road cutting at Mt. Ida Creek, 9 km north-east of Heathcote. Imbricated boulders indicated south to north transportation. The tops are faceted and striated with trends from 020° to 335°. Distorted sandstone bodies occur in associated diamictite. A fairly well preserved pavement is exposed on the north shore of Eppalock Reservoir east of the Permian outcrops. Talent and Thomas (1967) have recorded grooves and striations. These range from 005° to 335° with northerly flow indications. No associated tillites are known.

BACCHUS MARSH DISTRICT

Introduction

The general geology of this area was reviewed by Singleton (1968). Permian rocks are widespread but are in part covered by younger sediments and volcanic rocks. They are largely confined to the Ballan Graben bounded by the east-west trending Greendale and Spring Creek Faults. This graben forms part of a block uplifted by movement on the north-south trending Selwyn's Fault. Permian rocks lie east of Selwyn's Fault notably in the Lerderderg Valley and at Coimadai Creek on the downfaulted Werribee Plains Block. Fault movement is in large part of Tertiary and later age but Jacobson and Scott (1937) and Singleton (1968) have suggested Permian movements along the same east-west trends as the Ballan Graben. Such movements may have accompanied the unusually thick sedimentation.

The sequence of over 1100 metres is by far the thickest in Victoria. Both glacigene and post-glacial rocks are present. Good exposures occur at numerous localities, e.g. in the upper Korkuperrimul Creek Valley (B in figure 6), Bald Hill (C), the lower Lerderderg River (A), the lower Werribee River gorge, Pyke Creek, Coimadai Creek (E, now largely submerged) and other places.

The Permian rocks overlie with marked unconformity older Palaeozoic bedrock, mostly the strongly folded geosynclinal Ordovician sediments and Devonian granitic rocks. The Permian rocks dip regionally south-west at about 10° but are locally much steeper. The bedrock surface is commonly grooved and striated the prevailing directions being from south to south west. Bedrock relief is variable and is at least 600 feet in the lower Werribee Gorge area - Bowen (1959).

Korkuperrimul Creek and Bald Hill areas

The thick succession in the upper Korkuperrimul Creek valley, on the south side of Greendale Fault, was first described by David (1896), in greater detail by Jacobson and Scott (1937) and most fully by Bowen (1959). Crowell and
The Permian in Victoria

by Jacobson and Scott (1937) and most fully by Bowen (1959). Crowell and Frakes (1971) have examined this and other sections.

Bowen's composite section, as quoted by Spencer Jones (1969) is repeated below with minor modifications.

Composite Korkuperrimul Creek section (as measured by R.L. Bowen (1959) quoted in Spencer Jones 1969)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Thickness (ft.)</th>
<th>Lithology</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Covered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1'-1'4&quot;</td>
<td>Sandstone (Council Trench)</td>
<td>Triassic</td>
</tr>
<tr>
<td>3</td>
<td>10'-2'</td>
<td>Conglomerate, mostly quartz pebbles.</td>
<td>Triassic</td>
</tr>
<tr>
<td>4</td>
<td>10'-1'4&quot;</td>
<td>Mudstone-leaf fragments.</td>
<td>Triassic</td>
</tr>
<tr>
<td>5</td>
<td>2'</td>
<td>Medium grained sandstone.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6'</td>
<td>Conglomerate.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6'</td>
<td>Sandstone, shale, mudstone (with Glossopteris Late sp.) Permian</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>64'</td>
<td>Sandstone, mudstone.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>25'</td>
<td>Medium Grained sandstone.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8'</td>
<td>Sandstone.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>28'</td>
<td>Sandstone, silty sandstone.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>5'-7'</td>
<td>Sandstone, purplish.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>150'-160'</td>
<td>Sandstone and siltstone.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>10'-15'</td>
<td>Sandstone, pebbly sandstone, conglomerates (lenticular) 'Winnowed tillite' of David (1896) with Notocornularia inornata (Dana). to Artinskian to Kazanian</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>20'-30'</td>
<td>Sandstone, medium grained ('Morton's Quarry', Early Permian Permian plant remains).</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>30'-60'</td>
<td>Sandstone, medium grained, cross-bedded in upper part.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>30'</td>
<td>Sandstone, thinly bedded.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>40'</td>
<td>Sandstone, thinly bedded.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>40'-60'</td>
<td>Sandstone, medium grained.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>30'-50'</td>
<td>Sandstone, siltstone, some claystones.</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>10'-25'</td>
<td>Sandstone.</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>20'-30'</td>
<td>Tillite clay rich, pebbly.</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>10'-35'</td>
<td>Tillite, clay rich.</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>75'-85'</td>
<td>Tillite.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>15'-30'</td>
<td>Covered interval est.</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>4'</td>
<td>Silty sandstone.</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>4'</td>
<td>Pebbly conglomerate.</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>2'</td>
<td>Sandstone, medium grained.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>25'-35'</td>
<td>Tillite, sand to silt rich.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3'-25'</td>
<td>Sandstone, medium to coarse grained.</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>80'-130'</td>
<td>Tillite, silt rich, massive.</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>50'-60'</td>
<td>Sandstone, coarse grained, well sorted.</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>10'</td>
<td>Tillite.</td>
<td></td>
</tr>
</tbody>
</table>
The Permian in Victoria

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>7'-10' Sandstone, coarse grained.</td>
</tr>
<tr>
<td>35</td>
<td>20' Tillite, clay rich.</td>
</tr>
<tr>
<td>36</td>
<td>23'-25' Mixed thin bedded sandstone, siltstone, fine conglomerates, Tillites.</td>
</tr>
<tr>
<td>37</td>
<td>10' Tillite, sand rich.</td>
</tr>
<tr>
<td>38</td>
<td>6' Claystone, siltstone, fine sandstone.</td>
</tr>
<tr>
<td>39</td>
<td>2' Coarse sand, pebbly.</td>
</tr>
<tr>
<td>40</td>
<td>4' Sandstone, pebbly, silty - spores of Early Permian aspect.</td>
</tr>
<tr>
<td>41</td>
<td>1'6'' Tillite, sand rich.</td>
</tr>
<tr>
<td>42</td>
<td>8' Tillite, silty to clay rich.</td>
</tr>
<tr>
<td>43</td>
<td>16'-17' Sandstone, flaggy.</td>
</tr>
<tr>
<td>44</td>
<td>10' Tillite, clay rich.</td>
</tr>
<tr>
<td>45</td>
<td>3' Sandstone, fine grained, calcareous.</td>
</tr>
<tr>
<td>46</td>
<td>10' Sandstone, claystone, lenticular.</td>
</tr>
<tr>
<td>47</td>
<td>35' Tillite, clay rich.</td>
</tr>
<tr>
<td>48</td>
<td>15' Siltstone.</td>
</tr>
<tr>
<td>49</td>
<td>15' Siltstone - poorly indurated, lenses of silt, ferruginous and carbonaceous matter.</td>
</tr>
<tr>
<td>50</td>
<td>70'-80' Sandstone, massive.</td>
</tr>
<tr>
<td>51</td>
<td>15' Tillite.</td>
</tr>
<tr>
<td>52</td>
<td>14' Sandstone, massive, medium.</td>
</tr>
<tr>
<td>53</td>
<td>4' Tillite, sand rich.</td>
</tr>
<tr>
<td>54</td>
<td>20' Sandstone, medium grained, massive, some siltstones interbedded.</td>
</tr>
<tr>
<td>55</td>
<td>20' Sandstone, conglomerate.</td>
</tr>
<tr>
<td>56</td>
<td>40'-50' Tillite, sand rich.</td>
</tr>
<tr>
<td>57</td>
<td>50'-60' Tillite, clay rich.</td>
</tr>
<tr>
<td>58</td>
<td>50'-75' Covered interval.</td>
</tr>
<tr>
<td>59</td>
<td>10' Tillite.</td>
</tr>
<tr>
<td>60</td>
<td>30' Tillite, clay rich.</td>
</tr>
<tr>
<td>61</td>
<td>50'-60' Covered interval.</td>
</tr>
<tr>
<td>62</td>
<td>10' Sandstone.</td>
</tr>
<tr>
<td>63</td>
<td>7' Fine conglomerate.</td>
</tr>
<tr>
<td>64</td>
<td>30' Sandstones, medium to coarse.</td>
</tr>
<tr>
<td>65</td>
<td>45'-60' Tillite, sand rich.</td>
</tr>
<tr>
<td>66</td>
<td>20' Sandstone, silty to pebbly.</td>
</tr>
<tr>
<td>67</td>
<td>8' Siltstone to fine sandstone.</td>
</tr>
<tr>
<td>68</td>
<td>20'-25' Tillite, sand rich, pebbly.</td>
</tr>
<tr>
<td>69</td>
<td>15' Sandstone, contorted.</td>
</tr>
<tr>
<td>70</td>
<td>30' Tillite, sand rich.</td>
</tr>
<tr>
<td>71</td>
<td>0-100' Covered interval.</td>
</tr>
<tr>
<td>72</td>
<td>13' Sandstone, medium to coarse.</td>
</tr>
<tr>
<td>73</td>
<td>4' Tillite, sand rich, pebbly in patches.</td>
</tr>
<tr>
<td>74</td>
<td>20'-22' Sandstones, medium grained.</td>
</tr>
<tr>
<td>75</td>
<td>4' Tillite, sand rich, medium grained.</td>
</tr>
<tr>
<td>76</td>
<td>15' Sandstone.</td>
</tr>
<tr>
<td>77</td>
<td>10' Tillite, clay rich, sand lenses.</td>
</tr>
<tr>
<td>78</td>
<td>6' Conglomerate, crossbedded.</td>
</tr>
<tr>
<td>79</td>
<td>56' Tillite, clay rich.</td>
</tr>
<tr>
<td>80</td>
<td>200' Covered interval.</td>
</tr>
<tr>
<td>81</td>
<td>10' Tillite, sand rich.</td>
</tr>
<tr>
<td>82</td>
<td>20' Covered interval.</td>
</tr>
<tr>
<td>83</td>
<td>40' Sandstone.</td>
</tr>
</tbody>
</table>
The Permian in Victoria

84 8' Conglomerate and sandstone.
85 10'-12' Tillite, silt rich.
86 40' Conglomerate and sandstone.
87 5' Tillite, sand rich.
88 50' Sandstone and conglomerate.
89 20' Tillite, sand rich.
90 6' Sandstone and siltstone.
91 10'-14' Sandstone.
92 25'-30' Conglomerate crossbedded.
93 10' Sandstone.
94 15' Conglomerate.
95 15' Tillite, sand rich, indurated.
(Stage 10 of Jacobson & Scott).
96 15'-18' Sandstone, medium to coarse.
97 10' Conglomerate, sandstone, thin tillites.
98 10' Sandstone laminated, medium to fine.
99 30' Conglomerate.
100 6' Tillite, silt rich.
101 30' Lenticular sandstones and conglomerates grading down into laminated sands & silts.
102 15'-20' Sandstone, medium to coarse.
103 25' Tillite, sand rich, massive, medium.
104 2½' Sandstone.
105 10' Laminated fine sands and siltstones (varved).
106 20'-25' Pebblly sandstone or sandy tillite.
107 25'-30' Conglomerate.
108 7'-8' Tillite, sand rich.
109 40'-50' Tillite.
110 100'-125' Covered interval.
111 65' Sandstone, thinly bedded.
112 5'-10' Tillite, clay rich.
113 125'-175' Covered interval.
114 15'-20' Tillite, with thin bands of sand.
115 20'-30' Tillite, sand rich.
116 10'-15' Tillite, silt rich.
117 125' Covered interval.
118 10' Sandstone, crossbedded.
119 30' Tillite, silt to clay rich.

--- Erosion surface ---

120 15'-20' Sandstone, medium.
121 2' Tillite, sand rich.
122 25' Sandstone, poorly sorted.

--- Erosion surface ---

123 40' Tillite, poorly exposed.
124 15' Tillite, weak banded.
125 40' Covered interval.
126 4' Conglomerate, massive.
127 12' Sandstone.
128 14' Conglomerate.
129 5'-15' Sandstone.
130 16' Sandstone, laminated.
131 42' Covered interval.
The Permian in Victoria

132 20'  Covered interval.
133 5'-15'  Tillite, massive clay to silt rich.
134 15'-35'  Covered interval (some faulting?).
135 5'-15'  Tillite, poorly sorted.

--- Erosion surface ---
136 10'-40'  Tillite, clay rich.
137 0'-8'  Tillite, silt to sand rich.
138 5'-8'  Sandstone, fine grained.
139 25'-35'  Tillite, silt to clay rich.
140 2½'-3'  Tillite, clay rich.

Faulted contact

Ordovician bedrock

The beds dip southerly at 27° to 64°, average 38° in directions from 194° to 210° according to Scott. Faulting is present, mostly minor. Bowen's terminology is followed in the section. The section from units 140 to 22 is regarded as glacigene with 50 distinct tillitic levels. These represent repeated glacial advances interbedded with varying thicknesses of fluvi- and lacustriglacial beds. Well demonstrated interglacial deposits were not recognized. Erosion surfaces occur above level 22 and lower down. The base is faulted and no fossils have been recorded below level 40 which contains Early Permian spores (Douglas, 1969). Bowen discussed the history of this section in detail. Erratics are abundant. Many are faceted. Scott reported that the majority are of local origin derived from Ordovician sandstones and quartzites. Less common are igneous and metamorphic rocks - granites, pegmetites, greisen, quartz and felspar porphyries, rhyolite, reef quartz, gneiss, schist, cordierite hornfels, slate and phyllite. Heavy minerals are largely of local origin. Some erratics are exotic and not matched in Victoria. However much of the pre-Permian terrain in possible source areas to the south west is mantled by younger rocks. Kenley (1952) and Spencer Jones (1969) have also discussed the provenance of the erratics in Victoria.

Crowell and Frakes (1971) discussed this and other Bacchus Marsh sections. They consider that the bulk of the glacigene rocks were largely laid down by subaqueous currents and are mostly fluviatile. Laminated shales with thin sandstone layers may have been lacustrine: an outwash environment near lakes and at times adjacent to the sea is envisaged. The tillites (referred to as diamictites) are varied. Some are massive; many show internal stratification (This was recognized by early workers). Thin diamictites are conceded as identical to tillites. The tillitic character of some Bacchus Marsh sediments was earlier substantiated by Hamilton and Krinsley (1967) on electron microscopic and other lines of evidence. Crowell and Frakes reject the view that each thin diamictite was laid down directly from wasting glaciers and interpret them as remobilized till emplaced by distal portions of mudflows, sometimes into lakes. The thicker diamictites are thought to have a proximal mass movement mudflow origin as they often show contorted sandstone lenses. They pointed out various sedimentary structures suggestive of soft sediment movement.

Bowen considered the units above 22 to be non-glacial. Those from 21 to 15 comprise a succession of thin bedded sandstone and siltstone followed by thicker bedded medium grained sandstone. Unit 15 is well exposed on the south east side of Bald Hill, notably at Mortons Quarry. Bowen demonstrated that
The Permian in Victoria

Regional folding followed by erosion has affected the beds of units 21 to 15. Unit 15 comprises about 9 m of medium-grained crossbedded sandstone. Complex small folds and step-like small faults are exposed at Morton's Quarry. Diamicomite occurs in small dyke-like bodies. Scott interpreted the structural features as the result of glacial over-riding. Bowen regarded them as tectonic. Crowell and Frakes suggest down slope sliding resulting from "the impact and drag of strong traction currents, periglacial and solifluction activities or from ice-over-riding; more work is needed to decide which".

W.A.J. Saunders has recently mapped the Permian exposures at Bald Hill in some detail and has proposed unpublished formational names for the various beds. He has noted an interesting "chasm"-like fault bounded sedimentary dyke about 420 metres north of Morton's Quarry. Exotic blocks of higher beds have apparently moved downward. This structure appears to be of tectonic origin. Unit 15 at Morton's Quarry (locality 2) is of interest as the sequence from which M'Coy in 1875 described species of Gangamopteris angustifolia, obliqua and spatulata, having first noted plants from this locality in 1847. Gangamopteris was established in 1861. Pritchard (1909) reviewed the palaeobotany and described but did not figure Calamites macnabi from the same locality.

Overlying unit 14 at Morton's Quarry end in the Bald Hill area are massive conglomeratic beds, unit 14. This is the "winnowed tillite" of David (1896). W.A.J. Saunders (pers. comm.), describes it as comprising massive cross-beded sandstone, soft contorted sandstone and one or two bands of conglomerate, totalling 7.5 m in places. P.J. Arden (pers. comm.) has lately made morphological studies of the pebbles. The analyses suggest a composite origin, with both marine (beach) and warm fluviatile indications but ultimate derivation from a glacial source. Lithologies are very varied: they include granite, rhyolite, low and medium grade metamorphic sediments and metasomatised rocks, possibly derived from western Victoria or South Australia. The presence of Notoconularia inornata (Dana) described by Thomas (1969) indicates a shallow marine environment for unit 14. The age is probably that of the Maitland Group of New South Wales (Upper Artinskian to Early Kazanian).

Conformably overlying unit 14 at Bald Hill is a sequence of about 150 m of interbedded medium grained sandstone, silty sandstone and mudstone with a thin quartzitic conglomerate about 5 m from the top. W.A.J. Saunders has collected a plant, probably referable to Glossopteris, from 2 m below the conglomerate. He has noted cross-bedding, flow rolls, convolute laminations, flute casts and concretions and suggests a deltaic origin. Earlier workers have reported 'worm trails' and fragmentary bivalves. The Permian beds dip east at 40° and are truncated by the meridional Selwyn's Fault.

Fragmentary Triassic plants have long been known from silicified mudstone, associated with thin, probably fluviatile, sandstone and conglomerate at the Council Trench (locality 3), south of Bald Hill. Generally they are regarded as conformable with the underlying Permian. Saunders, however, has mapped a south east trending fault which separates the Triassic beds from the Permian. The plants were described by F. Chapman in 1927. Douglas (1969a) has lately redescribed them and confirmed their Triassic affinities.

Lerderderg River Area

An excellently preserved sequence of partly glacial sediments is exposed
The Permian in Victoria

in the Lerderderg River valley (loc. A) near Morvern swing bridge and upstream for about 0.6 km. This illustrates many features of the Bacchus Marsh Permian A sequence 140 m thick overlies Ordovician rocks. It dips southward at 10-15°. It was first recorded by Bowen (1959) who noted a succession of 9 tillites interbedded variously with fluvioglacial outwash and lacustrine sediments—siltstone, mudstone and conglomerate, in places with dumped erratics. The tillites are variously interpreted as basal and ablation tills on their fabric details. Contortions in some units suggest slumping; erosion surfaces were noted above or below certain tillites. Near the top at the swing bridge is a sand rich tillite with imbricated boulders indicating a northerly component of glacial movement and suggesting several glacial advances. Sandstone lenses in this tillite were regarded as melt water deposits. The highest tillite has several bands of large imbricated boulders of quartzite, greenstone, sandstone and granite etc., up to 80 cm in diameter. Bowen suggested at least 4 separate glacial advances were indicated by this unit. The abundance of boulders in the 3 bands suggests that a considerable thickness of till was removed between advances. Striated boulder pavements occur on the faceted boulders trending at 050°. This was regarded by Bowen as the least equivocal evidence for northerly ice movement in the area.

Crowell and Frakes (1971) have discussed this occurrence. They interpret the imbricated boulders with pavements as indicative of deposition of diamicrite as till from the wasting of heavily laden ice in place or by gentle movement down slope for a short distance. After emplacement running water flowed northerly with sufficient velocity to imbricate the boulders and remove fine material. Later ice over-rode the now tightly frozen boulders to facet and striate them. Highly deformed sandstone layers in the associated diamicrite indicate lifting and they suggest down slope movement as debris or mudflows. They allow for the possibility of ice-shoving and over-riding. "Freezing and thawing near glacier margins where ice alternately advanced and retreated is implied".

Bowen also described a set of possible varves and a pavement cut by an over-riding glacier on a previously deposited tillite at the Lerderderg Ford 1.4 km north of Morvern swing bridge. The pavement shows parallel grooves trending at 015°; some included pebbles are planed and a thin overlying tillite shows casts of grooves. Overlying silts and claystones are partly contorted. Crowell and Frakes noted channels at the basal contacts of sandstone and conglomerate lenses, and sole grooves in a sandstone with a latitudinal orientation in this area. Pebble imbrication nearby indicated a north to southerly fluvial current. They suggest an outwash environment near the sea margin.

Coimadai Creek Area

This area is of great interest, with a fossiliferous marine horizon and the best examples of pavements in the district. Unfortunately the main features are now submerged by Lake Merrimu Dam. Numerous authors, including Bowen and Crowell and Frakes, have described the grooved and striated pavements in Ordovician rock, including roches moutonnées with plastered tillite which were previously exposed. The groove and striation trends are north and north-easterly. The basal tillites have yielded Early Permian spores (including glossopterids) first described by Virkki (1939) and later by Pant and Mehra - Douglas (1969b).

The occurrences are isolated and represent less than 30 m thickness of
The Permian in Victoria

tillite, diamictite and interbedded fluvioglacial sandstone, the latter with dumped boulders. Basement relief of about 36 m was indicated by Bowen (1959). Recently a conglomerate lens with marine fossils (locality 2) was reported by Garratt (1969) and by Thomas (1969) from near the former bridge at Coimadai. The small fauna is now being described by these authors jointly. It comprises *Trigonotreta narsarhensis occidentalis* Thomas, a species known from the upper beds of the Sakmarian Lyons Group of Western Australia. Also present are species of *Fenestella* and *Paraconularia*. The conglomerate lens some 12 m diameter by 1.8 m in dimensions is interbedded with diamictite which contains scattered pebbles of shale, quartzite and igneous rocks. The conglomerate includes rounded and subangular pebbles of Ordovician shale, slate and quartzite in a fine grained silty to sandy matrix.

Although the Coimadai Creek exposures cannot be correlated with other sections in the Bacchus Marsh area, they probably occur near the base of the Permian succession. The complete extent of marine influence in the Bacchus Marsh Permian deposits has not yet been determined.

**ITINERARY**

A detailed itinerary and additional maps and sections will be provided for the excursion.

**SELECTED BIBLIOGRAPHY**


The Permian in Victoria


TASMANIA
PARMEENER SUPERGROUP

M.R. Banks, University of Tasmania
and
M.J. Clarke, Mines Department, Tasmania

INTRODUCTION

Late Carboniferous to Late Triassic rocks are widely distributed in Tasmania (figs. 7, 8). They have recently been grouped for regional mapping and general reference purposes as the "Parmeener Supergroup" (Banks 1973). The Parmeener Supergroup rests with pronounced angular unconformity on sedimentary rocks of Early Devonian and older ages and with nonconformity on igneous rocks as young as Late Devonian. The erosional surface beneath it had a relief of at least 850 m and was partly, and probably wholly, glaciated.

The thickness of the supergroup varies from a few metres to about 1100 m excluding the basal tillites which are very variable in thickness but reach of maximum thickness of over 550 m.

Except close to later faults the dips are shallow, usually less than 10° but minor folds have been recognised within a major south-east plunging syncline. The succession is broken by Jurassic and Tertiary normal faults and by major injections of Jurassic dolerite.

Knowledge of the section is based on natural sections in shore platforms, cliffs, creek beds and valley walls, and in artificial sections, particularly road cuts, but also in quarries, coal mines and a few drill holes. Several tens of complete and partial sections have been recorded. This gives a section density of very roughly 1 section per 1000 sq. km.

STRATIGRAPHY

Lithostratigraphy

The lithological succession is summarised below as a composite section:

Parmeener Supergroup
Upper Division
Upper Freshwater Sequence
Typical section - Poatina, northern Tasmania.
Brady Formation - lithic arenite, some quartz arenite, siltstone and shale including carbonaceous varieties, sub-bituminous coal; fossil plants including Dicroidium spp., Cladophlebis spp., Linguifolium, Phoenicopsis elongatus, Banksisporites pinguis, conchostracans; Karnian.

Tiers Formation - carbonaceous and other siltstones, minor quartz and lithic arenites; Aratripsorites cf. granulatus, Tigrisporites sp.; Late Scythian.

Cluan Formation - interbedded quartz arenite and quartz and carbonaceous siltstones; Deltasaurus kimberleyensis and other amphibians; Scythian, probably Otoceratan. Correlated palaeontologically and probably stratigraphically with the Knocklofty Sandstone and Shale in the Hobart area.
Fig. 7. Distribution of Upper Carboniferous and Permian rocks in Tasmania.
Fig. 8. Distribution of Triassic rocks in Tasmania.
Parmeener Supergroup

Ross Sandstone - quartz arenite with minor quartz siltstone; *Lundbladispora brevicula, Densoisporites playfordi*; Scythian, probably Otoceratan. Correlated lithologically and stratigraphically with the Springs Sandstone in southern Tasmania.

Cygnet Coal Measures - quartz arenite, feldspathic arenite, quartz and carbonaceous siltstone, bituminous coal; *Glossopteris, Vertebraria indica, Didelicitritelles ericianus, Marsupipollenites triradiatus*; Late Permian. Type area in southern Tasmania; correlated on lithological, stratigraphic and palynological grounds with the Jackey Formation at Poatina.

Lower Division

Upper Marine Sequence
typical section Hobart and south-eastern Tasmania.

Ferntree Mudstone (Group in places) - carbonaceous, poorly sorted, fissile and non-fissile siltstones and fine-grained sandstones with rare limestones and a basal and two other beds of quartz-feldspathic, wacke with pebbles and/or limestones in places; *Wyndhamia ovalis, Megademus grandis* in places; Late Permian. Correlated approximately with Bogan Gap Gp. at Poatina.

Malbina Formation - quartz-feldspathic wacke with pebbles and/or limestones in places, poorly-sorted fissile and non-fissile siltstone including units with many fossils; *Sulciplica stutchburii, Terrakea concava, Eurydesma, hobotartensis in places; T. concava, Deltopecten, Martiniopsis magna, Wyndhamia dalwoodensis* more widespread; *W. ovalis* very common near top. Permian.

Cascades Group - calcareous siltstone, biomicrite, biospararenite, bio-rudite, all with rare limestones; possibly metabentonites; richly fossiliferous; *Taeniothaerus subquadratus, Cancrinella farleyensis*; Permian.

Lower Freshwater Sequence

Faulkner Group - cyclothemic development of poorly-sorted carbonaceous siltstone with rare limestones and marine fossils, pebbly quartz-feldspathic, sandy wacke siltstone, quartz arenite, carbonaceous quartz siltstone; *Glossopteris, Gangamopteris*; Early Permian. Correlated on lithological and stratigraphic grounds with the Mersey and Liffey Groups of northern Tasmania, containing bituminous coal, cannel coal and *Noeggerathiopsis hislopis*.

Lower Marine Sequence

Golden Valley Group (northern Tasmania) - richly fossiliferous calcareous siltstone, biomicrite, biosparrudite, all with some limestones, carbonaceous siltstone; *Eurydesma cordatum, Sulciplica, notospiriferids*; Early Permian. Correlated with Darlington Limestone, Bundella Mudstone in south-eastern Tasmania.

Quamby Mudstone (northern Tasmania), Group (southern Tasmania) - carbonaceous, pyritic, poorly-bedded mudstone, richly fossiliferous on some horizons; glendonites present in many places; algal (*Tasmanites punctatus*) oil shale in northern Tasmania; a few limestones; *Ammodiscus*. 
Parmeener Supergroup

oonahensis, Cyrtella nagmargensis australis, Streptorhynochus; Early Permian (Sakmarian).

Glacial Sequence
typically in Wynyard district, north-western Tasmania, also at Woodbridge, Cygnet, Maydena in south-eastern Tasmania.

Wynyard tillite - tillite, other diamicritites, conglomerate, sandstone, siltstone and rhythmites, all with lonestones; associated in several places with striated pavements, including striated boulder pavements; Tasmanadia, "Rhacopteris" and microflora; Late Carboniferous. Elsewhere (Frankford, Maydena) tillite and associated glacifluvial beds contain Eurydesma and Deltoplecten and may be Early Permian. Correlates lithologically and stratigraphically with the Woodbridge Tillite at Woodbridge, Cygnet.

BIOSTRATIGRAPHY

Lower Division

Rhacopteris and Stage 1 microfloras (Dr. P.R. Evans pers. comm.) from rhythmite clays in the middle of the Wynyard Tillite in the Hellyer Gorge, NW Tasmania, indicate that the basal parts of the Parmeener Supergroup are of Late Carboniferous age. Above this, however, the marine faunas are of Permian age, and belong almost exclusively to the Gondwanan cold-water Eurydesma realm. Ten informal assemblage faunizones (1-10) are provisionally recognised.

Faunizones 1-3

These are restricted to the Lower Marine Sequence. They are collectively characterised by the brachiopods Martiniopsis ovulum-konincki group, a characteristic neospiriferid which is almost certainly Trigonotreta stokesi Koenig and Pseudosyrinx allandalensis; the bivalves Megadesmus globosus, Myonia morrisi, Neoschizodus australis and Pyramus laevis; and an enormous profusion of Eurydesma, coarse-ribbed Deltoplecten and the gastropod Keeneia. The detailed recognition of the individual faunizones is dependent on the presence or absence of such forms as Cyrtella nagmargensis australis, Streptorhynochus sp. nov., Sulciplica spp., a new notospiriferid genus and various species of Strophalosia and Costalosia; Phestia darwini and Pronytilus cancellatus; and Rhhabdaga. The detailed distribution of these faunizones indicates that the base of the Parmeener Supergroup varies in age from place to place; that conditions suitable for the establishment and proliferation of shallow-water benthonic faunas in rocks of "Golden Valley Group" facies varied in time from place to place; and that the base of the Lower Freshwater Sequence is diachronous.

Faunizones 4-5

These are characterised by the appearance of aulostegids and true produc-
tids which include Taeniotaenius, Anidanthus, Canorinella and Terrakea; a new suite of strophalosiids-Wyndhamia preovalis and W. jukesi-dalwoodensis group; and spiriferids such as Grantonia hobartensis, G. cracovensis, Sulciplica tasmaniensis, Punctospirifer, Martiniopsis ovata, M. profunda and M.valida. Faunal diversity increases with the appearance of simple rugose and tabulate corals (Euryphyllum, Cladochonus, Thamnopora), blastoids (Thauatoblastus), giant conulariids (Paraconularia), the algal-bryozoan association Lyroporella, certain bivalves ( Atomodesma (Aphanaia), Conocardium) rare occurrences of
Parmeener Supergroup

Spirigerella and trilobites, and an increase in the variety and abundance of crinoids (Calceoliapongia) and terebratelids (Fletcherithyris, Gilledia). Eurydesma, Deltopecten and Keeneia still persist in abundance, although never in quite the same extraordinary profusion as in the Lower Marine Sequence. The presence of these faunas immediately above the Lower Freshwater Sequence (Mersley Coal Measures and equivalents) proves that the first occurrence of coal-forming conditions in Tasmania was significantly earlier than that of the Greta Coal Measures in New South Wales.

Faunizones 6-10

True productids show a marked decline and Terrakea remains as the sole survivor from below. New forms include the brachiopods 'Aperispirifer' wairakiensis, A. lethamensis, Pusispirifer avicula, P. sp. nov., Martiniopsis ingelarensis, M. sp. nov. - M. undulosa group, M. isbelli, M. angulata - M. globosa group, M. magna, M. straileckii, Sulciplicia phalaena - S. transversa, Fletcherithyris parkest, Gilledia unadullensis and Wyndhamia ovalis; the bivalves Astartila, Megadesmus spp. (gryphoides, nobilissimus, grandis, Merismopteria macroptera and Vauumella; and the gastropods WalnichoUsia, Warthia and Mourlonopsis. The detailed recognition of the individual faunizones is based mainly on the varied vertical distributions of the new forms, but also partly on the disappearance of certain characteristic forms such as Eurydesma at the summit of Faunizone 7, and the disappearance of Deltopecten and strophalosiids of the Wyndhamia jukesii - dalwoodensis group at the summit of Faunizone 9.

External correlations

According to generally accepted correlations, the Tasmanian Eurydesma Fauna ranges in age from Sakmarian to Upper Kungurian or Lower Kazanian in terms of the world standard. On the basis of the macrofossils, Faunizones 1-3 collectively offer a firm correlation with the Sydney Basin Allandale Fauna. This correlation is supported by the co-occurrence of late Stage 2 (Sakmarian) microfloras, and Allandale macrofaunas in the Lower Marine Sequence at Golden Valley and the Cranky Corner Basin, N.S.W. (Dr. R.J. Helby, pers. comm.; Dr. B. Runnegar, pers. comm.). No faunas of this age are known in the Queensland Bowen Basin. Faunizones 4-5 offer a firm correlation with Fauna II (U. Sakmarian - L. Artinskian) in both the Sydney and Bowen Basins. Correlation of Faunizones 6-10 is less evident. Faunizone 10 is almost certainly equivalent to Fauna IV in the Sydney Basin and Funa IVB-C (U. Kungurian - L. Kazanian) in the Bowen Basin. Faunizone 9 probably equates with Fauna IVA in the Bowen Basin. Together Faunizones 9-10 approximate the New Zealand Flettian Stage. Faunizones 7-9 appear to be present within the Sydney Basin Ulladulla Fauna, but are almost totally dissimilar to Faunas IIIA, IIIB and IIIC in the Bowen Basin. The best equation of Faunizones 7-8 is with the New Zealand Barrettian (Baigendzhinian) Stage. Faunizones 5-6 are almost certainly pre-Barrettian and may therefore be Mangapirian, but resemblances are slight.

General faunal and floral observations

The marine Gondwanan Eurydesma Fauna in Tasmania is extremely rich in terms of numbers of individuals, but taxonomic diversity is low. Warmer-water forms such as reef-building corals, fusulinids and goniatites are absent. Faunal diversity increases slightly above the Lower Freshwater Sequence but even so, several genera of brachiopods, bivalves and gastropods which occur in varying degrees of abundance in the Sydney and Bowen Basins, are either rare
Parmeener Supergroup
(Anidanthus, Cleiothyridina, Spirigerella, Punctospirifer, Plekonella), or absent (Liasochonetes, Neochonetes, Filiconcha, Attenuatella, Martinia, Psilocamara, Stenocrisma, terebratulids other than Fletcherithyris and Cilledia; Australomya, Cypricardinia, Glendella, Veteranella; and Playteichum). Rather surprisingly, and unlike early Permian (Allandale) faunas in the Sydney Basin, brachiopods (particularly strophalosiids, neospiriferids and martiniopsids) dominate Tasmanian faunas from the first appearance of Eurydeema. The sudden appearance of true productids in Faunizones 4-5 is noteworthy, the more so in view of the abundance of strophalosiids throughout the Lower Marine Sequence. This again contrasts with the Sydney Basin where true productids such as Anidanthus and Cancrinella are present in the Allandale Fauna, yet strophalosiids are unknown from this level (Runnegar pers. comm.). The persistence of Eurydeema, Deltospecten and Keeneia at much younger horizons than in Queensland and W. Australia, probably indicates the continued influence of cold-water conditions throughout most of the marine Permian in Tasmania. Glossopteris, Gangamopteris, Noeggerathiothopsis and other elements of the Glossopteris Flora are locally abundant and appear approximately at the same level as the Eurydeema Fauna. As a consequence of the depositional environment, the Glossopteris Flora survives beyond the last occurrence of the Eurydeema Fauna.

Upper Division

Four florizones, one associated with vertebrates, can be recognised. The lowest contains a Vertebraria macroflora and a Dulhuntyispora microflora, the second a Cylostrobus macroflora and a Lundbladispora brevicula-Densoisporites playfordi microflora with Deltasaurus, Blinasaurus and a chasmatosauroid reptile, the third a Dicroidium odontopteroides macroflora and a Aratrisporites-Tigrisporites microflora and the highest a Phoenicopsis elongatus macroflora with a Banksisporites pingius microflora.

Vertebraria Macroflora

Gangamopteris spp., Vertebraria australis, Phyllotheca sp. and Schizoneura sp. have been recorded from the Cygnet Coal Measures and their lithological and stratigraphical correlates in several places. Vertebraria is fairly widespread and found rarely on other levels. Didecitriletes ericius, Marsupipollenites triradiatus Bascanisporites undosus and other palynomorphs occur on this level in at least four places. The palynomorphs named suggest correlation with the Dulhuntyispora Assemblage Zone (Stage 5 of Evans) which is post-Early Kungurian and pre-Latest Tatarian.

Cylostrobus Macroflora, Lundbladispora brevicula Microflora

Cylostrobus occurs fairly commonly in carbonaceous siltstones associated with cross-bedded siliceous sandstones and red and green siltstones in the Knocklofty Formation and similar rocks in south-eastern Tasmania. In places it is associated with Hoegia and Pterrorochis barrealeensis (J.A. Townrow, pers. comm.). Lundbladispora brevicula, Densoisporites playfordi, Krauselisporites cuspidus and Protokaployptina samoilovichii have been reported from the Ross Sandstone at Poatina and the first two spores from the Knocklofty Formation. The assemblage suggests a Scythian age, no younger than the top of the P. samoilovichii assemblage Zone of New South Wales. In many places in south-eastern Tasmania and at Poatina vertebrates occur with this flora. The vertebrates include actinopterygian fish, a dipnoan, Blinasaurus, Deltasaurus other amphibians and a chasmatosauroid reptile. These also indicate a very early
Parmeener Supergroup

Triassic, probably Otoceratan age.

_Dicroidium odontopteroides_ Macroflora, _Tigrisporites Microflora_

Higher horizons contain a flora characterized by _Dicroidium odontopteroides_, _Xylopteria elongata_, _Czechanowskia tenuifolia_, _Pterophyllum_ spp. and other cycads. With these is a microflora containing _Aratrisporites_ spp., including one resembling _granulatus_, _Tigrisporites_ sp., _Punctatisporites walkomi_ and _Osmundacidites fiscus_. The microflora has been regarded as Carnian by Playford, Late Scythian by Anderson and Anderson. The presence of _Aratrisporites tenuispinosus_ suggests an age no older than the _P. samoilovichii_ Assemblage Zone and the presence of an _Aratrisporites_ comparable to _granulatus_ suggests correlation with the Late Scythian _P. samoilovichii_ Assemblage Zone or zonule A of the _Falcisporites_ Assemblage Zone of New South Wales. This assemblage is probably late Early and early Mesial Triassic.

_Phoenicopsis elongatus_ Macroflora - _Banksisporites pinguis_ Microflora

The highest assemblage is the richest. It is defined on the presence of _Dicroidium obtusifolium_, _Pachypteris orassa_, _Phoenicopsis elongatus_ but contains many other macrofossils, especially _Cladophlebis_ spp. Palynomorphs in it include _Banksisporites pinguis_, _Punctatisporites leighensis_, _Stereisporites perforatus_, _Neoraistrickia taylorii_ and _Lundbladispora denmeadi_. Both macroflora and microflora suggest correlation with the Ipswich Coal Measures of Queensland. _Stereisporites perforatus_ occurs in the Karnian of Europe, _Baculatisporites comaumensis_ in the Upper Muschelkalk as well as in the Ipswich Coal Measures which also contain _Apiculatisporis globulosa_, also found in the Karnian of Europe. Thus the most likely age is Karnian, perhaps Lower Karnian as suggested by Anderson and Anderson. Conchostracans and rare insects have also been reported from rocks containing this flora. All Triassic coals so far dates belong to this horizon.

_SEDIMENTATION AND PALAEOGEOGRAPHY_

Tillite, other diamicrites, conglomerates, sandstones, siltstones and rhythmites with dropstones of glacial origin, occur at or near the base of the succession in many places in Tasmania. They rest on striated floors in a few places, such pavements suggesting movement more-or-less radial from an area north-west of Zeehan. Although most of the megaclasts in the tillite and diamicite can be matched in pre-Permian rocks in Tasmania, there are a few which cannot and there is a suggestion of ice flow from a land surface beyond the western coast of Tasmania. Striated boulder pavements occur within the glacigenic sequence at Wynyard. The section at Wynyard contains evidence of at least nine major advances and retreats and a multitude of minor ones. Rhythmites with plants and rare fossil insects south of Wynyard suggest the presence of glacial lakes. At Frankford, near Beaconsfield, and at Maydena, tillite and glacifluvial conglomerate contain fragmental marine fossils, suggestive of glacial advance across a pre-existing sea-floor.

On and marginal to topographic highs in the sub-Permian surface, the basal
Parmeener Supergroup

rocks are commonly siliceous conglomerates (or locally breccias) derived from underlying or nearby Precambrian or Lower Palaeozoic quartzites, quartz schists and vein quartz. In one or two places the breccia has steep bedding and is almost certainly a scree deposit. Near a granitic terrain the basal rocks are usually arkosic conglomerates or pebbly arkoses. On Maria Island the arkosic conglomerate and arkoses alternate and contain *Eurydesma* suggesting alternation of shingle beach and shallow marine environments and in one place such an alternation backed by a buried granitic cliff. At Friendly Beaches such a succession includes a conglomerate with granitic and metamorphic pebbles, the pebbles being on end low in the bed and imbricated higher in the bed. This could be interpreted as a shingle beach developed on a periglacially affected material. In other places, e.g. St. Marys, the arkosic conglomerates interdigitate with coal and plant-bearing cross-bedded quartz arenites and may be interpreted as fanglomerates developed on the granitic edge of a fluvial system. In several places in eastern Tasmania the basal conglomerates contain clasts which are not locally derived, a few of which are striated. Such clasts are taken to indicate stripping of a boulder clay veneer from the adjacent high areas, the petrology of the clasts suggesting that the ice depositing the boulder clay had a westerly source.

The glacigenic beds are almost everywhere succeeded by homogeneous, carbonaceous pyritic, dark-grey or black siltstone with calcareous concretions, glendonites and marine fossils. Glendonites are pseudomorphs in calcite after glauberite (Na₂SO₄·CaSO₄) and are thought to have been formed by progressive calcium metasomatism during early diagenesis of mirabilite (Na₂SO₄·10H₂O) deposited in the sediments from freezing seawater. Lonestones are present but rare. Within this siltstone unit in northern Tasmania an oil shale occurs as a bed up to 2 m thick. The oil shale consists of very abundant spore cases of an alga, *Tasmanites punctatus*, in a sparse matrix of silt grade clastic material. The oil shale contains rare lonestones, glendonites and marine fossils. It is commonly found close to islands in the Permian sea. In south-eastern Tasmania the siltstone passes shorewards into pebbly, sandy siltstones with more abundant marine fossils. A barred basin environment is indicated by the mineral composition and a cold sea by the lonestones and the composition of the fauna. The depth of the sea is more difficult to deduce but present thinking favours a shallow one because of the accumulations of light spore cases of the alga *Tasmanites*. The homogenisation of the siltstone is not obviously due to burrowing organisms and may be due to regular greezing of sea water in the pores of the silt beneath or in the bottom layers of pack-ice.

Fossils become more abundant in the higher part of the siltstone which in places passes up into richly polyzoal siltstones, in others, nearer to the Permian shoreline, into richly fossiliferous micrites. The micrites in northern Tasmania are commonly richly foraminiferal, the fauna dominated by mioloids such as *Calcitornella*. Along the eastern shoreline of the time and in places near the northern shoreline, the micrites have an extraordinary concentration of shells of *Eurydesma cordatum* and a lesser one of spiriferids such as *Grantonia*. Lonestones of distant derivation and commonly very large ones occur in the micrites and to a lesser extent in the polyzoal siltstones. They are presumably ice-berg or pack-ice rafted material. The *Eurydesma* biomicrites are demonstrably at Maria Island and on Forestier Peninsula very near shore deposits and represent clam banks in the shallower parts of a cold sea. The change from barred basin conditions with a sparse benthonic biota to those of the open sea with a rich benthos, may be attributed to a marine transgression.
Parmeener Supergroup

which also produced overlap of the earlier sediments.

The open sea conditions were, however, soon replaced by increasingly brackish conditions leading to deposition of bedded, carbonaceous, worm-burrowed or ostracode-rich muds with a decreasing benthonic component. An estuarine environment may be postulated. Very sparse limestones occur in the lower part of this succession and become even sparser upwards. Pebble and fossil-rich beds occur near the base of this succession in some places (e.g. Poatina). There is grading of pebble and fossil fragment size upward within such beds and they may represent turbidity current activity. Another, less favoured, explanation is that such beds are the result of winnowing of fossiliferous, sparsely-pebbly silts by increased wave or current action and this is supported by their relatively good sorting. The nearshore equivalent of the lower part of the carbonaceous mud succession appears to be spiriferid pebbly sandstone, (e.g. at Beaconsfield and on Maria Island).

The marine or brackish muds are followed by intensely bioturbated silty sands ("worm-cast" sandstone) in northern Tasmania and by very poorly-sorted pebbly, poorly-fossiliferous siltstones (Geiss "Conglomerate") in southern Tasmania. Both rock types seem to represent littoral environments at the shore-face of an advancing coastal plain as they are followed by non-marine beds. The Geiss "Conglomerate", for example, is comparable to tidal flat sediments at the mouth of a large river. Both types of rocks form units of the order of only a metre thick. Similar rocks also occur higher in the Permian section, always in stratigraphic or geographic positions consistent with a littoral environment (e.g. Middle Arm Group, Beaconsfield).

The units overlying the littoral beds are cross-bedded quartz arenites, quartz and carbonaceous siltstone, bituminous and cannel coals, the last two especially prominent in the northern and north-western part of the state. Grainsize and its variations suggest that these areas were close to higher land at the upstream end of the fluvial system, which may be inferred on other grounds. The sediments form characteristic fluvial cycles and contain plant fossils in many places. A paludine environment is envisaged for the coals. A temporary marine incursion over the fluvial coastal plain is indicated by a succession of littoral and shallow marine sediments similar to those beneath the non-marine beds, but within the fluvial sediments. The incursion affected areas near Hobart, Maria Island and Poatina at least near Hobart produced two symmetrical cyclothems.

A change in tectonic regime is thought to have produced downward movements leading to re-invasion by the sea. In some places, e.g. Maria Island, the non-marine succession is capped by a sediment resembling the Geiss "Conglomerate" followed by richly fossiliferous siltstone and micrite with rare limestones. The fossiliferous sediments represent deposits in a shallow sea of normal salinity and with occasional ice-bergs or ice-floes on the surface. In other places, e.g. Hobart, the non-marine beds are followed by carbonaceous mudstone with rare marine fossils and limestones and beds of pebbly silty sandstone like the Geiss "Conglomerate", and then by a feldspathic quartz arenite (Rayner Sandstone) with some limestones and fairly abundant marine fossils, especially spiriferids, e.g. Martintopsis. The succession is interpreted as the coastal plain followed by a shore-line, a marine lagoonal and then an off-shore bar environment. After this the environment became similar to that at Maria Island, i.e. shallow sea with normal salinity and occasional ice-bergs or floes. This
Parmeener Supergroup

Environment did not extend as far north-west as Poatina or as far south-east as Cygnet. Although richly fossiliferous marine mudstones, micrites and more rarely arenites occur extensively south of Aberfoyle and St. Marys, the same time interval at Frankford is represented by sandstones with marine fossils and at Poatina, if represented at all, is represented by poorly-fossiliferous sands and silts like those of the estuarine environment described earlier. West of Hobart at Maydena, Arcadian Siding and Bronte, this interval is also represented by fossiliferous sands and silts. South-east of Hobart micritic limestone gives place to richly fossiliferous mudstone, the mud probably being derived from a low lying area to the east or south-east. In the Cygnet area, a paraconformity occurs covering this interval and a low, but extensive, mudslab may have been present. Subsequently the island became submerged and as covered by highly fossiliferous marine muds with limestones, while further east the shallower water pebbly shelly sand facies gradually moved east and north-east, probably because of progressive uplift in western or north-western Tasmania. As the relief of the source area decreased the sand was succeeded by a mud association, very like the earlier estuarine mud association and similarly poorly fossiliferous. In parts of south-eastern Tasmania fully marine conditions developed just prior to development of off-shore bars, represented by thin units of fairly well-sorted, pebbly, worm burrowed sands. The bars are thought to have retreated westward, or north-westward and the sands are followed by richly fossiliferous siltstones with rare limestones formed in a shallow shallow sea. Subsequently withdrawal of the sea led to eastward or south-eastward migration of the off-shore bar facies (Risdon Sandstone) and the development of an estuary within the extensive gulf between a peninsula to the east and the land to the west. Within the gulf the main sediments were carbonaceous muds or sandy silts with a few shelly areas and horizons and with silty-sand, worm-burrowed in places, especially near the shorelines. Occasionally, and in places, migrating channels or wave action on exposed shores or both may have led to the development of thin, laterally persistent units of pebbly sand or pebble beds. Dropstones, some of them a couple of metres across in the muds attest to the presence of ice, probably pack ice, at times during deposition.

The carbonaceous muds are everywhere followed by a fluvial association of cross-bedded, quartz or quartz, feldspar or quartz-feldspar-muscovite-graphitearenites with quartz-mica-graphite siltstones with plant fossils, carbonaceous siltstone with plant fossils and coal seams. These sediments show characteristic fluvial cycles. The sediments differ from those earlier in the Permian in higher proportions of feldspar and graphite. In fact some of the sandstones are almost arkoses. The source of the feldspar is not clear. The climate at this time was humid enough to allow development of coal but higher units, of early Triassic age, contain no coal, include red and mottled red and green siltstone associations, abundant clay pellet conglomerates and produce halite florescences, all indicative of deposition under drier, probably monsoonal conditions. This Early Triassic part of the fluvial association contains actinopterygian fish, lung fish, several species of amphibians (Deltasaurus, Unasaurus and others), and at least one piscivorous reptile. A system of meandering and perhaps anastomosing river channels flowing generally from the north-west through extensive sandy plains covering much of eastern Tasmania may be envisaged.

In higher beds the proportion of siltstone and the abundance of plant fossils increase and a change to a more humid climate and more highly sinuous meandering streams is indicated with a concurrent decrease in relief of the
Parmeener Supergroup

source area. An even further increase in effective precipitation is shown by the presence in the highest unit of the Triassic of numerous coal seams over much of the eastern part of Tasmania. In addition to the coal swamps and lakes, there were extensive flood plains underlain by silt deposited in swamps and lakes, and river channels in which sand was being deposited. High sinuosity meandering streams may be postulated and fluvial cycles from conglomerate and clay-pellet conglomerate to coal are widely recognisable. The sands in the river system at the time differ in two important ways from the fluvial sands of the Early Triassic. In the first place they are feldspar rich and contain an abundance of rock fragments including volcanic fragments, of sand grade. They are predominantly lithic or feldspathic arenites, but a few real tuffs (of intermediate composition) may be present. In the second place they display few sedimentary structures, and are certainly not extensively cross-bedded as are the earlier arenites. Both differences could perhaps be explained by postulating high-sinuosity streams, sluggish, with movement mostly very low in the lower flow regime, swamped from time to time with showers of andesitic ash which could be moved, sorted and bedded but not usually rippled. No lavas of this age have yet been found in Tasmania and the ash may have been erupted from a number of small cinder cones.

WYNYARD - HELLYER GORGE AREA

The lower division of the Parmeener Supergroup rests on folded Precambrian mica and chlorite schists and quartzite. The surface of the underlying rocks is seen to be striated wherever it is exposed (e.g. Doctors Rocks), the striations indicating ice-movement from the south-west. The supergroup is overlain with slight angular unconformity by Cainozoic marine and non-marine sediments and volcanic rocks.

The succession within the Supergroup is tabulated below:-

Flowerdale Sandstone - unfossiliferous sandstone; 170 m
- fossiliferous pebbly sandstone; 16 m.
Preolenna Coal Measures - well sorted qz. sandstone, micaceous and carbonaceous shale with bituminous and cannel coal; 43 m.
Inglis Siltstone - medium to dark-grey, glendonitic mudstone with a bed of algal oil shale (tasmanite); 150 m; *Ammodiscus oonahensis* and other foraminifera near base.
Wynyard Tillite - tillite and other glacigene rocks; over 600 m thick; pteridic sperms and other plants, insects, arthropod tracks.

Five localities within the Wynyard Tillite and two in younger rocks may be visited.

The Wynyard Foreshore 41°1'S 145°42'E

The Wynyard Tillite is exposed in a series of magnificent shore platforms (tidal range about 4 m) from just east of Doctors Rock (loc.A, fig.9) to Fossil Bluff, just north of Wynyard. The bedded rocks in the tillite dip generally between 5° and 10° to the south-west but are folded gently along south-west plunging axes. Some of the bedded sequences also show intra-formational (pre-consolidation) folding along axes with the same trend.

The succession consists of tillite, other diamictites (thinly-bedded), conglomerate, sandstone, siltstone and rhythmites with dropstones.
Doctors Rock: Just east of Doctors Rock the basement is exposed. The contact between the Wynyard Tillite and the Precambrian rocks is polished and striated and to some extent is controlled by the folds in the basement rocks. The contact is overlain by basal tillite and then a succession of diamicrites, conglomerate, sandstone and laminated and graded lutites (rhythmites). The sandstone units are cross-bedded and rippled, the causative currents for the structures having flowed to the north-east. The rhythmites are very gently folded and overlain with slight angular unconformity by tillite.

Just west of Doctors Rock, tillite is associated with bedded diamicrites, conglomerate and sandstone in some very complex structures which may have been formed partly by partial redistribution of till by sub-glacial or marginal
streams, partly perhaps by collapse into kettle holes of coherent masses. Of considerable interest are fusiform bodies of sandstone showing a spiral arrangement of the internal bedding and contained within diamicite. The lon axis of the body is in the direction of ice flow. No adequate explanation of their origin is available. Also found in the shore platform west of Doctors Rock are striated boulder pavements; the striations having a north-easterly trend.

Point with pine trees just east of Wynyard: Rhythmites with interbedded cross-bedded and rippled sands are exposed in the shore platform overlying tillite. The siltstone also contains discoidal "concretions" up to 80 cm across, the concretions consisting of more or less concentric crumpled layers of siltstone and fine-sandstone. They may be a variety of pseudonodule. The rhythms have an abrupt, nearly straight and probably almost vertical contact with tillite and other diamicites to the west. This contact is thought to mark a re-advance of the ice. The diamicite succession contains the same sort of complexly folded succession of diamicite, sandstone and conglomerate as occurs just west of Doctors Rock.

Fossil Bluff: The low-angle unconformity between the Tillite and Tertiary marine beds is exposed. The Tillite here consists of tillite and other diamicites overlain by rhythmites and interbedded sandstone with cross-bedding and ripple-marking of south-westerly derivation. The rhythmites are gently folded into domes and basins with north-easterly trending axes. Above the rhythmites is unfolded tillite. The folding in the rhythmites dies out upwards and downwards and is therefore probably due to movement within the unit after deposition of the overlying tillite but prior to consolidation.

Seabrook Creek (between Elliott and Mt. Hicks; loc. F, fig. 9): Road and quarry sections reveal about 30 m of rhythmites with minor sandstone and diamicites overlying tillite exposed in the bed of Seabrook Creek. The diamicites form laminae or thin beds within the rhythmites and probably represent deposition from small turbidity currents derived from the ice front or moraine. The sandstones form beds ranging up to about half a metre in thickness and are commonly thin cross-bedded and ripple-marked, the cross-bedding indicating north-easterly flowing currents. The rhythmites with a modal thickness of about 3 mm for the rhythm consist of layers of very fine arenite or coarse siltstone grading up into very fine siltstone or clay. Some limestones occur in the rhythmites. Oscillation ripples and very small scale slump structures affect the top of some rhythmite pairs. Deposition in a lake fed by north-easterly flowing streams is indicated.

Hellyer River Area 41°14'S 145°43'E

Scolyers Hill: In road cuttings on the summit of Scolyers Hill a richly fossiliferous siltstone, part of the Inglis Siltstone is exposed. This outcrop contains Strophalosia sp. nov., Streptorhynchus sp., Trigonotretra stokesi, Cyrtella nagmargensis australis, Martiniopsis konincki, Keeneia platyschizomatoides, Neoschizodus australis, Merismopteria sp., Deltoplecten illawarenensis, Myonia morrisi, and Eurydesma hobartensis.

APPM Road near Hellyer River: A bed of algal oil shale less than 2 m thick occurs in the Inglis Siltstone only about 15 m above the top of the Wynyard Tillite. The oil shale contains an abundance of amber discs and spheres of
the alga *Tasmanites punctatus* in a matrix of siltstone. Some arenaceous foraminifera occur in the oil shale and in adjacent beds. The foraminiferal assemblage also occurs in the Cape Jervis Beds (see Ludbrook earlier).

APPM Road south of the Hellyer River: Rhythmites in the Wynyard Tillite contain an abundance of probable arthropod tracks, *Tasmanadia*, and on a slightly higher horizon, "Rhacopteris" *ovata*, palynomorphs and an insect.

**Palaeontology**

"Rhacopteris" *ovata* and Stage 1 microfloras (Dr. P.R. Evans pers. comm.) from the upper parts of a glaciolacustrine rhythmite sequence in the Hellyer Gorge prove a Late Carboniferous age for at least part of the Wynyard Tillite. The same beds have also yielded a well-preserved megasecopterid insect (Dr. E. Riek pers. comm.) which is the oldest known insect in the Southern Hemisphere. Below this, and within the lower parts of the rhythmite sequence, the probable arthropod track *Tasmanadia* occurs in profusion. Certain of the tracks assigned to *Diplolichnites* from the Dwyka Series in South Africa are similar to *Tasmnadia*. The remainder of the Wynyard Tillite has so far proved barren. Near the base of the Inglis Siltstone, oil shale contains *Tasmanites punctatus* in abundance and a unique assemblage of unusually large and distorted arenaceous foraminifera which include *Ammodiscus oonahensis*, *Digitina recurvata*, *Hippocrepinella biaperta*, *Pelosina ampulla* and *Thuramminoides sphaeroidalis*. The first diagnostic macrofauna belonging to Faunizone 1 occurs about 110 m above the base of the Inglis Siltstone at Scolyers Hill. Fragmentary *Eurydesma* (Sakmarian) faunas are known from the uppermost parts of tillitic sequences which have been correlated with the Wynyard Tillite in the Maydena andFrankford areas. It is therefore thought probable that the Permo-Carboniferous boundary occurs within the upper parts of the Wynyard Tillite. It must be admitted, however, that tillite deposition may have varied in time spatially.
General

The lower parts of the Parmeener Supergroup in the Beaconsfield area differ in certain respects from sequences elsewhere in N. Tasmania. The Lower Marine Sequence or Massey Creek Group is thick (350 m), and despite the development of various characteristic lithologies, is not easily subdivided. Discontinuous shore platform and stream sections at Middle Arm, West Arm, Massey Creek and Andersons Creek show the Massey Creek Group to comprise alternations of siltstone and mudstone, pebbly siltstone and tillitic conglomerate; with subordinate developments of calcareous siltstone, bryozoal shale, thin limestone at three distinct levels, and pebbly glauconitic sandstone. Glaucolithic sandstone is unknown elsewhere in Tasmania below the Upper Marine Sequence. Boreholes in the Andersons Creek area indicate that fossils occur intermittently through most of the Lower Marine Sequence except for the basal 70 m. The Lower Freshwater Sequence is represented by the Liffey Group which consists predominantly of thick- and cross-bedded, coarse-grained quartz sandstone with subordinate carbonaceous shale and coaly partings. Its summit is marked by worm-castings. The Liffey Group is an invaluable field marker horizon and retains a similar thickness and lithological character as far south as Poatina. The Upper Marine Sequence commences with the West Arm Group which is thin (45 m) and lithologically variable. The lowest beds comprise siltstone and pebbly siltstone rich in polyzoa. Then follow about 4 m of coarse conglomeratic sandstone with giant Paraconularia in some abundance. These beds are in turn followed by thin, but richly fossiliferous sandy limestone and limestone. The remainder of the sequence comprises siltstone with much fenestrate bryozoan debris and thin bands of pebbly sandstone with occasional large trunks of fossil wood. The Middle Arm Group (170 m) completes the Upper Marine Sequence and consists of a monotonous and unfossiliferous sequence of pebbly siltstone and sandstone with abundant worm-casts and other bioturbation. A thin, but distinctive horizon of quartz conglomerate occurs near its summit and occupies the same stratigraphical position as the Blackwood Conglomerate at Poatina. The Upper Freshwater Sequence or Clog Tom Sandstone, which com-

Fig. 11. Locality map of the Beaconsfield area.
Parmeener Supergroup

prises carbonaceous sandstone, grades imperceptibly into the overlying Triassic sequence.

Palaeontology

Faunizones 1-3 are present within the Lower Marine Sequence. Faunizone 1 with large *Streptorhynchus* sp. nov. is best developed at Massey Creek, but the exposure has deteriorated in recent years. Faunizone 3 is developed in conglomeratic and glauconitic sandstone immediately below the Liffey Sandstone. Bivalves including *Neoschizodus australis*, *Pyramus laevis*, *Deltopecten*, *Etheripecten*, *Myonia morrisi*, *Eurydesma*, *Megadesmus globosus* and *Stutchburia* are very abundant. *Trigonotreta stokesi*, a new notospiriferid genus, *Martiniopsis konincki* and *Pseudosyrinx* are also present. Thin limestone and calcareous shale immediately below this are crowded with prismatic shell fragments of *Merismopteria*. At Middle Arm, exposure above the Liffey Sandstone is far from perfect, but a few metres of conglomeratic sandstone yield *Paraconularia denwentensis*. Thin sandy limestone follows with abundant *Sulciplica stutchburii* and *Martiniopsis strzeleckii* and probably belong in Faunizone 6. Above this the limestone becomes purer and bivalves are abundant (*Schisodua*, *Astartila*, *Conocardium*, *Etheripecten*, *Myonia* and *Stutchburia*). Large michelinoceratids, hyolithids and blastoids also occur. At West Arm the equivalent beds are rich in brachiopods which include *Aperispirifer*, *Fusispirifer avicula*, *Martiniopsis* spp., *Sulciplica transversa*, *Wyndhamia dalwoodensis* and *Fletcherithyris* spp. These forms indicate Faunizone 9. The sandy limestone and conglomeratic sandstone with a Faunizone 6 assemblage has not been located at West Arm. This may result from inadequate exposure, but even if it is present, it seems almost certain that the West Arm Group in the Beaconsfield area includes at least one disconformity within it.

Stops

Tides permitting, examination of sections at Middle Arm, West Arm, Massey Creek and Andersons Creek will be made.

POATINA 41°48'S 146°57'E

Lower Division of Parmeener Supergroup

The Poatina section is well-exposed and geologically well-known largely because of excavations, diamond drilling and access roads necessitated by power developments by the Hydro-Electric Commission. It is also representative of the lower Parmeener Supergroup sequence throughout the Central Plateau area. Relief below the Parmeener Supergroup is rugged and sometimes the Lower Freshwater Sequence rests directly on the basement, e.g. Fisher River area and Frankford. At Poatina, basement rocks are not exposed, but occur at Palmerston a few km away. The Lower Marine Sequence commences with the Stockers Tillite which has been proved to a thickness of 110 m in H.E.C. boreholes. The Quamby Mudstone (100 m) is the lowest exposed unit on the Poatina road section and comprises massive - and poorly-bedded, dark, pyritic and glendonitic siltstone and mudstone. The crumbling nature of outcrops is characteristic. Fossils are extremely rare. The Golden Valley Group (85 m) completes the Lower Marine Sequence and comprises richly fossiliferous siltstone and calcareous siltstone with lenses of impure limestone (Glencoe Fm.), thin sandstone and conglomeratic sandstone (Billop Fm.), and thin-bedded pyritic mudstone and lighter-coloured siltstone (Macrae Fm.). Worm burrows and hydroplastic structures are characteristic. Erratics occur throughout the Lower Marine Sequence but are particularly abundant in the lower parts of the Golden Valley Group.
Fig. 12. Geological sketch map of the Poatina area (by courtesy H.E.C.).
The Lower Freshwater Sequence is represented by the Liffey Group (35 m) which comprises predominantly well-sorted, cross-bedded, coarse-grained, sparkling quartz sandstone with subordinate carbonaceous shale and coaly partings. The Upper Marine Sequence comprises the Poatina and Bogan Gap Groups. The Poatina Group (85 m) consists mainly of poorly-fossiliferous siltstone (Meander Fm.), but near its summit developments of conglomeratic sandstone (Dabool and Garcia Fms.) separated by bryozoan shale (Weston Fm.) are present. The Dabool and Weston Formations are richly fossiliferous. The Bogan Gap Group (200 m) is unfossiliferous and mostly comprises monotonous mudstone (Springmount, Drys and Eden Fms.). Thin, but characteristic and important marker horizons of sandstone (Palmer Fm.) and quartz conglomerate (Blackwood Fm.) also occur.

Palaeontology

The lower Parmeener Supergroup sequence at Poatina (as is typical of the Central Plateau area and N. Tasmania) is only sporadically fossiliferous. The oldest fauna at Poatina occurs well above the base of the Lower Marine Sequence in the Glencoe and Billop Formations, and belongs in Faunizone 2. The distinctive Tasmanite Shale does not occur at Poatina, but at Quamby Brook, Latrobe and elsewhere in N and NW Tasmania, this horizon is developed near the base of the Quamby Mudstone or near the base of beds which occupy the same stratigraphical position as the Quamby Mudstone. Although it, too, is usually unfossiliferous, at Latrobe the Tasmanite Shale and the enclosing Spreyton Beds yield rich faunas which belong in Faunizone 1. Thus inferentially the Quamby Mudstone at Poatina may be approximately equivalent to Faunizone 1. At Golden Valley the Quamby Mudstone and Golden Valley Group yield late Stage 2 (Sakmarian) microfloras. The Dabool and Weston Formations yield assemblages characteristic of Faunizones 8 and 9. In the Fisher River area Faunizone 8 is developed immediately above the Lower Freshwater Sequence. Elsewhere in Central and N. Tasmania (except at Beaconsfield and Frankford) Faunizone 8 is the oldest horizon which can be recognised in the Upper Marine Sequence. It is therefore inferred that a pronounced hiatus separates the Lower Freshwater and Upper Marine Sequences over the entire Central Plateau area, although lack of diagnostic faunas and/or lack of exposure immediately above the Lower Freshwater Sequence precludes certainty.

Stops

These will be made at several places on the Poatina Highway as it climbs up the steep scarp of the Great Western Tiers. Particular attention will be paid to the Lower Marine Sequence, the Liffey Sandstone, the Dabool-Weston-Garcia association, and the Palmer and Blackwood Formations.

Upper Division of Parmeener Supergroup

Road cuttings expose successively higher members of the Upper Division. The lowest unit of the Upper Freshwater Sequence is the Jackey Formation, a unit 40 m thick of carbonaceous siltstone and sandstone with a *Glossopteris* flora and *Dulhuntyaspore* microflora. It is Late Permian. It is exposed on the Poatina Highway at "J" (fig. 12).

The Jackey Formation is overlain by the Ross Sandstone (outcrop at "R", fig. 12), a formation of cliff-forming quartz arenite and quartz siltstone which is about 190 m thick. The arenite is well-sorted and cross-bedded and contains quartz grains with authigenic outgrowths producing "sparkling" crystal faces. A carbonaceous siltstone 85 m above the base contains *Densotisporites*...
Parmeener Supergroup

playfordi and Lundbladispora brevicula indicating an Early Triassic, probably Otoceratan, age.

Overlying the Ross Sandstone is the Cluan Formation, 140 m of well-sorted cross-bedded, quartz sandstone, clay-pellet conglomerate, quartz siltstone and carbonaceous siltstone. One of the clay-pellet conglomerate beds ("C" fig.12) has yielded amphibian tooth rows and one skull of an amphibian, Deltasaurus kimberleyensis. This amphibian also occurs in the Blina Shale in Western Australia which is Scythian.

The next unit in the succession consists of lithic, feldspathic arenites and interbedded siltstones and has been called the Tiers Formation. It is about 90 m thick. From a carbonaceous siltstone in the middle part of the formation ("T", fig. 12) a Tigrisporites-Aratrisporites microflora has been described and suggests a Late Scythian or somewhat younger age.

The highest formation is the Brady Formation which consists of lithic, feldspathic arenite, carbonaceous siltstone and sub-bituminous coal. In this area it is 165 m thick. The base of it is exposed at "B" (fig. 12) on the Poatina Highway. The formation contains abundant plants, especially Phoenicopsis elongatus, a microflora including Stereisporites perforatus and other paly-nomorphs suggesting a Karnian age. A few conchostracans also occur in this unit.

HOBART 42°52'S 147°20'E

Knocklofty Quarry, West Hobart

This quarry, situated at the top of Arthur Street, West Hobart, contains well-sorted, cross-bedded, quartz arenite, quartz siltstone, carbonaceous silt- stone, red and mottled red and green siltstone and clay-pellet conglomerate. There are parts of three alluvial cycles from cross-bedded (point bar) sandstone on an erosional surface with pebble beds in places, up into interbedded sandstone and siltstone with the red and red and green sediments representing aerated flood plain deposits and soils and overlain by grey or greenish grey sands and silts. Plants have been found in this quarry in carbonaceous silt- stone, Cystostrobus being noteworthy. More rarely fish such as Cleithrolepis and Ceratodus teeth, amphibian bones (Blinaurus and a lydekkerinid) and a reptile skeleton have been found. The teeth and bones occur in clay pellet beds, the other fish occurring with Cystostrobus sp. and the reptile, a form closely related to Chasmatosaurus, in a carbonaceous siltstone near the top of the second cycle. The siltstone also yielded Demosporites playfordi and Lundbladispora brevicula. Vertebrate tracks and probably tail skid marks occur as sole marks on the base of the lowest sandstone bed of the second cycle. The fossils suggest a Scythian, probably Otoceratan age for this unit, the Knock- lofty Sandstone and Shale.

Old Beach Vertebrate Locality

On the east bank of the Derwent River opposite Dogshear Point about 11 km upstream from Hobart, is a cliff of well-sorted, cross-bedded, quartz arenite containing a 15 cm thick bed of clay-pellet conglomerate about 3 m above the level of the Old Beach Road. This has yielded a very rich fauna of fish, including lung fish, amphibian bones and skulls and rarely reptilian bones. The fish include Cleithrolepis, the amphibians include Deltasaurus kimberleyensis and new genera of rhytidosteid and lydekkerinid. Red siltstones occur higher
Fig. 13. Map and columnar section of the Old Beach vertebrate locality. The vertebrates suggest an Early Scythian age, as at Knocklofty and Poatina. The vertebrates have been studied by Dr. J.W. Cosgriff to whom we are indebted for the identifications.

The Mt. Nassau Permian Section

General

On the western slopes of the valley of the Derwent River about 2 km upstream of the bridge at Bridgewater, is situated the type section for the Hobart area of the Permian System. In bare hillsides, cliff, quarry, creek and road sections on the slopes of Mt. Nassau, a well exposed, flat-lying, virtually unfaulted section of the Permian rocks is available for study (fig. 14).

Fig. 14. Geological map of the area containing the Permian type section for the Hobart area at Mt. Nassau.
Parmeener Supergroup

The section comprises:

Ferntree Mudstone: carbonaceous, poorly-sorted fissile and non-fissile mudstone with rare limestones and marine fossils; at the base a bed a few metres thick of quartzo-feldspathic wacke with pebbles and limestones (the Risdon Sandstone); total thickness about 200 m.

Malbina Formation: quartzo-feldspathic wacke with pebbles and/or limestones, poorly-sorted fissile and non-fissile siltstone; divisible locally into five members of which the basal one (Member A) and the topmost (Member E) are fossiliferous, the latter highly so; the assemblage in Member E is biocoenotic; thickness about 90 m.

Cascades Group: richly fossiliferous calcareous siltstone and limestone, predominantly micritic; the limestone dominant in the middle formation, Berriedale Limestone; all formations contain rare limestones; several beds of metabentonite have been recognised; about 90 m thick.

Rayner Sandstone: a quartzo-feldspathic sandstone with fair to good sorting and some marine fossils; about 3 m thick.

Faulkner Group: composed of two cyclothems, the basal unit, Geiss "Conglomerate", is a littoral deposit and rests on poorly fossiliferous, poorly-sorted carbonaceous mudstone of the top part of the underlying formation; above the Geiss "Conglomerate" is a formation of quartz arenite and well-sorted quartz and carbonaceous lutite, representing non-marine (flood plain) conditions; followed by a littoral deposit, Byers Sandstone, then beds similar to those beneath the Geiss; these in turn are followed in some places (but not in the type section) by another littoral deposit and then by another unit of fluvial sandstone and siltstone capped by a fourth littoral "conglomerate"; the group terminates with a poorly-sorted, poorly fossiliferous, carbonaceous mudstone, probably estuarine in origin; the total thickness of the group is 4½ m.

Bundella Mudstone: fossiliferous mudstone and sandstone, both with limestones including one a metre across, passing up into less fossiliferous mudstones; the mudstones are very calcareous in some places; the base is not exposed; thickness is at least 42.5 m.

Palaeontology

Diagnostic Faunizone 2 assemblage are well-developed in the main part of the Bundella Mudstone. Below this the Glenorchy borehole proved an abnormally thick, unfossiliferous, pyritic siltstone sequence, and an absence of tillite. The Nassau Siltstone and the Berriedale Limestone yield rich Faunizone 4 and Faunizone 5 assemblages with Canerinella farleyensis and Taeniothaerus subquadratus. South of the Granton-Bridgewater area the Berriedale Limestone thins rapidly so that at Taroona, 6 miles south of Hobart, the same faunas are developed in siltstone and calcareous siltstone which is the Grange Mudstone. West of Granton, in the Maydena area, the same interval is occupied by sandstone and conglomeratic sandstone. Above the Cascades Group there is an abrupt change in lithology. The coarse sandstone which comprises Malbina A yields an assemblage indicative of Faunizone 8. It is therefore evident that a hiatus must occur between the Cascades Group and the Malbina Formation. This is presumably the expression of an event which caused an even greater hiatus in the Cygnet area further south. However, in detail the nature of this hiatus is complex because at Cygnet, age equivalents of the Cascades Group are absent, yet beds older than Malbina A are well-developed. Hopefully the position will
Parmeener Supergroup

become clearer as detailed regional mapping moves north from Cygnet. Immediately below the Risdon Sandstone rich biocenotic Faunizone 10 assemblages with *Terrakea brachythaera*, *Wyndhamia ovalis*, *Fusispirifer avicula* and *Mega-desmus grandis* are present in Malbina E. The Ferntree Group is, for most part, sparsely fossiliferous, but diagnostic Faunizone 10 assemblages occur at three separate and restricted horizons. One of these has yielded the sole Tasmanian specimen of *Plekonella* (another single rhynchonellid is also known from a much lower stratigraphic interval in northeast Tasmania).

**CYGNET 43°10'S 147°7'E**

In the Cygnet area, about 48 km south of Hobart, rocks of the Parmeener Supergroup are magnificently exposed in a series of coastal exposures. In essence the structure of the Cygnet area is a broad, but much faulted dome centred on Cygnet itself. The sedimentary sequence is much intruded by thick dykes and sills of Jurassic dolerite, and also by a suite of smaller sills and dykes of Cretaceous alkaline syenite. The lower parts of the Parmeener Supergroup display several important differences compared with the Hobart sequence; (a) the Lower Freshwater Sequence and the essentially calcareous Cascades Group (Faunizones 4-5) are absent, so that an incomplete Upper Marine Sequence rests with paraconformity on an incomplete Lower Marine Sequence; (b) the basal tillite, absent in the Hobart area, is very thick; and (c) coarse sandstone of Malbina A type is younger than in the Hobart area. The Lower Marine Sequence commences with the Woodbridge Tillite which is at least 300 m thick. Characteristically it consists of massive diamicrite with a silty matrix with clasts up to 60 cm in diameter. Some clasts are striated and some are coated with clay. The Woody Island Siltstone (100 m) consists of a monotonous sequence of pyritic and glendonitic siltstone broadly similar to the Quamby Mudstone at Poatina, but is rather coarser-grained. The Bundella Mudstone (85 m) completes the Lower Marine Sequence and comprises richly fossiliferous, medium- to thick-bedded siltstone and fine sandstone with abundant erratics. The Upper Marine Sequence commences with an unnamed unit (Formation X) about 120 m thick.

Fig. 15. Locality map of Cygnet district.
Parameener Supergroup

This unit comprises a more or less uniform alternation of medium-bedded, compact siltstone and fine sandstone with thinner partings of softer shaley material and occasional coarse gritty layers, with subordinate massive Stenopora siltstone and fenestellid shale. Erratics are abundant throughout. At its base, the paraconformity between this unit and the underlying Bundella is marked by a few metres of flaser-bedded siltstone and a few bands of coarse grit and conglomerate. Above this the entire unit is richly fossiliferous. The next unit is the 'Malbina' Formation (35 m). This comprises thick-bedded, coarse-grained sandstone with subordinate very coarse gritty and pebbly felspathic horizons, together with darker, pyritic and strongly-bioturbated siltstone and sandstone. Fossils are less abundant than below and are often fragmentary. The Upper Marine Sequence is completed by the Ferntree Group (200 m). For most part the Ferntree Group comprises monotonous, ill-sorted, much bioturbated mudstone and siltstone, but at its base a very coarse-grained, cross-bedded friable sandstone is developed. This is the Risdon Sandstone (8 m) which is an invaluable field marker horizon. The Cygnet Coal Measures comprise sandstone with subordinate carbonaceous shale and coal.

Palaeontology

Faunizone 1 with large Streptorhynchus sp. nov. in profusion, and Faunizone 2 are well-developed in the Lower Marine Sequence. At Deep Bay a continuously exposed unfaulted and continuously fossiliferous sequence contains Faunizones 6-10. Faunizones 6-8 occur in Formation X, and Faunizones 9-10 occur in the 'Malbina' Formation. The Ferntree Group is sparsely fossiliferous but diagnostic Faunizone 10 assemblages occur at two horizons near its summit. At Deep Bay Faunizone 6 is additionally characterised by an abundance of Megaedemus gryphoides, smooth ostracods and pockets crowded with the small gastropod Peruvispira. Although the paraconformity is not exposed at Deep Bay, diamond drilling has proved that the details of this break are essentially similar to those elsewhere in the Cygnet area. It is not yet clear whether the paraconformity results from non-deposition or erosion. The Cygnet Coal Measures have yielded Glossopteris and Dulhuntyispora (Late Permian) microfloras but lithologically they are difficult to separate from the upper (Triassic) parts of the Parameener Supergroup.

Stops

These will be organised so as to allow an examination of the entire sequence in stratigraphic order (time and tides permitting).

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STATUS AND SUBDIVISION OF THE PARMEENER SUPER-GROUP

by

S. M. Forsyth, N. Farmer, A. B. Gulline, M. R. Banks, E. Williams and M. J. Clarke

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STATUS AND SUBDIVISION OF THE PARMEENER SUPER-GROUP

by
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(with one text figure)

ABSTRACT

Late Palaeozoic and Early Mesozoic rocks of the Parmeener Super-Group are subdivided on a strict lithostratigraphical basis, and not in the time terms 'Permian' and 'Triassic'.

DISCUSSION

The name Parmeener Super-Group (Banks 1973) has recently been introduced to define a widespread Tasmanian sequence of Late Palaeozoic and Early Mesozoic rocks. These strata are almost always sub-horizontal, and they rest with pronounced landscape unconformity on a folded basement which includes rocks as young as Late Devonian or Early Carboniferous. The Parmeener Super-Group ranges in age from Late Carboniferous to Late Triassic, and this litho-stratigraphical unit has at many localities often been incorrectly described in the international time-rock unit terms. Whereas no further formal subdivision of the Parmeener Super-Group was proposed in the original definition, it was indicated that everywhere in Tasmania two broad lithological and environmental associations can be recognised. These are (1) a lower division which includes all glacial and glaciomarine beds; and (2) an upper and essentially freshwater division. Both divisions include subordinate coal measures.

The Permian/Triassic boundary, which has been used as a major division of the Parmeener Super-Group in the past, does not coincide with the boundary between the two broad lithological units, but occurs within the lower part of the essentially freshwater division. The Permian/Triassic boundary has proved unsatisfactory because of lack of fossils and it cannot be determined with sufficient accuracy for mapping purposes. The litho-stratigraphical boundary between the two major rock units, however, can be determined accurately during routine mapping, and it is proposed that this division be referred to in future.

The boundary between the Lower [division of the] Parmeener Super-Group and the Upper [division of the] Parmeener Super-Group is here defined as that between the 'Upper Marine Sequence' and the 'Upper Freshwater Sequence' of Clarke and Banks (in press) and Clarke, Farmer and Gulline (in press). It occurs at the base of the Cygnet Coal Measures (Late Permian) in southern Tasmania, and at the base of correlative horizons such as the Jackey Formation (Late Permian) at Poatina. In detail the Lower division includes such characteristic units as the Wynyard Tillite Formation, the Quamby Formation, the Golden Valley Group, the Masseys Creek Group, the Woody Island Siltstone Formation, the Darlington Limestone and the Bundella Formation ("Lower Marine Sequence"); the Liffey Group, the Mersey Coal Measures, the Faulkner Group and the Preolenna Coal Measures ("Upper Freshwater Sequence"); and the Cascades Group, the Malbina Formation, the Risdon Sandstone, the Ferntree Mudstone, the Poatina Group and the Bogan Gap Group ("Upper Marine Sequence").
The Sequences indicated in the diagram include the following characteristic units:

'Triassic' - Ross Sandstone Formation, Cluan Formation, Tiers Formation, Brady Formation, Springs Sandstone Formation and Knocklofty Formation.

'Upper Freshwater Sequence' - Cygnet Coal Measures, Jackey Formation, Clog Tom Sandstone Formation.

'Upper Marine Sequence' - Cascades Group, Malbina Formation, Ferntree Group, Poatina Group and Bogan Gap Group.

'Lower Freshwater Sequence' - Liffey Group, Faulkner Group, Mersey Coal Measures and Preolenna Coal Measures.

'Lower Marine Sequence' - Wynyard Tillite Formation, Quamby Formation, Golden Valley Group, Maseys Creek Group, Woody Island Siltstone Formation, Darlington Limestone Formation, Spreyton Beds, Kansas Creek Formation and Bundella Formation.
The Upper division includes the Cygnet Coal Measures, the Jackey Formation and the Clog Tom Sandstone Formation (= 'Upper Freshwater Sequence'); and the Ross Sandstone Formation, the Cluan Formation, the Tiers Formation, the Brady Formation, the Springs Sandstone Formation, the Knocklofty Formation and the Triassic coal measures (= 'Triassic').

In other words, the subdivision of Tasmanian Late Palaeozoic and Early Mesozoic rocks is based on local lithostratigraphical considerations. This procedure is considered to be an improvement on previous practice since neither the Permo-Carboniferous boundary nor the Permo-Triassic boundary can be located with any accuracy in Tasmania. All printed geological maps issued by the Geological Survey of Tasmania after July 1973, will incorporate the proposed lithostratigraphic subdivisions.

REFERENCES


33 The Stratigraphy of the Lower (Permo-Carboniferous) Parts of the Parmeener Super-Group, Tasmania

M. J. CLARKE and M. R. BANKS

ABSTRACT

Detailed information obtained from the systematic 1:15,840 mapping program of the Geological Survey of Tasmania, fully cored diamond drill holes, and certain largescale civil engineering projects is used to supplement and amend existing published accounts of the lithostratigraphy of the lower (Permo-Carboniferous) parts of the Parmeener Super-Group. Whereas macro- and microfloral criteria prove the lowermost parts of the Parmeener Super-Group to be of Late Carboniferous age, for most part the faunas and floras are of Permian age and display affinities which are almost exclusively with the Eurydesma-Glossopteris cold-water realm. Biostratigraphically, the Tasmanian sequence is as complete as any in eastern Australia, if not more so, and ten informal assemblage faunizones are recognised within the Gondwana Eurydesma fauna. The detailed distributions of these faunizones indicate considerable lateral variations in lithofacies from place to place, and demonstrate the presence of a depositional and/or erosional hiatus of variable duration over much of the Tasmania Basin. On the basis of Glossopteris and Dulhuntyispora microfloras, the uppermost Permian is represented in non-marine sequences which persist until the end of Triassic times. No satisfactory method of tracing the Permo-Triassic boundary in Tasmania is known.

INTRODUCTION

In Tasmania, the lower (Permo-Carboniferous) rocks of the Parmeener Super-Group (Banks, 1973) are almost everywhere subhorizontal, and rest with pronounced landscape unconformity on a folded basement composed of Precambrian and early Palaeozoic strata intruded by Late Devonian to Early Carboniferous granites (McDougall and Leggo, 1965). Compared with other eastern Australian sequences in the Sydney and Bowen Basins, that of the Tasmania Basin is much thinner, and (excluding the basal tillite which is extremely variable in its development) rarely exceeds 500 m in thickness. However, despite this much reduced thickness, palaeontological evidence demonstrates that the Tasmanian sequence is as complete as any in eastern Australia, if not more so. Lateral variations in lithofacies are considerable, particularly in the vicinity of basement highs. As a consequence, rock unit terminology varies widely from place to place, and palaeontological criteria provide the sole means of detailed correlation. Nevertheless, rocks of the lower parts of the Parmeener Super-Group lend themselves to a broad quadripartite lithological or environmental subdivision. These divisions are: 'Lower Marine Sequence' (including the basal tillite); 'Lower Freshwater Sequence'; 'Upper Marine Sequence'; and 'Upper Freshwater Sequence' (c.f. Johnston, 1888; Twelvetrees, 1911; David, 1950). Such a
subdivision is applicable to most of Tasmania, and for the sake of simplicity is used herein. Important exceptions include the Cygnet area, southern Tasmania, where the Lower Freshwater Sequence is absent, and most of northeastern Tasmania where the Lower Marine Sequence is absent and the remainder of the succession is much attenuated. The use of this crude quadripartite subdivision does not imply that the lower and upper boundaries of any one unit are necessarily everywhere of the same age. On the contrary, evidence is presented which demonstrates that the boundaries of the Lower Marine Sequence, Lower Freshwater Sequence and Upper Marine Sequence vary in age from place to place.

The adoption of this simplified subdivision may appear to be a retrograde step in view of the more detailed lithostratigraphic scheme used in the last major compilation of Tasmanian Permo-Carboniferous stratigraphy (Banks, 1962). However, progress in several fields has been rapid, and it is now considered necessary to adopt a more rigorous separation of lithostratigraphic and biostratigraphic criteria. In particular, officers of the Geological Survey of Tasmania have completed the detailed 1:15,840 regional mapping of Parmeener Super-Group rocks in northern Tasmania, and since 1968, have extended this to southern Tasmania. This program in itself has solved many lithostratigraphic problems, but as is only to be expected, other

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Fig. 33.1. Generalised lithological faunal characters, Parmeener Super-Group (lower part), and suggested external correlations.
difficulties have been brought to light. Many of these have been resolved by fully cored stratigraphic bore holes. In addition, certain large-scale civil engineering projects such as the Hydro-Electric Commission Fisher Tunnel and the Associated Pulp and Paper Manufacturers Mersey Great Bend-Wesley Vale pipeline, have provided a wealth of detail in critical, and until recently, little-known sequences.

The last decade has also witnessed the welcome innovation of local biostratigraphic 'zonal' schemes (Dickins et al., 1964 et seq; Waterhouse, 1965 et seq; Runnegar, 1967 et seq. See Fig. 33.1). Whereas various tentative correlations of the Tasmanian sequence have been attempted, most are incomplete, and only those of Runnegar (1967, 1969a) withstand critical examination, and then only in part. This is understandable, partly because most outside workers lack familiarity with Tasmanian lithostratigraphic details, but also because of the lack of modern biostratigraphic data for the Tasmania Basin. It is hoped that some of these deficiencies will be rectified herein. The new lithostratigraphic information is summarised where appropriate and a preliminary statement of Tasmanian faunal distributions is presented. Lithostratigraphic and biostratigraphic considerations are rigorously differentiated. References earlier than Banks (1962) are given only where certain lithostratigraphic names as used herein differ from that work. Details of the authorship and original definitions of many of these names are given in Smith (1957).

PARMEENER SUPER-GROUP (LOWER PART)

The oldest rocks within the lower parts of the Parmeener Super-Group which can be reliably dated comprise rhythmite clays which occur stratigraphically near the middle of the Wynyard Tillite in its type area in the Wynyard-Hellyer Gorge area, northwestern Tasmania. Near the summit of the rhythmite sequence the occurrence of *Rhacopteris ovata* (M'Coy) (Banks, 1967) and a Stage 1 microflora (Evans, pers. comm.) indicate a Late Carboniferous age. This horizon has also yielded the oldest known fossil insect in the southern hemisphere (Riek, pers. comm.).

Below this and within the lower parts of the rhythmite sequence, the probable arthropod track *Tasmanadia twelvetreesi* Chapman occurs in profusion. *Tasmanadia* is similar to certain of the tracks described and figured as *Diplichnites* from the Dwyka Series in South Africa (Savage, 1970). The remainder of the Wynyard Tillite has so far proved unfossiliferous. At a much higher stratigraphic level in the Maydena area, *Deltopecten illawarensis* (Morris), *Eurydesma* and *Pyramus* have been recorded from conglomerate near the summit of a sequence which has been correlated with the Wynyard Tillite (Runnegar, 1969a; Jago, 1972). A fragmentary *Eurydesma* (Allandale) fauna also occurs towards the summit of a tillitic conglomerate in the Frankford area. It is therefore evident that tillite deposition occurred during the Late Carboniferous and persisted until the Early Permian. It is less evident that deposition began and ceased everywhere at the same time. Nevertheless, it is believed that the Permo-Carboniferous boundary occurs within the upper parts of the Wynyard Tillite, although in its type area, the first appearance of the *Eurydesma* fauna is about 100 m above its summit. It must also be admitted that outside Tasmania, considerable doubts still remain about the relative ranges of the *Rhacopteris* and *Glossopteris* floras, about the coincidence of the incoming of the *Eurydesma* fauna with that of the *Glossopteris* flora, and about the exact relationship of these changes with respect to the Permo-Carboniferous boundary (Helby, 1969; Black, Morgan and White, 1972).

Basal tillite occurs in many places west of the meridian of Hobart. The thickest proved development is in the type area of the Wynyard Tillite where a thickness of about 600 m includes glaciolacustrine rhythmite clays as well as tillite (Gulline, 1967; Gee and Gulline, in press). In the Woodbridge-Cygnet area diamond drilling has so far proved a minimum thickness of 300 m for the Woodbridge Tillite, and it may be far thicker. At Maydena, the tillite is 175 m thick (Jago, 1972), and at Poatina the Stockers Tillite is at least 110 m thick (McKellar, 1957). Generally, these thick developments of tillite occur in basement troughs. However, in the
Strophalosia sp. nov.
Cytella nagnargensis australis
Phestia darwini
Promytilus cancellatus
Streptophychnus sp. nov.
Neoschizodus australis
Megadesmus globosus var. nov.
Trigonotreta stokesi sensu stricto
Myonia morrisi
Martiniopsis konincki - ovulum gp.
Deltpecten waterfordi
Pyramus laevis
Eurydesma hobartensis
Deltpecten illawarensis
Pseudosyrinx allandaeensis and P. spp.
Keenea ocula-twelve treesi - playtschismoides
Herisompteria carrandibbiensis-macroptera
Peruvispira-Ptychomphalina spp.
Eurydesma cordatum
Costalosia apicallosa
Strophalosia subarcularis
Eurydesma cf. playfordi
Eurydesma sacculum
Sulcipica sp. nov.
Notospiriferid gen. nov.
Rhabdocantha sp.
Sulcipica stutchburi
Cancrinella farleyensis
Martiniopsis ovata
Martiniopsis profunda
Martiniopsis valida
Gilledia homevalensis
Grantonia obartensis
Deltpecten ilmaeformis
Wyndhamia preovalis
Wyndhamia jukei-dalwoodensis
Stenopora crinita
Atomodesma (Apahmaia) sp.
Terrakea pollex sp.
Taaniothaerus subquadatus
Cладохонус sp.
Lyroporella sp.
Megadesmus nobilissimus
Amianthus spursurensis-solitus
Grantonia cracovenesis
Sulcipica tasmaniensis
Paraconularia derwentensis
Thamnoropa spp.
Conocardium spp.
Punctospirifer australis-etheridgei
Etheripecten fittoni
Euryphyllum spp.
Megadesmus gryphoides
Aperispirifer weirakensis
Gilledia oaktensis
Martiniopsis ingelarensis
Martiniopsis brevis-undulosa
Martiniopsis angula-globosa
Fletcherithyris parkesi
Martiniopsis magna
Terrakea brachythaera
Myonia carinata
Myonia corrugata
Fusispirifer malbinensis
Terrakea concava
Martiniopsis streeleckii and sp. nov.
Vacunella curvata
Astartilla intrepidra
Malinchollia subcancellata
Gilledia uilladullensis
Aperispirifer leathamensis
Sulcipica transversa
Volsellina mytiliformis
Martina microphala
Notospirifer minutus
'Motospirifer' duodecencostatus
Etheripecten leniusculus
Myonia triangulata
Fusispirifer avicula
Martiniopsis isbelli
Wyndhamia ovalis
Megadesmus grandis
Hobart area the Glenorchy Borehole showed an absence of tillite. This, coupled with a much increased thickness of the pyritic and glendonitic Woody Island siltstone compared with surrounding areas, may indicate that the Hobart area formed part of a deeper water zone beyond the limits of tillite deposition. In the region of basement highs such as Golden Valley, Western Bluff, Fisher River, Beaconsfield, Frankford, Cradle Mountain and Maria Island, the tillite is either very thin or absent, and is generally replaced by much thinner developments of conglomerate.

Above the poorly fossiliferous Wynyard Tillite and its lithological correlates, rich marine faunas become established. They are almost wholly of the Gondwanan Eurydesma realm. Ten successive informal assemblage faunizones are recognised (Fig. 33.1). The palaeontological basis of these assemblages is shown diagrammatically (Fig. 33.2) and summarised in the following paragraphs.

**Faunizones 1-3**

Collectively, these assemblages are characterised by the presence of *Megadesmus globosus* (J. Sowerby) var. nov., *Myonia morrisi* Etheridge, *Neoschizodus australis* Runnegar, *Pyramus laevis* (J. Sowerby) and an enormous profusion of *Deltoperia* (il-lawarensis-waterfordi) (Dickins group), *Eurydesma* (mainly *hobartenses* (Johnston)) and *Keeniea* (twelvetreesi Dun—ocula (J. Sowerby)—*platyschismoides* Etheridge). In addition, brachiopods are well represented and diagnostic forms include a characteristic neospiriferid which is almost certainly *Trigonotreta stokesi* Koenig sensu stricto non Armstrong 1968, *Martiniopsis ovulum* (Waterhouse)—*konincki* Etheridge group, and *Pseudosyrinx allandaliensis* Armstrong. Faunizone 1 is characterised by the additional occurrence of *Strophalosia* sp. nov. (generally similar to *Wyndhamia ovalis* (Maxwell), but smaller, no dorsal valve spines, and brachial ridges strongly developed), *Streptorhynchus* sp. nov. (aff. *S. pelicanensis* Fletcher—dorsal valve more inflated, ears more differentiated), *Cyrteella nagmargensis australis* Thomas, *Phestia darwini* (de Koninck) and *Promytilus cancellatus* Maxwell. *Costalosia apicallosa* Clarke, *Strophalosia subcircularis* Clarke and *Eurydesma cordatum* Morris are confined to Faunizone 2. Strophalosiids and *E. cordatum* are not present in Faunizone 3, but more importantly, *Sulciplicata stutchburi* Auctt, *Sulciplicata* sp. nov., a new notospiriferid genus and *Rhabdocantha* appear for the first time.

On the basis of the bivalves and gastropods, Faunizones 1-3 can be confidently correlated with the Sydney Basin Allandale Fauna. This correlation is also supported by the comparatively meagre brachiopod evidence from the Sydney Basin (Runnegar, 1969b; McClung, pers. comm.), and the presence of late Stage 2 microfloras throughout the Golden Valley Group and most of the Quamby Mudstone at Golden Valley. A similar association of an Allandale macrofauna and late Stage 2 microfloras occurs in the Cranky Corner Basin, New South Wales (Helby, pers. comm.; Runnegar, pers. comm.).

Whereas the comparative rarity of brachiopods in the Sydney Basin Allandale Fauna, and developments of poorly fossiliferous volcanic sequences at this level in the Bowen Basin may prevent a more widespread individual recognition of Faunizones 1-3, their value in Tasmania is considerable. Thus the establishment of conditions suitable for the proliferation of shallow water benthonic faunas in erratic-rich siltstone, sandstone, calcareous siltstone and limestone of 'Golden Valley Group' facies (Golden Valley Group proper (Clarke, 1968); Massey Creek Group (Gee, 1971), in part; Kansas Creek Beds, in part; Spreyton Beds (Burns, 1964), in part; Inglis Siltstone (Gee, Gulline and Bravo, 1968), in part; Darlington Limestone; Bundella Mudstone) varied in time from place to place (Fig. 33.4). The dark, massive-bedded, pyritic and glendonitic Quamby Mudstone, which is a litho-stratigraphic unit, is more or less confined to the Golden Valley- Poatina area and lacks diagnostic macrofaunas (Wells, 1957; Clarke, 1968). However, Tasmanite Shale occurs near the base of the formation at Quamby Brook, near the base of the Spreyton Beds at Latrobe, and
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Stratigraphy of the Parmeener Super-Group

near the base of the Inglis Siltstone in the Hellyer Gorge, as well as several other localities in northern and northwestern Tasmania (Fig. 33.4). At this latter locality an Ammodiscus oonahensis Crespin formainferal assemblage occurs. Usually the Tasmanite Shale lacks macrofossils, but at Latrobe it (together with the Spreyton Beds immediately above) yields rich macrofaunas which can be confidently assigned to Faunizone 1 (Clarke, in Jennings, in press). On this basis, the Quamby Mudstone in its type area may be indirectly inferred to approximate in age to Faunizone 1. The Tasmanite Shale probably formed marginal to basement ridges in a restricted basinal environment.

In southern Tasmania diagnostic macrofaunas commence with the Bundella Mudstone. In the Hobart area all assemblages belong to Faunizone 2, but further south in the Cygnet district, the lowermost parts of the formation are significantly older and yield assemblages typical of Faunizone 1.

On Maria Island the Lower Marine Sequence is much reduced in thickness and rocks of Faunizone 1 age are absent. The lowermost beds comprising the 'Erratic Zone' and the Darlington Limestone both belong in Faunizone 2. Above these units the Lower Freshwater Sequence rests directly on a few metres of thin-bedded calcareous siltstone rich in bryozoans and spiriferids and belonging to Faunizone 3. Elsewhere in most of eastern and northeastern Tasmania the Lower Marine Sequence is absent (Fig. 33.4). The sole exception is at Musselroe Bay in the extreme northeastern corner of the island, where rich Faunizone 2 assemblages are developed immediately above granite basement. This occurrence delimits a northern or eastern margin to an elongate peninsula-like land area which occupied most of northeastern Tasmania during Lower Marine Sequence times (Banks, 1962).

The recognition of a tripartite subdivision of a more broadly conceived Allandale Fauna within the Lower Marine Sequence is also important with respect to the base of the

Lower Freshwater Sequence. In the Hellyer Gorge-Preolenna area, the Fisher River area, and the Mersey Coal Basin, only Faunizone 1 can be recognised within the Lower Marine Sequence. To the east and northeast, through the Frankford, Quamby and Beaconsfield Quadrangles the Lower Freshwater Sequence rests successively on Faunizone 2 and Faunizone 3 assemblages (Fig. 33.4). Usually, as at Poatina and Golden Valley, the passage from the Lower Marine Sequence into the Lower Freshwater Sequence is gradational, but in the Fisher Tunnel it is abrupt (Clarke and Farmer, in press). It is possible, therefore, that a disconformity may be locally developed at the base of the Lower Freshwater Sequence and/or Faunizones 2 and 3 may be represented in unfossiliferous beds such as the upper parts of the Kansas Creek Beds in the Fisher River area, and the Macrae Mudstone at Poatina and Golden Valley. Overall, however, this seems to be unlikely and the simplest interpretation of the available evidence suggests that the base of the Lower Freshwater Sequence is diachronous, with the onset of non-marine conditions occurring first in the north and northwest and only later spreading to the east, northeast and southeast.

Faunizones 4-5

Together, Faunizones 4 and 5 witness a profound change in faunal composition. Part of this abruptness is due to the fact that no continuously marine sequence is developed through the Faunizone 3-Faunizone 4 interval because of the intervention of the Lower Freshwater Sequence. The most important faunal changes include the appearance of true productids and aulostegids (Anidanthus, Cancrinella, Terrakea, Taeniothaerus), the appearance of Martiniopsis of the ovata (Campbell), profunda (Campbell) and valida (Campbell) species groups, the appearance of costate spiriferids such as Grantonia hobartensis Brown, G. cracovensis Wass and Sulciplica tasmaniensis (Morris), and the appearance of Punctospirifer. Syringothyroids become very rare but strophalosids continue in profusion and include members of the Wyndhamia preovalis (Maxwell), W. enorme Clarke and W. jukesii (Etheridge)—
REFERENCE

- Coarse-grained quartz sandstone, coal, and other non-marine rocks
- Conglomerate
- Siltstone
- Limestone
- Bi-sector, pyritic siltstone and mudstone (poorly fossiliferous)
- Richly fossiliferous, pebbly siltstone with subordinate limestone
- Familiarly siltstone and fine sandstone
- Tuffite
- Tornado (rhythmite)

Location of sections

VERTICAL SCALE

LOCATION OF SECTIONS
Stratigraphy of the Parmeener Super-Group

dalwoodensis Booker species groups. Faunal diversity increases with the appearance of simple rugose and tabulate corals such as *Euryphyllum*, *Cladochonus* and *Thamno*pora, blastoids such as *Thaumatoblastus*, conulariids such as the giant *Paraconularia*, certain bivalves such as *Conocardium* and *Atomodesma* (*Aphanaia*), rare occurrences of *Spirigerella* and trilobites (Wass and Banks, 1971), and an increase in the variety and abundance of *Fletcherithyris* and *Gilledia*, together with crinoids such as *Calceolispongia*. Part of the increased faunal diversity of Faunizone 5 and the predominance of carbonate rocks at this level may indicate slightly higher water temperatures. The restricted vertical distribution of *Taeniothaerus* and *Terrakea* appears to be more fundamental since both occur in a variety of rock types. Despite the pronounced faunal changes which take place between Faunizone 3 and Faunizone 4, several Lower Marine Sequence species groups persist. In particular, *Deltopeeten*, *Eurydesma* and *Keeneia* continue in abundance, although never in quite the same extraordinary profusion as in the Lower Marine Sequence.

The occurrence of *Anidanthus springsur*ensis (Booker), *Cancrinella farleyensis* (Etheridge and Dun), *Taeniotaerhus subquadratus* (Morris), *Terrakea pollex* Hill group, *Wyndhamia preovalis*, *W. enorme*, *W. jukes*dalwoodensis, *Martiniopsis ovata*, *M. profunda*, *M. valida*, *Gilledia homevalensis* Campbell and many other forms indicates that collectively, Faunizones 4 and 5 can be confidently equated with Fauna II in the Bowen and Sydney Basins. Faunizone 4 may approximate the New Zealand Telfordian Stage, and Faunizone 5 appears to have a rather more restricted distribution than hitherto thought. They are certainly present in the Hobart area (Rayner Sandstone and Cascades Group), Maria Island (*Productus* and 'Crinoidal Zones'), Friendly Beaches (Peter Limestone), Elephant Pass (Gray Siltstone (McNeil, 1965)) and various other localities in northeastern Tasmania, at Maydena (Jago, 1972) and Frankford. At the last two localities the faunas are associated with developments of sandstone and conglomeratic sandstone, but elsewhere the predominant rock types are calcareous siltstone and limestone. Faunizones 4-5 have not been recognised in the extensive Parmeener Super-Group outcrop of the Great Western Tiers nor elsewhere in northern and northwestern Tasmania other than at Frankford. In the Fisher River area, and inferentially over much of northern and northwestern Tasmania, a pronounced hiatus or paraconformity separates the Lower Freshwater Sequence and the Upper Marine Sequence. In the Cygnet area, southern Tasmania, this hiatus additionally embraces the Lower Freshwater Sequence, so that an incomplete Upper Marine Sequence rests on an incomplete Lower Marine Sequence. In detail the situation is complex because at Cygnet the base of the Upper Marine Sequence is younger than in the Hobart area, but older than in the Fisher River area (Fig. 33.4 and see later).

Faunizones 6-10

Assemblages younger than Fauna II are well developed in Tasmania. Rich Fauna IV assemblages with *Wyndhamia ovalis* are known from Malbina Member E of the Hobart area and its correlates at Eaglehawk Neck and elsewhere in southern Tasmania (Banks and Read, 1962). Below this level,
rich post-Fauna II — pre-Fauna IV assemblages are developed. Basically these faunas are not like the distinctive Queensland Fauna III, but like the mixed Sydney Basin Ulladulla Fauna. These faunas, despite an overall similarity of character, show disconcerting variations from place to place. They are also rather sporadically developed in otherwise unfossiliferous rocks of the Upper Marine Sequence, a sequence which is much affected by rapid lateral variations in lithofacies, particularly in its lower parts. As a consequence a more detailed evaluation of these faunas has proved difficult. However, the recent discovery of a continuously exposed and continuously fossiliferous sequence through this critical interval at Deep Bay, Cygnet, now permits a clarification of most of these difficulties. The Deep Bay section realises many of the attributes of the ideal stratigraphic section. It is continuously exposed and unfaulted, continuously fossiliferous, the fossils are well-preserved, and for most part, there are no abrupt changes in lithology. The details of the Deep Bay section are shown diagrammatically (Fig. 33.3) and summarised below.

Faunizone 6 This assemblage is marked by the incoming of Martiniopsis ingelarenis (Campbell), M. sp. nov.—M. undulosa (Campbell) group, M. angulata (Campbell) —M. globosa (Campbell) group, M. magna (Campbell), Fletcherithyris parkesi Campbell and Myonia corrugata Fletcher. Sulciplica stutchburi occurs in profusion. Aperispirifer wairakienis (Waterhouse) is the dominant neospiriferid. Deltopecten and Eurydesma are still abundant. Characteristic of this faunizone at Deep Bay is an enormous profusion of smooth ostracods, Peruwispire-Ptychomphalina, and Megadesmus gryphoides (de Koninck).

Faunizones 7-8 Species confined to these faunizones include Terrakea concava Waterhouse, Fusispirifer sp. nov. (a very transverse form with obsolescent ornament) and Martiniopsis sp. nov. (a medium-sized, strongly plicate, transverse form with a deep groove on the dorsal fold). Important new species which enter near the base of Faunizone 7 include Aperispirifer lethamensis Waterhouse, Sulciplica phalaena (Dana) —

transversa Waterhouse group, Terrakea brachythaera (Morris), Walnichollia cancellata (de Koninck), Asturla intrepidida (Dana), Vacunella curvata (Morris), Myonia carinata (Morris), and Giliated ulladullensis Campbell. New entrants in Faunizone 8 include Martiniopsis strzeleckii (de Koninck), Warthia micromphala (Morris), Volsellina mytiliformis (Etheridge) and possibly Etheripecten leniusculus (Dana). Eurydesma hobartense and Sulciplica stutchburi are abundant at the base of Faunizone 7 but rapidly decrease in numbers and disappear below its summit, whereas Deltopecten, Wyndhamia preovalis and W. jukesi-dalwoodensis remain abundant throughout both faunizones. Many species characteristic of Faunizones 4-5 (=Fauna II) or even older horizons, such as Schuchertella, Thamnospora, Sulciplica tasmaniensis, Grantonia crovensis, Concocardium and Paraconularia derwentensis (Johnston), finally disappear at the top of Faunizone 8.

Faunizone 9 This faunizone marks the entrance of Martiniopsis isbelli (Campbell), Fusispirifer avicula (Morris) and 'Notospirifer' duodecemcostatus (M'Coy), the acme of Martiniopsis magna, together with the continued persistence but eventual extinction of Deltopecten, Etheripecten fittoni (Morris), Aperispirifer lethamensis and Wyndhamia jukesi-dalwoodensis. At Deep Bay Atomo-desma (Aphanaia) occurs in profusion near the summit of the zone and Punctospirifer is abundant towards its base.

Faunizone 10 Wyndhamia ovalis and Megadesmus grandis (Dana) enter for the first time and distinguish this faunizone. No overlap of these species with Deltopecten and Wyndhamia jukesi-dalwoodensis occurs in Tasmania.

Many lineages, but particularly the martiniopsids, neospiriferids, Sulciplica and strophalosiids show gradual upward change. Speciation within these continuously variable lineages is therefore somewhat arbitrary. Doubtless, a more refined taxonomy beyond that currently available is necessary and would give the definition of each faunizone a greater distinctiveness. Such a process should be approached with caution since the proliferation of new taxa for minor morpho-
logical variations is to be deplored. A detailed external correlation of Faunizones 6-10 poses several problems. Faunizone 10 with *Wyndhamia ovalis*, *Fusispirifer avicula* and *Megadesmus grandis* appears to offer a reasonably sure correlation with Fauna IVB-IVC in Queensland. Below this, firm correlations are less evident. Stratigraphic position and the occurrence of *Martiniopsis isbelli* with the peak development of *Martiniopsis magna* suggests a broad equivalence of Faunizone 9 with Fauna IVA. Together, Faunizones 9-10 offer a reasonably sound correlation with the New Zealand Flettian Stage. On stratigraphic position, general faunal characters, but particularly on the basis of the very distinctive *Terrakea concava*, Faunizones 7-8 may approximate in age to the New Zealand Barrettian Stage. Faunizone 6 is most certainly post-Fauna II on the basis of the martiniopsids, *Fletcherithyris parkesi* and *Myonia corrugata*, and may therefore approximate with Fauna IIIA. This conclusion is based largely on stratigraphic position since faunal resemblances are slight. Indeed, Fauna IIIA is largely distinguished by characteristic bivalves and some gastropods, most of which do not occur in Tasmania (*Veteranella*, *Atomodesma* cf. *mytiloides* Beyrich, *?Wilkingia*, *?Pseudomonotis* and *Platyteichum*). The long-ranging *Martiniopsis ingelarensis*, *Stutchburia* cf. *costata* (Morris) and *Streblopteria* are the only forms common to both assemblages. Equally Faunizone 6 is almost certainly pre-Barrettian and therefore presumably Mangapirian, assuming the completeness of the New Zealand sequence. However, once again faunal resemblances are slight; indeed, Faunizone 5 appears to approximate more closely with the Mangapirian.

At Deep Bay the base of Faunizone 6 is not exposed. However, the Deep Bay Borehole proved this faunizone to rest directly on the Lower Marine Sequence (Bundella Mudstone) about 35 m below the lowest exposed horizons. Faunal assemblages from the Bundella Mudstone unequivocally belong to Faunizone 2. Consequently, a pronounced hiatus or paraconformity involving Faunizone 3, the Lower Freshwater Sequence and Faunizones 4-5, separates the Upper and Lower Marine Sequences. In the borehole, and in other sections of the Cygnet area, there is little physical evidence of this hiatus apart from a few thin bands of conglomerate, flaser-bedded siltstone and some lenses of coarse gritty sandstone crowded with *Peruissipra-Ptychomphalina* immediately above the Bundella Mudstone. This is most surprising in view of the Hobart sequence. Whether Faunizone 3, the Lower Freshwater Sequence and Faunizones 4-5 were deposited, and then removed by subsequent erosion prior to Faunizone 6, or never deposited is unknown. To date, the Lower Freshwater Sequence is unknown south of Taroona where it is immediately followed by the Grange Mudstone (Banks, 1952) which yields rich Faunizone 4-5 assemblages. South of Taroona large-scale block faulting has caused this critical interval to be obscured by higher Permian and Triassic rocks intruded by thick sheets of dolerite. However, in the Whitewater Creek area, south of Kingston, *Cancrinella farleyensis* occurs abundantly in gritty sandstone and siltstone. Elsewhere in Tasmania, this species is a reliable index for Faunizones 4-5, but the lithofacies at Whitewater Creek is quite foreign to the Cascades Group. This may indicate a facies change causing a southward thinning and disappearance of the Cascades Group. However, faulting obscures the relationship of the Whitewater Creek *Cancrinella* horizon to the beds above and below, so it is impossible to be sure. It is to be hoped that as detailed mapping proceeds north from Cygnet, more definite evidence will come to light. Ultimately, stratigraphic drilling may have to be utilised. Away from the Cygnet area Faunizone 6 has so far only been recognised in sections in the Beaconsfield Quadrangle. As noted by Green the West Arm Group (Gee, 1971) is much reduced in thickness, contains several prominent bands of conglomerate, and may display several internal disconformities. At Middle Arm Faunizone 6 is developed in sandy limestone about 20 m above the Liffey Sandstone. Even allowing further possible disconformities within the West Arm Group, in all probability it rests with dis- or paraconformity on the Lower Freshwater Sequence.

Faunizones 7-9 are more widely distribu-
In the Hobart area Malbina Member A (Banks and Read, 1962) is not richly fossiliferous, but persistent collecting of the outcrop at Mt Nassau has yielded assemblages diagnostic of Faunizone 8 (Clarke, 1971). It is therefore necessary to postulate a dis- or paraconformity between Malbina Member A and the Cascades Group (Fig. 33.4). The lithologic break is certainly an abrupt one. It is interesting to note that coarse sandstone of Malbina Member A type is of Faunizone 7 age at Arcadian Siding in the Maydena area and at Bronte Park, whereas similar lithologies are associated with Faunizone 9 assemblages in the Cygnet area. Thus coarse sandstone of Malbina A type becomes progressively younger away from the Bronte Park-Maydena area towards the east and southeast.

On Maria Island, at Friendly Beaches and elsewhere in eastern and northeastern Tasmania, Faunizones 7-9 are often present in thin, much attenuated sequences of arkosic and glauconitic sandstone. At Beaconsfield, Faunizone 9 is developed in reasonably pure limestone and rests directly and with inferred paraconformity on Faunizone 6. In the Fisher Tunnel, Faunizone 8 rests with proven paraconformity on the Lower Freshwater Sequence (Clarke and Farmer, in press). This paraconformity is probably developed over the entire extensive Parmeener Super-Group outcrop of the Great Western Tiers and western and northwestern Tasmania, since Faunizone 8 is the oldest detectable horizon within the Upper Marine Sequence at Poatina, Golden Valley, Western Bluff and the Cradle Mountain area (Fig. 33.4). However, lack of outcrop or paucity of diagnostic faunas immediately above the Lower Freshwater Sequence precludes certainty.

Faunizone 10 has so far been proved only on Maria Island and in southern Tasmania. Assemblages diagnostic of this faunizone are first encountered immediately below the Risdon Sandstone in Malbina Member E at Mt Nassau (Banks and Read, 1962) and at a similar stratigraphic level at countless other localities in the Brighton, Hobart, Kingborough and Sorell Quadrangles. One of these is at Eaglehawk Neck which is the type locality for *Fusispirifer avicula* (Banks, 1971). Rich Faunizone 10 assemblages (Clarke, in press) are also known from over a dozen localities within the Ferntree Mudstone of southern Tasmania. Previously this formation was thought to be poorly fossiliferous and no external correlations were possible (Banks, 1962). However, the presence of *Astartilla intrepida*, *Megadesmus grandis* and *Vaccinella curvata* at a horizon about 40 m below the summit of the formation at Blackmans Bay, suggested to Runnegar (1967) that it was not significantly younger than the Peawaddy Formation in Queensland (= Fauna IVB-IVC). However, Waterhouse (1969, 1970) recorded *Martiniopsis antesulcata* (Waterhouse), *Deltopecten* and *Eurydesma* from 'tillite' in the Ferntree Mudstone at Grasstree Hill, and favoured a correlation with the New Zealand Waitaiian Stage which he equates with the Tatarian Stage of the world standard. More recent work (Clarke, in press) supports the original conclusion of Runnegar. In essence, diagnostic faunas occur at three separate and restricted horizons within the Ferntree Mudstone. One horizon (about 2 m thick) occurs in the middle of the formation, a second (6-8 m thick) occurs about 40 m below its summit, and a third (about 3 m thick) occurs no more than 15 m below its summit. Both the Blackmans Bay locality and the Grasstree Hill locality belong to the second horizon, which is the most widespread. Individually the three horizons within the Ferntree Mudstone show some differences in faunal composition, but these differences can be easily explained by slight differences in depositional environment or bottom conditions in so far as these are reflected in the lithology. Collectively over thirty species are represented within the faunas and most, including *Wyndhamia ovalis*, *Fusispirifer avicula* and *Megadesmus grandis*, are known from Malbina Member E. The remaining species, which include *Martiniopsis magna*, *M. isbelli*, *M. globosa* and *Terrakea brachythaera*, are known from even older horizons as well as Malbina Member E (Fig. 33.2). Tillite is not developed at Grasstree Hill, or anywhere else in the Ferntree Mudstone. Indeed, tillite is unknown in Tasmania above the basal Wynyard Tillite and its correlates. *Martiniopsis antesulcata*,
the critical species of the Waiitian Stage, is based on inadequate material so that its recognition is problematical. The vertical distribution of *Deltopecten* and *Eurydesma* everywhere in Tasmania strongly suggests that neither is likely to be found in faunas from the Ferntree Mudstone.

The Upper Freshwater Sequence marks the re-establishment of non-marine sedimentation and marine conditions are never again established in Tasmania during the Permian Period. Lithologically the Upper Freshwater Sequence is more closely related to the upper (Triassic) parts of the Parmeener Super-Group, but since it is of Permian age it is briefly mentioned here. It has long been known that the Cygnet Coal Measures at Cygnet and correlative horizons such as the Jackey Formation at Poatina, contain a *Glossopteris* flora and *Dulhuntyispora* microflora (Balme, 1962, 1967) and are therefore of Permian age. However, recent drilling of the once productive Cygnet Coal Measures at Mt Cygnet demonstrates that the Cygnet Coal Measures and Barnetts Member (Banks and Naqvi, 1967) of the Springs Sandstone (‘Triassic’) are the same lithostratigraphic unit. Clearly, much further work is required before any detailed understanding of the lithostratigraphic and biostratigraphic relationships of units close to the Permo-Triassic boundary in Tasmania can be expected.

**GENERAL FAUNAL OBSERVATIONS**

The marine Gondwanan *Eurydesma* Fauna in Tasmania is extremely rich in terms of numbers of individuals, but diversity is low. There are no warmer-water forms such as reef-building corals, fusulinids and goniatites. Diversity increases above the Lower Freshwater Sequence but even so, several genera of brachiopods, bivalves and gastropods, which occur in varying degrees of abundance in the Sydney and Bowen Basins, are either rare (*Anidanthus*, *Cleiothyridina*, *Spirigerella*, *Punctospirifer*, *Pleonella*), or absent (*Lissochonetes*, *Neochonetes*, *Filiconcha*, *Attenuatella*, *Martinia*, *Stenocisma*, *Psilocamara*, terebratuloids other than *Fletcherithyris* and *Gilledia*; *Australomya*, *Cypricardinia*, *Glendella*, *Veteranella*; and *Platyteichum*). Rather surprisingly and unlike Early Permian (Allandale) faunas in the Sydney Basin, brachiopods (particularly strophalosids, neospiriferids and martiniopsids) dominate Tasmanian faunas from the first appearance of *Eurydesma*. Bryozoa occur in profusion at many levels. The sudden appearance and abundance of true productids in Faunizons 4-5 is noteworthy, the more so in view of the abundance of strophalosids throughout the Lower Marine Sequence. This again contrasts with the Sydney Basin where true productids such as *Anidanthus* and *Cancrinella* are present in the Allandale Fauna, yet strophalosids are unknown (Runnegar, pers. comm.). The persistence of *Eurydesma*, *Deltopecten* and *Keeneia* at much younger horizons than in Queensland and Western Australia, probably indicates the continued influence of cold-water conditions throughout most of the Permian in Tasmania.

**SUMMARY AND CONCLUSIONS**

Macro- and microfloral evidence proves the lowermost parts of the Parmeener Super-Group to be of Late Carboniferous age. Above these horizons rich Permian marine faunas separated by one thin horizon of coal measures and other non-marine rocks are developed. These faunas prove that the Tasmanian sequence, though much reduced in thickness, much affected by lateral changes in lithofacies, and with breaks of variable duration from place to place, is as complete as any in eastern Australia. In detail, these faunas belong almost exclusively to the Gondwana cold-water realm and probably represent the most extreme development of the marine *Eurydesma* fauna anywhere in the world. According to generally accepted world correlations (Dickins, 1968; Runnegar, 1969a) marine sedimentation ceased in Late Kungurian or Early Kazanian times, and thereafter non-marine conditions persisted until the end of the Triassic (Townrow, 1962). On the basis of the *Glossopteris* flora and *Dulhuntyispora* microfloras, the lowest parts of this non-marine sequence are of Permian age. However, no satisfactory method of recognising the Permo-Triassic boundary in Tasmania is known. This is equally true of the Permo-Carboniferous boundary.
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REFERENCES


First Record of Permian Varves in Tasmania

Abstract

Varved claystones and siltstones occur on at least three horizons in the Wynyard Glacial Formation in the Wynyard district, northwestern Tasmania. David recorded 'lamellated clay shales' but did not recognize them as glacial varves. The Wynyard Glacial Formation at least in part is probably Permian.

Introduction

During the 1953-4 field season of the Soils Division of C.S.I.R.O. two of the authors (J.L. and D.L.S.) found some laminated, highly coloured claystones associated with tillites in the area behind Wynyard. The other author suggested that these might be glacial varves and subsequent field observations have confirmed this suggestion. This short paper is a preliminary note and fuller details will be presented later for publication by the Royal Society of Tasmania.

Field Occurrence

At Doctor's Rock on the coast three miles east of Wynyard, graded claystones are well exposed in the shore platform and show a close association with sandstones and tillites. David (1908, p. 275) referred to these as 'lamellated clay shales' but did not record them as varves, probably because weathering has obscured the graded bedding. This is, however, visible on close examination. Graded claystones, again associated with tillite, occur in road cuttings beside the lower parts of Camp Creek, just south of Wynyard. In a road-metal quarry beside the lower Seabrook Creek section, well-graded claystones are associated with erratics and the bedding planes diverge around the erratics. One such erratic of quartzite exposed in the upper Seabrook Creek section was one foot across, well-faceted and deeply grooved on several facets. Normally the bedding planes of the claystones are remarkably flat, but occasionally they are disturbed by minor slump folds. Because of the well-developed graded bedding and the close association of these graded claystones with erratics and tillite bands, they are considered to be glacial varves.

Figure 1.

Glacial varves, Upper Camp Creek, Wynyard, showing graded bedding. Scale in inches.

These graded claystones contain thin bands of fine siltstone, grading upwards into thick bands of claystone with sharp boundaries against the overlying siltstone. The graded beds themselves contain erratics and the bedding planes diverge around the erratics. One such erratic of quartzite exposed in the upper Seabrook Creek section was one foot across, well-faceted and deeply grooved on several facets. Normally the bedding planes of the claystones are remarkably flat, but occasionally they are disturbed by minor slump folds. Because of the well-developed graded bedding and the close association of these graded claystones with erratics and tillite bands, they are considered to be glacial varves.
Age

From field observations it appears, then, that there are at least three glacial varve members in the Wynyard Glacial Formation. Near Oonah, the top of this formation is separated by less than 50 feet of siltstone and sandstone from a bed of oil shale from which Crespin (1944, p. 59) recorded the foraminifera: *Ammoidiscus milletianus*, *A. multicinctus*, *Hyperamminoides acicula*, *Ammobaculites woolnoughi*, *Digitina recurvata*, *Pelosina hemispherica*, etc. These indicate a correlation with the Upper Marine Group (Voisey, 1952, p. 52) of New South Wales, which is now considered to be Artinskian in age (Teichert & Fletcher, 1943). According to David's section (1908, p. 278), the 'lamellated clay shales' occur near the top of the formation; but a section near Oonah revealed at least 250 feet of tillite below the top of the formation without any varves. Browne (in David, 1953, p. 303) considers this formation to be Carboniferous; but from its relationship with the oil shale the top part of it is almost certainly Permian, and the varves are probably in this part of the formation and, therefore, probably Permian. No direct evidence on this point, however, has been found.

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References


PERMIAN VARVES FROM WYNYARD, TASMANIA

by

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Permian Varves from Wynyard, Tasmania

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(WITH 3 PLATES AND 6 TEXT FIGURES)

ABSTRACT

Thinly laminated to very thinly bedded varved mudstones are associated with tillite and thinly cross-laminated sandstone in the Wynyard Tillite in the Wynyard area, north-west Tasmania. Many of the varves are highly coloured. Simple drainage and composite varves are present. The varves show slump structures and ripple marking. Sedimentary structures, textures and the types of erratics indicate derivation from the south or south-west. Oil shale, probably of Upper Artinskian age, occurs within fifty feet of the top of the tillite and is conformable with it. At least three advances and retreats of the Permian ice sheet are indicated. The Wynyard Tillite is defined in terms of the Australian Code of Stratigraphic Nomenclature.

INTRODUCTION

The Wynyard Tillite was first recorded by Stephens (1869) who, although recognising it as a glacial deposit, did not comment on its age or formally name it. It was called the Wynyard Formation by Montgomery (1896) but it is mainly known through the detailed description by David (1907). Although earlier authors describe rocks in the formation which could be varves, they did not recognise them as such. The present authors have recorded their discovery in a short preliminary note (Banks, Loveday and Scott, 1954).

During a survey by the Soils Division, C.S.I.R.O., in the summer of 1953-4, Messrs. Loveday and Scott first noticed these rocks and described them to the other author who suggested they might be varves. On a subsequent trip to the area, closer observations were made and specimens collected for examination. All the facts confirm the earlier suggestion that these rocks are varves.
Colours were determined by the use of the Rock-colour Chart (Goddard et al, 1948) and the formulae which accompany colours in the text refer to this notation. Bedding and cross-bedding terminology is that of McKee and Weir (1953). The authors wish to acknowledge, with many thanks, the assistance of Mr. G. E. A. Hale, of the Tasmanian Museum, in determining the clay minerals.
WYNYARD TILLITE

The Wynyard Tillite is defined as that formation of tillite, with subordinate sandstones and varved mudstones, resting unconformably on Devonian or older rocks and overlain conformably by sandstones and siltstones, as exposed in the creek bed east of Oonah Post Office. The tillite is 1220 ft. thick according to David (1907) and is probably Sakmarian and Artinskian in age. The type area is the Wynyard district, but no uninterrupted section can be quoted.

This formation has received various names in the past, as shown in the following list:

Wynyard Formation:
Montgomery, 1896
Waller, 1902
Twelvetrees, 1905
Noetling, 1909

Wynyard Glacial Formation:
Hills and Carey, 1949
Banks, Loveday and Scott, 1954

Wynyard Glacial Stage: Voisey, 1938
Wynyard Mudstone Conglomerate: Hills, 1913
non Wynyard Stage: Nye and Lewis, 1928

The geographic name was first applied by Montgomery (1896), but it had been recognized as a tillite by Stephens (1869). Montgomery gave its age as Permo-Carboniferous and has been followed in this by Kitson (1902), Twelvetrees (1905), David (1907) and most other authors. However, Noetling (1909) incorrectly considered it to be Pleistocene. The name tillite is here used in preference to glacial formation as the formation is dominantly tillitic. The tillite occurs at least as far south as the Hellyer Gorge (Lewis, 1929) and as far south-west as the junction of the Arthur and Keith Rivers. It is commonly exposed in gullies, cut through the basalt south of Wynyard. Details of the lithology and age of this formation are discussed by David (1907) and the present authors (see later).

The varved mudstones occur on several horizons within the tillite formation and may eventually prove to be members occupying consistent stratigraphic horizons. The geographic distribution of the varved mudstones is shown in the accompanying map (fig. 1) and the occurrences will be discussed in the order used on the map.

STRATIGRAPHY AND FIELD OCCURRENCE

At Doctors Rock (A in fig. 1)* two miles east of Wynyard on the coast Tertiary basalt unconformably overlies varved mudstones and tillites on the shore platform. Several hundred yards further east, the tillite rests unconformably on pre-Dundas Group rocks. On the shore platform immediately east of Doctors Rock varved mudstones are found closely associated with tillite near the base of the formation. The varved mudstones include many thin beds of cross-laminated sandstone and these show the cross-lamination dipping in a northerly direction. The surface of these sandstone beds is frequently ripple-marked.

* Exposure sites, subsequently referred to by capital letters, are shown in fig. 1.
Several exposures of varved mudstones (B and E) occur in cuttings on the road along Camp Creek to the reservoir and the best exposure occurs a few yards down-stream from the reservoir wall (E). All specimens of varved mudstone collected from here showed simple varves, varying in thickness from 0.8 to 8 mm. The winter layers of these specimens were also much thicker than the summer layers which in several cases were of claystone grade and which were usually no coarser than very fine siltstone with some fine erratics. These would seem to be distal simple varves (Antevs, 1951) and this is borne out by the occasional

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**Fig. 2**

(a).—Columnar section of part of Wynyard Tillite at Elliott.

(b).—Columnar section of part of Wynyard Tillite at Tewkesbury.
unvarved claystone beds. At B on the lower part of Camp Creek, the varved mudstones are associated with tillite.

In a road metal quarry beside Seabrook Creek (C) a thickness of about 20 feet of varved mudstones with erratics is revealed. The siltstone layers are ripple-marked. The most notable feature of the rocks in this quarry is the presence of elliptical concretions up to 60 cm. in length, which appear to be restricted to a narrow band. These concretions, which will be described a little later, show contorted bedding and are slump structures.

Where the West Calder Road crosses the Calder River (D) tillite can be seen at river level passing up into varved mudstones which in turn pass up into tillite as seen in road cuttings on the West Calder Road south of the bridge.

The best exposure of varved mudstones seen in the area was in road cuttings and quarries near the Seabrook Creek crossing on the Elliott-Mt. Hicks Road (F). Here, almost 100 feet of varved mudstone, tillite and fine-grained sandstone are exposed resting on tillite in the creek bed. This tillite is described in a later section. The section beside the road to north and south is given (fig. 2 (a)). Several granite erratics were found in the tillitic bands, the largest observed being four feet in diameter.

The section above this tillite consists of alternations of fine-grained, cross-laminated, laminae or very thin beds of sandstone, with thinly laminated and laminated sets of varved mudstone. Laminae and thin beds of tillite are present on at least eleven horizons but these seem to become rarer between 50 and 80 feet and above this they are uncommon.

![Graph showing distribution of thickness of beds of the varved mudstones](image-url)
The sandstone bands are of interest, as they consist of fine-grained quartz with some clay matrix. They are dusky yellowish brown (10YR2/2) and brownish black (5YR2/1). They are thinly cross-laminated, the cross-lamination being revealed by dark bands. It was observed here and at Doctors Rock that the surfaces of these bands were usually ripple-marked. The varved mudstones were observed to be usually laminated, some thinly laminated and some very thinly bedded. Figure 3 shows the relative distribution of thicknesses of varves.

These varved mudstones were frequently highly coloured, especially on the south side of the bridge. The colour is normally olive grey, with some summer layers a light brown, but on weathering, iron minerals present are oxidised especially along joints and bedding planes, producing rich purples, reds and deep browns, which give the rock a most striking appearance.

The southernmost outcrop of varved mudstones observed was in a cutting on a disused road at Tewkesbury (G). Here three varved mudstone members are interbedded with tillites as shown in fig. 2 (b).

A most interesting section was examined in the bed and valley walls of the creek immediately east of Oonah Post Office (see fig. 4).

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![Diagram](image)

**Fig. 4.**—Columnar section of Permian near Oonah.
The bottom of the tillite was not seen, but at least 250 feet of this rock were exposed in the creek below and just above the falls. No sign of varved mudstones was seen in this section either in the form of outcrops or as fragments in the creek debris. The tillite is overlain by six inches of dark-grey siltstone, eighteen inches of fine-grained, white, massive, very tough sandstone, a foot of grey siltstone, eighteen inches of sandstone, again white, massive and very tough and then twenty to forty feet of dark-grey siltstone. This siltstone is followed by two beds of oil shale separated by six to ten feet of dark-grey shaly siltstone, with some spores. The top oil shale is overlain by a dark siltstone, which is in turn unconformably overlain by Tertiary basalt. Large pyritic nodules are common in all these sediments above the tillite, but fossils are rare. The importance of this section is that the oil shale contains foraminifera identified by Crespin (1947) as Ammodiscus multicinctus Crespin and Parr, Hyperamminoides acicula Parr, Critithion teicherti Parr, Pelosina hemispherica Chapman and Howchin, Ammobaculites woolnoughi Crespin and Parr and Digitina recurvata Crespin and Parr, indicating correlation with the Latrobe Tasmanite and the Upper Marine Group of New South Wales. Thus the oil shale is Upper Artinskian in age. Because of the small stratigraphic thickness (less than 50 feet) between the oil shale and the top of the tillite, it is probable that the top of the tillite goes well into the Artinskian and that glaciers were active late in the Artinskian in this area.

NOTES ON THE SEDIMENTARY PETROLOGY AND STRUCTURES

Tillite

A specimen of tillite (U.T.G.D. 6055) from the base of the Elliott section was examined under the microscope. The tillite band of the fresh rock is medium dark-grey (N4). The associated siltstone is medium bluish-grey (5B5/1), but becomes light olive-grey (5Y5/1) on weathering. Claystone associated with the tillite is also medium bluish-grey. Both graded and ungraded beds are present. In the ungraded specimen (6055b) the modal grain size is about 0.25 mm. with about 30 per cent of the particles in the modal grade. Grains from 0.06 mm. to 2.2 mm. were measured but about 25 per cent of the band was unresolvable under the highest power of the microscope. The grains are dominantly angular, with some sub-angular and a few sub-rounded ones. Larger fragments tend to be slightly more rounded than the smaller and some have flat surfaces. The particles vary from almost equidimensional to very elongated. An orientation parallel to the bedding plane is distinctly preferred. Quartz is the only common mineral and forms about 10 per cent of the coarse band. The matrix consists of quartz, a micaceous material which may be a clay mineral and unresolvable material. Rock fragments constitute about 55 per cent of the coarse band. The rock fragments include quartz schist, quartz mica schist, carbonaceous siltstone, chloritic quartzite, quartzite, crystalline dolomite, calcite (some of which may be authigenic), graphitic mica schist, ilmenitic chloritic feldspar schist, siliceous granular limestone, puckered quartz sericite schist, plagioclase with chlorite inclusions, fossiliferous siltstone, chloritic quartz keratophyric tuff, chlorite haematite quartz rock, pyritic carbonaceous silty sandstone,
ilmenitic fragments, micaceous slightly ilmenitic sandstone and oolitic dolomite. The most common rock types are the granular limestone and graphitic mica schist and phyllite.

The fine band, with modal grain size about 0.009 mm. and variation from 0.002-0.012 mm., contains inclusions of tillitic material up to 2.7 mm. long by 1 mm. wide. There are also distinct bands of particles from 0.015-0.02 mm., which diverge around the tillitic erratics. These coarser bands contain micaceous minerals, which are possibly clays, quartz and some calcite. The quartz and calcite grains are angular and from equidimensional to slightly elongated. The micaceous minerals in both coarse and fine bands are distinctly lath shaped and orientated parallel to the bedding plane. The finer bands are dominantly micaceous with some quartz and other minerals.

The contact between the coarse band (a tillitic arenite) and the fine band (a tillitic fine lutite) is sharp but irregular due to the uneven surface of the arenite on which the siltstone was deposited. The rock is considered as of glacial origin because of the presence of large numbers of varied rock fragments, the angularity and the poor sorting. The presence of tillitic erratics in the fine siltstone is of particular interest.

The other specimen examined (6055A) showed distinct gradation from a modal grain size of 1.5 mm. in the coarsest part down to 0.01 mm. in the finest part. Thus the rock varies from a medium arenite to a fine siltstone. Sorting is poor throughout and a considerable proportion of clay material is present, at least 15 per cent in the fine siltstone portion. Probably only 40-50 per cent of the particles would fall into the modal grade of each portion. In all grades the fragments are dominantly angular, with many sub-angular and a few sub-rounded ones. Fragments vary extremely in sphericity from almost equidimensional to elongated forms 6:4 times as long as wide. Many distinctly tabular fragments are present. Quartz varies in amount from about 10 per cent in the arenite portion to 40 per cent in the siltstone and 50 per cent in the fine siltstone fraction. Several fragments of feldspar were seen. Clay minerals or sericitic mica are abundant in the matrix and form at least 40 per cent of the finest grade of the rock. Rock fragments form about 60 per cent of the rock in the arenite grades, but are less than 5 per cent in the lutite grades. They consist of quartzite, quartz mica schist, quartz feldspar mica schist, chlorite schist, quartz schist, fine chloritic sandstone, carbonaceous siltstone with sandstone bands, serpentinite, phyllite, mica schist, spilithe, laminated carbonaceous siltstones, quartz-chlorite rock, graphitic schist, and an older tillite or subgreywacke. A feature of the slide is the occurrence of about 10 per cent of carbonaceous material, much of which may be graphite, as it is flaky and oriented parallel to the bedding. Haematitic and limonic staining is present, but not common. This rock is considered to be of glacial origin on the same grounds as the previous rock, with the additional evidence in this case of graded bedding.

Varved Mudstones

Twelve specimens of varved mudstones were carefully measured and examined under the binocular microscope and a thin section (6046b) was also examined.
The thin section showed portions of eight varves and details of this slide are summarised as Table I.

**TABLE I**

*Summary of Characters of Varved Mudstone U.T.G.D. 6046 (b)*

<table>
<thead>
<tr>
<th>Varve No.</th>
<th>Thickness Component Bands</th>
<th>Total</th>
<th>Grade</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Modal</td>
</tr>
<tr>
<td></td>
<td>mm.</td>
<td>mm.</td>
<td>mm.</td>
<td>n.d.</td>
</tr>
<tr>
<td>VIII</td>
<td>0.78 mm.</td>
<td>0.78</td>
<td>0.01</td>
<td>n.d.</td>
</tr>
<tr>
<td>VII</td>
<td>1.20 W.L. 0.30 S.L.</td>
<td>1.50</td>
<td>0.009</td>
<td>n.d.</td>
</tr>
<tr>
<td>VI</td>
<td>0.42 W.L. 0.12 S.L.</td>
<td>0.54</td>
<td>0.009</td>
<td>n.d.</td>
</tr>
<tr>
<td>V</td>
<td>0.30 W.L. 0.30 S.L.</td>
<td>0.60</td>
<td>0.009</td>
<td>n.d.</td>
</tr>
<tr>
<td>IV</td>
<td>0.54 W.L. 0.60 S.L.</td>
<td>1.14</td>
<td>0.005</td>
<td>up to 0.009</td>
</tr>
<tr>
<td>III</td>
<td>0.24 W.L. 0.24 S.L. 1.44 mm.</td>
<td>6.58</td>
<td>0.005</td>
<td>up to 0.55</td>
</tr>
<tr>
<td>II</td>
<td>0.66 W.L. 0.12 S.L. 0.24 0.18 mm.</td>
<td>1.20</td>
<td>0.012</td>
<td>up to 0.06</td>
</tr>
<tr>
<td>I</td>
<td>0.42 W.L. 0.36 0.72 mm. 1.5</td>
<td>—</td>
<td>0.016</td>
<td>up to 0.23</td>
</tr>
</tbody>
</table>

S.L. indicates Summer Layer.
W.L. indicates Winter Layer

Examination of this table will show that the varves are dominantly thinly laminated but varve III is laminated. The maximum grade of the summer layers is 0.08 mm. with most of them about 0.03 mm., while the maximum grade in the winter layers is 0.009 mm., with several varves showing a grade in the winter layers of less than 0.005 mm. Thus the varves vary from very fine arenites to very fine siltstones or claystones, with many of the winter layers down to the clay grade. Quartz and micaceous (or clay) minerals are dominant with only occasional fragments of plagioclase and rocks. The micaceous minerals are particularly common in the winter layers and they usually are elongated parallel or sub-parallel to the bedding. Haematitic and limonitic stains are com-
mon throughout, with some concentrations. The grains are dominantly angular, with very little rounding shown. Varves I and IV to VIII are simple varves in Antev's terminology, although Varve I has coarse bands in the winter layer. The winter layers become proportionally thicker upwards as compared with the summer layers. Varves II and III have fine layers in the summer layer and are thus the composite varves of Antevs. Varve III is especially interesting because of its thickness and the very thin winter layer as compared to the summer layer. It represents, perhaps, a year in which the glacier approached much closer than in any of the other seven years.

Some details of three specimens, one from Camp Creek, one from Elliott and one from Tewkesbury, are here shown as fig. 5. The Camp Creek varved mudstones are mainly thinly laminated to laminated, with individual varves from 0.8 to 8 mm. thick. The summer layers are usually fine siltstone, with a coarse siltstone or fine sandstone in a few cases and are rarely silty claystones. The winter layers are invariably
claystone. Erratics present are usually less than 3 mm. in greatest dimension and the majority are less than 1 mm.; however, one reached 25 mm. in longest dimension. In many varves they are concentrated as a thin line at the base of the summer layer. In one or two varves a siltstone band occurs within the claystone of the winter layer. In the majority of varves measured from Camp Creek the winter layer was distinctly thicker than the summer layer and only rarely did the proportion drop to approach unity. In the case of the eighth varve of the specimen recorded as fig. 5 (a) the summer layer lensed out rapidly and within the specimen almost thinned out completely. The colours do not vary greatly. Summer layers are mostly dusky yellow (5Y5/4, 5Y6/4) with some pale olive (10Y6/2) and greyish orange (5Y7/4). One band was purple (5P5/2). The winter layers are dominantly olive-grey (5Y3/2, 5GY3/2, 5Y5/2, 10Y5/2, 10Y4/2, 5Y3/4). Weathering has produced ferruginous concretions in the silty layers in some cases. Sixty-seven varves were measured in specimens from this locality. All are simple varves in Antevs' (1951) terminology. Because the winter layers are usually thicker than the summer layers these varves are thought to have been formed at some distance from the ice front, i.e., they are distal varves. Because of the fine grainsize of the summer layers, the lake in which these varves were deposited is considered to have been deep at Camp Creek.

The varves measured from Elliott were from 1-2 mm. to 18 mm. thick, the latter being an exceptional figure. Most of these varves are thinly laminated or laminated, with a few very thinly-bedded. The summer layers are usually siltstone, but quite a number are fine sandstone and unusually thick; rarely the summer layers consist of very fine siltstone or silty claystone. The winter layers are dominantly claystone but a few are very fine siltstones. The winter layers commonly have bands of coarser material in them and they also commonly contain erratics up to 2 mm. and rarely up to 12 mm. in longest dimension. Erratics also occur in the summer layers and most of the erratics in the varves are less than 1 mm. in longest dimension. However, one was 2 cm. long. Concentration of erratics at the base of the summer layers was not observed in these varves as it was in the Camp Creek specimens. Much more variation in the ratio of thickness of the winter to that of the summer layer was found in the Elliott varves than in those from Camp Creek. In a number of cases from Elliott the summer layer was very much thicker than the winter layer, e.g., Varve 9 (fig. 5, b). In many cases the two layers were almost equal and in perhaps a very slight majority of cases the winter layer was the thicker. The colour of the Elliott varves was extremely variable probably due to oxidation on weathering and in some cases this oxidation was demonstrably joint controlled. The summer layers vary from olive-brown (5Y3/4), pink (5R8/4), pale red (10R6/2), orange-pink (5YR7/4) to other combinations of red and yellow. The winter layers are much less variable, the predominant colour being greyish-olive (10Y4/2), with olive (10Y5/2) and light olive-grey (5Y5/2). A total of 83 varves was measured from this locality. All the varves measured from Elliott are simple varves, although more from this locality have coarse bands in the winter layer than is the case with the specimens from Camp Creek. Varve 11 (fig. 5b) is excessively thick, being one and a half times as thick as any other varve
measured and over six times the modal thickness of the Elliott varves measured (2.85 mm. approx.), which is a little lower than that of all varves measured (3.0 mm. approx.). Six very thinly bedded varves occur among all those measured, all six being from Elliott, and it is probable that all of these are drainage varves. Because of the greater relative thickness of summer layers to winter layers in the Elliott varves as compared to the Camp Creek varves, the former are considered to have formed closer to the ice front as a whole than the latter. The Elliott varves are also generally coarser in grade in both summer and winter layers than those from Camp Creek, suggesting deposition in shallower water.

One specimen of varved mudstone from Tewkesbury was measured and contained nine varves. The thicknesses varied from 2 to 7 mm., most of the varves being laminated. Summer layers were mostly fine sandstone or coarse siltstone and winter layers mostly silty claystones or very fine siltstones. All the varves are simple. Occasional erratics up to 2 mm. occur. The colour varies from moderate greenish-yellow (10Y7/4, 10Y7/6) in summer layers to light olive-grey (5Y4/1) and greyish-olive (10Y4/2) in the winter layers. The properties of the specimen are summarised as fig. 5c. No general conclusions can be drawn from these observations on a single specimen.

Clay Minerals

The winter layers from several specimens from Camp Creek and Elliott were examined by differential thermal analysis by G. E. Hale who reported that the clay mineral present was kaolinite.

Sedimentary Structures

The most striking feature of the varved mudstones is the graded bedding, which is very well displayed indeed. Usually this grading is from siltstone up to claystone, but occasionally from silty claystone up to fine claystone and also from fine sandstone up to clayey siltstone. This grading is shown in Plate, figs. 2 and 3.

The bedding varies from thinly laminated in a few varves to laminated in the majority of varves (82%) and very thinly bedded in a few varves (4%) (see fig. 3). The modal thickness of the varves measured is about 3.0 mm. The associated sandstones and tillites are mostly very thin-bedded with rare one thin-bedded, but no detailed measurements were made on these. The tillites outside the varve members are frequently thick or very thick-bedded.

Fig. 6.—Sketch section of slump structure from Seabrook Creek.
Bedding planes in the varves are usually flat, but disturbances of two types, slumping and ripple-marking, are present. No detailed observations were made on either of these structures. Ripple-marking was seen particularly at Doctors Rock, Lower Seabrook Creek and Elliott. Many of the ripples were due to wave action and one set in the floor of the southern quarry at the Elliott locality trended just east of north. Frequently the cross-laminated sets in the varves had a rippled upper surface—in most cases wave-rippled. Most of the slump structures in the Elliott varves are extremely small folds (amplitude about 1 mm. or less) of a complicated character, on the top of the varves. They do not occur on the top of every varve. These may be associated with the beginning of circulation in the glacial lake at the onset of unusually warm spring seasons. This type of small scale slumping was not seen elsewhere but at Elliott. However, evidence of slumping on a larger scale was seen in the Lower Seabrook Creek locality. In the road metal quarry here, concretions up to 50 cm. in longest dimension are common on a restricted horizon. These concretions are discoidal with the short axis perpendicular to the bedding. Sections cut through several of these with a hacksaw showed that the siltstone bands in them were very contorted and broken with overfolds, recumbent folds and thrust faults on a minor scale. Most of these structures seem to be directed from a southerly direction. A sketch of a section of one of these is included (fig. 6). They would seem to indicate that the floor of deposition sloped down to the north. David (1907, p. 276) described similar concretions (in his coastal section) varying in length from 1 to 27 feet. However, he ascribed no origin to these.

A very noticeable feature of the varves at the Elliott locality (F.) and at Doctors Rock (A.) is the presence of numerous sets of cross-laminae interbedded with the sets of varved strata. As far as could be seen the sets of cross-laminae are tabular and laminated-to-thinly bedded. Specimens measured had sets from 4 to 22 mm. thick, but some seen in the field were thicker than this. The sets measured were all thinly cross-laminated. They were formed of brownish-black (5YR2/1) and dusky yellowish-brown (10YR2/2) fine sandstones composed dominantly of angular quartz fragments with a clayey matrix. The top surface of these sets is frequently ripple marked. Cross-laminae at Doctors Rock and Elliott indicate current directions from the south-east, south, or south-west.

**Age and Palaeoecology**

**Age**

The base of the Wynyard Tillite is exposed at several places on the shoreline east of Wynyard. The tillite rests here with marked angular unconformity on rocks of Lower Cambrian or Precambrian age, which are steeply folded, while the tillite dips slightly to the north-west. The tillite itself contains fragments of fossiliferous rocks as young as Lower Devonian (e.g., Florence Quartzite is common as erratics) as well as granites, lithologically very similar to those thought to have been intruded in the Middle Devonian. The upper age limit of the Wynyard Tillite has not previously been fixed with any certainty, but the section observed
at Oonah now provides this limit. The oil shale, 30-50 feet above the top of the tillite contains foraminifera which suggested to Crespin (1947, p. 15) a correlation with the lower part of the Upper Marine Group of New South Wales. This group is considered by Teichert and Fletcher (1943, p. 159) to be of "Artinskian age or only slightly younger." Thus, unless a long diastem has been overlooked, it is probable that the top of the Wynyard Tillite is high in the Artinskian. As this formation is probably the product of essentially continuous, fairly rapid deposition, its base is unlikely to be older than Sakmarian. Thus, until more positive fossil evidence is available, the Wynyard Tillite will be regarded as of Sakmarian and Artinskian age.

Palaeogeography

The composition of the erratics in the tillite and varved mudstones as observed in the field and under the microscope adds little to the list of rock types provided by David (1907) and Kitson (1902). All were recognisable or deducible as belonging to Precambrian, Cambrian, Ordovician, Silurian or Devonian Systems as developed in Western Tasmania. Cross-lamination seen at Elliott, Lower Seabrook Creek and Doctors Rock indicated currents from a southerly direction and the slump structures indicate that the original floor of deposition sloped down to the north. These deductions are in accord with the provenance of the erratics and confirm the idea of an ice-covered land to the south and south-west.

At the beginning of the Permian, ice-sheets probably covered the whole area and as they retreated southward they left thick deposits of ground moraine behind them on the land surface. Glacial lakes developed on this moraine where streams were dammed by surface irregularities, terminal moraines or subsidiary glaciers. In these lakes varved muds were deposited and in some years the winter was interrupted by warm spells, resulting in the deposition of coarser layers in the winter clays or fine silts. These coarser layers may have been the result, on the other hand, of sudden access of new drainage from a subsidiary lake in which the moraine or ice barrier was suddenly removed. This sort of event certainly happened as is shown by the presence of drainage varves at Elliott. If the varves at Camp Creek and Elliott were deposited in the same glacial lake, as is possible, the lake was deeper at Camp Creek than at Elliott and Elliott was closer to the source of the varved muds than was Camp Creek as shown earlier. Minor variations in the intensity of glaciation are indicated by the presence of thin tillite beds in the varves, indicating short-term advances of the ice-sheet. Beds of cross-laminated normal sandstones may indicate short-term retreats whereby more water was made available to the streams flowing from the ice-front. Because of the retreat, these streams had to carry the rock-flour and boulders greater distances, thus producing normal sandstones by sorting. Major advances of the ice-front are recorded where varves are overlain by thick tillites and this is seen to have occurred at least three times by the succession in the disused road at Tewkesbury. The exact number of advances and retreats of the ice front cannot yet be stated. Much more work remains to be done before the detailed palaeogeographical history of the area is finally elucidated.
As the ice retreated for the last time the sea flooded in over some barrier, probably to the north, and pyritic siltstones and sandstones, with a few marine fossils, were deposited. The water may well have been brackish, which would account for the rarity of fossils. Poor circulation is indicated by the presence of pyrite nodules and carbonaceous matter and this suggests a partially closed, cold-water basin. Shallow water, poor circulation conditions with the accumulation of gymnosperm spore cases resulted in formation of the oil shale, probably near an old shore line.

REFERENCES


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Fig. 1.—Photomicrograph of tillite (spec. U.T.G.D. 6055 (b)).

Fig. 2.—Photomicrograph of varved mudstone (spec. U.T.G.D. 6046 (b)).

Fig. 3.—Photograph of varved mudstone from Elliott showing grading and slumping.
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THE PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF
TASMANIA, VOL. 89

THE PERMIAN ROCKS OF WOODY ISLAND, TASMANIA

by

MAXWELL R. BANKS, G. E. A. HALE
AND M. L. YAXLEY

Hobart, 1955
The Permian Rocks of Woody Island, Tasmania

By

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University of Tasmania

G. E. A. HALE
Tasmanian Museum

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Hobart High School

(WITH 2 TEXT FIGURES AND 1 PLATE)

ABSTRACT

The Permian section at Woody Island, Tasmania, begins with a pyritic siltstone, passes upwards through glendonitic, pyritic sandstone, siltstone and sandstone, tillite, siltstone and sandstone, a thin bed of bryozoal limestone and finally into a fossiliferous siltstone tentatively correlated with the Porters Hill Siltstone at Sandy Bay and the Bundella Mudstone at Mt. Nassau. The seventeen units, referred to nine formations, total about 330 feet and are considered to be Sakmarian and Lower Artinskian. The section is well-exposed in cliffs and on a shore platform developed just below high tide mark. A fault striking north-west and down throwing at least 260 feet to the east cuts the island.

INTRODUCTION

A visit by M. L. Yaxley to the island in 1953 showed that a good Permian section was exposed there and this was subsequently measured by all three authors. The island, situated about half a mile off Alonnah, Bruny Island, in D'Entrecasteaux Channel, has an area of about 70 acres and a height of about 120 feet. It is rimmed by cliffs up to 50 feet in height and a shore platform up to 20 yards wide at low tide. The only previously published report on the geology of Woody Island is by Scott, Roberts and Hobbs (1861) which mentions limestone on Satellite (Woody) Island.

We are greatly indebted to Mr. George Dibbern, owner of the island, for his hospitality during the visits.

PHYSIOGRAPHIC NOTES

The island has a gently rolling surface from about 50 to 120 feet above sea-level. Drainage from it is poor due to the relatively impermeable siltstones. What valleys are present are joint controlled or along the fault which intersects the island. The weathering is deep and produces clayey podzolic soils of which some are very pale. The fault acts as a passage for groundwater as evidenced by the seepages where it intersects the cliffs.
FIG. 1.—Geological Map and Section of Woody Island.

The Topographic Nomenclature Board ruled that Johnston Point be replaced by Lewis Point as another Johnston Point exists. The Johnston Point Sandstone of this paper is here renamed Alonnah Sandstone.
Steep cliffs have been developed by marine undercutting in the soft sediments and the cliffs are almost everywhere flanked by a wave-cut platform which is just flooded at high tide. The platform is interrupted by joint-controlled chines, by fallen blocks, and, at the western end of the island, by undercut masses of calcareous concretions, slightly more resistant than the enclosing siltstones. Landslips occur in the clayey soils in several places. The island is being actively eroded by the sea at the present time, the only depositional features being small pocket beaches of shingles.

**PERMIAN ROCKS**

The island is composed entirely of rocks of Permian age, good sections being exposed from the eastern end to the fault which roughly bisects the island. A sketch geological map of the island is included as fig. 1 and the succession is summarised in columnar form in fig. 2. Essentially the section is siltstone and sandstone with two tillitic bands and a thin bed of limestone. Seventeen units were measured but these could be grouped for mapping and description into nine formations.

**Woody Island Siltstone**

The Woody Island Siltstone is that formation of pyritic siltstone at least 86 feet thick as exposed on the eastern end of Woody Island where it is overlain by the Sunset Bay Sandstone. The underlying formation is not exposed. The formation contains *Eurydesma cordata*, crinoid columnals, and worm burrows. Its age is considered to be Sakmarian.

The lower member of this formation as exposed at the eastern end of the island is 73 feet thick and consists of blue-grey siltstone with rare erratics of quartz and quartzite and rare marine fossils. Bedding is thick to very thick but the rock breaks easily but irregularly into small blocks. Concretions of pyrite are very common. They are irregular in shape and orientation but there is a preference for elongation perpendicular to the bedding. Concretions of calcite up to twelve feet in diameter are also common and are lenticular with the greatest diameter parallel to the bedding. In places they contain small disarticulated crinoid columnals and some of them, when viewed from a distance, show rough cross-bedding. Large lenticular concretions, apparently of siltstone, with marked concentric fissility are also present in the cliffs at the eastern end of the island. Another feature of interest is the occurrence of alum efflorescence on the cliffs cut in this member. This would be the result of the attack of sulphuric acid, from the oxidation of the pyrite, on the clay minerals in the siltstone. The fossils in this lower member include small individuals of *Eurydesma cordata* but fossils are rare.

The upper member of this formation east of the fault is a well-sorted, yellow to white, siltstone with rare erratics of aplite and rare pyritic concretions. Worm tracks and burrows are common in this member and a few small pelecypods also occur. It is finely cross-bedded. Arrowhead markings in this member probably represent infilling of worm burrows.
FIGURE 2  COLUMNAR SECTION OF Permian ON WOODY ISLAND

Porters Hill Siltstone

"Eurydesma" Limestone

Dreamy Bay Tillitic Sandstone

Johnston Point Sandstone

Lewis Point Sandstone and Siltstone

D'Entrecasteaux Tillite

Satellite Siltstone

Sunset Bay Sandstone

Woody Island Siltstone

SCALE

FEET 200

Fig. 2.—Columnar section of Permian on Woody Island.
West of the fault, the island consists entirely of a dark-grey siltstone with large pyritic concretions, large lenticular calcareous concretions and numerous glendonites, as large single crystals, stars of four large crystals or as rosettes of numerous small crystals. One single crystal measured was 20 cms. long. Fossils are rare but include Eurydesma cordata and others. This is included as a member of the Woody Island Siltstone on the grounds of extreme lithological similarity but is considered to lie below the lower member exposed at the eastern end of the island because no glendonites occur there.

Sunset Bay Sandstone

The Sunset Bay Sandstone is that formation of sandstone, 21 feet in thickness, which overlies the Woody Island Siltstone and is overlain by the Satellite Siltstone as exposed on the northern side of Woody Island. Fossils are rare but include Eurydesma cordata. The formation is Permian, probably Sakmarian. Sunset Bay, after which the formation is named, is on the southern side of Woody Island.

This formation consists of two units, both of which are well-sorted, fine-grained sandstones with a few erratics of granite and quartzite. The grains are angular. Quartz is the only mineral identified macroscopically in the lower unit and quartz and feldspar are present in the upper unit. Bedding in both is thick and cross-bedding occurs in the lower member. Both are grey, or mottled dark and light-grey in colour. Glendonites are present in both units and one from the lower unit is illustrated (plate I). The higher unit contains pyrite concretions but these are not large. In the lower unit worm tracks and burrows are common but macrofossils are rare, only Eurydesma cordata being collected.

Satellite Siltstone

The Satellite Siltstone is that formation of fossiliferous siltstone 20 feet thick, overlying the Sunset Bay Sandstone and overlain by the D'Entrecasteaux Tillite on the northern shore of Woody (or Satellite) Island. It contains many fossils but especially noticeable is Stenopora tasmaniensis. It is Permian, and probably Sakmarian, in age.

The Satellite Siltstone is a richly fossiliferous siltstone with thick bedding, good sorting and rare erratics. Quartz and feldspar are present and the siltstone is a medium dark-grey (N 4) in colour and has a blocky fracture. The most noticeable feature of the formation is the abundance of fossils which form at least 20 per cent of the rock and, on the southern shore, are preserved as the original skeletons. Dominant in numbers among these is Stenopora tasmaniensis which forms dense mats at a slight angle to the bedding. The ramose colonies are markedly oriented, the main direction being to the north-east, as if they had been oriented by currents flowing from the south-west. Other fossils are listed below:

Bryozoa.

| Stenopora tasmaniensis | very common |
| Stenopora spp. | v.c. |
| Fenestella dispersa | c. |
| Fenestellidae | v.c. |
| Strebloclypa marmionensis | rare |
Brachiopoda.

- *Strophalosia* spp. v.c.
- *Grantonia hobartensis* few to common
- “*Martiniopsis*” sp. few
- *Spiriferidae* common

Mollusca.

- *Merismopteria macroptera* rare
- *Deltopeneten* sp. common
- *Mourlonia* sp. common

Echinodermata.

- *Calceolispongia* sp. few disarticulated columnals
- *Jimbacrinus* sp. radials, basals and brachials

D’Entrecasteaux Tillite

The D’Entrecasteaux Tillite is that formation of tillite six inches thick underlain by the Satellite Silstone and overlain by the Lewis Point. Sandstone and Siltstone as exposed on the northern shore of Woody Island. Fossils are rare and are mainly spiriferids. The age is Permian and probably Sakmarian. The formation is named after the D’Entrecasteaux Channel, in which Woody Island occurs.

This formation is a medium-grained sandstone with poor sorting and angular to sub-angular grains. Quartz is the main mineral in the matrix but feldspar is also present. Sub-rounded to faceted erratics of sandstone, schist and slate are common. The cement is kaolinitic, the colour dark bluish grey and the bedding thick. Spiriferids are rare and are essentially the only fossils.

Lewis Point Siltstone and Sandstone

The Lewis Point Siltstone and Sandstone is that formation of siltstone and sandstone 54 feet thick underlain by the D’Entrecasteaux Tillite and overlain by the Johnston Point Sandstone as exposed along the northern shore of Woody Island. It is fossiliferous, the fossils including *Grantonia hobartensis*, *Mourlonia* sp., *Platyschisma ocula* and *Eurydesma* sp. It is Permian, and probably Sakmarian, in age. Lewis Point is on the northern shore of Woody Island.

This formation consists of a rough alternation of siltstone and sandstone. The lowest member is a coarse fossiliferous siltstone composed of quartz and feldspar in a clayey matrix with a few rounded erratics up to 8 cms. in diameter of claystone, quartz and granite. The beds are thick and the fracture is blocky. Cross-bedding and slump structures on a very small scale are present. The siltstone is light blue-grey and fossils are common. The fossils include *Grantonia hobartensis* and other spiriferids, *Stenopora* sp., *Eurydesma* sp., *Mourlonia* sp. and *Fenestella* spp. in the lowest 11 feet. After an unfossiliferous section to 23 feet there are four feet of fossiliferous siltstone with *Neospirifer* spp., *Stenopora* sp., *Platyschisma ocula* (rare), large aviculopectinids, and *Eurydesma* sp. The top three feet of siltstone contain many fenestellids, “*Martiniopsis*” spp. and crinoid columnals.

This unit is followed by a greenish grey (5 GY 6/1), micaeous, fossiliferous siltstone without erratics and with lenticular clayey concretions up to three feet in diameter. This siltstone has thick bedding and
poor fissility. The fossils which are few in number are mainly small pelecypods including *Paralleloodon costellata* (McCoy), *Nuculana darwini* (de Koninck) and *Edmondia* sp. The strophomenid *Streptorhynchus* sp. is also present. Small rectangular carbonaceous fragments are common but their relationship is unknown.

A fine micaceous, white or yellowish sandstone follows. The sorting is good and both quartz and feldspar are present. The cement is clayey and the sandstone is friable where exposed. The bedding is thick. The bounding surfaces with adjacent units are irregular, suggesting penecontemporaneous erosion. Pelecypods and *Fenestella* occur in patches.

Three feet of fine-grained, well-sorted quartz sandstone, of bluish-grey colour, follows. Bedding is very thin but the rock splits massively. Occasional worm tracks are the only fossils. A well-sorted fine-grained, sandstone with sub-angular fragments of quartz and feldspar in a clayey matrix is the next unit. It is light grey in colour and has rare erratics of quartzite and slate. Pentagonal crinoid columnals are common in this member and are associated with pelecypods and numerous *Stenopora* prob. *tasmaniensis*. It is thickly bedded. These last two rock types alternate for the topmost 10 feet of the formation.

Johnston Point Sandstone (Here renamed Alonnah Sandstone (see footnote page 220.)

The Johnston Point Sandstone is that formation of glendonitic sandstone 51 feet thick overlying the Lewis Point Siltstone and Sandstone and underlying the Dreamy Bay Tilitic Sandstone on the northern shore of Woody Island. Fossils are very common and include *Eurydesma cordata*, *Strophalosia clarkei* and *Calcitornella stephensi*. It is Permian, and probably Sakmarian or early Artinskian, in age.

The lower member is a spiriferid sandstone of medium to fine grain-size, with poor sorting and erratics forming up to 15 per cent of the rock. The erratics are up to 8 inches in diameter and include quartz, quartzite, granite, schist, sandstone and slate. The matrix consists of angular to sub-angular grains of quartz (about 60 per cent of the rock) and feldspar. The rock is grey and has thick bedding. The cement is mainly clayey but may be calcareous in part. Fossils, as the original shells, form up to 25 per cent of the rock and are mainly spiriferids such as *Trigonotreta stokesii*, *Granitonia hobartensis* and *Neospirifer* spp. Other fossils include Aviculopectinidae, *Eurydesma cordata*, *Merismopteria macroptera*, *Strophalosia* spp. and *Stenopora* sp. Although many of the fossils are broken, some are complete but they lack orientation.

The higher member is mineralogically and texturally very similar. It is light olive grey (5Y6/1) when fresh but weathers brownish yellow. The bedding is thick but due to the abundance of fenestellids some parts are laminated, and others thinly bedded. Arrowhead markings, representing infilled worm burrows, are common. Fossils are very common and are predominantly productids but fenestellids are also common. The fossils include: *Calcitornella stephensi*, *Stenopora* sp., *Polypora ampla*, *Polypora* spp., other fenestellids, *?Anidanthus* sp., "Martiniopsis" sp., *Neospirifer* spp., *Granitonia hobartensis* and other spiriferids, *Eurydesma cordata*, *Merismopteria* sp., *Aviculopecten* sp., *Platyschisma ocula*, *Mourlonia* sp. and pentagonal crinoid columnals. *Strophalosia clarkei* and
other *Strophalosia* spp. are very common. Ostracodes are rare as also are plant fragments. *Spiriferina duodecimcostata*, *Dielasma* sp. and *Stutchburia* sp. are also present.

Glendonites occur in this formation as external moulds on the southern side of the island.

Dreamy Bay Tillitic Sandstone

The Dreamy Bay Tillitic Sandstone is that formation of poorly-sorted, erratic-rich sandstone 50 feet thick resting on the Johnston Point Sandstone and overlain by the "*Eurydesma*" Limestone as exposed on the northern shore of Woody Island. Fossils include *Stenopora tasmaniensis* and *S. johnstoni*. Its age is Permian and probably Sakmarian or early Artinskian. Dreamy Bay is on the northern side of Woody Island.

This sandstone is medium-grained, dark-grey, thickly bedded and poorly sorted. The grains and erratics in it are angular fragments of granite, limestone, quartzite and quartz. Both quartz and quartzite are very common in the erratics and in the matrix. Fossils are also abundant, haphazardly arranged and the bryozoans frequently broken. The texture suggests quite strong current conditions. The fossils include large sheets of *Stenopora johnstoni* and branches of *S. tasmaniensis*. The original shell material is usually preserved.

"*Eurydesma*" Limestone

No formal definition of this unit is offered here as it is hoped shortly to publish a detailed account of the stratigraphy of Maria Island with formal definitions of the units including the "*Eurydesma*" Limestone.

Although this unit is only five feet thick, it is an important one for correlation. It is a limestone, composed of fine-grained calcite as a matrix with rare, small erratics. Crinoid columnals and calyx plates are common. It is medium-grey (N 5) in colour and the fossils which are of all sizes, are extremely common. *Stenopora tasmaniensis* is the main form present but *S. johnstoni* also occurs as also does *Eurydesma cordata*. *Calcitornella stephensi* is revealed in thin sections. It is a thick-bedded bryozoal, crinoidal limestone. It is correlated with the "*Eurydesma*" Limestone of Maria Island on the evidence of the *Stenopora* spp. and *Eurydesma cordata* as well as on lithology. It was probably formed in deeper water than the limestone on Maria Island. It is also correlated with the Permian Limestone at Lilydale on the east Tamar, on the grounds of the presence of *Calcitornella stephensi*.

"Porters Hill" Siltstone

The final formation measured east of the fault is a fossiliferous siltstone composed of sub-angular grains of quartz and feldspar in a clayey matrix. It weathers to a buff colour and consists of alternating thickly-bedded and thinly-bedded to laminated layers. Erratics are few but fossils are abundant and include bryozoan in sufficient numbers to cause lamination of the rock. The fossils include *Keeneia platyschismoides*, *Eurydesma cordata*, &c. This formation is correlated with the beds in the cliffs above the shoreline at Porters Hill, Sandy Bay, the Porters Hill Beds of Johnston, 1888, and the Bundella Mudstone of the Mt. Nassau section on the evidence of lithological similarity and the occurrence common to all three of *Keeneia platyschismoides*, *Eurydesma cordata*, and abundant ostracodes.
The beds dip slightly west of north at about 8° and are intersected by a fault striking about 335° M near the western end of the island. The fault downthrows to the north-east by at least 250 feet. Jointing at 335° M and 45° M occurs close to the fault with jointing at 75° M and sheet jointing at 45° M on the western tip of the island. A sketch section, fig. 1, illustrates the structure.

Correlations and Age

The evidence for correlation within Tasmania of the formations exposed on Woody Island has been given where appropriate in the preceding text. However, the correlation of these formations with formations outside Tasmania has not been considered, and it is useful to do so here.

The species important for correlation are the foraminifera Calcitornella stephensi, the bryozoa Stenopora johnstoni and S. tasmaniensis and the gastropod Keeneia platyschismoides. Calcitornella stephensi occurs (Crespin, 1947, pp. 11-12) in New South Wales in the Lower Marine Group in the Lochinvar, Allandale and Farley Stages. However, Osborne (1949, p. 222) records it only from the Allandale Stage, although from his text (p. 214) it is clear that the actual horizon is that described by Chapman and Howchin (1905) from Pokolbin which is at the base of the Rutherford Stage. At this level foraminiferal limestones occur and it is tempting to correlate the "Eurydesma" Limestone on Woody Island with these limestones in New South Wales, and such a correlation would certainly not be far wrong. It is probable on the evidence of Calcitornella that the "Eurydesma" Limestone is equivalent to part of the Lower Marine Group and most probably to the lower part of the Rutherford Stage. Crockford (1951, p. 110) records Stenopora johnstoni from the Allandale and Rutherford Stages and Osborne (1949, p. 222) records S. tasmaniensis from the Rutherford Stage. The occurrence of these two species together with Calcitornella in the "Eurydesma" Limestone of Woody Island strongly suggests correlation with some part of these two stages. Keeneia platyschismoides, here recorded for the first time from Tasmania, is restricted in New South Wales to the Lower Marine Group and Osborne records it only in the Allandale Stage. In Tasmania it is found at Woody Island in the beds above the "Eurydesma" Limestone, at Porters Hill, Sandy Bay, in the beds just a few feet above high-water mark, and in a road cutting half a mile beyond Rathbone's Lime Kiln on the Lyell Highway, in the Bundella Mudstone. This suggests that these beds are about equivalent to the top of the Allandale Stage, and are certainly equivalent to a part of the Lower Marine Group.

In Western Australia the range of Calcitornella stephensi is from the Callytharra Limestone to the Quinannie Shale but it is commonest in the Callytharra Limestone (Teichert, 1952, and Crespin, 1947). Other fossils from Woody Island which also occur in Western Australia are Streblotrypa marmionensis, here recorded for the first time from Tasmania, Calceolispongia sp. and Jimbacinus sp. The presence of these forms indicates that even at an early stage in the Permian a relationship existed between the faunas of Western Australia and Tasmania. Streb-
lotrypa marmionensis occurs over a wide stratigraphic range in Western Australia as also do Calcéolispongia spp. Jimbocrinus sp. has been recorded from only one area in Western Australia and it is too early to know if it has any stratigraphic value. The "Eurydesma" Limestone of Woody Island is therefore most likely equivalent to the Callytharra Limestone of Western Australia but may be as young as the Quinannie Shale. According to Teichert (1952, p. 122) the Callytharra Limestone is Artinskian in age but probably close to the base of the Artinskian, so that it is possible that the underlying formations at Woody Island are Lower Artinskian or more probably Sakmarian.

Finally, it might be emphasised that the "Eurydesma" Limestone of Woody Island is not equivalent to the Berriedale Limestone of the Hobart district and Maria Island but is much lower in the section.

SUMMARY

The Lower Permian section on Woody Island consists of the Woody Island Siltstone at the base followed by the Sunset Bay Sandstone, the Satellite Siltstone, the D'Entrecasteaux Tillite, the Lewis Point Sandstone and Siltstone, the Johnston Point Sandstone, the Dreamy Bay Tillitic Sandstone, the "Eurydesma" Limestone and the "Porters Hill" Siltstone. The total thickness of the section is about 330 feet. The "Eurydesma" Limestone is correlated with the limestone near the base of the Rutherford Stage of the Lower Marine Group of New South Wales and the Callytharra Limestone of Western Australia and the whole section on Woody Island is considered to lie within the time range of the deposition of the Lower Marine Group of New South Wales. The formations below the "Eurydesma" Limestone may be Sakmarian while this formation and the higher one are probably Artinskian.

Glendonites occur in the Woody Island Siltstone, the Sunset Bay Sandstone and the Johnston Point Sandstone.

The Permian section is cut by a north-westerly trending fault with a throw of at least 260 feet down to the east.

REFERENCES


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PLATE I.—Photograph of glendonite.
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A TYPE SECTION OF THE PERMIAN SYSTEM IN THE HOBART AREA, TASMANIA

by

M. R. BANKS AND G. E. HALE.

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A TYPE SECTION OF THE PERMIAN SYSTEM IN THE HOBART AREA, TASMANIA

By
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(With 9 Text Figures)

ABSTRACT

An unbroken succession of Permian sediments about 1430 feet thick on the northern flanks of Mt. Nassau, about 10 miles north-west of Hobart, Tasmania, shows the following succession of formations from the base upwards: Bundella Mudstone; Faulkner Group including the Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Siltstone, Altamont Conglomerate and Fergusson Siltstone; Rayner Sandstone; Cascades Group including the Nassau Siltstone, Berriedale Limestone and Grange Mudstone; "Woodbridge Glacial Formation"; Risdon Sandstone and finally the Ferntree Mudstone. These range in age from Lower Artinskian to Kungurian. These formations, except the "Woodbridge Glacial Formation", are defined. The Faulkner Group consists of two cyclothems, recording two brief emergences, one soon after the other, in a time of general submergence. The Grange Mudstone and Berriedale Limestone are at least partly facies variants of one another. A notable feature is the presence of erratics, except in the two non-marine formations in the Faulkner Group, and this is perhaps related to the poor sorting, and mineralogical immaturity of the sediments and the angularity of most of the grains in all rocks. All of these features are considered as the result of glacio-marine deposition. The source area included granitic, sedimentary and regionally metamorphosed rocks.

Fig. 1

N.B.—On the advice of the Nomenclature Board of Tasmania, the names of Parramore Creek and Rayner Creek should be transposed.
INTRODUCTION

Mapping of the Hobart district indicated that the Permian succession suggested by Lewis (1946) was inadequate for close mapping so that when a section was discovered which is not complicated by faulting, it was studied in some detail for use as a standard of reference. The type section lies between road level of the Lyell Highway from Rayner Creek to Geiss Creek and the base of the Knocklofty Sandstone and Shale (Triassic) on Mt. Nassau. It is all included on air photo Hobart, Run 1, No. 9744, of the Department of Lands and Surveys, Tasmania, and is shown on the map, text figure 1.

The section was initially taken from point A (see map) along Rayner Creek for a couple of hundred yards, then up the east bank across the present access road to the western quarry to the former access road to the eastern quarry and along and up this road to that quarry. From this quarry the section crosses Rayner Creek and goes up and along an old timber track which skirts the southern edge of the western quarry and goes on up the spur over the Lake Fenton Pipeline to the foot of the last slope up to Mt. Nassau at point B. All thicknesses in this section were measured by means of an Abney level as the beds have a very low dip. Attention should be drawn here to the more detailed sections of the Berriedale Limestone measured in the quarries on the eastern and western sides of Rayner Creek by Brill and published as section 4 of fig. 1 of Brill (1956). These sections were measured on the quarry faces with a tape and are thus rather more accurate than the general section. The authors' attention was directed by Mr. H. A. Bartlett to fossiliferous mudstones on the Lyell Highway at point C on the map. On investigation these proved to be well exposed and below the lowest beds in Rayner Creek. A section was therefore measured up from the gutter on the western side of the Lyell Highway just west of Parramore Creek at the eastern end of the road cutting and westwards along the cuttings to Geiss Creek and then up to Geiss Creek to the top of the well-exposed portion of the succession. The Bundella Mudstone in the road cuttings and in the lower part of Geiss Creek was measured with a steel tape but the creek section and road section are not connected by good exposures. They were joined by measuring up from the top exposures in the road cutting to the base of the Geiss Conglomerate, tracing this conglomerate around the hill slope and into the creek where the beds immediately below the Geiss Conglomerate are exposed and were measured. This leaves a gap in the section due to inadequate exposures. The beds in Geiss Creek from the upper part of the Bundella Mudstone into the Fergusson Siltstone are well exposed and were measured with a steel tape but the section above that was measured up the western hill slope to the Rayner Sandstone, back into the bed of Geiss Creek and along the creek bed with an Abney Level until good exposures of the Nassau Siltstone were reached when the tape was used again for a few feet and then the Abney Level was used to complete the section to point E. Co-ordinates quoted refer to the state grid on the 8-mile map (Lands Dept., Hobart).

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HISTORY OF STRATIGRAPHIC NOMENCLATURE IN THE PERMIAN SYSTEM IN THE HOBART AREA

Darwin (1844) and Strzelecki (1845) were perhaps two of the earliest authors to deal with Permian rocks from the Hobart area. Later Jukes (1847) and Selwyn (1855) added further observations. The first author to deal at length with the Hobart Permian was Harrison in 1865 who noted that the colonists referred to the "Mountain Lime- stone" (now Berriedale Limestone) and this name was used, albeit informally, by Wintle (1865). In 1866 Gould formally proposed the first formational name for a Permian rock in this area—"the appropriate formation heading. Johnston also seems to have laid the foundation of an error which has led all workers astray. He correlated the limestone at the shoreline at Lower Sandy Bay, i.e., Porter Hill, with the limestone at Cascades and Bridgewater (i.e., Mt. Nassau), which is now considered on stratigraphical, lithological and palaeontological grounds to be a distinct and higher formation, the Berriedale Limestone. By so doing he caused later workers to assume that the Grange Mudstone was above the Berriedale Limestone and separated from it by several hundred feet of sediment instead of equivalent to it as will be suggested later in this paper. This latter assumption confused Voisey (1938), Lewis (1946) and Banks (1952) and all workers in Tasmania and elsewhere who tried to make faunal correlations. It also led to
the idea of very great similarity in the faunas on all horizons and blinded workers to the differences between the faunas from different horizons.

The first worker to consistently use stratigraphic names for Permian formations in this area was Voisey (1938) who proposed formation names later used also by Lewis (1946). These names were in some cases not very clearly defined and the beds below the supposed Berriecake Limestone were covered only by a wide term “Snug Stage”, synonymy of which will be considered later.

Establishment of good sections below the Berriecake Limestone has indicated a number of formations previously included as Snug Stage or ignored. These new formations are defined here and formal definitions suggested for those terms used earlier. When dealing with each formation whether new or old, apparent synonymy will be listed and the nomenclature discussed.

**STRATIGRAPHY**

In the detailed section on the eastern flanks of Mt. Nassau there are at least 15 formations and by considering sections elsewhere in the district at least two more can be recognised below the lowest one at Mt. Nassau. The type section will be discussed in detail and then short notes on other sections will provide comparisons with the type.

**Bundella Mudstone**

The Bundella Mudstone is that formation consisting dominantly of siltstone with subordinate sandstone bands which is exposed in road cuttings on the Lyell Highway between Parramore Creek and Geiss Creek and in the lower part of Geiss Creek. It is overlain by the Geiss Conglomerate and its base is hidden by alluvium. It is at least 140 feet thick and contains *Eurydesma cordatum*, *Keenela platychismidea*, *Stenopora johnstoni* and *S. tasmaniensis*. It is Permian and probably Lower Artinskian in age. The name is derived from Bundella Railway Station on the northern bank of the Derwent River, near which this formation was first recognised. The coordinates of the centre of the type area are 504:8 E-736:8 N.

**Synonymy**

**Bundella Mudstone**

Banks, Hale and Yaxley, 1955, pp. 219, 227.

Banks in Hill, 1955.

**Porter Hill Beds**

Johnston 1888, pp. 105 et seq., very approximately only.

“Porters Hill” Siltstone

Banks, Hale and Yaxley, 1955.

**Snug Stage**

Lewis, 1946, p. 26 et. seq., very approximately only, if at all.

**Lithology**

For the most part this formation is a regular alternation of fissile and non-fissile siltstone which in the lower parts of the formation as exposed in the type section is richly fossiliferous. Near the base there at least four beds of sandstone which weathers into small, somewhat cuboidal blocks. Most of the beds contain erratics, one of which is an irregular block of quartzite three feet across but most of the erratics are less than eight inches in diameter. The erratics are frequently faceted and a few are also striated. There are many rock types represented by the erratics. The succession in the type section along the road cuttings and in the lower parts of Geiss Creek is shown in text figure 2.

Thin sections were cut of the representative rock types in the Bundella Mudstone. The non-fissile siltstone consists of 30-40 per cent of rock fragments which include quartzite, schist, phyllite and granite, 20-30 per cent of quartz some of which shows undulose extinction and some of which appears to have reacted with the matrix, 20 per cent of fine grained groundmass, 5-10 per cent of feldspar including orthoclase, microcline and plagioclase both fresh and altered to sericite, 5-10 per cent of mica mostly muscovite which appears to be squeezed around the other grains, and a few grains of zircon, apatite and tourmaline. The grains are dominantly in the silt grade but particles from clay grade to sand grade (1-5 mm.) are present. On the whole sorting is poor but there are a few finer bands. However, no mechanical analyses have been done. Particles of all grades are sub-angular to angular and equidimensional to bladed. There is no preferred orientation visible. The fissile siltstone is essentially the same as the non-fissile but shows better sorting, bedding is apparent and there is some orientation of the micas. In addition some finer-grained, the dominant size in the sand grade being about 0.2 mm., whereas that in the non-fissile is 0.25-0.3 mm. Iron staining occurs in both types and in the fissile type is parallel to the finer beds but in the coarser beds is at an angle to the bedding.

The colour of the rock when weathered is buff but they tend to be yellowish-grey or light olive-grey when fresh.

A thin section of an unfossiliferous siltstone from the top of the Bundella Mudstone showed that it consists mainly of quartz and mica of coarse silt grade in a fine silt to clay grade matrix. The grains are dominantly angular and are equant to bladed. The micas show distinct parallel orientation which is reflected also by lines of haematite. In addition to quartz and muscovite the rock contains rare grains of plagioclase, some blue tourmaline, green biotite and some chlorite. Rock fragments include some of quartz muscovite schist and some of the quartz in the rock shows undulose extinction indicating possible derivation from a metamorphic source.

The sandstones are olive in colour. They consist of about 30 per cent of quartz, 5-10 per cent of feldspar, both orthoclase and plagioclase, 10-15 per cent of mica, mainly muscovite but with some biotite and 40-50 per cent of groundmass and rock fragments with minor amounts of zircon, apatite and garnet. The rock fragments are mainly of metamorphic rocks rich in mica. Many of the quartz grains have inclusions of garnet, apatite and zircon. Sorting is good with most of the grains in the sand grade (0.06 to 0.1 mm.). No bedding is apparent in the thin sections nor is there any apparent orientation of the micas, which are of
the same grain size as the other minerals in the sections. The grains are equidimensional to bladed and sub-rounded to sub-angular.

A thin section of a conglomeratic siltstone close to the top of the formation showed that the rock is composed dominantly of rock fragments, with up to 15 per cent of quartz, 5-10 per cent of muscovite, 5 per cent of feldspar, mainly plagioclase with some orthoclase, and 5-10 per cent of groundmass. Heavy minerals present include zircon, garnet and calcite. The quartz is usually bladed and the muscovite twisted around the other grains. Particles in the groundmass range in size from clay grade to near the top of the silt grade (0.04 mm.) although there were a few longer, very thin almost acicular fragments composed of a number of grains of quartz forming a mosaic. In some places these very long grains show a preferred orientation but in most parts there is no preference. Grains other than the acicular grains are bladed to equidimensional and angular to sub-rounded. A few flakes of green biotite are present in addition to the more abundant muscovite. The rock could probably best be described as a poorly sorted conglomeratic siltstone.

One of the most noticeable features of this formation in the field is the alternation of fissile and non-fissile beds. Near the base the non-fissile bands are consistently rather thicker than the fissile bed above them, but towards the top the position is reversed. It seems from preliminary examination that the fissility could be a function of the better sorting and the orientation of the micas.
Both of these differences suggest that current or wave action was stronger during the deposition of the fissile beds than during the formation of the non-fissile beds. The alternation in the intensity of current and wave action could be a function of changes in sea-level, involving changes in depth and/or distance from shore, or of climate affecting the velocity and volume of water entering the sea in rivers, or of climate affecting the intensity of glaciation and altering the mode of transport and distance of transport of the sediment, or of several of these factors and perhaps others operating together. Tectonic activity in the source or depositional area could also cause changes in the intensity of current action but it is difficult, but by no means impossible, to account for the remarkably regular alternation on such a small scale under a tectonic hypothesis. As far as can be judged on the information at present available the beds are of almost constant thickness over distances of half a mile along the dip and a quarter of a mile along the strike. They show no or very little cross-bedding which is in accord with the general lack of sorting of these factors and perhaps others operating together. Thus there is little if any evidence of the coarser grades, e.g., erratics. They possibly represent times of fall in sea-level producing shallowing of the water and increase in current action and at the same time a reduction in the density of icebergs in the vicinity of the source of the basins but some of the fissility is not controlled by abundance and type of fossils except near the base where fenestellid fronds parallel the bedding and increase fissility. Many phyla are represented but bryozoa and brachiopods are the most abundant. The brachiopods are predominantly spiriferids but some Strophalosia spp. are also present. Significant bryozoans are Stenopora johnstoni and S. tasmaniensis which are commonest in, if not restricted to the lower part of the Permian sequence of Tasmania. Fennesseilids including Fennesella spp., Polypora spp. and Protoretetepora are common. The pelecypod Eurydesma cordatum is present on several horizons and other pelecypods are present without, however, being abundant. Gastropods are also common, the main forms being species of Mournoria but Platyschisma ocula and a Straparollus are also present. An important gasteropod which occurs in the lower part of the formation is Keeneia platyschismoides which is significant for correlation. Ostracodes are present and abundant on some horizons. Near the top of the formation fossils become very rare and the rock could easily be mistaken for the Ferntree Mudstone, a feature noted by Lewis (1946, p. 30).

Correlation

The abundance of Stenopora johnstoni, S. tasmaniensis with the presence of Eurydesma cordatum and Keeneia platyschismoides as well as the lithology suggests that the Bundella Mudstone is equivalent to the beds along the foreshore at Sandy Bay just above the blue-grey limestone with Calcitonna which has been correlated by Banks (1957 b) with the Darlington Limestone. These beds are what Johnston referred to in 1888 as the Porter Hill Beds but beds referred to by this name seem to go higher into the sequence than the Bundella Mudstone and the name has been used by later workers for the beds in the top of Johnston’s (1888) Porter Hill Beds which are almost certainly not equivalent to the Bundella Mudstone. The Bundella Mudstone was first recognised on the northern side of the Derwent River on the slopes of Mt. Dromedary above Bundella Station. Recently in this area I. McDougall discovered a richly fossiliferous limestone, in which Eurydesma cordatum was a prominent fossil on some horizons, just below the Bundella Mudstone. This is correlated with the Darlington Limestone and on the flanks of Mt. Dromedary occurs about 140 feet below the base of the Faulkner Group so that it might be expected to occur just below the lowest outcrop in the Mt. Nassau section. In the Collinsvale and Glen Lusk Road sections a Eurydesma-rich limestone with Calcitonna is overlain by richly fossiliferous mudstones which would therefore be equivalent to the Bundella Mudstone. At Snug the section is not clear but the base of it exposed in cuttings on the Channel Highway just north of the bridge over the Snug Falls River is an alternation of fissile and non-fissile siltstone with some limestone bands and the siltstones are very rich in Eurydesma cordatum. These are probably correlates of the Bundella Mudstone but more detailed stratigraphic work is necessary to establish this. They underlie a fossiliferous erratic-rich conglomerate which is probably the equivalent of the Geiss Conglomerate and this is succeeded by the mottled-brown mudstone and sandstone of the Snug Stage of Lewis (1946) in its type area. It will be shown later that on present stratigraphic knowledge the best correlation of the Snug Stage is with the Faulkner Group. In the Collinsvale Road section in the Darlington Limestone is underlain by a considerable thickness of dark-grey pyritic siltstone which is probably equivalent in a general way to the beds below the Darlington Limestone on Woody Island, especially the Woody Island Siltstone. It appears then that these beds in the lower part of the section on the Collinsvale Road are the lowest exposed in the Hobart area although the section on the Huon Road section should be investigated in this connection. On Woody Island the Darlington Limestone is overlain by about 40 feet of richly fossiliferous alternating fissile and non-fissile siltstone which contains,
among other fossils, *Keeneia platyballum*. These beds are correlated on lithological and palaeontological grounds with the Bundella Mudstone (Banks, Hale and Yaxley, 1955). On the northern end of Maria Island the Darlington Lime- stone is much thicker than in the Hobart area and may be partially equivalent in time to the Bundella Mudstone. It is overlain by sandstones and silt- stones which could also be equivalent to the Bundella Mudstone but they are lithologically rather different. The Bundella Mudstone would appear on stratigraphic evidence to be equivalent to the rich fossiliferous siltstones above the Darlington Lime- stone in the Deloraine area, i.e., to the top part of the Golden Valley Limestone and Shale of Wells (1957).

The presence of *Stenopora johnstoni*, *S. tas- maniensis*, *Eurydesma cordatum* and *Keeneia platy- ballum* suggests correlation with part of the Dalwood Group of New South Wales. The fact that it overlies a limestone with *Calcitorrella* suggests correlation with part of the Rutherford Formation (in New South Wales) which includes and overlies a foraminiferous limestone with the same fossils.

**Conditions of Deposition**

The Bundella Mudstone is a marine formation for the most part and even in the top part of the formation where fossils are rare it is still marine although the relative absence of fossils suggests that the conditions of life deteriorated during the latter part of the time during which the Bundella Mudstone was being deposited. Possibly the water became brackish at this time although there are other possibilities. The fossils, especially the pelecypods gastropods, spiriferids and *Stenopora johnstoni* all suggest shallow water deposition, but currents and waves apparently did not affect the bottom very greatly. Judging from the erratics in the siltstone icebergs were common in the sea in which the Bundella Mudstone was being deposited. Alternations in the intensity of current and wave action occurred. The land surface supplying the sediment included schists and quartzites of several types and some granite masses. The metamorphic rocks correspond best to the Precambrian rocks of Tasmania but no diagnostic types have been noticed.

**Faulkner Group**

The Faulkner Group is here defined as all those formations lying between the Bundella Mudstone below and the Rayner Sandstone above and consists in this, the type area, of seven formations as listed below from the base upwards: Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Shale, Altamont Conglomerate and Ferguson Siltstone. The type area for all of these formations is along Geiss Creek.

The rocks in the succession in Geiss Creek pose a problem in stratigraphical nomenclature. Some of the formations listed above are very thin and can only be traced for short distances on the ground away from the creek and some have been recognised with certainty only in the creek bed itself. Several of them are not strictly formations in the sense that they are mappable units, because they are not mappable except on a very large scale. Each formation is however, composed of a single rock type or alternation of rock types. The group on the other hand is composed of a variety of rock types but is the mapping unit for work on air photo scale (20 chains to the inch). To regard the group as a formation and each individual formation as a member is perhaps the obvious thing to do but it ignores the diversity of rock types, subgreywacke conglomerates, subgreywackes siltstone, siliceous sandstones and siliceous siltstones and makes it impossible to express this diversity adequately without considerable circumlocution. It is impossible to find a lithological term to adequately describe the rocks in such a formation. Although several of the formations are only 18 inches thick, and are not mappable units in the usual sense of the words and thus perhaps do not warrant separate status, similar rocks occur in similar stratigraphic positions in other parts of the State and to express correlations concisely it is necessary to name them. Finally all the formations in this group are parts of two cycloths and are thus genetically connected for that is the only way to describe such a collection in the terms of the recent defini- tion of the word in the revised code of stratigraphic nomenclature for Australia (Raggatt, 1956).

**Geiss Conglomerate**

The Geiss Conglomerate is that formation of subgreywacke conglomerate 18 inches thick which occurs in the lower part of Geiss Creek (co-ordinates 504’7 E-736’6 N) and on the hill slopes to the east. It is underlain by the Bundella Mudstone and overlain by the Rathbones Sandstone and Siltstone. It is Permian, probably lower Artinskian, in age.

Although this formation is so thin it can be traced for about half a mile around the hill slope between Geiss Creek and Parramore Creek and can be identified again in Rayner Creek, it has an uneven base on the underlying fissile siltstone of the Bundella Mudstone where the contact is exposed in Geiss Creek. It is olive-brown in colour (5 Y 5/4) and in the field is apparently a poorly-sorted conglomerate with many irregularly rounded rock frag- ments up to cobble size in a groundmass of angular to sub-rounded grains of quartz, felspar and mica. It has no internal bedding planes and is not fissile. The rock fragments which in Geiss Creek are up to three inches in longest dimension and in Rayner Creek are up to eight inches long, are of quartz, quartzite, granite, schist, phyllite, slate and feld- spar porphyry and are commonly faceted. In the Rayner Creek occurrence the top of the bed contains plant stems and a few *Gangamopteris* leaves.

A thin section showed that the rock consists of rock fragments at least up to pebble size in a very poorly sorted groundmass of sand, silt and clay grade. Mineral fragments include much quartz, both fresh and weathered microcline, plagioclase, muscovite and a little biotite. The groundmass is composed of quartz, muscovite, much chlorite and carbonaceous material. The mineral fragments in air dry to black, tan, red and greenish-brown. The rock fragments include sheared quartzite, mica- ceous quartzite, muscovite schist, and muscovite
chlorite schist. Other rock fragments are now mainly ferruginous material. There is no bedding or any other type of orientation of the fragments. The rock is a sub-greywacke conglomerate.

The Geiss Conglomerate was apparently deposited in an environment of little or no current or wave action and under conditions of little water or wind transport from its source. The only fossils known in it are plants so that the a priori assumption is that it was deposited on land but a marine origin under conditions where marine life was inhibited is not impossible. Until more is known of its areal distribution and variations in thickness and lithology it is premature to assign it to any specific environment.

Rathbones Sandstone and Siltstone

The Rathbones Sandstone and Siltstone is that formation of quartz rich sandstone and fissile siltstone overlying the Geiss Conglomerate and underlying the Byers Sandstone in the bed of Geiss Creek. It is 35 feet thick. Fossils include worm casts and plant fragments. It is Permian, probably Lower Artinskian, in age. It is named for Rathbones Lime Kilns on the eastern side of Rayner Creek (506 8 E-737 8 N) in the bed of which the formation was first recognized.

In Geiss Creek this formation consists of four units, the succession being illustrated as text figure 3.

The basal unit is a well-sorted, light olive-grey carbonaceous siltstone with thin bedding containing some worm casts. It is followed by a yellowish-grey quartz sandstone with feldspar visible in hand specimen. The next unit is a dark-grey, very thinly bedded fissile siltstone which is noticeably micaceous and contains lenses of cross-bedded sandstone. The final unit is a yellowish-grey, pale-red or medium-grey sandstone composed dominantly of quartz but with quite a lot of feldspar and golden mica. It is essentially an alternation of thin-bedded fissile beds and thick-bedded non-fissile beds. Sets of cross bedding up to three feet thick were noticed in the field and ripple marks and mud pellets are common.

A thin section of the fissile, thin-bedded siltstone shows that it contains quartz, both muscovite and biotite, and some rock fragments in a groundmass of clay, chloritic material and mica. The content of feldspar is very low. Zircon and tourmaline are present in minor quantities. The grains are not even in grain size and are angular except for the zircon in the finer bands which is rounded. Cross bedding is visible in the thin section.

A sandstone from the top unit was sectioned and the section showed that it is composed mostly of quartz (70%) and mica (25%) with the rest made up of zircon, tourmaline and garnet grains with some opaque iron minerals. There is very little groundmass and very few rock fragments most of them quartzitic. No feldspar is visible. Both muscovite and biotite are present with the former more abundant than the latter. It is well-sorted with the grain size about 05-1 mm. The grains are equidimensional and with the exception of the zircon lack rounding and are remarkably angular. There is some suturing of the quartz grains producing a mosaic texture. The micas are well oriented.

The overall lithology of this formation is very reminiscent of that of the lower part of the Triassic of Tasmania, i.e., the Knocklofty Sandstone and Shale and when first found in the lower part of Rayner Creek the question of a fault dropping the Triassic into the Permian sequence was seriously entertained but the exposures in both creek beds are such that there is no doubt of the Permian age of the formation. The similarity of this formation to the Triassic is heightened in the vicinity of Rayner Creek by the occurrence of slump structures in the sandstone and the occurrence of graphite flakes on the bedding planes. Current ripples with currents coming from a generally southerly direction are present in a generally southerly direction are present in a cliff section on the western side of Rayner Creek.

The only fossils found were some plant fragments and the worm casts in the basal unit in the Geiss Creek section.

This formation is very different from the underlying formations in several important respects. Rock fragments are much less common, sorting is very much better and cross bedding, ripple marking and slump structures occur. Mica is much more abundant and better oriented than in the silt-
stones of the Bundella Mudstone. Also significant is the occurrence of pellets of mudstone in the higher sandstones. Apparently current action was much stronger during the deposition of this formation than the earlier ones and icebergs not present in the depositional area. The mud pellets suggest very shallow water and the plant fossils and carbonaceous material suggest a terrestrial origin although the worm casts are more difficult to interpret. Similar types of worm casts are present in the Ferntree Mudstone which is generally considered to be marine, or at least estuarine. However, the occurrences of worm casts elsewhere in the Permian in Tasmania need further study before their significance is finally appreciated. It is possible that the lower part of the formation is marine and the upper part lacustrine or paludine in origin. The angularity of almost all the grains in the rocks of this formation is somewhat anomalous but is consistent with brief reworking of earlier Permian rocks with the sorting of the various grades by streams or in lakes or swamps and short transport to the depositional site. The mica could well also have been concentrated from earlier Permian sediments in the same way as the quartz while the feldspars from the older sediments were either physically or chemically removed. The presence of such a high proportion of heavy minerals in the top unit also supports some reworking hypothesis. Variations in competence of the transporting medium are reflected in the presence of both siltstone and sandstone.

This formation has not been recognized with any certainty anywhere else in the Hobart area but similar beds occur in the same relationship to beds correlated with the Bundella Mudstone on Maria Island and in the Cressy-Deloraine area where they form part of the Liffey Sandstone of Wells (1957). No direct palaeontological evidence for this correlation is available.

Byers Sandstone

The Byers Sandstone is that formation of sub-greywacke sandstone exposed in Geiss Creek between the Rathbones Sandstone and Siltstone below and the Jarvis Siltstone above. It is only two inches thick. It is Permian, probably Lower Artinskian, in age. It is named after Byers Creek, which has the co-ordinates 506.3 E-737.5 N.

In the field this rock appears to be a poorly sorted, medium to coarse-grained sandstone with pebbles of porphyry, quartz and quartzite in a groundmass of angular to sub-angular grains of quartz, feldspar and mica. It is dusky yellow in colour. A thin section revealed that it contains 40 per cent of quartz, 30 per cent of rock fragments, 15 per cent of mica, 10 per cent feldspar and 5 per cent of groundmass with minor quantities of zircon, tourmaline, apatite, garnet and epidote. The groundmass is chloritic and micaceous with some haematitic cement. The feldspar includes plagioclase and both muscovite and green biotite are present.

Examination of the thin section reveals that the rock is better sorted than it appears to be in the field. Many grains from 0.125-0.25 mm. in size occur in a groundmass of fine silt to clay grade.

The grains and the groundmass are in about equal proportion. The grains are angular, even cuspat, to sub-angular and equidimensional to somewhat bladed. There is distinct parallelism of the bladed grains in some parts of the section but in others their orientation is apparently random. Some of the mica flakes have been moulded around the other grains in a complex fashion.

No fossils were seen in thin section or in the field.

The rock could best be described as a very fine sub-greywacke sandstone, with fair sorting only.

Jarvis Siltstone

The Jarvis Siltstone is that formation of siltstone exposed in Geiss Creek between the Byers Sandstone below and the Parramore Sandstone and Siltstone above. It is approximately 27 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Jarvis Creek, the mouth of which has the co-ordinates 504.0 E-736.8 N.

This formation consists in the creek exposure essentially of an alternation of fissile and non-fissile sub-greywacke siltstones which resemble the upper part of the Bundella Mudstone very much. This alternation is shown in the section (text figure 4) from which it will be seen that the two lower units are rather coarser-grained and in the field are a little better sorted than units higher in the formation.

Erratics are absent in the lowest unit but in higher beds are always present and in one or two cases common. The first three units are non-fissile
but higher beds show the alternation mentioned above, the fissile beds being usually slightly thicker than the non-fissile. The lowest unit is dusky-yellow, the next one light olive-grey and in the higher beds there is an alternation of mottled (olive-grey and dark-grey) and dark-grey beds, the mottled beds being the non-fissile, slightly coarser beds. Lithologically this unit is very like the Ferntree Mudstone higher in the sequence. Fossils are very uncommon and were observed only in the second and third units where only worm tubes were seen. The fissile units in the formation become progressively thicker upwards.

Examination of thin sections showed that the rock is composed of granules of quartz, quartzite and biotite in a matrix of very fine sand and coarse silt. The rock is poorly sorted but one slide showed signs of very rude bedding and even slump structure. In the other slide it is noticeable that the larger grains are clumped together. The grains are angular to cuspatc except for some of the granules which show signs of rounding. The rock fragments include quartzite, micaceous quartzite, quartz muscovite and quartz biotite schist. The dominant mineral is quartz but plagioclase, muscovite, brown biotite and haematite are also present. The rock is a sub-greywacke siltstone.

Parramore Sandstone and Siltstone

The Parramore Sandstone and Siltstone is that formation of sandstone and carbonaceous siltstone which outcrops in Geiss Creek between the underlying Jarvis Siltstone and the overlying Altamont Conglomerate. It is 20 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Parramore Creek, the mouth of which has the co-ordinates of 504.7 E-736.6 N. It contains only plant fragments.

In the creek outcrop of this formation, of which text figure 5 is a columnar section, the basal unit is a micaceous quartz sandstone which appears to be very fine grained and well sorted.

SECTION OF PARRAMORE SANDSTONE AND SILTSTONE

MT. NASSAU SECTION

FIG. 5

(for legend see fig. 2)

It is a very pale greenish-yellow colour. Within the unit are five sets, each about eight inches thick, of fine-grained cross-bedded sandstone. The only fossils found to date are a few carbonaceous fragments. There are no erratics. The next unit is a fine-grained, cross-bedded sandstone and this is followed by a thinly bedded carbonaceous siltstone which contains lenses of cross-bedded or slumped sandstone. It is dark-grey in colour. The top surface of this unit is quite uneven suggesting some disconformity. The next unit is a thickly bedded quartz sandstone with some feldspar and mica visible in the field and also a few pebbles of quartz and quartzite. Cross-bedding sets of up to two feet thick are present but the thickness of the sets varies considerably.

Thin sections were cut and examination of these showed that the siltstone consists almost entirely of quartz and muscovite with a few grains of biotite, both brown and green, plagioclase and tourmaline. Haematite is common. It is a very well sorted medium-grained siltstone.

This formation is similar in lithology to the Rathbones Sandstone and Siltstone. Again well sorted quartz rich sandstones are associated with quartz-rich carbonaceous siltstones. Cross-bedding and slumping are present in the sandstones in both and both contain plant fragments. The association of characters suggests similar conditions of formation to those applying during deposition of the Rathbones Formation and in this case there is a suggestion in the uneven surface of the second last unit and the basal fine-grained conglomerate of the top unit of penecontemporaneous erosion, producing a sort of scour and fill structure.

Altamont Conglomerate

The Altamont Conglomerate is that formation of sub-greywacke conglomerate overlying the Parramore Sandstone and Siltstone and underlying the Ferguson Siltstone in Geiss Creek. It is 18 inches thick. It is Permian, probably Lower Artinskian, in age. It is named after the township reserve of Altamont about a mile to the west of Geiss Creek. The co-ordinates of the type section are 504.7 E-736.6 N.

This formation consists of a single bed of light olive-grey conglomerate composed of pebbles of quartz, quartzite and mudstone in poorly-sorted matrix of sand grade composed of angular to sub-angular grains of quartz, feldspar and mica. The pebbles are sub-angular to rounded. The rock also contains pellets of mudstone which are angular and suggest shallow water conditions with some penecontemporaneous scour.

Fergusson Siltstone

The Fergusson Siltstone is that formation of siltstone with minor conglomeratic bands which occurs in Geiss Creek between the Altamont Conglomerate below and the Rayner Sandstone above. It is 57 feet thick. It is Permian, probably Artinskian, in age. It is named after Ferguson Creek which is a tributary of Jarvis Creek to the west of Geiss Creek. The co-ordinates of the type area are 504.7 E-736.6 N.

This formation is essentially an alternation of fissile and non-fissile siltstone in which two of the non-fissile units are markedly conglomeratic. The
lowest unit is a medium to dark-grey fissile siltstone containing some sub-rounded quartz pebbles in a fairly well-sorted groundmass of quartz, feldspar and abundant mica. This is succeeded by a fissile siltstone which appears to be otherwise like the first unit, then another similar alternation. The next alternation commences normally with a fissile siltstone but the other member is a very tough, thick-bedded, conglomeratic unit. It contains numerous erratics up to eight inches in diameter in a poorly-sorted groundmass of angular to sub-angular grains of quartz and feldspar. It is dark-grey to medium dark-grey. It might best be called a greywacke breccia and is very like the rock which Montgomery (1891) called a "tuff" on Maria Island. The next cycle is also abnormal although it again commences normally with a fissile siltstone. The top member is again a conglomeratic bed with erratics up to three and a half inches in diameter distributed through it. It is dominantly fissile but there are thin non-fissile bands in it. This is succeeded by a brittle, dark-grey siltstone after which is one normal cycle before the formation ends with a fissile siltstone in which there are rare marine fossils near the top. This succession is summarised in columnar form as text figure 8. The formation thus consists of five complete alternations and the lower half of another. With the exception of the cycle involving the greywacke breccia all cycles have a thicker fissile than non-fissile component. In this respect the cycles are like those high in the Bundella Mudstone.

Lithologically the rocks in this formation are very like those in the Jarvis Siltstone and the top of the Bundella Mudstone and also like the Fern-tree Mudstone. In the Fergusson Siltstone the presence of marine fossils in the upper part of the formation indicates that it at least is partly marine. As the lower beds in the formation are very similar to these higher fossiliferous ones except for the fossils it is probable that they were formed under similar conditions except for some factor, perhaps relative freshness of water.

Near the base of the formation is a well-sorted bed called a siltstone in the field. This was sectioned and seen to be composed of quartz, fresh and weathered plagioclase, muscovite, brown biotite, blue tourmaline, microcline, zircon and magnetite and fragments of quartz muscovite schist and biotite schist. The grains are mainly of sand size but there are a few granules and some silt. The rock is somewhat sorted, as there is only a minor amount in the silt grade. The sand grains are frequently in contact and have developed a mosaic texture in several places. The grains are mainly equant but a few are bladed. No bedding is apparent in the slide.

A fissile siltstone from higher in the formation contains a few grains of sand grade in a matrix which is dominantly fine to medium-grained silt. The grains are angular. There is a rude parallelism of the carbonaceous patches in the slide and the muscovite flakes. The main minerals present are quartz and muscovite but there is also much carbonaceous matter and haematite.

The greywacke breccia is very poorly sorted and consists of pebbles, granules and sand grade fragments in a groundmass which forms 20 per cent of the rock. The granules include large pieces of quartz, plagioclase, and brown biotite as well as quartzites. Magnetite is common. The grains are mainly angular to cuspatel but a few are sub-rounded. The groundmass is mainly quartz but there is much other material present.

Cyclic Deposition in the Faulkner Group

It has been noted that the Faulkner Group consists of two distinctly different associations of lithological types, conglomerates, sandstones and siltstones of the sub-greywacke suite and sandstones and siltstone of the ortho quartzite (quartz sandstone suite). What is perhaps more interesting is that the rocks of these two suites occur in regular alternation and still further form parts of two cyclothems as will be seen from the following summary:

Top:

- Sub-greywacke siltstone (Fergusson Siltstone)
- Sub-greywacke conglomerate (Altamont Conglomerate)
- Quartz sandstone and carbonaceous quartz siltstone (Parramore Formation)
Sub-greywacke siltstone (Jarvis Siltstone)
Sub-greywacke sandstone with erratics (Byers Sandstone)
Quartz sandstone and quartz siltstone (Rathbones Formation)
Sub-greywacke siltstone with erratics (Geiss Conglomerate)
Sub-greywacke siltstone (Bundella Mudstone)

It is further noteworthy that the base of the Bundella Mudstone and the top of the Ferguson Siltstone are fossiliferous while the top of the Bundella Mudstone and the base of the Ferguson Siltstone are unfossiliferous. Thus the Faulkner Group consists of two cyclothsms beginning with a sub-greywacke siltstone, passing through a thin sub-greywacke conglomerate into quartz-rich sediments back into sub-greywacke sandstone with erratics and finally back into sub-greywacke siltstone when the whole cycle commences afresh, the second cycle however lacking the second unit in the cycle, the conglomeratic one, but showing the higher conglomerate, the fourth unit.

The fossiliferous nature of the two ends of the double cyclothem suggest that they began and ended under marine conditions, normal except for the presence of floating ice. The presence of the reworked quartz-rich rocks on two horizons with plant remains suggests two emergences so that the cyclothsms could be interpreted as due to two emergences separated by a short submergence. Thus the fossiliferous marine sub-greywacke siltstones represent normal marine conditions in this area followed by rather shallower, perhaps brackish estuarine conditions, unfossiliferous sub-greywacke siltstone, then shoreline conditions, the conglomerates, and finally lacustrine and paludine conditions on a flat coastal plain with reworking of the underlying marine sediments (quartz sandstone and carbonaceous siltstone). Then the sea began coming in over the coastal plain till the Mt. Nassau area was again covered by a shallow, perhaps brackish sea. After a short period emergence began again and the second cycle commenced, ending with the return to normal marine conditions.

This interpretation requires that the sub-greywacke conglomerates should be shoreline deposits formed by advancing and retreating seas. Such deposits could be formed where the rate of advance and retreat was fairly rapid, so that time for sorting was short, and where the supply of detrital material was greater than the amount able to be winnowed by the sea before emergence or burial under later marine sediment.

This interpretation of the cyclothsms seems to meet all the facts known in this restricted area but requires confirmation from detailed work in other areas. Of particular interest is the distribution of the conglomeratic members of the cyclothsms and any variations in thickness and lithology that they show.

The Faulkner Group is possibly partly equivalent to the Porter Hill Beds of Johnston (1886) who used this term originally for shales with Cythere and Gangamopteris. The usage of the unit called "Porter Hill" has varied from one author to another and even Johnston (1888) included more beds in it than he had originally so that his second meaning became all the beds between the limestone on the shoreline at Sandy Bay and the Grange Mudstone. This unit is thought to be equivalent to the Bundella Mudstone, the Faulkner Group and the Rayner Sandstone of the Mt. Nassau section. Voisey's (1938) Porter's Hill Stage is the same as that of Johnston (1888) and this usage was followed also by Lewis (1946, Porter's Hill Beds) and David (1950, Porters Hill Stage). Banks (1952) used the term for those beds in the road cutting at Porter Hill which contain plants at road level and are probably equivalent to the Altamont Conglomerate and Ferguson Siltstone. Finally Banks, Hale and Yaxley (1955) used the term "Porters Hill" Siltstone for the siltstones and sandstones just above the limestone at Sandy Bay which are thought to be equivalent to the Bundella Mudstone. It will be seen that there are several interpretations of this unit and that the spelling has varied also. We are advised that Porter Hill or Porter's Hill is not a name recognized by the Topographic Nomenclature Board but that either name would be suitable as a Mr. Porter owned land in this vicinity during the last century. We propose to suggest to the Board that the spur on which the section is found should be called Porter Hill to revert to Johnston's original spelling. The exact position of the Porter Hill Beds in the sequence must await detailed stratigraphic work on the type section. This group is also partly equivalent to the Preo- lenna Coal Measures of Hills and Carey (1949) and Fairbridge (1953).

The Faulkner Group, representing emergence, can be correlated on this ground with the Liffey Sandstone of Wells (1957) and this has been correlated by Banks (1957a) with the Mersey, Preo- lenna and Mt. Pelion Coal Measures. This terrestrial interlude in the marine sequence corresponds approximately to the Greta Coal Measures of New South Wales but exact equivalence is not suggested. Detailed correlations both within and outside Tasmania must await more detailed stratigraphical and palaeontological work.

Rayner Sandstone

The Rayner Sandstone is that formation of sandstone overcropping on the hill slope west of Geiss Creek and overlying the Ferguson Siltstone and underlying the Casades Group. It is about nine feet thick. It contains marine fossils and is Permian, probably Artinskian in age. It is named after Rayner Creek. The co-ordinates of the type area are 504-T E-736-6 N.

This is the Bridgewater Sandstone of Banks in Hill (1955) which was established on the imperfect sections available in the Rayner Creek section and as formerly used included the Ferguson Siltstone. However, the name "Bridgewater" is not available as a stratigraphic name having been used by Lewis (1946) for the basalts near Bridgewater and earlier as the name of a phase in Pleistocene history of Tasmania. The better sections in and around Geiss Creek allowed this formation to be more correctly restricted.

The Rayner Sandstone is widespread in the Hobart area. It was first recognized on the hill slopes to the east of Rayner Creek, then on the
slopes of Mt. Dromedary where it has since been mapped over several miles by I. McDougall. The Rayner Sandstone is also recognizable beneath the Cascades Group on the Berriedale-Collinsvale Road just below the limestone quarries. Brill (1956, p. 140) records a sandstone below his Berriedale Limestone section at Welly's Quarry, Glenorchy, and a sandstone occurs in road cuts on Porter Hill at the base of the Cascade Group. Finally a greywacke sandstone occurs in this same stratigraphic position on Maria Island.

In the Geiss Creek section the basal unit of the Rayner Sandstone is an olive-grey to light olive-grey, thick bedded, poorly sorted, medium grained sub-greywacke sandstone, with erratics in a groundmass of angular to sub-angular quartz and feldspar. Fossils are present, though rare and include plants and marine fossils, especially Martiniopsis. The next unit is similar but more friable and the next unit again is like the first. The top unit is similar to the first but fossils are common and are predominantly marine.

Examination of thin sections of this rock showed that except for the relative scarcity of rock fragments it is like the greywacke breccia in the Fergusson Siltstone. The dominant grade is sand with particles of quartz, plagioclase, muscovite, biotite and zircon up to 1 mm. in length. Most of the grains are bladed but some are equant, most of them are angular but a few are sub-rounded. Schists are present as rock fragments. The groundmass forms 20 per cent of the rock. It is a sub-greywacke sandstone.

In the section up Rayner Creek the Geiss Conglomerate is succeeded by the Rathbones Formation but then the section is covered and the next unit recognized is exposed in the road to the eastern quarry. It is lithologically very like the greywacke breccia in the Jarvis Siltstone which has been likened earlier to the "tuff" on Maria Island. It contains Glossopteris and other plant fragments. It is approximately the same distance below the Rayner Sandstone as the bed in Geiss Creek. The Rayner Sandstone outcrops on the access road to the eastern quarry, and in this locality is a coarse feldspathic sandstone with small erratics near the base and larger ones towards the top. The boulders are angular and frequently faceted. Fossils occur abundantly in patches and include bryozoa, Strophalosia spp., Martiniopsis, Platyschisma and Moultonia, as well as ostracodes.

Cascades Group

The Cascades Group is here defined as consisting of all those formations between the Rayner Sandstone below and the "Woodbridge Glacial Formation" above, that is of the Nassau Siltstone, the Berriedale Limestone and the Grange Mudstone in that order from the base upwards. The name is derived from the Cascades district about two miles west of Hobart. The type area of the group is, however, on the eastern flank of Mt. Nassau where all three formations are exposed in succession. The co-ordinates of the type area are 506E3E-136°8N.

Lewis (1946, pp. 22, 25, 30, 90) was the first to use this term or its equivalent (Cascades Stage) for the rocks included in this group. Later Hills and Carey (1949, pp. 31-2) used the term "Cascades Formation" to include the Granton Limestone and Marl, Porters Hill Mudstone and the Grange Mudstones and in effect applied it to all formations between the Wynyard Tillite and "Woodbridge Glacial Formation" which is a much wider usage than that proposed here. Fairbridge (1953) used the term "Marlborough Series" in 1948 for the beds under the Woodbridge Glacial Formation at Marlborough and included the Bronte, Granton and Grange Facies. The Cascades and Marlborough Groups overlap to some extent, but the exact situation is not yet known. The formations of this group have been referred to as the Lower Marine Beds by Stephens (1885, pp. 218-219) and Johnston (1888), and as the Lower Marine Series by Lewis (1927, pp. 9, 10). Nye and Lewis (1928, p. 34) Nye and Blake (1938, pp. 43, 44, 100) and David (1950). Present correlations on the other hand, see Banks (1957a), suggest rather that the Cascades Group is equivalent to part of the former Upper Marine Series of New South Wales, now the Maitland Group. In fact, even in Tasmania, detailed stratigraphic work has indicated that there are two major sequences of marine sediments separated by a fresh-water sequence, and of these the Cascades Group is part of the higher marine sequence. The unfortunate confusion resulting from the old naming has been dealt with earlier.

The total thickness of the Cascades Group is normally of the order of 300 feet but the thicknesses of the constituent formations vary considerably. In places, e.g., Coles Bay, Seymour, the group consists dominantly of the Berriedale Limestone with some Grange Mudstone. On Maria Island there is an appreciable thickness of Nassau Siltstone and rather a greater thickness of the Berriedale Limestone than of the Grange Mudstone. At Mt. Nassau the Nassau Siltstone is thin and the Berriedale Limestone thicker than the Grange Mudstone while at the type area of the Grange Mudstone, at Porter Hill, Sandy Bay, there is no Nassau Siltstone known, the Berriedale Limestone is thin and the Grange Mudstone is the predominant formation. Further south neither the Berriedale Limestone nor the Nassau Siltstone can be positively identified and the group consisted of a single formation, the Grange Mudstone.

The group is known from as far north as Avoca and Bothwell to as far south as Mt. La Perouse and from Marlborough in the west to the east coast. The apparent absence of this group from the Cressy and Deloraine areas and probably all parts of the north-west coastal area is an interesting problem.

The variations within the Group are attributed to facies changes as will be developed later. As a summary it might be said that the group consists of an alternation of fissile siltstones with limestones or calcareous siltstone, the fissile siltstone members predominating in the Nassau Siltstone, the limestone in the Berriedale Limestone and the siltstone in the Grange Mudstone. In essence there is an increase in lime content up to some part of the Berriedale Limestone after which the lime content decreases.
Nassau Siltstone

The Nassau Siltstone is defined as that formation of siltstone and limestone, with the siltstone predominating, which overlies the Rayner Sandstone and underlies the Berriedale Limestone on the northern flank of Mt. Nassau, especially in Geiss Creek and along the access road to the eastern quarry. It is named after Mt. Nassau. The co-ordinates of the type section are 504-7 E-736-6 N. In the type section it is of the order of 40 feet thick. It contains numerous fossils, especially Strophalosia spp. and Fenestella spp. It is Permian, probably Artinskian, in age.

This formation had not been recorded until Banks in Hill (1955) reported it as the "Granton Siltstone". This name is, however, undesirable because of the previous use of the geographic term "Granton" for a limestone and a stage of the Permian, the synonymy of which will be dealt with later.

The formation consists of an alternation of fissile siltstones and non-fissile siltstones or limestone, with the siltstone members being thinner than the limestone members. The formation grades up into the Berriedale Limestone and in the absence of good sections it is impossible to define the top of this formation accurately.

In the Geiss Creek section this formation is poorly exposed. The lower 30 feet consist of an alternation of greenish-grey, fissile calcareous siltstone with tough medium-grey limestone. Both rock types are richly fossiliferous. There is then a gap of 15 feet before outcrops of limestone with some siltstones commence.

Thin sections of the siltstones were examined. The siltstone is composed of angular grains of quartz, some of which are strained, and contain rutile, and some show lines of inclusions outlining former rounded grains which had suffered regrowth before transport to their present site. Magnetite, hematite, muscovite, some biotite, calcite, carbonaceous matter, and chlorite are also present. Some grains of plagioclase were also noticed. The grains are equidimensional to bladed or even acicular and are angular, the only round material in the slide being produtcid spines. It is stratified in that there are fine-grained lenses of dark-coloured claystone and siltstone in a rock which is dominantly in the silt grade with some fragments up to fine sand grade. Sorting is poor with most of the grades present in about equal amount. Some rock fragments are present and include large pieces of quartzite, chlorite schist and a chloritic micaceous schist. However, only the fossil fragments are larger than sand grade and these are up to a couple of inches long. The fossil fragments include pieces of Stenopora, fenestellids, productid spines, echinoderm plates and pelecypods. A productid spine and a fenestellid zoecium were lined with granular calcite and the centre of the cavity filled with quartz. The rock is essentially an impure, productid calcarenite with much mineral matter.

Berriedale Limestone

The Berriedale Limestone is defined as that formation composed dominantly of limestone which lies above the Nassau Siltstone, where that formation is present, or the Rayner Sandstone, in the absence of the Nassau Siltstone, and below the Grange Mudstone or where that formation is absent, the "Woodbridge Glacial Formation". In the Mt. Nassau section, here designated as the type section, it is about 150 feet thick. The co-ordinates of the type section are 506-3 E-736-8 N. It contains Taucnithacrus subquadratus, Strophalosia jukesi, Lyropyrella, Eurydesma cordatum var. sacculum, Pterotoblastus and Conularia dorsoentenia. It is Permian, probably Middle or Upper Artinskian in age. The name is derived from quarries close to Berriedale where the limestone was quarried.

This formation has been referred to by a number of names and the synonymy is shown below:

- Mt. Wellington Limestone
- Gould (1866, p. 29).
- Mountain Limestone
- Wintle (1865).
- Crinoidal Zone
- Johnston (1901).
Berriedale Limestone
Voisey (1938, p. 315).
Brown (1953, p. 59).
Crockford (1951).
David (1950, p. 359).
Hale and Brill (1955, p. 231, &c.).
Brill (1956, pp. 131-140).
Ford (1956, p. 149).
Banks (1957a and 1957b).

Granton Stage
Voisey (1938, p. 313, &c.), includes Berriedale Limestone and other lower beds.
non Voisey (1949), probably part of Golden Valley Group.
David (1950), as Voisey (1938).

Granton Sub-Stage
Lewis (1946, pp. 22 et seq.).

Granton Limestone and Marl
Hills and Carey (1949, p. 31) for Berriedale Limestone and the limestone on the shoreline at Porter Hill (= Darlington Limestone).
Banks (1952, p. 66) as Hills and Carey with addition of correlation with the Lower Marine Series of New South Wales.

Granton Formation
Fairbridge (1953) as for Granton Stage of Voisey (1938).
Hosking and Hueber (1954) as Voisey (1938).

Granton Limestone
Hale (1953, pp. 107, 8, 10).
non Ford (1964, pp. 153, 157, 158) which is Woody Island Siltstone and contiguous formations.

Gray Stage
Voisey (1938, p. 323) limestone part only.

Peter Limestone
Banks in Hill (1955, p. 89).

The Berriedale Limestone is composed of fragments of Stenopora, Fenestella, productid brachiopods, spiriferoids, pelecypods, ostracodes and echinoderms. Siliceous sponges, spicules, monaxons, were recognized. Some of the fossil fragments show solution along narrow tunnels and infilling with groundmass suggesting the action of some burrowing organism. Some of the fragments, especially the echinoderm pieces, show rounding. Rare grains of sericitised feldspar, magnetite and rounded fragments of green biotite are also present. The rock is well sorted with most of the fossil fragments in the sand grade with a few fragments in the granule and one in the pebble grade. The mineral particles are of sand grade. Much of the groundmass is recrystallised and is now a mosaic of calcite grains. This rock is a bryoool calcarenite.

The type section for this formation should be in the Berriedale Quarries or in that vicinity but the structure there is not yet clear. The longest quarry exposure is at Weily's Quarry, Tolosa Street, Glenorchy (see Brill, 1956, for section), also text figure 7), but the underlying and overlying sections are not well exposed. At Mt. Nassau the formations above and below the limestone are present but again not well-exposed so that only the total thickness of the Cascade Group can be measured with any accuracy at about 300 feet. Of this about 40 feet at the base is Nassau Siltstone and then there is at least 50 feet of limestone exposed in the quarries but neither the bottom or the top of the limestone is included in the quarries. From poor exposures on the hill slopes it would appear that there is about 50 feet of this formation above and below the quarries making a minimum thickness of 150 feet but there is more than this due to the difficulty of along the boundary between the Berriedale Limestone and its bedings in formations in the absence of cliff or quarry sections. Brill (1956) has published sections through this formation in a number of places in the Hobart district and gave the details of the section at Weily's Quarry. Of this section the present authors would include units 11-60 only as the Berriedale Limestone—the higher units being considered here as the Grange Mudstone. This section is reproduced here in columnar form as text figure 6 which includes also the section measured by the authors in Geiss Creek, which is poorly exposed.

Fossils are abundant in this formation and represent almost every animal phylum as well as plants. Fragments of leaves and stems and pieces of fossil wood occur in it in places, e.g., Black Snake Gully Quarries, Granton, and the Rathbone's Quarries, Mt. Nassau. Foraminifers are present at least at Weily's Quarry but have not been identified. Sponges have been identified in a section of the Rathbone's Quarries. Corals occur also in the Rathbone's Quarries and include Euryphyllum. The brachiopod fauna is very rich and includes Schuchertella, Taeniocathes subquadratus (Weily's Quarry, Berriedale Quarry and Rathbone's Quarries at least), Strophalosia jukesii, Grantonia hobartensis, Trigonotreta stokesii, Martinpopsis, and Dieslana. Bryozoa include Polypora woodsi, Stenopora pustulosa, S. hirsuta and Steno-
Fig. 7
discus moniliformis from the Berriedale Quarries and Stenopora pustulosa, Polyplora magnafenes-
trata, and Fenestella fossula from Welly's Quarry. The bryozoans quoted are only those determined by
Crockford in a series of papers summarized in 1951. Only one further bryozoan should be mentioned, 
Lyroporella, which has been found so far in the Hobart area at Rathbone's Quarries and at the 
Berriedale Quarries. Pelecypods are common and include Astartilla, Deltoplecten limeformis and D. 
subquinquaneatus, Aviculopecten englehardi, A. Mitchell, A. splinti, and A. squamulifera, from the 
Berriedale Quarries. Eurydesma cordatum var. 
saccatum has been found in the Mt. Nassau section 
and also in the Black Snake Gully Quarries. Many 
other pelecypods are present and have been recorded 
by authors last century, the only ones quoted being 
recent determinations. Gasteropods are not so 
common but many are present and include Mour-
tonia murristana from both Berriedale Quarries and the Mt. Nassau section. There are numerous 
undertermined ostracodes in a blastoid, probably 
Pterotoblastus, has been found at Rathbone's 
and at Berriedale Quarries. Crinoid elements are 
very common and have been identified 

as belonging to Calceolispongia noeltlingii, and 
Campactruris tasmaniensis in the Mt. Nassau 
and/or Black Snake Gully Quarries. There are 
probably other species as well. Interambulacral 
plates and spines of Archaeooides have been 
found at Rathbone's Quarries. Although Conularia 
is not common it is represented by one large species, 
C. dereventensis which occurs at the Black Snake 
Gully Quarries and Rathbone's Quarries at least.

Of these fossils Taeniotaenus subquadtratus, 
Lyroporella and Pterotoblastus can be easily identi-

fied and one or more of them are found in the 
Cringidal Zone on Maria Island, the Peter Lime-
stone at Coles Bay and the Gray Stage Limestone 
at St. Marys, the Enstone Park Limestone north of 
St. Marys, at Fingal, and at Avoca. In the Hobart 
sections these fossils occur low in the Berriedale 
limestone. Euphyllinaeum is restricted to 
the lower parts of the Cascade Group and 
occurs in that position in the Mt. Nassau section, on 
Maria Island, at Coles Bay, St. Marys and north of 
St. Marys. Thus the limestones at these places are 
correlated with the Berriedale Limestone although 
exact equivalence is not suggested. The matter of 
the correlation of the Berriedale Limestone within 
Tasmania has been dealt with elsewhere in more 
detail (Banks, 1957a).

Some of the bryozoans, brachiopods, and pelecypods suggest a correlation of the Berriedale Lime-
stone with some part of the Branxton Sub-Group 
in the Maitland Group of New South Wales and the 
Cattle Creek and/or Ingelara Stages in Queens-
land. The correlation with Western Australia is 
not at all certain for although there are some 
Westralian elements in the fauna these have not 
yet been studied. Interstate correlations have 
been dealt with by Banks (1957a) in more detail.

The comparative lack of elastic material in this 
formation probably indicates a lower land surface 
than during the deposition of the earlier forma-
tions. The erratics would indicate that icebergs 
were floating about in the sea and slowly melting.

and their number and composition suggest deriv-
ation from a westerly or north-westerly direction 
(see Brill, 1956). As Brill has pointed out (1956), 
the cycles of limestone and mudstone in this for-
formation could be due to several causes. One of 
the common occurrence of glacial deposits in the 
Permian of Tasmania and the comparative rarity 
of pyroclastic deposits. Brill's fourth hypothesis 
is thought to be the most likely. This is, namely, 
that the changes in the rate of sedimentation (or 
type of sediment, authors) may reflect the waxing 
and waning of glaciers. Thus the limestone (cal-
carenite) beds would represent times of increased 
current activity and shallower water and presum-
ably also of increased supply of material from an 
uplifted surface on which glaciers are retreating 
and stream erosion is greater, while the mudstone 
beds represent periods of glacial advance, lower 
land surfaces and smaller stream capacities. Brill's 
observation that the erratics tend to occur in the 
mudstone or in the limestone close to the mudstone 
suggests fairly strong currents as also does the weight and coarse ornamentation of the pelecypod 
and spiriferid shells. Stenopora and fenestellid 
zoaria are usually broken. On the other hand the 
prodromids often occur in the mudstones with their 
spines still attached and some complete fenesi-

tellid colonies have been found associated with 
them. This indicates very quiet deposition for the 
mudstones. Normally limestone is considered as a 
warm water deposit but the presence of erratics 
suggests cold water conditions. At the present time 
icybergs drift as far north as 35° S in the Atlantic 
where the surface temperature in the summer is 
about 20° and the bottom temperature about 10°. 
This provides some idea of the maximum tempera-
ture at which the Berriedale Limestone might have 
been deposited. In view of the number of erratics 
in the formation it is probable that the limestone 
was deposited closer to the edge of the Permian 
shelf than this limit of 1600 miles. From the 
evidence of the areal distribution of the limestone 
and the nature of the erratics it is probable that 
the land with the ice-sheet was of the order of 
100-200 miles away in which case the temperature 
would have been much lower on the sea floor, 
probably only a few degrees above zero centigrade. 
The simple horn corals which occur in this for-
mation suggest deposition in cold, deep or murky 
water (Hill, 1948), and the foraminifera are mainly 
arenaceous types, again suggesting cold or deep 
water. The large size and weight of the pelecypod 
shells would normally be taken to indicate 
that they lived in warm water. However, it 
seems possible that some of the pelecypods, e.g., 
Eurydesma cordatum, and the brachiopods, e.g., 
Taeniotaenus subquadtratus, may have been 
adapted to cold conditions and produced bigger 
heavier shells in the colder seas. The consistent 
association of Eurydesma with glacial deposits 
throughout the Gondwana countries supports this, 
as also does the fact that the shells of T. subqua-
dratus are thinner in Western Australia, where 
 glaciation was less severe, than in Eastern Aus-
tralia (see Prendergast, 1943). Thus the bulk of evidence suggests deposition in fairly quiet, cold water of varying depth.

Grange Mudstone

The Grange Mudstone is here defined as that formation of siltstone and calcareous siltstone which overlies the Berriedale Limestone, or where that formation is absent, the Rayner Sandstone, and underlies the "Woodbridge Glacial Formation". In its type area, at Porter Hill, Sandy Bay, it is about 290 feet thick. The co-ordinates of the type area are 521.5 E-715.5 N.

The formation is named after the Grange Quarry, the beds in which are continuous along the strike with the beds at Porter Hill, about half a mile to the north. It is richly fossiliferous, Strophalosia and fenestellids, including Polypropa woodai, being particularly abundant. It is Permian, probably Middle or Upper Artinskian, in age.

This formation has been known under one name or another since Johnston (1888, p. 118) referred to it as the "Fenestella Zone". Usage since that date is detailed hereunder:

Fenestella Zone
Johnston (1888, p. 118), Cascades, Porter Hill and Grange, non Maria Island.

non Fenestella Zone
Montgomery (1891); beds below Crinoidal Zone on Maria Island.
Johnston (1901); as Montgomery 1891.
non Fenestella Shales
Gregory (1905), formation at top of Junee Group (Ordovician) at Gormanston.

Grange Stage
Voisey (1938, p. 313).
non Voisey (1949, p. 106), probably Golden Valley Limestone and Shale.
David (1950, p. 359-360).

Grange Mudstones
Hills and Carey (1949, p. 31).
Banks in Hill (1955, p. 89).

Grange Sub-Stage
Lewis (1946, pp. 22 et seq.).

Grange Facies
Prider (1948, p. 173), probably partly equivalent.
Fairbridge (1949, pp. 114, 5, 6), probably partly equivalent.

Grange Mudstone
Banks (1952, p. 67).
Hale (1953a, pp. 107 et seq.).
Hale and Brill (1955, p. 233).
Brill (1956, p. 135).

Grange Formation
Fairbridge (1953).
Hosking and Hueber (1954).

The Grange Mudstone consists essentially of siltstone, calcareous siltstone and minor beds of limestone, dolomite and nontronite. The section at the Grange Quarry which is the best exposure in the type area is here published in columnar form as text figure 8 with the kind permission of K. G. Brill, who measured it.

This section is not quite as long as that at Porter Hill but is better exposed. The top of the section is missing at Grange Quarry, being replaced by a transgressive dolerite body. The lithology of the formation has been described by Voisey (1938),
Lewis (1946), Banks (1952), Hosking and Hueber production of contact metamorphic effects. As a result, the calcite of the shells is often recrystallised and diopside and other calc-silicate minerals develop. In addition to this, there is extensive silification so that both calc-silicate and siliceous hornfelses are produced.

Thin sections were cut of two of the limestones of this formation from Mt. Nassau. Both are calcitellites with an abundance of Strophalosia. One section consists of numerous shell fragments up to pebble size, but mainly in the sand grade, with fragments of quartz of sand grade in a groundmass of silt and clay grade grains of calcite with a little quartz. The groundmass is not uniform in grain size, there being irregular areas of clay grade in the groundmass which is dominantly silt grade. Most of the grains of quartz are angular. Fragments of quartz muscovite schist and other rocks are also present. Angular, often bent, grains of green biotite, magnetite and small grains of zircon are present. The shell fragments which show recrystallisation in some cases include those of productid spines, a perforate uniserial foraminifera, pseudopunctate brachiopods, pelecypods, Stenopora and rare fenestellids. The other section is that of a well-bedded limestone with beds of fine calcarenite and fine calcitellite. The calcite grains in the calcarenite are mostly recrystallised. Angular grains of quartz of fine sand grade are present. The shell fragments are mainly fenestellids but some baciopod spines and fragments of pseudopunctate shells, pelecypod fragments and Stenopora are also present.

At Porter Hill the Grange Mudstone overlies about 20 feet of medium-grey, richly fossiliferous, foetid limestone which is lithologically like the Berriedale Limestone. This thin limestone unit overlies a bed of sub-greywacke sandstone which is about ten feet thick and similar to the Rayner Sandstone. Over the thin limestone unit there is typical Grange Mudstone which continues upwards for about 290 feet (Abney level figure) but in several places contains beds of greyish limestone up to two feet thick. These limestone beds are quite subordinate as will be seen also from the columnar section, based on exposures at the Grange Quarry. Above the Grange Mudstone at Porter Hill is a conglomeratic sandstone with rare marine fossils and plant fragments, which is lithologically very like the sandstone at the base of the "Woodbridge Glacial Formation". Throughout the Hobart area, then, creamy fenestellid, Strophalosia-rich mudstones may be seen overlying the Grange Mudstone directly and under the "Woodbridge Glacial Formation". They increase in thickness from Mt. Nassau south to Sandy Bay at the expense of the lower formations of the Cascades Group which maintains a fairly constant thickness throughout this area. Thus while the Grange Mudstone always overlies the Berriedale Limestone where this latter formation is present, it is possible that the Berriedale Limestone was deposited in its entirety before deposition of the Grange Mudstone began and that the areal distribution of the limestone and its thickness variations may be in no way related to the distribution and variation in thickness of the Grange Mudstone.

The Grange Mudstone is richly fossiliferous. It is interesting to note that Johnston (1888, p. 118) recorded Taeniothaerus subquadratus from his 'Fenestella Zone, now called the Grange Mudstone, at either Cascades, Porter Hill or the Grange. As this fossil is restricted to a narrow zone within the Berriedale Limestone in Tasmania, this record suggests that the two formations are at least partly equivalent. The present authors have not yet been able to verify this report, nor to find Lyroporella or Pterotoblastus in the Grange Mudstone, but there is a strong possibility that these fossils are restricted to the Grange Mudstone in Tasmania. From the Grange Quarry, Fletcher (in Voisey, 1938) recorded Deltiopecten subquinquelatus, Platyschisma oculus and Mourlonia morrisiana as well as numerous other fossils. From Fletcher's list it will be seen that every species listed from the Grange Quarry, with the exception of Platyschisma oculus, occurs also in the Berriedale Limestone at Collinsvale Lime Kilns (referred to in this paper...
as the Berriedale Quarry and at Granton (either the Black Snake Gully or Rathbone's Quarry, or both). Voysey's fossil localities 6 and 7 (1938, p. 326) are not now considered as equivalent to the Grange Mudstone but to the richly fossiliferous beds just below the top of the "Woodbridge Glacial Formation". From the Grange Quarry, Crockford (1951) recorded the bryozoa Fenestella dispersa, F. fossula and Polyopora woodsi, all of which also occur in the Berriedale Limestone (Crockford, 1951, pp. 110, 111). Polyopora woodsi is restricted to part of the Branxton Sub-group in New South Wales but has a longer range in Queensland and Western Australia apparently.

It is remarkable that although Winchamia dalwoodensis (equals Strophalosia typica) is regarded as characteristic of the Grange Mudstone by Voysey (1938, p. 328), on the list of fossils in his paper it is recorded from the Berriedale Limestone in two places and from the richly fossiliferous horizon just below the top of the "Woodbridge Glacial Formation" on Mount Faulkner, but not from Grange Quarry. Both Voisey (1938) and Crockford (1951) suggest correlation of the Grange Mudstone with the Branxton Sub-group of New South Wales and Banks (1957a) has suggested that the Berriedale Limestone is also at least partly equivalent to the same sub-group. Recorded fossil evidence thus also supports the hypothesis that the Berriedale Limestone is at least partly a facies variant of the Grange Mudstone but further work is necessary before the hypothesis can be regarded as proved, Hills and Carey (1949, p. 31) state that there is considerable facies variation between sections of their Cascades Formation, but this term has a much wider meaning than the Cascades Group as here used, and it is not clear that they envisaged the facies variation postulated here.

"Woodbridge Glacial Formation"

It is not appropriate here to define the formation between the top of the Cascades Group and the base of the Risdon Sandstone as another worker who has studied the formation over a wide area hopes to do this shortly.

In the Mt. Nassau section the Cascades Group is overlain by a formation of sandstone and siltstone which is about 275 feet thick (measured with Abney level) and overlain by the Risdon Sandstone. At the base is a conglomeratic sandstone which contains numerous erratics and fossils, except bryozoa, which are rare. About 60 feet above the base the formation becomes finer-grained and is dominantly siltstone with numerous sandstone bands. In this part of the formation the fossils become uncommon, and although erratics are present they are not very common, and there is no really tillitic bed. About 50 feet from the top of the formation there is a bed of siltstone which is very rich in fossils, mainly productids but with some spiriferids and pelecypods. This bed is only a few feet thick. Lenses of limestone occur in the formation on Mt. Nassau from 23 feet to 21 feet 6 inches from the top of the formation. The limestone lenses are at least 18 inches thick and the rock is olive-grey, foetid and fossiliferous. The fossils include Martiniopsis, Stenopora crinita, Strophalosia, Mourlonia and fenestellids.

In the main part of the "Woodbridge Glacial Formation" the commonest fossils are spiriferids and pelecypods and plant fragments are rare. A very alate spiriferid is common in the formation and occurs in the excavations for the Lake Fenton Pipeline above Rathbone's Quarries.

Thin sections were cut of several rock types in the formation on the flanks of Mt. Nassau. The sandstone at the base contains much quartz, some feldspar (slightly weathered orthoclase, microcline and andesine), muscovite and green biotite. Accessory minerals include ilmenite, sphene, zircon, tourmaline (schorlite) and rutile. The groundmass is composed of quartz, muscovite, chlorite and limonite. Rock fragments are common and include micaaceous quartzite, haematitic quartzite, mica schist, graphitic mica schist and muscovite gneiss. Some of the quartz grains contain zircon crystals, some contain muscovite, some show undulose extinction and some show regrowth, one piece having two rings of inclusions inside an angular grain. Rutile occurs as grains in the rock and also as crystals in quartz grains, one of these being twinned in the characteristic fashion. This rutile is angular, but some is sub-rounded, some is in the form of crystals and some shows regrowth. The rock is a fine sandstone, average grain size about 0.25 mm. The largest grain present in the slide is a pebble (4-5 mm.) and there are small interstitial patches of very fine siltstone (0.015 mm.). The grains are mostly highly angular, and many have sutured boundaries with neighbouring grains, so that the overall texture is mosaic. There is no obvious preferred orientation. The rock is a conglomeratic, somewhat impure, partially recrystallised sandstone.

A siltstone from higher in the formation contains grains of quartz microcline, andesine, microperthite, chlorite, mica flakes and zircon. The total feldspar content is only about 5 per cent. Fragments of mica schist with tourmaline, quartz biotite schist (green biotite), and a rock with feldspar phenocrysts with rude flow structure are present. The grains are dominantly in the silt grade (about 0.015 mm.) but fragments up to 0.56 mm. long are present and much of the groundmass is probably in the clay grade. Sorting appears to be poor. The larger grains are mainly angular to sub-angular but some are sub-rounded. Rounding appears to be a little better in the finer grades. Most of the grains are equant, but a few, especially the micas, are bladed to almost acicular.

The limestone from close to the top of the formation is composed of fragments of quartz and shell material. The shell fragments are up to 2 mm. long but the quartz grains are smaller, from 0.03 to 0.25 mm. only. The groundmass is of calcite and quartz fragments mainly of the silt grade but with some in the clay grade. There are angular fragments of quartz, plagioclase, green biotite, magnetite, chlorite, microcline and muscovite and some of the quartz grains are almost cuspatate. Some of
the quartz contains zircon. The shell fragments some of which show resorption, include productid spines, foraminifera, pelecypods and probably ostracodes. It is essentially a productid calcilutite.

No attempt will be made here to deal with the conditions of deposition of this formation except to point out the predominance of metamorphic types in the rock fragments and of the minerals derived from these. These appear to be more like the Precambrian rocks than any later rocks in Tasmania. There is evidence also of derivation of some of the sediment from pre-existing sediment and of some from a granitic and pegmatitic terrane. There has been extensive recrystallisation of the rock, particularly of the sandstone at the base with its mosaic texture.

Risdon Sandstone

The Risdon Sandstone is here defined as that formation of feldspathic sandstone which lies between the "Woodbridge Glacial Formation" below and the Ferntree Mudstone above, in the Mt. Nassau section. The type area is in a road cutting on the north-east side of the road up Risdon Creek near Bowen's Monument, about two chains from its junction with the Risdon-Richmond Road. The co-ordinates of the type area are 510 4 E-719 2 N. The name is derived from the village of Risdon. It is ten feet thick. It is Permian, probably Upper Artinskian or Lower Kungurian, in age.

This name was first used by Carey and Henderson in an unreported paper to the Mines Department in 1946 for the basal member of the Ferntree Mudstone. It has been used since in that sense by Carey (1947, p. 32) (the first published use of the term), Pridr (1948, p. 134), Hills and Carey (1949, p. 32), Volsey (1949, p. 106), Banks (1952, p. 70), Hale (1953, p. 20; 1953a, p. 107) Ford (1954, p. 154), Hale and Brill (1955) and Mather (1955). It is a very widespread, easily recognizable and very mappable unit and for these reasons is here considered as a formation.

On the flanks of Mt. Nassau it is present as a bench-making horizon and shows the characters described earlier by Banks (1952, p. 71). One feature not noted earlier is the occurrence of tubular casts perpendicular or at a high angle to the bedding in the Mt. Nassau section.

A section of this rock was examined and showed the presence of quartz, much plagioclase (20-25%), muscovite, zircon, haematite and limonite, as well as a few pieces of microcline, ilmenite, brown biotite, and tourmaline. The plagioclase includes albite and andesine, and there is one piece of quartz and microperthite present. Rock fragments are not common but there are a few including a piece of quartzite. Most of the grains are about 0.16 mm. long with a few grains up to 1 mm. long and a small amount of finer material. Most of the grains are angular but there are a few sub-angular grains present. The grains are dominantly equidimensional but a few are tabular. Many of the grains have developed sutured outlines by regrowth so that a mosaic texture is produced. The rock on Mt. Nassau is a richly feldspathic sandstone.

Ferntree Mudstone

The Ferntree Mudstone may be defined as that formation consisting dominantly of an alternation of fissile and non-fissile siltstone which overlies the Risdon Sandstone and underlies the Cygnet Coal Measure or, where these are absent, the Knocklofty Sandstone and Shale of the Triassic System. It is 600 feet thick. The formation is named after the village of Ferntree where it outcrops (co-ordinates 512 6 E-715 9 N) and which should be the type area. The formation is Permian, probably Kungurian, in age.

This formation has received a number of different names since Johnston (1888, p. 118) referred to it as the Mudstone Zone. The synonymy is as follows:

Mudstone Zone
Johnston (1888, p. 118).
Upper Marine Series
Johnston (1888, p. 118).
Lindsfarne Stage
Voisey (1938, pp. 313 et seq.).
David (1950).
non Lewis (1946); for "Woodbridge Glacial Formation".
Lindsfarne Mudstone
Carey (1947).
Ferntree Mudstone Stage
Lewis (1946, pp. 22 et seq.).
Ferntree Mudstones
Carey (1947, pp. 32, 33, 36).
Hills and Carey (1949, p. 32).
Ferntree Formation
Pridr (1948, pp. 127 et seq.).
Ford (1956, p. 150).
Ferntree Stage
Ferntree Mudstone Formation
Fairbridge (1949, pp. 114, 118).
Fairbridge (1953).
Ferntree Mudstone
Banks (1952, pp. 70 et seq.).
Hale (1953a, pp. 98 et seq.).
Brill and Hale (1954, pp. 279, 281).
Ford (1954, pp. 155 et seq.).
Ford (1954a, p. 185).
Hale and Brill (1955, pp. 233-4).
Jennings (1955, pp. 172 et seq.).
Mather (1955, pp. 193 et seq.).

In the Mt. Nassau section the Ferntree Mudstone consists of an alternation of fissile and non-fissile siltstone but the exposures are not good and detailed stratigraphic work could not be done. Exposures in the Ferntree district are rather better because of the presence of numerous road cuttings but still not good enough for preliminary detailed measurement due to very complex faulting and a thick cover of vegetation. The best section avail-
in the Hobart area is probably in the bed of Town Creek and it is hoped to measure this in detail shortly.

In the Mt. Nassau section the Ferntree Mudstone is 300 feet thick but this may not represent the total thickness of the formation as the next highest formation, the Cygnet Coal Measures, does not crop in this section. This lack of outcrop may be due to erosion before the deposition of theassic System or to non-deposition, but no choice can yet be made between the alternatives although erosional hypothesis is supported by disconformities between the Ferntree Mudstone and theassic System in at least two places in the Huon district. Lewis (1946, p. 94) gives a section in Town Creek and it is notable that in it there are 25-30 feet of Cygnet Coal Measures. The lack of Cygnet Coal Measures at Mt. Nassau may be apparent rather than real as the outcrop near the base of the Ferntree Mudstone is very poor and the coal measures could be covered by talus.

It is not proposed to give a full description of the Ferntree Mudstone on Mt. Nassau but to wait until the detailed section is measured in New Town Creek. Observations on this formation in the Mt. Nassau section which have not earlier been recorded are that marine fossils occur sparsely and are particularly noticeable just above the base. Also again about 400 feet above the base. Even at these levels they are not common. Spiriferids are the commonest types. Worm tubes are common.

Examination of a thin section showed that the mudstone consists of rock and mineral fragments to 1 mm. in length in a groundmass about 2 mm. in average grade. It is not well-sorted but intermediate grades appear to be present in about equal amount. The fragments are very regular to almost cuspate and tend to be tabular or oblong rather than equant and a few are prolate. There are signs of rude bedding in the rough pation of fragments. Quartz is the dominant mineral but microcline, plagioclase, muscovite and small amount of biotite are also present. The groundmass is haematitic. Rock fragments are present and include quartzite and micaceous phyllite.

As has been remarked earlier, the beds at the top of the Bundella Mudstone, the Jarvis Siltstone, the Fergusson Siltstone and the Ferntree Mudstone are all lithologically very similar and this suggests recurrence of similar conditions at those levels. It has been suggested earlier (Banks, 1952) that the Ferntree was deposited in a fresh, shallow, possibly estuarine conditions with occasional access of ice-bergs. Such conditions would seem to satisfy all that is known about other formations and also their position in the sections.

SUMMARY

On the northern slopes of Mt. Nassau about 1430 (1436 as measured) of Permian sediments are exposed in an uninterrupted sequence. This is the best section known in the Hobart district for the Permian succession but in other places exposures of individual formations are better. The Geiss section is particularly noteworthy for the exposures of the formations below the Berriedale Limestone.

The succession is summarized in columnar form in text figure 9.
Unfortunately the section does not reach the base of the Permian as developed in Tasmania but correlation of the basal formation in this section with beds on Maria and Woody Islands suggests that it is underlain at no great depth by the Darlington Limestone beneath which is the sequence on Woody Island, about 300 feet thick, and below that again the basal beds in the Fiorentine Valley, about 200 feet thick. On top of the section in some places is the Cygnet Coal Measures, about 300 feet thick, giving a maximum thickness for the south-eastern Permian as about 2250 to 2300 feet. The correlations involved, as well as the successes, have been dealt with by Banks (1957a).

The succession on Mt. Nassau probably begins in the lower part of Artinskian, judging from correlations of the Darlington Limestone with beds in New South Wales and Western Australia, and the ages determined on the beds in the other States, especially on the ammonites in the Western Australian succession. On bryozoan evidence Crockford (1951) considered the "Woodbridge Glacial Formation" at Eaglehawk Neck to be basal Kungurian, so that the higher formations are probably Kungurian or possibly younger.

Of special significance is the occurrence of the fresh water beds in the Faulkner Group, signifying a period of emergence, broken here by a minor submergent phase, in the general submergence during the Permian. The Permian succession in south-eastern Tasmania, when considered as a whole show initial deposition of tillite on a land surface, then marine deposition, an emergence, followed by another submergence and finally an emergence. This sequence of events has considerable parallel with those in the Permian in New South Wales but whether similar events were actually contemporaneous in the two areas is not yet established. There is some evidence from correlation already made that they could have been roughly simultaneous. The parts played in the movements of sea level in Tasmania by glaciation and by tectonic activity cannot yet be elucidated. This mode of transport is supported by the texture and icebergs were important in transportation. The erratics include granite, feldspar porphyry and large pieces of vein quartz, limestone, mudstone, quartzite, micaceous quartzite, haematitic quartzite, slate, phyllite, muscovite schist, muscovite chlorite schist, quartz muscovite schist, quartz biotite schist (with green biotite), biotite schist, chlorite schist, graphic mica schist, tourmaline-bearing mica schist, and muscovite gneiss. The metamorphic types are much commoner than the igneous or sedimentary types. The presence of these metamorphic rocks suggests a source within the Precambrian areas of Tasmania to the south-west, west or north-west of Hobart, and all of the rock types and minerals present could come from the Precambrian, Lower and Middle Palaeozoic and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Inferences based on the mineralogy of the sediments as to the provenance are confirmed and amplified by the types of erratics present.

The erratics include granite, feldspar porphyry and large pieces of vein quartz, limestone, mudstone, quartzite, micaceous quartzite, haematitic quartzite, slate, phyllite, muscovite schist, muscovite chlorite schist, quartz muscovite schist, quartz biotite schist (with green biotite), biotite schist, chlorite schist, graphitic mica schist, tourmaline-bearing mica schist, and muscovite gneiss. The metamorphic types are much commoner than the igneous or sedimentary types. The presence of these metamorphic rocks suggests a source within the Precambrian areas of Tasmania to the south-west, west or north-west of Hobart, and all of the rock types and minerals present could come from the Precambrian, Lower and Middle Palaeozoic and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Mineralogically the sediments in this section are remarkably constant and even in the limestones of some of the characteristic minerals occur. There does not seem to be any change in overall mineral composition from bottom to top of the section. Quartz is the most common mineral and several varieties are present. Quartz with undulose extinction, quartz with rutile inclusions, quartz with zircon inclusions and quartz showing up to two zones of inclusions indicating regrowth are all present. The dominant feldspar present is microcline but orthoclase, albite, andesine and microcline are also present, andesine being more common than the others. In most formations the feldspar forms less than 10 per cent of the rock, but in the Risdon Sandstone up to 25 per cent is present. The micas include muscovite, the commonest type, green biotite and brown biotite. Minor amounts of chlorite, clay minerals and carbonaceous matter occur in several formations and hydrated iron oxides occur in most formations. Heavy, accessory minerals include zircon, apatite, tourmaline (usually chlorite), garnet, ilmenite, magnetite, pyrite, epidote and rutile. Calcite is common on several horizons and dolomite has been noted in the Grange Mudstone. Montmorillonite occurs in the Berriedale Limestone and nontronite in the Grange Mudstone. The presence of up to 10 per cent of fresh feldspar in most formations, except the Rathbones and Parramore Formations, and up to 25 per cent in the Risdon Sandstone indicates some mineralogical immaturity in the sediments. The minerals suggest that the Permian sediments were derived from a terrain of granitic and pegmatitic rocks, quartzose sedimentary rocks and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Inferences based on the mineralogy of the sediments as to the provenance are confirmed and amplified by the types of erratics present.

While the Berriedale Limestone is overlain by the Grange Mudstone in many places, there is stratigraphical and palaeontological evidence that the Berriedale and Grange Formations are equivalent in age and that the Berriedale Limestone is replaced in stratigraphic position to the south-east by the Grange Mudstone. Thus the two formations are considered to be at least partly facies variants of one another.

Mineralogically the sediments in this section are remarkably constant and even in the limestones of some of the characteristic minerals occur. There does not seem to be any change in overall mineral composition from bottom to top of the section. Quartz is the most common mineral and several varieties are present. Quartz with undulose extinction, quartz with rutile inclusions, quartz with zircon inclusions and quartz showing up to two zones of inclusions indicating regrowth are all present. The dominant feldspar present is microcline but orthoclase, albite, andesine and microcline are also present, andesine being more common than the others. In most formations the feldspar forms less than 10 per cent of the rock, but in the Risdon Sandstone up to 25 per cent is present. The micas include muscovite, the commonest type, green biotite and brown biotite. Minor amounts of chlorite, clay minerals and carbonaceous matter occur in several formations and hydrated iron oxides occur in most formations. Heavy, accessory minerals include zircon, apatite, tourmaline (usually chlorite), garnet, ilmenite, magnetite, pyrite, epidote and rutile. Calcite is common on several horizons and dolomite has been noted in the Grange Mudstone. Montmorillonite occurs in the Berriedale Limestone and nontronite in the Grange Mudstone. The presence of up to 10 per cent of fresh feldspar in most formations, except the Rathbones and Parramore Formations, and up to 25 per cent in the Risdon Sandstone indicates some mineralogical immaturity in the sediments. The minerals suggest that the Permian sediments were derived from a terrain of granitic and pegmatitic rocks, quartzose sedimentary rocks and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Inferences based on the mineralogy of the sediments as to the provenance are confirmed and amplified by the types of erratics present.

With some exceptions to be dealt with shortly the rocks of the section all show some common textural features, namely the poor sorting, exemplified megascopically by the presence of erratics, lack of cross or graded-bedding, and marked angularity of grains, many of which are almost cuspatel. In conjunction with the mineralogical immaturity, these features could be taken to indicate tectonic instability in the source and depositional areas, but the shape of the beds (tabular) and known distribution of thickness of beds and formations indicates a fairly stable depositional area. The presence of numerous erratics and fresh feldspars indicate that disintegration predominated over decomposition in the source area and that glaciers and icebergs were important in transportation. This mode of transport is supported by the texture
of the rocks. Deposition apparently occurred below wave base as shown by the poor sorting and lack of current or wave structures. This does not necessarily mean deep water. Slump structures are uncommon and graded bedding absent so that turbidity currents do not seem to have been important agents of transportation. The best explanation of most features of the sediments seems to be one involving glacial interaction and transportation. The exception to these remarks are the Rathbones and Parramore Formations which combine relative mineralogical maturity with good sorting, lack of erratics, cross-bedding ripple marking, slump structure and intraformational conglomerates. Except for the high degree of angularity of their grains they are normal members of the ortho-quartzite-limestone suite. It has been suggested earlier that they were produced mainly by reworking of earlier Permian sediments.

One feature of special interest is the development of a mosaic texture in several of the sandstones, e.g., Rathbones, Jarvis, "Woodbridge" and Risdon Formations, by the regrowth of quartz so that the quartz grains often have sutured contacts. This produces a texture similar to that of contact metamorphism, but in this section there is at least 140 feet of sediment below the Rathbones Formation and 600 feet of sediment above metamorphic hornfelses, but in this section there is at least 140 feet of sediment below the Rathbones Formation and 600 feet of sediment above the Risdon with no dolerite and the nearest dolerite laterally is over half a mile away. Because of this the mosaic texture is regarded as a product of normal lithification rather than contact metamorphism.

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### TYPE SECTION OF THE PERMIAN SYSTEM IN HOBART

**LOCALITY INDEX**

<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>East</th>
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<td>Bothwell</td>
<td>42° 23'</td>
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<td>Coles Bay</td>
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<td>Cressey</td>
<td>41° 01'</td>
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<td>735.6</td>
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<td></td>
<td>509.1</td>
<td>735.3</td>
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<tr>
<td>Quarrries, Granton</td>
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<td>568.5</td>
<td>727.4</td>
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<tr>
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<td>513.5</td>
<td>717.6</td>
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<tr>
<td>Huon Road</td>
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<td>504.0</td>
<td>726.3</td>
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<tr>
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<tr>
<td>Mt. Faulkner</td>
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<tr>
<td>Mt. Nassau</td>
<td></td>
<td></td>
<td>511.3</td>
<td>729.7</td>
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<tr>
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<td>521.5</td>
<td>715.5</td>
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<tr>
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<tr>
<td>Glenorchy</td>
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The following localities are all close to Hobart so that their co-ordinates are given in terms of the state grid system. Co-ordinates are given as thousands of yards east and north of the origin of that grid system.
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UNIVERSITY OF TASMANIA

DEPARTMENT OF GEOLOGY

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THE MALBINA SILTSTONE AND SANDSTONE

by

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University of Tasmania

and

DONALD E. READ
Launceston High School

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44. TEACHERS' EDITION OF NO. 48.

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ABSTRACT

The Malbina Siltstone and Sandstone overlies the Cascades Group and underlies the Risdon Sandstone in the Hobart area, Tasmania. This unit has been called "Woodbridge Glacial Formation" and other names. In the type section five members can be recognized: "A", a basal sandstone; followed by "B", a siltstone; "C", a thin-pebbly sandstone; "D", a siltstone; and "E", the uppermost richly fossiliferous sandstone and siltstone. Some of the sandstone beds are poorly sorted and graded. The silts were deposited in fairly deep water and deposition of silt was interrupted from time to time by inrushes of turbidity currents bringing pebbles, sand and shells from shallower water. Erratics indicate the presence of rare icebergs. The formation is Upper Artinskian or Kungurian.

INTRODUCTION

This formation was first recognized by Voisey (1938, p. 313) who referred to it as the "Woodbridge Glacial Stage". Lewis (1946, p. 22) called it "Lindisfarne Conglomerate Stage" but was not consistent (see Smith, 1959, pp. 148-149) so that Prider (1948, p. 34) suggested the retention of Voisey's term, which was amended to "Woodbridge Glacial Formation" by Hills and Carey (1949, p. 31) and used in that form by a number of later authors.

McKellar (1957) used the term "Woodbridge Group" for the rocks between the Liffey Group and the Ferntree Group in the Western Tiers. In terms of the Hobart succession his "Woodbridge Group" would probably be equivalent to the top of the Faulkner Group, the Rayner Sandstone, Cascades Group of Banks and Hale (1957) and the formation here called Malbina Siltstone and Sandstone. The term "Woodbridge" was first used by Lewis (1937, p. 434) for rocks at Woodbridge which he correlated with rocks at Cape Lamanon on the basis of the presence of "erratics" in both. The "Cape Paul Lamanon Series" is probably equivalent to the Malbina Formation as here used but has not been carefully studied. The "Woodbridge Series" at Woodbridge is an unbedded, poorly-sorted, ungraded rock with numerous striated and faceted pebbles and is a true tillite. It is lithologically quite distinct from the bedded, fossiliferous, pebbly sandstones and siltstones of the "Woodbridge Glacial Formation" in the Hobart area. In the Woodbridge area the section is not clear but the tillite appears to be overlain at some distance by a mudstone identifiable on fossil evidence as Bundella Mudstone. In this same area rocks having the lithology and fossils of the Malbina Formation overly the Cascades Group which rests in turn on the Faulkner Group which contains typical carbonaceous siltstones near Oyster Cove Post Office. The Faulkner Group overlies, in turn, the Bundella Mudstone. It is, thus, very unlikely that the "Woodbridge Series" at Woodbridge and the "Woodbridge Glacial Formation" are the same formation or correlates. The "Woodbridge Series" is probably equivalent to the Wynyard Tillite at the base of the Permian succession in Tasmania.

It seems wisest to discontinue the use of the term "Woodbridge" except for the tillite at Woodbridge. The formation called "Woodbridge Glacial Formation" in the Hobart area is here named the "Malbina Siltstone and Sandstone" to which the "Cape Paul Lamanon Series" may be equivalent. The "Woodbridge Group" of McKellar should be given a different name.

When Banks and Hale described the Permian sequence in the Hobart area in 1957 they were unable to quote a suitable type section for the "Woodbridge Glacial Formation". Every section examined at that stage was unsuitable because of lack of outcrop, lack of base or top, or faulting.

During 1959 Read mapped the area west of Granton as part of an honours course in geology at the University of Tasmania. A good section in and around Jarvis Creek (see map, fig. 1, Banks
and Hale, 1957) was found and then surveyed in detail by both authors. The section occurs on the hill slopes west of Jarvis Creek and in the bed of Fergusson Creek and the southern slope of the valley of Fergusson Creek just above its junction with Jarvis Creek. Thicknesses were measured by level and staff and thicknesses between stations on steep slopes or cliffs with a steel tape. A dip of 34° degrees to the south-west was used in the thickness calculations. It is unlikely that any of the thicknesses are in error by as much as a foot and many of them are in error by less than an inch. The authors wish to acknowledge their indebtedness to Dr. E. Williams, now of the Geological Survey of British Guiana, for many stimulating discussions on the conditions of formation of the unit being discussed, and to Mr. A. H. Spry for assistance with the mineral identifications and helpful comments on the manuscript and to Professor S. W. Carey for helpful criticism.

**STRATIGRAPHY**

The Malbina Siltstone and Sandstone is defined as that formation of siltstone and sandstone 300 feet thick which conformably overlies the Grange Mudstone and underlies the Risdon Sandstone in Jarvis Creek (co-ordinates 50422.73528). The name is derived from the old Malbina Cemetery nearby. The formation contains *Stenopora crinita*, *Strophalosia typica* and *Strophalosia ovalis* and is Upper Artinskian or Kurganian in age.

In the type area the formation can be divided into five members, A, B, C, D, E, which can also be recognized in the South Arm area (see Green, 1961) and at Eaglehawk Neck.

**Member A**

The lowest member ("A") is composed of sandstone with subordinate siltstone and is about 150 feet thick. The detailed section is given as Appendix A.

Coarse sandstone occurs on four horizons, the main development being that of unit 19 which probably consists of three beds each of which have fossils and pebbles at the base. The coarse sandstone units vary from 0.10-4.40 feet thick, averaging 0.97 feet thick in Member A and 1.34 feet thick in the whole formation. Medium sandstone is more common (23% approx. of Member A, 11.5% approx. of whole formation) than the coarse sandstone. The beds of medium sandstone vary from 0.20-2.30 feet thick, averaging 1.34 feet thick in Member A, 1.20 feet in the whole formation and having a modal thickness of beds of 1.0 feet. Fine sandstone forms 46% of Member A, 29% of the whole formation. It occurs in beds from 0.10-4.40 feet thick, averaging 1.19 feet for Member A and having a modal thickness of 0.5 feet for Members A-D. Siltstone forms a relatively small proportion (about 13%) of Member A but almost half (about 49%) of the whole formation. The beds of siltstone in Member A vary from 0.05-1.00 feet thick, averaging 0.41 feet and having a modal thickness of 0.2 feet. The siltstone units in higher members are much thicker but each may consist of a number of beds. The bedding thicknesses are summarized in Table I.

Member "A" can be divided into two sub-members, the lower about 90 feet thick in which most of the medium and coarse sandstones occur and the higher about 40 feet thick which consists mainly of fine sandstone with some siltstone. The lower sub-member, and especially the lower 35 feet of it (Units 1-19) in which the medium and coarse sandstone is concentrated, outcrops strongly in the Hobart area, e.g., Porter Hill, Glenorchy, Claremont, Mt. Nassau and Mt. Dromedary, and near New Norfolk, and has drawn the attention of a number of geologists for this reason (e.g., Brill 1956, Banks and Hale 1957, McDougall 1959, Woolley 1959). It outcrops somewhat similarly to the Risdon Sandstone, with low scarps backed by a bench. This sub-member conformably overlies the Grange Mudstone on the Sky Farm Road at Claremont (323092) and probably in the type area.

A sandstone from near the base of this member was briefly described by Banks and Hale (1957, p. 59). In connection with the present study, thin sections of the numbered specimens referred to in the detailed section above were examined using magnifications 24, 75, 340, and 750. Percentages were estimated by visual comparison with charts (Terry and Chillingar, 1955), the roundness of grains estimated by comparison with those figured on A.G.I. Data Sheet 7 (Geotimes, vol. III, No. 1) and sphericities by comparison with silhouettes.

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**Table I**

**Relationship of Bedding Thickness to Grain size in Malbina Siltstone and Sandstone.**

<table>
<thead>
<tr>
<th></th>
<th><strong>MEMBER A</strong></th>
<th><strong>MODAL THICKNESS</strong></th>
<th><strong>WITH FORMATION</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THICKNESS</strong></td>
<td><strong>NO. OF BEDS</strong></td>
<td><strong>LIMITS OF THICKNESS OF BEDS</strong></td>
<td><strong>AV. THICKNESS</strong></td>
</tr>
<tr>
<td>Coarse Sandstone</td>
<td>9.71</td>
<td>10</td>
<td>0.10 - 2.60</td>
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<tr>
<td>Medium Sandstone</td>
<td>29.40</td>
<td>22</td>
<td>0.20 - 2.30</td>
</tr>
<tr>
<td>Fine Sandstone</td>
<td>60.79</td>
<td>51</td>
<td>0.10 - 4.40</td>
</tr>
<tr>
<td>Siltstone</td>
<td>17.15</td>
<td>42</td>
<td>0.05 - 1.10</td>
</tr>
</tbody>
</table>

All figures quoted in feet.
shown by Krumbein and Sloss (1951, p. 81, f. 4-9). Grainsize was measured by micrometer ocular and referred to the Wentworth grade scale. Results of the examination of the thin sections are summarized in Table II (Appendix B).

The rocks all have a disrupted framework with phenoclasts in an abundant to predominant matrix. The main component of the phenoclasts is quartz. The quartz includes varieties with undulose extinction, lines of gas bubbles, inclusions of rutile, secondary regrowth, inclusions of crystallised zircon, inclusions of rounded zircon and some with inclusions of microcline. Rock fragments, mainly schist and quartzite but with some igneous rocks, are generally more abundant than feldspar phenoclasts. These latter include orthoclase, microcline, mica perthite and soda-rich plagioclase. Muscovite occurs as detrital flakes in some of the sandstone but is only a minor constituent. Fossil fragments are seen in this section but are uncommon. Their distribution is somewhat irregular and they are generally concentrated at the base of the sandstone.

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The rocks may thus be referred to as poorly to very poorly sorted. Examination of the thin sections in that they are rarely straight for more than a few millimetres and some completely enclose ovoid or tear-drop shaped patches of coarser material and they branch and are discontinuous along their length. The strings are roughly parallel to the bedding. In three specimens some of the strings are very thin and so arranged as to suggest festoon cross-bedding. One specimen (1145) consists of a section across two sedimentation units totalling eight inches thick. At the base is sandstone with a few medium pebbles and almost free of strings. A little higher is a zone in which strings are more common and the grains somewhat smaller. Near the top of the first unit is a zone of light grey siltstone. This is followed upwards by sandstone with very fine pebbles then at the top light grey siltstone with strings suggesting festoon cross-bedding. In both sedimentation units the zone of admixture includes vertical structures delineated by strings and in the top unit a "Y"-shaped structure in sand defined by light grey siltstone which is probably a replacement structure produced by load (i.e., a flame structure). This specimen shows graded bedding in two poorly-sorted units and the texture and structure are best explained by deposition from turbidity currents.

The sediments examined in thin section all belong to the greywacke suite on textural and structural grounds and could be referred to as sub-labile greywackes (Packham, 1954) or more specifically as lithic and feldspatho-lithic sub-labile arenites (Crook, 1960).

Fossils are present but not abundant. They tend to be concentrated at the base of the sandstone units and associated with pebble bands above bedding planes. In the lower part of Member A they are much more common than in the upper and dominant fossil types in the sandstones are spiriferids including Ingelarella, but gastropods and fenestellids are also present. Many of the fossils appear to be fragmentary and some of the spiriferids have become disarticulated. Fossils are more common in the lower part of Member A than in the higher part. Fenestellids occur rarely in the sandstone units and somewhat more commonly in siltstones at the top of graded units and in siltstones interbedded with the sandstone. Some fragments which may have been plants occur near the top of the member (unit 90) associated with spiriferids.

The rocks which form up to 5% of the rock, are concentrated in the sandstone beds but occur rarely in the siltstones. Most of the rock fragments are rounded or sub-rounded and less than two cms. long. The longest rock fragment seen in this section was about 18 cms. long. The main fragments are of quartz and quartzite but phyllite, slate, vein quartz, quartz-mica schist, quartz feldspar porphyry, siltstone, shale and clay also occur. It is notable that many of the sandstone bands especially those near the base contain no "erratics" within the area examined in detail.
The pebbles in most beds show no obvious preferred orientation but in unit 97 some of the pebbles stand on end. Graded bedding was identified in the field in a number of units, e.g., 3, 13, 43, 53, 62, 73, 76, and suspected in others, e.g., 1.

The siltstones in some units are laminated and carbonaceous and in unit 2 contain pyrite, indicating deposition in quiet, somewhat stagnant, water. Some siltstones contain fenestellids.

From adjacent areas Strophalosia typica, Granotonia, Neospirifer, Dielasma and pectinaceans have been reported (McDougall, 1959, p. 62; Woolley, 1959, pp. 99-101) from the basal member.

**Member B**

The second member ("B"), 85 feet in thickness, consists predominantly of fissile and non-fissile siltstone with eight beds of medium or fine sandstone varying from 0.1 to 4.60 feet in thickness. Bedding is difficult to identify in the siltstones. Pebbles are uncommon except in unit 107 where they reach a length of 5 cms. No fossils were seen in the siltstone but occur in the sandstones where they are associated with pebbles. The fossils noted are spiriferids, especially Ingelarella. Most of the sandstones are poorly sorted and unit 113 is clearly graded. The pebbles in unit 121 have long axes orientated sub-horizontally. The range of pebble types is similar to that in Member "A". The siltstones consist essentially of quartz with some feldspar, chlorite and mica flakes as well as very small rock fragments. Sorting which appears to be fairly good in hand specimen, is shown by thin-sections to be poor (Banks and Hale, 1957, p. 59). Fissile siltstones become more common near the top of the member. A detailed section through the member is shown as Appendix C.

**Member C**

Member "C", five feet thick, consists of very pebbly sandstone which is almost a conglomerate and is very similar in lithology to the basal part of the Risdon Sandstone. In addition to lithological similarity to the Risdon Sandstone, the member shows similarity in type of weathering, outcropping boldly as a low cliff backed by a narrow bench. It could easily be mistaken in field mapping for the Risdon Sandstone but it has no richly fossiliferous member below it as has the Risdon Sandstone. The lower contact has irregularities up to an inch or two in depth but no current direction could be deduced from the irregularities. The pebbles which consist mainly of quartz and quartzite, are fairly well rounded and with the exception of a quartzite block over 30 cms. long are less than 10 cms. long. The matrix consists of particles of quartz and a small amount of feldspar of coarse sand grade.

**Member D**

The next member, "D", consists of 55 feet of fissile siltstone with some non-fissile bands. In hand specimen the siltstones appear to be fairly well sorted and composed mainly of quartz. Fossils and pebbles were not observed in this member.

**Member E**

The top member, "E", consists of 25 to 27 feet of fossiliferous fine-grained sandstone and siltstone. Fossils, which are not common near the base where spiriferids do occur, become very abundant in the top 10 to 11 feet and lenses of dark grey, foetid limestone occur on this level (Banks and Hale, 1957, pp. 59-60). Pebbles of quartz up to 2.5 cms. long were observed in this member; the sandstones are well-sorted and consist of poorly rounded particles of high sphericity. The rocks are compact and brittle or tough. The fossils in this member are spiriferids, including Ingelarella, Strophalosia ovalis, Terrakea, fenestellids, Stenopora, Pervispira and a pectinacean. The bivalves are commonly complete, the spinose brachiopods still have spines attached to the shells, some of which are in growth position, and several funnel-shaped fenestellid colonies were observed to be complete and in growth position. On the whole the assemblage is biocoenotic in this member in contrast to the probably thanatoocoenotic faunal assemblages in the other members. In adjacent areas this member contains Strophalosia ovalis, Terrakea solida, long-hinged spiriferids, fenestellids and pectinaceans (McDougall, 1959, p. 62), Prototemporapano ampla (Woolley, 1959, p. 100), Ingelarella ("Martiniopsis") and Stenopora crinita (Banks and Hale, 1957, p. 59).

**CORRELATION**

The Malbina Siltstone and Sandstone occurs widely in Tasmania and may be provisionally identified at Firewood Siding (south of Zeehan), in the north-west coastal area, at Coles Bay, Maria Island and at Mount La Perouse. Some facies variations occur within Tasmania but cannot yet be fully assessed. Even in areas close to the type section, e.g., New Norfolk, the succession seems to be somewhat different from that in the type section (Woolley, 1959) but the stratigraphy is not so well known.

Voisey (1938, p. 326) recorded "Spirifer" vespertilio, "Martiniopsis" oviformis, "M" subradiata, "Platytschisma" oculus, Astartila and Hyolithes from this formation on the shore-platform at Linhisarne where Member "A" is exposed: From Eaglehawk Neck he recorded Fenestella fusca, F. internata and Stenopora crinita. The richly fossiliferous beds at Eaglehawk Neck occur near the Blowhole or just north of the northern headland of Pirates Bay but in both places are above a coarse sandstone correlated on lithological grounds and place in the succession with member "C". The record of S. crinita was confirmed by Crockford (1951) who correlated the beds at Eaglehawk Neck with the Mulbring Sub-group in New South Wales. The occurrence of Strophalosia typica in the lower part of the Malbina Siltstone and Sandstone suggests correlation with some part of the Bangert Sub-group of New South Wales (Upper Arthurskian-Lower Kungurian) and the Ingelara Beds of Queensland. The presence of Strophalosia ovalis in the uppermost member suggests correlation with the Mantuan Productus Bed in Queensland (Maxwell, 1954).
CONDITIONS OF DEPOSITION

The sources of the clastic material in this formation have been considered by Banks and Hale (1957, p. 60) to be predominantly metamorphic rocks like the Precambrian rocks of Tasmania but some older sediments, granitic and pegmatitic rocks were included in the provenance. Observations in the type section give further evidence of these sources and also suggest some old volcanic rocks in the provenance.

All previous authors have postulated that the numerous "erratics" in the Malbina Siltstone and Sandstone were dropped from icebergs into marine sediments and that the abundance of them relative to that in the underlying formations indicated an increase in the intensity of glaciation. Observations in the type section did not reveal any abundance of undoubted erratics. The pebbles tend to be sorted than the sandstones. Some siltstones are noticed also that in the sandstones the fossils are sub-angular to sub-rounded and in a few cases show preferred orientation parallel to the bedding. Only in Unit 97 were pebbles seen to be standing on end. Unfortunately, exposure of this unit did not allow observation of broken laminae, indicative of dropped pebbles. Green (1961, p. 20) does, however, record one undoubted erratic in this formation on the shoreline west of Mount Mather. This erratic is elongated and oriented with the long axis almost vertical and clearly breaks the laminations of the siltstone enclosing it. Most of the pebbles in the type section are sub-angular to sub-rounded and no clear examples of faceted pebbles were observed.

Graded bedding was observed in a number of units. The graded beds are poorly sorted. It is noticeable also that in the sandstones the fossils are sub-angular to sub-rounded and associated with the pebble bands. The siltstones are better sorted than the sandstones. Some siltstones are laminated, most are carbonaceous and one pyritic, thus indicating deposition under quiet conditions with reducing conditions during deposition. Conditions were, however, favourable at times for growth of fenestellids in the silt environment.

The reconstruction which accounts most satisfactorily for observations made to date, is that of a relatively deep sea floor on which silt transported by slow currents from some distant source was being deposited while melting of comparatively rare icebergs contributed a few dropped pebbles to the sediment. In a shallower area gravel, coarse, medium and fine sands were being deposited and heavy-shelled spiriferids, pelieycods and gastropods were living. From time to time instability in the source area probably in northwestern, western, or south-western Tasmania (Banks and Hale, 1957, p. 62) or beyond the present confines of Tasmania in those directions. The causes of the instability may have been climatic or tectonic and it is perhaps significant that similar rocks occur at about the same time in New South Wales and that orogenic movements are postulated in the Hunter River area of New South Wales at about this time (Browne, 1950, Vol. 1, p. 386). Dropped pebbles occur in the Hobart area in the Berriedale Limestone (quarries near Collinsvale) as shown by orientation of the pebbles and breaking of laminae. There does not seem to be any significant difference in the abundance of such pebbles in the upper part of the Cascades Group from that in the Malbina Formation. Thus there is no clear evidence of an increase in intensity of glaciation at this level as postulated by Lewis (1937) and later authors.

The increase in the sandstone and pebble content of the sediments from the Grange Mudstone into the Malbina Formation is thus not directly due to increasing intensity of glaciation but to greater instability in a source area probably in northwestern, western, or south-western Tasmania (Banks and Hale, 1957, p. 60) to have been predominantly metaceous, richly-fossiliferous siltstone of the Grange type and below the lowest poorly-fossiliferous, grey, non-calcareous siltstone of the Malbina type. It is suggested that the change in faunal content does not necessarily reflect a significant change in physical or chemical conditions at the site of deposition but can well be explained as due to the mass killing of the benthonic fauna by suffocation under the sediments deposited by turbidity currents, the frequency of occurrence of which was too high to allow recolonisation of the area from parts of the sea-floor unaffected by these currents.

Member "C" and the Risdon Sandstone are also thought to be turbidity current deposits but more detailed work will have to be done to establish this. If they are, they again reflect instability in the source area.

The topmost member of the formation shows a return of abundant life to the area, and it is probably significant that this occurs after the longest interval of uninterrupted silt deposition in the area. Quiet conditions prevailed during deposition of the member and the faunal assemblage is dominantly biocoenotic. The dominant organism in this assemblage varies from place to place in southern Tasmania—"Strophalosia, Terrakea, spiriferids, fenestellids and pelieycods or gastropods being the dominant forms in different places. Such variation would be expected if the faunas were biocoenotic. Local marine life was again destroyed by the widespread deposition of the Malbina Sandstone and reappeared only fitfully during deposition of the Ferntree Mudstone.
References


Appendix A

Detailed Stratigraphy of Member A.

Top:

Unit 100.
0.1 feet.—Fine sandstone—fissile with a few small pebbles.

Unit 101.
0.6 feet.—Medium sandstone—similar to unit 100 but this unit is fissile.

Unit 102.
1.0 feet.—Medium sandstone—very pebbly with pebbles of quartzite and slate up to 4 cms. in length.—sorting poor, splicity high, roundness low—compact, brittle, non-fissile.

Unit 99.
0.3 feet.—Siltstone—top three inches fissile—pebbles up to 1.5 cms. long.

Unit 98.
0.25 feet.—Fine sandstone—quartzite pebbles up to 2 cms. in length.—fragments of muscovite near the base.

Unit 97.
0.55 feet.—Fine sandstone—pebbles up to 8 cms. in length.—some pebbles of this bed standing on end—top of this bed fissile in places.

Unit 96.
1.0 feet.—Fine sandstone—similar to unit 93.

Unit 95.
0.05 feet.—Fissile siltstone.

Unit 94.
0.05 feet.—Fine sandstone—similar to unit 92—pebbles up to 0.5 cms.

Unit 93.
0.15 feet.—Fine sandstone—sorting good, splicity high, roundness low—fissile.

Unit 92.
0.75 feet.—Fine sandstone—dominantly quartz and some feldspar—quartz pebbles up to 5 cms. in length properties similar to unit 90 but with no fossils.

Unit 91.
0.1 feet.—Fissile siltstone with some pebbles.

Unit 90.
0.7 feet.—Fine sandstone—quartz—sorting poor, splicity high, roundness low—fragments of phyllite up to 5 cms. in length—fragments of spiriferids and 1 plant fragments.

0.4 feet.—Sandstone and siltstone—medium sandstone with a clay matrix—quartzite pebbles up to 2 cms. in length—most pebbles well rounded—top three-quarters of an inch of the unit fissile siltstone.

0.3 feet.—Sandstone and siltstone—basal two and a half inches medium sandstone containing pebbles up to 2.5 cms. in length overlain by 4 inches of laminated, non-fissile siltstone—overlain by 4 inches of fissile, laminated siltstone—medium grey.

Unit 87.
0.4 feet.—Fissile siltstone—similar to unit 77.

Unit 86.
1.05 feet.—Fine sandstone—similar to unit 78—pebbles up to 1 cm. at base of unit.

Unit 85.
0.65 feet.—Fine sandstone—quartz present—no fissile sorting good, splicity high, roundness low—compact and mostly non-fissile although the top 2 inches are fissile and with an increase in silt size material.

0.5 feet.—Fine sandstone—pebbles of slate, quartzite and quartz-feldspar porphyry—pebbles up to 4 cms. in length specimen 1150.

Unit 83.
0.30 feet.—Fissile siltstone—similar to unit 77.

Unit 82.
2.65 feet.—Fine sandstone—few pebbles up to 1.25 cms. in length—partings at 2, 5, 10, and 25 inches above the base.

Unit 81.
0.45 feet.—Fissile siltstone—similar to unit 77.

Unit 80.
2.6 feet.—Fine sandstone—similar to unit 78—parting 7 inches above the base.

Unit 79.
0.33 feet.—Fissile siltstone—similar to unit 77.

Unit 78.
3.0 feet.—Fine sandstone—about 40 to 50 per cent quartz—matrix not seen—rock fragments not seen—no fossils—sorting good, splicity fairly high, roundness low—compact, brittle, non-fissile.

Unit 77.
0.2 feet.—Fissile siltstone—light bluish grey—sorting good—other properties not obvious.

Unit 76.
1.75 feet.—Medium sandstone at base with numerous pebbles of quartzite—grades into a fine sandstone at approximately 0.5 feet above the base.

Unit 75.
0.1 feet.—Fissile siltstone—similar to unit 72.

Unit 74.
0.25 feet.—Fissile siltstone—similar to base of unit 73.

Unit 73.
0.75 feet.—Fine sandstone—similar properties to unit 71 but grading into a fissile siltstone in the top 0.1 feet.

Unit 72.
0.2 feet.—Siltstone—fissile—sorting good.

Unit 71.
1.0 feet.—Fine sandstone—quartz—matrix not obvious—rock fragments not obvious—no fossils—sorting good, splicity high, roundness low—compact, brittle, tough.

Unit 70.
0.4 feet.—Laminated non-fissile siltstone—sorting good—compact, brittle.

Unit 69.
2.7 feet.—Fine sandstone—quartz and some feldspar—matrix not seen—rock fragments of quartzite at base and at 2.24 feet above base—one pebble measured 10 cms. in length—no fossils seen—sorting poor, splicity high, roundness low—compact, brittle, non-fissile.

Unit 68.
0.8 feet.—Siltstone—laminated—fissile—sorting good.

THE MALBINA SILTSTONE AND SANDSTONE
Unit 67. 1.5 feet. —Fine sandstone—properties similar to unit 65.

Unit 66. 0.4 feet.—Coarse sandstone—dominantly quartz with a little feldspar—clay matrix—no fossils—no rock fragments seen—some of the quartz fragments up to 3 mm.—sorting poor, sphericity high, roundness poor—compact, brittle, non-fissile.

Unit 65. 0.65 feet.—Fine sandstone—sorting good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 64. 3.0 feet.—Fine sandstone—quartz with coarse grade quartz fragments which are vertical up to 5 cm. in length—tough—base up to 8 cms. in length—patch of pebbles 7 inches from top of unit with a parting under it.

Unit 63. 0.35 feet.—Siltstone—fissile—similar properties to unit 61.

Unit 62. 2.5 feet.—Sandstone and siltstone—40 per cent quartz, some feldspar—rock fragments rare but in the top part of the unit occurred one piece of slate 18 cms. by about 2.5 cm. long. Some other medium to coarse quartz pebbles up to 1 cm. in length—medium sandstone—quartz—many quartz particles up to 0.15 mm. in size—clay matrix—no fossils except this unit is fissile.

Unit 61. 0.4 feet.—Siltstone—laminated—fissile, colour blue grey—sphericity high, roundness low—compact, brittle, non-fissile—light bluish grey with white patches—specimen 1149.

Unit 60. 0.6 feet.—Fine sandstone—similar to unit 39.

Unit 59. 1.1 feet.—Siltstone—fine-grained—sorting poor, sphericity fairly high, roundness low—compact, brittle, non-fissile.

Unit 58. 0.9 feet.—Fine sandstone—quartz—carbonaceous laminations—specimen 1144.

Unit 57. 1.2 feet.—Medium sandstone—quartz—clay matrix—specimen 1143.

Unit 56. 0.8 feet.—Fissile siltstone—olive grey colour—matrix not visible—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 55. 0.5 feet.—Fissile siltstone—similar to unit 61 except this unit is fissile.

Unit 54. 0.3 feet.—Fine sandstone—fissile—similar properties to unit 31 except this unit is fissile.

Unit 53. 0.7 feet.—Fine sandstone—fissile—similar properties to unit 31.

Unit 52. 1.7 feet.—Fine sandstone—quartz—carbonaceous laminations—matrix not visible—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 51. 2.3 feet.—Fine sandstone—quartz—quartz fragments coarser at base than at top—fragments abundant—no fossils—sorting poor, sphericity medium to high, roundness low—compact, brittle, massive—light grey blue.

Unit 50. 1.1 feet.—Siltstone—fine-grained—most properties not obvious—matrix—fissile—grey green.

Unit 49. 0.4 feet.—Fine sandstone—similar to unit 39.

Unit 48. 0.2 feet.—Siltstone—similar to unit 42.

Unit 47. 1.05 feet.—Medium sandstone—quartz—sorting—middling, sphericity high, roundness, low—compact, brittle, non-fissile.

Unit 46. 0.15 feet.—Siltstone—similar to unit 42.

Unit 45. 0.8 feet.—Fine sandstone—similar to unit 39.

Unit 44. 0.1 feet.—Siltstone—similar to unit 42.

Unit 43. 1.2 feet.—Medium sandstone—slightly coarser at base with 0.5 cms. long quartz fragments and rock fragments—at the top becomes a fine sandstone with some small quartz fragments—this may represent grading—sorting from middling at top to poor at base—sphericity fairly high and roundness low—compact, brittle, non-fissile.

Unit 42. 0.10 feet.—Siltstone—sorting middling—compact, non-fissile.

Unit 41. 0.45 feet.—Fine sandstone—similar properties to unit 39.

Unit 40. 0.18 feet.—Fissile siltstone—similar properties to unit 26.

Unit 39. 0.1 feet.—Fine sandstone—quartz—sorting—middling, sphericity medium, roundness low—compact, brittle, non-fissile.

Unit 38. 0.4 feet.—Siltstone—laminated—fissile, colour blue grey.

Unit 37. 2.5 feet.—Medium sandstone—quartz—few quartz particles and small rock fragments up to 0.3 cms.—clay matrix—sorting middling, sphericity high, roundness low—compact, non-fissile.

Unit 36. 0.5 feet.—Fine sandstone—fissile—similar to unit 34.

Unit 35. 2.0 feet.—Fine sandstone—quartz and a little feldspar—no rock fragments—no fossils—matrix not visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 34. 0.5 feet.—Fine sandstone—fissile—similar to unit 34.

Unit 33. 0.7 feet.—Fine sandstone—fissile—properties similar to unit 31.

Unit 32. 0.6 feet.—Fissile siltstone—similar properties to unit 28.

Unit 31. 0.7 feet.—Fine sandstone—quartz—no rock fragments—no fossils—matrix not visible—sorting good, sphericity medium, roundness low—compact, fairly brittle, non-fissile.

Unit 30. 0.5 feet.—Fissile siltstone—similar properties to unit 28.

Unit 29. 4.4 feet.—Fine sandstone—quartz and rare particles of feldspar—pebbles of vein quartz—matrix siliceous—compact, brittle, tough.

Unit 28. 0.6 feet.—Fissile siltstone—blue grey colour, most properties not visible.

Unit 27. 3.1 feet.—Fine sandstone—quartz, some feldspar—slate pebbles—matrix not visible—no fossils—sorting middling, sphericity high, roundness low—compact, brittle, tough.

Unit 26. 0.1 feet.—Fissile siltstone—olive grey colour—matrix not visible—no rock particles or fossils.

Unit 25. 1.5 feet.—Medium sandstone—quartz—clay matrix—at base small lenses of coarse grained quartz particles and rock fragments up to 0.15 cms.—slate pebbles—a few spiro-

ferids—sorting middling to poor, sphericity medium to fairly high, roundness low—compact, brittle, non-fissile.

Unit 24. 0.6 feet.—Fine sandstone—quartz—carbonaceous laminations—matrix not visible—no rock fragments—no fossils—sorting good—sphericity high—roundness low—fissile.

Unit 23. 2.2 feet.—Medium sandstone—quartz with some particles up to 1 cm. long—matrix not visible—rock fragments mainly quartzite up to 1.25 cms.—spiriferids—sorting middling to poor, sphericity high, roundness low—compact, brittle, non-fissile.
Unit 22.
1.0 feet.—Siltstone—quartz, some feldspar—rock fragments and fossils not seen—sorting middling to poor—sphericity fairly high, roundness low—compact, brittle, non-fissile—light bluish grey.

Unit 21.
1.6 feet.—Fine to medium sandstone—quartz with fragments and rock pebbles up to 0.6 cms.—long—matrix siliceous—no fossils—sorting poor, sphericity medium to high, roundness low—light yellow brown.

Unit 20.
0.45 feet.—Fissile siltstone—quartz—matrix not obvious—rock particles not obvious—no fossils—sorting good, sphericity high, roundness low—olive grey.

Unit 19.
0.1 feet.—Coarse sandstone—quartz and about 10 per cent feldspar—matrix siliceous—pebbles up to 5 cms. in length at the base and 3 cms. above—fossils in basinal at 1.9 and 4.5 feet above base—sorting poor to middling—sphericity medium to high, roundness low—fossil and pebble bands may indicate the base of beds—compact, brittle, non-fissile.

Unit 18.
0.75 feet.—Light blue fissile siltstone—similar to unit 14.

Unit 17.
2.05 feet.—Medium sandstone—quartz, some large quartz fragments—matrix partly ferruginous—fossils (about 2 per cent)—spiriferids—sorting good, sphericity high, roundness low—compact, brittle, tough.

Unit 16.
0.25 feet.—Fine fissile sandstone—quartz—rock pebbles (quartzite) up to 2.5 cms.—long—matrix not visible—no fossils—sorting poor, sphericity high, roundness low—blue grey.

Unit 15.
1.5 feet.—Fine sandstone—quartz—some quartz fragments up to 0.3 cms.—long—no rock particles visible—matrix not visible—no fossils—bluish grey—grain size is coarser at bottom of unit than at top—may represent grading—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 14.
0.3 feet.—Light blue fissile siltstone—similar properties to unit 12—but in this unit there are no fossils.

Unit 13.
2.0 feet.—Fine sandstone with fissile siltstone layers—about 1 inch thick at 0.55 and 1.1 feet above the base—physical properties similar to unit 11—spiriferids occur just above each fissile layer—sandstone layers may show graded bedding into the fissile siltstone.

Unit 12.
0.3 feet.—Fissile siltstone—mottled light bluish grey—quartz—sorting middling, sphericity medium to high—roundness low—fossils are fenestellids.

Unit 11.
0.7 feet.—Fine sandstone—some quartz fragments up to 0.6 cms.—long—quartz dominant mineral, some feldspar—rock particles not visible—matrix partly ferruginous—sorting middling, sphericity high, roundness low—Fossils occur in bands—1.3 feet above the base of the unit—bryozoans—2.15 feet above base—mainly sili casts and spiriferids—2.8 feet above base—spirognaths and gastropods—yellowish grey.

Unit 10.
0.6 feet.—Alternating fine sandstone and siltstone—quartz and feldspar—sorting middling, sphericity high, roundness low—fossiliferous—rock particles not visible—compact, brittle, tough.

Unit 9.
3.8 feet.—Medium to coarse fossiliferous sandstone—proper ties the same as unit 7 but with fewer fossils—one pebble of quartzite over 8 cms. long.

Unit 8.
0.4 feet.—Alternating fine sandstone and siltstone—quartz and feldspar—sorting middling, sphericity high, roundness low—rock particles not visible—compact, brittle, tough—contains some calcareous fossils—specimen 1142.

Unit 7.
3.6 feet.—Medium to coarse fossiliferous sandstone—70 per cent quartz, 10 per cent feldspar and 10 per cent calcareous shells—approximately 1 per cent rock particles—mainly quartzite up to 5 cms., in length—up to 10 per cent fossils—mainly spiriferids which occur in bands—10 per cent of partly ferruginous matrix—sorting middling to good, sphericity high, roundness low—bedding units about 7 inches thick—base of beds determined by coarser pebble concentrations—top 9 inches highly fossiliferous with abundant fenestellids—compact, brittle, non-fissile—light grey—specimen 1142.

Unit 6.
0.25 feet.—Fine sandstone—quartz and about 15 per cent feldspar—rock particles not visible—a few spiriferids—matrix partly ferruginous—sorting middling, sphericity is greater than 0.3, roundness less than 0.3—compact, brittle and non-fissile—yellowish grey.

Unit 5.
1.2 feet.—Alternating fine sandstone with finely laminated dark grey siltstone (4-inch units)—sandstone of quartz and feldspar with beds up to 2 inches thick—sorting middling, sphericity high, roundness low—compact, brittle, tough—yellowish grey—specimen 1141.

Unit 4.
1.8 feet.—Medium sandstone—60 per cent quartz, 20 to 30 per cent feldspar—rock particles not visible—rare Ingelarella—clay matrix—bedding plane 1.1 feet above base—sorting middling to good—sphericity greater than 0.5, roundness less than 0.3—compact, brittle, light bluish grey.

Unit 3.
1.4 feet.—Medium sandstone—70 per cent quartz—rock particles not visible—one bedding plane in centre of unit—ferruginous matrix in lower half and siliceous in top half—top half graded—rare spiriferids and fenestellids right at top of unit in some fissile material—sorting is middling sphericity greater than 0.7, roundness less than 0.3—light bluish grey—mainly unit is compact and brittle—specimen 1140.

Unit 2.
1.0 feet.—Siltstone—probably one unit—60 per cent quartz—30 per cent feldspar—pyrite—rock fragments and fossils not obvious—matrix not visible—sorting middling to poor—sphericity between 0.3 and 0.9—roundness less than 0.3—carbonaceous laminations present—compact, brittle, weathered to thin laminations—negligible porosity—light bluish grey.

Unit 1.
1.85 feet.—Medium sandstone—some particles in coarse sand grade at top of bed—80 per cent quartz particles—sili ceous matrix—no rock fragments visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile—spiriferids at base and band of fragmentary fossils 13 ins. above base—specimen 1139—yellowish grey.

There is a break of 4.53 feet below the lowest exposure of the Malbina Siltstone and Sandstone and the topmost exposure of the underlying Grange Mudstone.

Specimen numbers refer to specimens in the collection of the University of Tasmania, Geology Department. Grain sizes were measured in the field by comparison under a hand lens of the rock with a standard chart (similar to that illustrated by Chillingar (1939)). Colours quoted refer to those listed in Goddard et al. (1948).
### Appendix B.

#### Table II — Tabular Summary of Microscopic Characters of Some Rocks in Member A, Malbina Formation

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<thead>
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<th>No.</th>
<th>COMPOSITION</th>
<th>TEXTURE</th>
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<td>PHENOCLASTS</td>
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<td>% MATRIX</td>
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<td>(percentages quoted on matrix-free basis)</td>
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<td></td>
<td>Opaque .. 5</td>
<td>Grossularite 5</td>
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<td></td>
<td>(Fossils formed about 2% of hand specimen)</td>
<td>Glitter</td>
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<td>Fossil Frags. .. 8</td>
<td>Grossularite 10</td>
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<td>(in hand specimen)</td>
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<td>Orthoclase .. 1</td>
<td>Opaque .. 2</td>
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<tr>
<td></td>
<td>Zircon .. &lt;1</td>
<td>Muscovite .. 85</td>
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<td></td>
<td>Albite .. &lt;1</td>
<td>Limonite .. 5</td>
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<tr>
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<td>Quartz .. 90</td>
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<td>Feldspar incl.</td>
<td>Limonite .. 5</td>
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<td>Andesine, Microcline</td>
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<td></td>
<td>Opaque .. 1</td>
<td>Limonite .. 2</td>
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</table>

- **STRUCTURE**:
  - Mainly disrupted framework but some patches of mosaic texture of phenoclasts
  - Mosaic of quartz grains with laths and plates of prehnite, euhedral crystals of grossularite and plates and spherulites of nontronite
  - Mainly disrupted framework but some patches with mosaic texture
  - Crude bedding seen in thin section with suggestion of flame structure; in hand specimen bedding shown by stringers richer in matrix
  - Disrupted framework shown by stringers of very fine, opaque material; stringers partly limonitic but not entirely so
  - Mosaic texture with laths of muscovite with no preferred orientation noticeable
  - Disrupted framework; large plates of calcite with inclusions of quartz
  - Fossil fragments recrystallised
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<tr>
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<td>Chlorite rock</td>
<td></td>
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<tr>
<td></td>
<td>Quartz-albite rock</td>
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<tr>
<td></td>
<td>Feldspar</td>
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<td></td>
<td>Micropertlite</td>
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<td>Zircon</td>
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<td></td>
<td>Tournilene</td>
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<td>Micropertlite</td>
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<td>Tournilene</td>
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</tr>
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<td>Rutile</td>
<td></td>
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<tr>
<td></td>
<td>Opaque</td>
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**THE MALBINA SILTSTONE AND SANDSTONE**

*C is at base; **A** towards top of bed; **B** towards top of bed.

Stringsers of light grey material in hand spec.: forms two graded beds, bedding shown by preferred orientation of elongate phenoclasts in places and by lines of phenoclasts.
<table>
<thead>
<tr>
<th>No.</th>
<th>PHENOCLASTS % MATRIX</th>
<th>MATRIX % PHENOCLASTS</th>
<th>PHENOCLASTS</th>
<th>TEXTURE</th>
<th>STRUCTURE</th>
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<td></td>
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<td>(percentages quoted on matrix-free basis)</td>
<td>Grainsize</td>
<td>Roundness</td>
<td>Sphericity</td>
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<td>1146</td>
<td>Quartz... .86 Muscovite schist... 5</td>
<td>Quartz... 60 (Unit 54) Nontronite 15 Muscovite... 7 Limonite... 10</td>
<td>Coarse sand</td>
<td>Very fine sand</td>
<td>Very angular to angular</td>
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<td>Quartz... .80 Muscovite schist... 10</td>
<td>Quartz... 40 (Unit 56) Nontronite 38 Muscovite... 2</td>
<td>Hand specimen has small cobbles; thin section has grains to coarse sand</td>
<td>Very fine sand</td>
<td>Fine silt</td>
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<td>1148</td>
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<td>Quartz... 93 (Unit 58) Nontronite 5 Muscovite... 2</td>
<td>Hand specimen has fine pebbles</td>
<td>Medium fine sand</td>
<td>Very fine silt</td>
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<td>Quartzite Muscovite... 4</td>
<td>Quartzite... 75</td>
<td>Feldspar microcline albite... 2</td>
<td>Zircon... 1 Opaque... 2</td>
<td>A— Medium fine sand</td>
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<td></td>
<td>Tourmaline... &lt; 1</td>
<td>Zircon... &lt; 1</td>
<td>Feldspar— Plagioclase (sclhl) Orthoclase Microcline</td>
<td>5</td>
<td>B— Very coarse sand</td>
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<td>TEXTURE</td>
<td>STRUCTURE</td>
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<td>Texture</td>
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<td>Modal</td>
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<td>Quartz schist</td>
<td>Hand specimen has wood fragment of fine pebbles</td>
<td>Very fine sand</td>
<td>Very fine silt</td>
<td>Angular to very angular</td>
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<tr>
<td></td>
<td>Muscovite</td>
<td>Hand specimen has wood fragment of fine pebbles</td>
<td>Very fine sand</td>
<td>Very fine silt</td>
<td>Angular to very angular</td>
</tr>
<tr>
<td></td>
<td>Quartz</td>
<td>Hand specimen has wood fragment of fine pebbles</td>
<td>Very fine sand</td>
<td>Very fine silt</td>
<td>Angular to very angular</td>
</tr>
<tr>
<td></td>
<td>Muscovite</td>
<td>Hand specimen has wood fragment of fine pebbles</td>
<td>Very fine sand</td>
<td>Very fine silt</td>
<td>Angular to very angular</td>
</tr>
</tbody>
</table>
Appendix C

Detailed Stratigraphy of Member B.

Top:

Unit 124.
12.6 feet.—Fissile and non-fissile siltstone—similar in properties to unit 110.

Unit 123.
4.6 feet.—Fine to medium sandstone—pebbles up to 4 cms. in length—pebbles of quartz and quartz feldspar porphyry.

Unit 122.
10.6 feet.—Fissile siltstone—similar to unit 110.

Unit 121.
0.9 feet.—Medium sandstone—rounded pebbles up to 5 ems. long near base—pebbles of quartz, quartzite, phyllite—long axes of pebbles are sub-horizontal.

Unit 120.
5.2 feet.—Fissile siltstone—similar to unit 110.

Unit 119.
1.1 feet.—Fine sandstone with a few rounded pebbles.

Unit 118.
5.2 feet.—Fissile siltstone—similar to unit 110.

Unit 117.
0.3 feet.—Medium sandstone—fossils are rare, Ingelarella, and rare small pebbles.

Unit 116.
18.15 feet.—Fissile siltstone—similar to unit 110.

Unit 115.
0.25 feet.—Fine to medium sandstone sorting fair to good, sphericity high, roundness low—compact, brittle, tough.

Unit 114.
1.6 feet.—Fissile siltstone—similar to unit 110.

Unit 113.
0.3 feet.—Medium sandstone—graded bedding—very poorly sorted, sphericity high, roundness low—pebbles up to 2.5 ems. in length.

Unit 112.
1.95 feet.—Fissile siltstone—similar to unit 110.

Unit 111.
0.25 feet.—Medium sandstone—rare fossils (spiriferids)—pebbles up to 2.5 ems. in length—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 110.
3.1 feet.—Siltstone—sorting good—fissile.

Unit 109.
1.1 feet.—Medium sandstone—pebbles up to 4.5 ems., in length—sorting poor, sphericity high, roundness low—matrix not visible—contains quartz pebbles up to 4.5 ems. in length—no fossils—compact, brittle, non-fissile.

Unit 108.
1.9 feet.—Siltstone—sorting good—no pebbles visible—fissile.

Unit 107.
9.0 feet.—Siltstone—sorting fair to poor—abundant pebbles—mostly quartzite—some up to 5 ems. in length—fissile.

Unit 106.
3.0 feet.—Siltstone—sorting good—compact, brittle, massive—light grey—partings at 1.5 and 2.4 feet above base.

Unit 105.
1.5 feet.—Siltstone—sorting poor—contains abundant sand grade quartz fragments—non-fissile—light grey.

Unit 104.
1.6 feet.—Siltstone—sorting middling to poor—pebbles (well rounded) up to 2.6 ems. in length—contains sandy lenses of quartz particles.

Unit 103.
2.0 feet.—Siltstone—most properties not visible—sorting appears to be good—contains rare pebbles up to 0.1 inches in length—compact, brittle, non-fissile—light grey.
Publications from the Department of Geology
University of Tasmania—(continued)


59g. RUNNINSCHWEIZER, R. O.—Indo-Pacific Faunal Relations during the Mesozoic. Univ. of Tas. Cont. Drift Sym., pp. 128-161.


60. Symposium on Dolerite, November, 1958.


60d. MCDUGALL, I.—A Note on the Petrography of the Great Lake Dolerite Sill. Univ. of Tas. Dol. Sym., pp. 52-60.

60e. LOVING, J. K.—Differentiation Problems in Basic Complexes in Relation to an Area in the Sierra Nevada, California. Univ. of Tas. Dol. Sym., pp. 89-92.

60f. LOVING, J. K.—A Note on Dolerite Dykes in Western Tasmania. Univ. of Tas. Dol. Sym., p. 92.

60g. RICHEY, J. E.—Feldspathic Types of Basaltic Rocks. Univ. of Tas. Dol. Sym., pp. 63-69.


60i. JAEGER, J. C.—The Solidification and Cooling of Intrusive Sheets. Univ. of Tas. Dol. Sym., pp. 77-87.


61b. CAREY, S. W.—Relation of Basic Intrusions to Thickness of Sediments. Univ. of Tas. Dol. Sym., pp. 165-169.


61f. NICOLS, K. D.—Soil Formation on Dolerite in Tasmania. Univ. of Tas. Dol. Sym., pp. 204-209.


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75. CAREY, S. W., 1959.—North-South Asymmetry of the Earth's Figure. Science, Vol. 130, No. 3381, pp. 978-979.
84. Tasmania University Seismic Net.

THE PERMIAN SYSTEM IN WESTERN TASMANIA

by
MAXWELL R. BANKS
University of Tasmania
and
N. AHMAD
University of Aligarh

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Publications from the Department of Geology, University of Tasmania


26. CAYES, S. W., 1955a.—Wegener’s South America-Africa assembly, fit or misfit? Geol. Mag., Vol. XCII, No. 3, pp. 190-209.


44. TEACHERS’ Edition of No. 48.


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THE PERMIAN SYSTEM IN WESTERN TASMANIA

By

MAXWELL R. BANKS
University of Tasmania

and

N. AHMAD
University of Aligarh

(With 12 text figures.)

ABSTRACT

Permian rocks occur at Mount Read, Mount Dundas, Mount Sedgwick, Zeehan, Firewood Siding, Strahan and Point Hibbs in Western Tasmania. The basal formation is exposed at Mount Read, Mount Sedgwick, Zeehan and Point Hibbs and consists of tillite. Striaions on the basement at Mount Sedgwick indicate ice moving from the west. Sections up to and including the Golden Valley Group (Lower Artinskian) occur at Mount Sedgwick and Point Hibbs and a section from the Mersey Group up to and including the Cygnet Formation is found in the Firewood Siding Area near the mouth of the Henty River. The sections at Mount Sedgwick and Firewood Siding are much thinner than corresponding ones in north-western and south-eastern Tasmania but that at Point Hibbs is as thick as or thicker than corresponding sections.

INTRODUCTION

The first record of Permian rocks in the area studied seems to be that of Montgomery (1891) who made brief reference to coal on the Henty River (see map, fig. 1). Johnston (1892) recorded some fossil plants from the Henty River area and correlated the coal measure there with the Mersey Coal Measures. In 1894 Dunn noted the tillite near Mount Read and commented on its similarity to the Dwyka of South Africa and to the conglomerates at Wild Duck Creek (Derrinal), Victoria. In the same year Moore noted the Permian fossiliferous and glacial beds on Mount Sedgwick and those at Zeehan (Zeehan Tillite) which he also described as Permian. The fluvio-glacial beds near Strahan were first described by Officer, Balfour and Hogg (1895). Several later workers dealt with the deposits mentioned above but no new work was added until Hills (1914) dealt with the Point Hibbs section. In 1925 Reid noted the probable presence of Permian rocks on Mount Dundas. Voisey (1938) included references to this area, particularly to the Point Hibbs and Malanna sections in his work on the Permian of Tasmania. Edwards (1941) noted the exhumed Permian surface on Mount Sedgwick and the Permian of...
Mount Sedgwick was mentioned by Bradley (1954). Some of the Permian rocks at Firewood Siding, near Malanna, were described by Gill and Banks (1950), Campana et al. (1958) and Spry (1958).

Serious investigation of the Permian sections in this area began in November, 1953, when Professor K. G. Brill, Visiting Professor at the University of Tasmania, G. E. Hale and M. R. Banks spent a week measuring sections in the Malanna area. In January, 1957, the authors measured sections in the Malanna area, at Point Hibbs and on Mount Sedgwick and made observations on the Permian rocks on Mount Read and at Strahan. During the 1953 trip to Malanna sections were measured in railway cuttings and creek beds using a steel tape and abney level. The Mount Sedgwick section was measured by using a Brunton compass as a level and measuring cliff sections. The Point Hibbs section was measured by laying a steel tape along the dip of the vertical beds and reading off thicknesses directly until the fault zone was met and then by using the abney level. Thicknesses in the section in Geologists Creek, near Malanna, studied in 1957, were only estimates due to thick undergrowth.

During the work the authors were aided by the explicit directions on the route to Mount Sedgwick given by geologists of the Mount Lyell Company. This company also made available the services of Mr. Jock Gilfillan who was of considerable assistance. The Lyell-E.Z. Exploration Company made the work at Point Hibbs possible by making available to the authors one trip each way in a helicopter and later made aerial photographs available. The Electrolytic Zinc Company kindly allowed us to use their facilities and made Mr. John Druett available as a guide. The authors acknowledge with gratitude the assistance of these companies and their officers. The authors are also indebted to Mr. M. Longman, Geologist at the Tasmanian Museum for access to plant bearing shales from which Johnston had described fossil plants from the Henty River.

All bearings are related to true north.

**MOUNT READ.**

The earliest mention of Permian rocks near Mount Read is that of Dunn (1894) who mentioned a conglomerate with a great variety of pebbles on the south side of the track half way from Mount Read to Moore's Pimple. He remarked on its similarity to the Dwyka of South Africa and the conglomerate on Wild Duck Creek (Derri-nal), Victoria, both considered as Permian. Hills (1915) gave further details. He considered that it was Permian as it contained fragments of undoubted "Silurian" rocks (now known to be Ordovician). Bradley (1954, p. 199) also mentioned this occurrence as showing that the Carboniferous peneplain in this area has an undulating surface with variations up to 80 feet in height.

A complete survey was not made by the present authors but two areas of Permian rocks were examined. On the track from Mount Read to Zeehan about half a mile south of the “L” Lode open cut on the south-west side of Mount Hamilton, tillite was found in a small depression (co-ordinates 8.5 cms. S.S.W. by S. of C.P., Zeehan 8, 23627) (see map, fig. 2).

The Permian rests on "sheared pyroclastics" of probable Cambrian age which have a steep easterly dip and the Permian has a horizontal fissility although no bedding could be seen. The rock is greenish grey. It is very poorly sorted with boulders up to 18 inches long in a fine-grained (clay and silt grade) matrix. The boulders are angular and sub-angular and are grey Owen Conglomerate, pink Owen Conglomerate, Eldon Group quartzites, green sandstone, black slate, quartz and rare feldspar porphyry. The rock is fairly well lithified. The tillite is probably not more than two feet thick and is a small remnant preserved in a hollow between hills of "sheared pyroclastics" which rise locally to more than 50 feet above the level of the Permian. There is no internal evidence in this exposure of a Permian age. The lithology and degree of lithification are very similar to known Permian tillites elsewhere in the State and quite dissimilar from those of the Pleistocene till in
the West Coast area. The top of the plateau at Mount Read shows no sign of Pleistocene glaciation so that all available evidence from this outcrop suggests a Permian age.

The Permian age is confirmed by the other exposure of tillite and associated rocks. In a depression between hills of sheared pyroclastics about three-quarters of a mile south-west of "L" Lode Open Cut, tillite is found, resting on the pyroclastics (at point 10 cms. S.S.E. by S. of C.P. Zeehan 8, 23627) and in a runnel of an old track a surface of the pyroclastics shows a polished surface with striations trending 0 approximately. This may be part of the pavement beneath the Permian but this could not be established beyond doubt as the striations may be due to log hauling. Erratics in this vicinity reached a length of 33 inches and in addition to the types reported from the first locality include a black fine-grained quartzite. Otherwise the tillite at this second locality is very like that from the first. About 100 yards north-east along this track (at point with co-ordinates 9.7 cms. S.S.E. of C.P. Zeehan 8, 23627) olive-grey siltstones are exposed dipping at a moderate angle to the west off a small hillock of "sheared pyroclastics". These are well-sorted in that erratics are rare and small. They are poorly bedded. These siltstones contain articulated crinoid columns and attached cirri of a type common in the Permian System in Tasmania. The siltstones are overlain by tillitic material and similar siltstones occur, apparently above the tillitic material, but in view of the poor exposure the succession cannot be regarded as established. The presence of the crinoid of Permian type established the age of the succession.

The surface of the plateau north and east of these occurrences was not examined and there may be further outcrops. The two areas of Permian rocks found occupied small depressions in the surface of the "sheared pyroclastics" which rises perhaps as much as a hundred feet above the base of the Permian. To some extent the present topography on this part of Mount Read is a slightly subdued expression of the pre-Permian topography.

SECTION AT MOUNT DUNDAS.

This section was not visited due to inaccessibility. Reid (1925) postulated that Permian sediments on the south-western fall of Mount Dundas on the evidence of fossiliferous boulders in some of the creek systems near Dundas. Elliston (1954, p. 172) stated that a thin layer of mudstone occurs between dolerite sills on Mount Dundas.

SECTION AT ZEEHAN.

In 1894, Moore discovered the tillite north-west of Zeehan and considered it (1896a, p. 60) to be Permian in age on lithological grounds as also did Twelvetrees and Ward (1910). It has also been regarded as Precambrian (Hills and Carey, 1949; Carey, 1953) and Cambrian (Carey and Scott, 1952, p. 70; Elliston, 1954, p. 177) but Banks (1956, p. 193) regarded the age of the Zeehan Tillite as not then established. More recently Spry (1958) has suggested that the Zeehan Tillite is Permian on structural grounds and because it contains fragments of Dundas Group and Eldon Group rocks. He has also found a further occurrence of it north of the Pieman River and describes the rock from the different areas in some detail. The authors did not visit these areas. Campana and King (1958) give detailed evidence for a Permian age for the Zeehan Tillite.

SECTION AT MALANNA (MOUTH OF HENTY RIVER).

The Permian rocks here were first noted by Montgomery (1891, p. 42) who gave the section as coal bearing beds overlain by sandstones and limestones with marine fossils and by white grit or sandstone. Johnston (1932) recorded Glossopteris browniana, Gangamopteris spatula, G. obliqua and Noeggerathiopsis hislopi associated with curious botryoidal concretions from the coal bearing beds and correlated them with the Mersey Coal Measures. Twelvetrees (1902a) noted that the impure limestones and mudstones overlie the coal measures. Twelvetrees (1902b, 1903) recorded details of two bores put down near Malanna in a search for coal and suggested (1902, p. lxxii) that the coal occurred on two horizons, one exposed near Malanna and the other below the limestone. Vossey (1938, p. 322) considered that only one formation containing coal was present, that above the beds with marine fossils. In this he was possibly influenced by the undoubted presence of coal bearing or carbonaceous beds above the marine beds in the railway sections. However, investigations by the authors suggest that there are two coal bearing formations separated by marine beds. The authors were unable to find any of the "curious botryoidal concretions" in the railway cuttings nor any Noeggerathiopsis and it is clear from Montgomery's statement (1891, p. 43) that the coal being investigated was on the flats just north of the Henty River, not as far north as the railway cutting. This has been checked in conversation with local residents. Specimens of the shale containing the plant fossils described by Johnston are in the Tasmanian Museum. The rock is a micaceous siltstone containing decomposed concretions probably of pyrite, now in the form of melanterite. It is thinly bedded with beds of dark-grey and medium-grey siltstone alternating from 0.1 inches to 0.25 inches thick. It is well lithified and shows some curved slickensided surfaces. No fossil seeds, nor sphenopsids, nor Vertebraria are present in the Museum specimens but large specimens of Glossopteris are present. One of the botryoidal concretions referred to by Johnston may be present but this is not certain. This material is much more lithified than any of the plant bearing siltstones seen in the railway cuttings and described later and the types of fossils are somewhat different in the two formations. The specimens in the Museum are characterised by extraordinarily large specimens of Glossopteris while the specimens from the railway cutting contain numerous seeds, Vertebraria and sphenopsids. On the grounds of difference in degree of lithification and in the overall aspect of the plant assemblages it is considered that John-
FIGURE 3
THE PERMIAN SYSTEM IN WESTERN TASMANIA

MAP OF HENTY RIVER (MALANNA) AREA SHOWING PERMIAN LOCALITIES
ston's specimens did not come from the railway cuttings, and on the grounds of Montgomery's description and Johnston's description, further supported by conversation with local residents, it is considered that they come from the flat ground on the north side of the Henty River, probably between Geologists Creek and the railway bridge. Thus, the coal measures referred to by Johnston as equivalent to the Mersey Coal Measures are thought to be below the marine beds but there are further coal measure beds above these marine beds and the present authors suggest that these are equivalent approximately to the Cygnet Coal Measures. Gill and Banks (1950, p. 266-7) described rocks from two formations close to Firewood Siding and suggested that the marine ones might be equivalent to the "Granton Formation" (= Cascades Group).

The present study was made in a traverse down Geologists Creek, in cuttings along the railway line and in a section along a creek flowing north into the Badger River just west of Firewood Siding (see map, fig. 3).

Due to thick vegetation and flooding of Geologists Creek no measurements of thickness were possible. Sections of the upper coal measure beds in railway cuttings and a creek were made with a steel tape but due to faulting and irregularities in dip correlation between them is poor. Exposures of the marine beds in the railway cuttings were too discontinuous for measurement and the thickness is calculated trigonometrically. Localities mentioned are shown in the map (fig. 3).

The lowest formation in the section consists of carbonaceous, micaceous, quartz-rich sandstones which are well sorted. These occur in the lower part of geologists Creek where they are apparently associated with black shale containing Glossopteris browniana, Gangamopteris spatula, G. obliqua and Noeggerathiopsis hislopi (Montgomery, 1891, and Johnston, 1892).

This is followed after an interval with no obvious outcrop by alternating sandstone and fissile siltstone containing some fossils and a few erratics. In one place this shows north-west trending jointing planes less than a foot apart suggesting some faulting but there is no obvious displacement of beds and no change of dip. There follows a sandstone and siltstone alternation in which fenestellids, stenoporids, spiriferids and one specimen of Eurydesma cordatum were seen.

This is overlain by a fissile, calcareous siltstone containing spirifireds, stenoporids and predominant fenestellids. This is perhaps one of Montgomery's impure limestone beds.

After a further gap in the section the next unit is a buff sandstone with rare small erratics which forms small flats above creek level. This is richly fossiliferous with fenestellids, Stenopora, Strophalosina, Terrakea, Dielasma, spiriferids (including Neospirifer), Spiriferellina, Ingelerella and pelecypods. Of particular interest is the occurrence in bands of numerous small, inarticulate brachiopods.

A few feet above this and also forming a small flat area is a greyish feldspathic pebbly sandstone. This is followed by a considerable thickness of greyish, feldspathic sandstone with numerous small pebbles and small cobbles occurring in bands. The bedding in this sandstone is thick and the unit forms several large waterfalls. The final unit, exposed in the uppermost waterfall in the gorge of Geologists Creek, is a white, quartz-rich, well sorted sandstone with a few pebbles of white

**Columnar Section of Permian Rocks in Geologists Creek**

<table>
<thead>
<tr>
<th>Quartz Sandstone</th>
<th>Thick-Bedded, Erratic Rich Sandstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felspathic Sandstone</td>
<td>Fossiliferous Sandstone</td>
</tr>
<tr>
<td>Fossiliferous Sandstone and Siltstone</td>
<td>Sandstone and Siltstone</td>
</tr>
<tr>
<td>Carbonaceous Sandstone</td>
<td>Scale</td>
</tr>
</tbody>
</table>

FIGURE 4
quartzite and this type of rock covers much of the surface between the Henty River and the railway line west of Firewood Siding. The basal sandstone and the plant-bearing shale formation is of the order of 40 feet thick and the marine sequence is of the order of 300 feet thick based on measurements of height of the top of the plateau cut in the Permian (525 feet above the level of the Henty River at the railway bridge) and on estimated heights in the gorge of Geologists Creek. The beds in the creek section are essentially horizontal. The thickness given is considerably in excess of that given by Montgomery which is thought to be much too small. The section in Geologists Creek is summarized in fig. 4.

In a railway cutting ("B") (Strahan 11, 3292, 1", E.N.E. of C.P. and see map, fig. 3) a section of Permian rocks is exposed. This shows:

Top—
20 feet: medium to fine grained feldspathic sandstone with occasional "erratics" or lenses of "erratics".
1 foot 8 inches: greenish-grey, medium-coarse grained sandstone with many erratics (up to 15 inches long) including quartzite, quartz schist, mica schist, chlorite schist and granite, very angular, un-oriented, unsorted; large (4" wide) Ingelarella (?) subradiata and other spiriferids.
3 feet: dark-grey, medium-fine grained sandstone with pebbles and cylindrical bodies outlined by carbonaceous matter (? worm tubes).
4 feet: dark-greenish yellow sandstone with a few "erratics".
4 feet: greenish-yellow, fine-grained sandstone with occasional small angular and rounded "erratics".

The next cutting to the north ("C") also contains "erratic"-bearing sandstones but fossils are commoner and occur in lenses. The fossils include Stenopora (massive type like crinita, and ramose types), fenestellids, Strophalosia, spiriferids, including Ingelarella subradiata, Spiriferella, Aviculopecten, other pelecypods, and calcareous worm tubes.

East of Firewood Siding a series of railway cuttings expose Permian beds. The easternmost one (co-ordinates 3.5 cms. S. C.P. Zeehan 1,23435) contains alternating thick-bedded impure sandstone and fissile siltstone with sandstone predominating in thickness in the alternations. Pebbles up to an inch long are present but no fossils have been found. The boundaries between the members of the alternating beds are gradational. The next cutting west (Locality 76 of Gill and Banks, 1950) contains thickly-bedded and well sorted sandstone without pebbles. The fossils include Platyschisma oculus, Camptocrinus other pectinaceans. The apparent thickness of marine or "erratic"-bearing beds exposed is of the order of 800 feet. The section east of Firewood Siding is summarized as fig. 6.

The total thickness shown is thought to be excessive. Dips are up to 25°, indicating proximity to faulting, and possible faulting within the section. The numerous long gaps in the section are doubtful. Similar pebbly beds occur in some of the depressions south-east of the railway line where they outcrop beneath the quartz-rich sandstones. One such outcrop occurs at a locality 1" N.N.E. C.P. Strahan 11, 3293 and consists of grey, poorly-sorted sandstone with angular to sub-angular boulders of schist, slate, phyllite and quartzite.

Above the unconformity the basal beds are quartz-rich sandstones with carbonaceous fragments. These are thickly bedded and well sorted but have a few sub-ridden to rounded pebbles of quartz and quartzite. Between this cutting and Firewood Siding sandstone and fine-grained carbonaceous sandstone occur in the cuttings.
Columnar Section of Permian Rocks east of Firewood Siding

**DISCONFORMATION**

**SILTSTONE WITH "ERRATICS"**

**SILTSTONE AND SANDSTONE WITH MARINE FOSSILS**

**SILTSTONE WITHOUT FOSSILS**

**SANDSTONE**

**SILTSTONE AND SANDSTONE WITH MARINE FOSSILS**

**SANDSTONE AND SILTSTONE WITH "ERRATICS"**

**FAULT**

**LOWER PALAEOZOIC**

---

Siltstone which is very rich in plant remains including *Glossopteris, Gangamopteris* and *Vertebraria*. Pyrite occurs associated with the carbonaceous siltstones.

The next cutting to the west ("F") (co-ordinates 3.5 cm. S.S.W. C.P. Zeehan Run 1, 23437) is thought to be that figured by David (1926, p. 102). At the eastern end of the figured cutting a bed of brecciated siltstone underlies a strongly-jointed sandstone in a small syncline. Just to the west in an anticline is sandstone with pebble bands and thin carbonaceous bands. Beyond a fault is a sandstone with a few thin carbonaceous siltstone bands, one of which shows circular, approximately horizontal sand-filled tubes, overlain by interbedded thin beds of sandstone and carbonaceous siltstone. To the west of another fault the basal section of the cut is in carbonaceous siltstone with the thin beds of sandstone overlain by two feet of sandstone, carbonaceous siltstone and finally 11 feet of thinly-bedded sandstone. In the basal siltstone unit there are worm tubes, current ripple marks (currents from west) and cross-bedding occurs in the sandstone layers indicating mostly currents from the east or south-east but some from the west. Next to the west is a fault zone in sandstone and carbonaceous siltstone. In the western section of the cut the basal portion consists of an alternation of thin beds of sandstone with very thinly interbedded sandstone and carbonaceous siltstone. This is overlain by a brecciated sequence of carbonaceous siltstone and thin sandstone bands. This is followed by several thick beds of sandstone which shows no brecciation or faulting like that in the underlying bed. The top unit in this part of the cutting is a thinly-bedded sandstone sequence.

Sandstone occurs in low cuttings further west in the axis of a flat anticline. The sandstone is medium-grained at the base and finer-grained and thinly-bedded above. In the next major cutting ("Q"), (co-ordinates 5.3 cm. S.W. C.P. Zeehan 1, 23437) a fault divides the cutting. At the eastern end of the figure there is a thickness of nine feet of medium-grained sandstone with thin bedding and cross-bedding, mainly dipping south-west and overlain by nine feet of thinly-bedded fine-grained sandstone. Some cross-bedding dipping to the west and more rarely to the east occurs in the basal part. West of the fault the following section was measured:

**Top—**

2 feet: Sandstone, white, micaceous, feldspathic, with clayey and carbonaceous partings producing flaggy breaks.

5 feet 6 inches: Brown and black carbonaceous and micaceous with minor superimposed on major rhythms. i.e., carbonaceous siltstone and siltstone alternate and each member consists of alternations of carbonaceous siltstone and siltstone; there are 8 cycles, the carbonaceous siltstone members being the thinner; a prominent sandstone band from 3' 6" to 4' above the base.

3 feet: White, micaceous, feldspathic sandstone with thin bedding.

The basal sandstone contains bodies of concentric laminae of carbonaceous matter, the exact nature of which is unknown. The siltstones of the second
unit contain worm tubes and ripple marks and the top is recrcciated and crumpled. This unit is very reminiscent of the brecciated beds in the previous cutting ("R").

Another section is exposed in the next cutting to the west ("P", co-ordinates 5.6 cms. S.W. C.P., Zeehan 1, 23437) and is as follows:—

Top—

1 foot 6 inches: Thickly bedded, medium-coarse grained feldspathic sandstone.
2 feet: Fine-grained, feldspathic, micaceous sandstone; quartz grains angular; cross bedding rare; flaggy splitting.
1 foot: Medium to coarse grained quartz sandstone with angular grains; thickness to 6 feet at east end of cutting.
3 feet: Black to brown, carbonaceous, micaceous, feldspathic siltstone, very thinly bedded with irregular bedding and some worm tubes.
3 feet 6 inches: White, friable, thinly bedded, flaggy-platy, feldspathic, micaceous sandstone becoming carbonaceous near the top; some bedding planes show rippling.
20 feet: (Top) 4 feet in cut, bottom 16 feet in cliff to north) white, medium grained feldspathic sandstone.

Cross bedding in this cutting dips south-west, west and north-west.

A section was measured up the bed of a creek tributary to the Badger River, with the co-ordinates 4.6 cms. S.S.E. C.P., Zeehan 1, 23438 (on railway line). This section is given in detail below:—

Top—

Interbedded carbonaceous and non-carbonaceous siltstones with shattering, overthrusting, and normal faulting (as in section figured by David).
30 feet: Fine to medium grained, cross-bedded sandstone with quartz, feldspar, muscovite; thickly-bedded.
40 feet 2 inches: Medium to coarse grained sandstone, with quartz, feldspar and a few quartz pebbles up to 30 feet above the base then some pebble bands, thickly bedded.
5 feet 9 inches: Coarse sandstone to fine conglomerate with large pebbles (up to 25 mms.) of quartz, red chert and quartzite; angular to sub-rounded pebbles; thickly bedded.
4 feet 9 inches: Fine to medium grained quartz sandstone with a few pebbles of quartz and quartzite sub-angular to sub-rounded; thickly-bedded; flaggy to massive.
10 feet 9 inches: Brown-yellow, fine-grained quartz, mica, feldspar sandstone with very thin to thick bedding and some carbonaceous partings, flaggy and platy.
11 feet: Interbedded black micaceous siltstones with disseminated carbonaceous matter, and brown micaceous siliceous siltstones; very thinly bedded; distinct band of quartz pebbles 8 feet above base; some distinct plant fragments.

The grain-size decreases upwards to unit 2 then increases upwards to unit 5 with higher decrease to unit 8. This latter is overlain by sandstones in the railway cuttings but the succession is broken. From the top of unit 8 to the highest point on the hills to the south on which the quartz-rich sandstones occur, is well over 50 feet so that a minimum thickness for this formation is 150 feet.

Further to the west (cutting "O", co-ordinates 4.2 cms. S.C.P., Zeehan 1, 23438) white, siliceous sandstones outcrop. Some of these are pebbly and there are beds of siliceous and carbonaceous siltstones. Small limonitic concretions are present and there are also curved cylindrical worm burrows in it. Cross-bedding dips north-west to south-west with some dipping east, and ripple marks and slump structures are also present.

In the next cutting west ("N", co-ordinates 4.7 cms. S.S.W. C.P., Zeehan 1, 23438) a fault divides the cutting. At the eastern end of the cutting a cross-bedded sandstone is overlain by a micaceous sandstone containing plant fragments, a siltstone containing a sphenopsid, Glossopteris, both small and large species, and Vertebra, and finally by a coarse sandstone with rare boulders up to four inches long. At the western end of the cutting the following section was measured:—

Top—

4 feet: White quartz sandstone, with much feldspar.
6 feet: Alternating fine micaceous sandstone and carbonaceous siltstone; sandstone beds ½" to 2" thick, siltstone bands up to ½" thick.
4 feet: White to brown carbonaceous, micaceous, feldspathic sandstone; carbonaceous partings and bands, thick bedding.
2 feet: Carbonaceous, micaceous, siltstone; thinly bedded.
4 feet 8 inches: Brown-yellow sandstone; fine to medium-grained; few quartz pebbles at 1' 6" above base sub-angular to sub-rounded; above this bed becomes more carbonaceous and micaceous with some plant remains.
6 inches: Carbonaceous, micaceous brown-black siltstone with *Glossopteris*, *Gangamopteris*, *Vertebraria*, *Phyllotheca*, *Schizoneura*, and seeds.

5 feet: White, thick bedded sandstone, with fine conglomeratic bands of angular to sub-rounded quartz pebbles; cross bedding dipping south-west.

This section shows an alternation of sandstone and siltstone with some of the siltstone units themselves composed of alternating sandstone and siltstone beds. The sandstone units are consistently thicker than those of siltstone.

The final cutting in Permian rocks ("M", coordinates 5.5 cms. S.S.W. C.P. Zeehan 1, 23438) consists mainly of sandstone as shown in the following section.

Top—

1 foot: Cross-bedded, white, medium-grained sandstone.

2 ins.: Sandstone.

6 ins.: Clayey sandstone.

9 ins.: Sandstone.

1½ ins.: Clayey sandstone.

6 ins.: Sandstone, top surface ripple marked.

1 in.: Clay.

2 ins.: Sandstone.

4 ins.: Yellow clay.

9 ins.: Sandstone.

9 ins.: Micaceous, feldspathic sandstone with 1 in. clay seam.

1 foot 8 ins.: Yellow-brown limonitic, clayey sandstone.

6 ft. 8 ins.: Yellow quartz sandstone with cross-bedding; muscovite and feldspar present, grains angular; bedding planes about 1 inch apart.

5 feet 1 in.: Conglomeratic sandstone pebbles of quartz, quartz schist up to 1½ inches long, sub-rounded to sub-angular; matrix coarse sandstone to fine conglomerate, mainly quartz with some feldspar, very angular; lower surface uneven.

1 in.: White sandy micaceous clay.

2 feet 6 ins.: Medium-grained, micaceous (muscovite), feldspathic sandstone with occasional pebbles of quartz; grains angular; thickly bedded.

The prevalence of faulting, lack of distinctive marker beds, and common occurrence of cyclic sedimentation makes correlation between all these sections virtually impossible without very detailed work. On dip the last section ("M") should overlie the second last ("N") and this latter should overlie the creek section and due to lack of any possible correlation between them may well do so. However, the presence of faults is such that this superposition cannot yet be proved.

This, the highest formation in the Permian section in this area, consists of siliceous sandstones dominantly but with some minor conglomerates, mainly quartz-rich with some muscovite and feldspar, well-sorted, with some rounded pebbles of resistant types in a matrix of angular grains. Bedding varies from thin to thick and cross-bedding on a fairly fine scale is common. No consistent current direction is shown but currents from the eastern quarter seem to have been somewhat stronger than those from the west with very few from north or south. As exposed the sandstones are mainly white. Cyclic sedimentation is well shown in several sections with a major sandstone-siltstone alternation on which is superimposed finer alternations of fine-grained parallel bedding to anastomosing lamination with carbonaceous siltstones. These cycles represent changes in competency of the streams in the depositional area with perhaps the development of peaty swamps during times of low competence. The causes of the variations in competency may have been climatic or tectonic but more regional work is needed to establish the cause of the variation. There were at least three major cycles and many minor ones. The siltstones commonly show slumping, cross-bedding and ripple marking as well as the presence of worm tubes of several types. On at least one horizon plant remains are common and include *Glossopteris* spp., *Gangamopteris*, *Vertebraria*, *Phyllotheca*, *Schizoneura* and seeds.

The bores described by Twelvetrees (1902a, b, 1903) are of some interest although neither can now be located accurately. Eden Bore No. 1 was placed north of the railway line (and probably south of the Badger River) fifteen and a half miles from Strahan probably somewhere near cuttings M, N, O, as Eden Bore No. 2 was stated to be 11 miles further north-east on the Edin Coal Company's section (probably 4210, 43 M, on the West Coast Mineral Chart) and must certainly have been south-west of the fault north of Firewood Siding. This means that Bore No. 1 was almost certainly not east of Cutting Q nor west of Cutting M. In Bore No 1 it seems likely that the sandstones, shales and coal markings down to 115 feet belong to the topmost formation of the present authors. The beds from 115 feet down to 291 feet consisting of pebbly sandstone and mudstone may be the equivalent of the Ferntree Formation in the Geologists Creek section, the conglomerate between 291' and 309' to the Risdon Sandstone and the underlying pebbly and calcareous mudstones to the marine beds low in the Geologists Creek section. The order of thickness of the marine beds under this correlation is the same as that found in Geologists Creek. The correlations must, however, be regarded as very tentative only, in view of the lack of detailed information about the rocks in the bore. Eden Bore No. 2 passed through 108 feet of sandstone before entering a hard, indurated, broken-up slate which may well belong to the Eldon Group.

The Permian section in this area could be considered as consisting of five formations, a basal carbonaceous, micaceous well-sorted sandstone associated with plant-bearing shales, followed by poorly-sorted sandstones and siltstones with marine fossils, then an "erratic"-rich sandstone, a thick-bedded impure sandstone and finally a well-sorted siliceous sandstone with plant-bearing siltstones. The sequence is summarized in fig. 7.

The lowest formation, in addition to *Glossopteris* and *Gangamopteris* contains *Noeggerathiopsis histopi* which is known elsewhere in Tasmania from
the lower or Mersey Coal Measures, now roughly correlated with the Liffey Group of McKellar (1957) and the Faulkner Group of Banks and Hale (1957). The succeeding formation contains Stenopora.

The thin, pebbly sandstone may be correlated on lithological and stratigraphical ground with the Risdon Sandstone but this is not at all certain. The thickly-beded impure sandstones are in the stratigraphical position of the Ferntree Mudstone but are coarser and contain more pebbles. The uppermost formation has in addition to sphenopsidea, Glossopteris and Gangamopteris, many specimens of Vertebbraria which is known elsewhere in Tasmania from terrestrial sediments correlated with the Cygnet Coal Measures. Thus on the occurrence of Vertebbraria this formation is correlated with the Cygnet Coal Measures in the southeast. In addition carbonaceous siltstone from this formation is considered (Balme, letter 18.6.1959) to be Upper Permian on palynological grounds.

In this area the marine beds and the correlates of the Cygnet Coal Measures all show signs suggesting closer proximity to the shoreline or source than those near Hobart. The "Woodbridge" correlate is rather coarser than its Hobart equivalent and in addition contains inarticulate brachiopods indicative of shallow water, perhaps shoreline conditions. The correlates of the Ferntree Mudstone are much coarser and contain more pebbles than that formation. The equivalent of the Cygnet Coal Measures has generally much coarser sand grains and a greater preponderance of pebbles and boulders than in the south-east. Of interest also is the fact that the marine beds estimated at 300+ feet thick, are thinner than at Hobart where corresponding beds total at least 885 feet thick.

**SECTION ON MT. SEDGWICK.**

This seems to have been first noticed by Moore (1894, p. 148) who assigned a coal measure age (= Permian) to it. He became involved in a controversy with Montgomery (1894, p. 161) who suggested that the beds observed by Moore were due to Pleistocene redistribution of Permian material. Edwards (1941, pp. 19-22) also dealt with the area as part of an exhumed Permian or pre-Permian surface and correlated the beds on Mt. Sedgwick with Voicey's (1938) Achilles Stage on the grounds of the presence of Spirifer and Asdivclopecten. Bradley (1954, p. 199) mentioned the Permian rocks briefly.

On the southern side of Mount Sedgwick (fig. 8) a section of Permian rocks is exposed in creek and cliff sections overlying quartz feldspar porphyries with slate fragments and overlain by dolerite which has baked the Permian. The dolerite contact is irregular and where best exposed is dipping west at a steep angle and cutting across the bedding. The Permian beds have a very low dip to the west. The basement on which the Permian rests varies considerably in height. Just east of Mount Sedgwick Owen Conglomerate occurs at least 200 feet.
MAP SHOWING OCCURRENCE OF PERMIAN
SOUTH OF MOUNT SEDGWICK (Based on air-photo, Lyell, Run 2, no. 774)

above the base of the Permian and has no Permian on it. Just to the west dolerite rests on porphyry about 20 feet above the base of the Permian and the Permian is absent. Thus it seems that there is either a valley in the pre-Permian surface at least 20 feet deep or a post-Permian graben. No evidence can be advanced as yet to favour either hypothesis. The depression occupied by the Permian is no more than 1,500 feet across (i.e., in an east-west direction).

On the southern side of Mount Sedgwick two streams flow south in the Comstock Valley. The section measured began on basement about 100 feet west of the easternmost and bigger stream. The section was carried to the north along cliff sections on the western side of the creek until a narrow shelf was reached which ran back to the foot of the dolerite cliffs. The section was carried north-westerly across this shelf and to the foot of a cliff in Permian then up this cliff to the dolerite contact. The total thickness measured between basement and dolerite was 210 feet approximately.

The contact between the Permian and the underlying rocks is exposed in a cliff section west of the creek mentioned above (1.8 cm., E.N.E., C.P., Lyell Run 2, No. 774). The contact is smooth and striated in some places but is jagged and irregular in other places within ten feet of the smoothed areas. Striations occur on both the slate fragments in the porphyry and on the porphyry itself but are clearer on the slate. The striations trend 106° and are deepest on the west side and shallowest towards the east thus indicating movement of the ice from west to east approximately. The contact is somewhat curved in section suggesting a roche moutonnée and it is perhaps significant that the surface is smoothed to the west and jagged to the east. Thus if the contact locally is the surface of a roche moutonnée, which cannot be positively established, the smooth upstream surface is to the west, the jagged plucked downstream surface is to the east, this agreeing with the evidence of the striations.

The basal Permian unit which is 39 feet thick (see text fig. 9) consists of well-striated boulders up to four feet in length consisting of porphyry, Owen Conglomerate, slates, quartzites and other rock types, in a poorly-sorted, dark-grey clayey matrix with poorly-marked horizontal fissility. No bedding was apparent. About six inches above the base at one place where the basement is jagged, there is a lense-like body of varved siltstone which is about six inches thick and about 30 inches wide. This lenticular body is slumped along the north-south axis. There is a slight discontinuity just above the varved siltstone body. The basal unit is a tillite.

The second unit is a well-sorted pebbly tillite which is six feet thick. Much of the smaller material is lacking and the pebbles are well rounded. Faceting and striations are rare. No bedding is present. It is possibly an outwash deposit of supra-glacial material. This is followed by 14 feet of silicified conglomerate, rather resembling Owen Conglomerate, which differs from the underlying unit only in degree of silification. The next unit consists of six feet of compact conglomerate with small, rounded, mainly siliceous pebbles. This is well sorted. It tends to form the lip of a cliff. It is probably an outwash deposit. A thickness of 50 feet of unfossiliferous thickly-bedded, erratic-rich siltstone follows the conglomerate. The pebbles and boulders show some faceting and striations. This rock was possibly deposited by a floating ice sheet in very shallow water. There follows a thickness of 11 feet of conglomerate with somewhat rounded pebbles and few large boulders. This is possibly an outwash deposit.

The next unit represents a marked change in lithology. It is 11 feet thick and consists of dark-grey, fissile siltstone with a few small pebbles. Near the base this is unfossiliferous but higher up becomes fossiliferous, the main fossils being ramose stenoporids (S. tasmaniensis) but with some spiriferids and crinoids.

A limestone, 21 inches thick, succeeds the siltstone. It is medium to dark-grey in colour and fine-grained with a few rather rounded pebbles. Fossils are common and are dominantly stenoporids (S. tasmaniensis) although Eurydesma cordatum is common and crinoid plates are present. The Eurydesma shells are disarticulated and usually convex side up. The stenoporid colonies are broken and the crinoids fragmented.

The succeeding unit is about 63 feet thick and consists of a thickly-bedded, grey, pebbly siltstone with numerous fossils of which Eurydesma cordatum is prominent. However, spiriferids and stenoporids also occur in considerable numbers. The last unit is at least 11 feet thick and is a richly fossiliferous siltstone containing some erratics. Close to the dolerite contact it is baked and assumes a light-grey to creamy colour. It is thinly-bedded and rests on the underlying unit with a sharp contact. The fossils are dominantly ramose stenoporids (S. tasmaniensis) some of which show...
Columnar Section of Permian Rocks on Mount Sedgwick

**DOLE RITE**

**SILTSTONE WITH FOSSILS**

**SILTSTONE WITH "ERRATICS" AND FOSSILS**

**LIMESTONE**

**FOSSILIFEROUS SILTSTONE**

**CONglomerATE**

**SILTSTONE WITH ERRATICS**

**CONglomerATE**

**CONglomerATE**

**PEBBLY TILLITE**

**TILLITE**

**CAMBRIAN PORPHYRIES**

The section consists of a basal formation of tillite and outwash conglomerate, then another similar formation differing from the lower one particularly in possessing bedding. The lower one is correlated on lithological and stratigraphical grounds with the Wynyard (= Stockers) Tillite and the higher one with the erratic-rich beds at the base of the Quamby Mudstone at Deloraine. The fissile siltstone which follows this is lithologically like the Quamby Mudstone. The succeeding limestone unit can be correlated with the basal limestone of the Golden Valley Limestone and Shale and with the Darlington Limestone as it is lithologically similar, occupies a similar stratigraphical position and contains *Eurydesma cardatum* and *Stenopora tasmaniensis*. The Darlington Limestone correlate is followed by a pebbly fossiliferous siltstone and this by a fossiliferous siltstone. These are correlated on stratigraphical and palaeontological grounds with the higher parts of the Golden Valley Group near Delbaine and the formations above the Darlington Limestone at Darlington (Banks, 1957). The section does not go high enough to include the Liffey Sandstone and its correlates.

The basal formation indicates initial terrestrial glaciation followed by an ice retreat (units 2, 3, 4). The next formation marks a second advance of the ice sheet which was possibly not grounded and was floating in a shallow water, possibly a marine basin. This second advance was less intense than the earlier one and the sheet thinner. This was followed by further retreat leading to the development of outwash. Shallow marine conditions succeeded the formation of outwash, in which the icebergs deposited small erratics in the silt. Then the limestone unit represents reduction in the amount of clastic material supplied to the site of deposition and rich marine life. Some icebergs were still present. The next formation indicated a third ice advance but in a deeper sea with icebergs depositing erratics. This third phase of the glaciation was less intense than either of the earlier phases. The topmost formation shows a decreased intensity of glaciation, possibly marking the retreat from the third phase maximum. Lack of outwash deposits also supports the idea of floating ice.

**SECTION AT STRAHAN.**

This deposit was probably first noted by Moore (1896b, p. 74) in a paper read before the Royal Society of Tasmania in August, 1895, and by Officer, Balfour and Hogg (1895) who noted a "deposit of unstratified or faintly stratified clay of great hardness . . . " which contained some boulders which bore striae. They remarked that similar deposits occurred on Mount Sedgwick and Mount Tyndall. The Strahan deposits were considered to be Pleistocene by Moore because they contained no erratics "foreign to the country". Moore (1896b, p. 75) also noted another outcrop of a similar sort of rock two miles north-east of the outcrop being discussed on "Gould's old track". Lewis (1939, p. 165) commented on these deposits which he considered to be a Pleistocene moraine associated with the "fluvio-glacial" terraces at Strahan.
Road cuttings on the Queenstown-Strahan Road between 3 miles and 1½ miles from Strahan expose a tillitic conglomerate. It shows some fissility and rough bedding, which dips south-east at a low angle. This rock contains boulders up to two feet in length of greenish quartzite, quartz, very fine-grained black quartzite, slate, greywacke conglomerate like those of the Dundas Group and a biotite rich granite. Despite careful search no boulder of Owen Conglomerate or dolerite were seen. Some of the boulders are faceted and striated. The rock shows marked fracture planes and in places both matrix and boulders are badly shattered. There are a few beds of sandstone with rare rounded boulders and good bedding. On the whole sorting is very poor but there is lenses of comparatively well-sorted material which may be buried ice deposits or deposits of melt water streams. Boulders in the main body of the rock are more rounded than might be expected in a sub-glacial terrestrial till, and this rounding may have been produced by water transport.

On the first cutting south of the S 2 milepost steep faces trending 76° show slickensides which are either horizontal or dip slightly south and indicate north side west movement.

The present authors regard these beds as Permian because of their degree of lithification reflected in the fracturing of matrix and boulders, the jointing and the slickensiding. They have the same degree of lithification as is common in the known Permian beds in this region (e.g., the Firewood Siding and Geologists Creek area and on Mount Sedgwick) and considerably greater than that of the alleged Pleistocene beds at Strahan and Malanna. Lack of dolerite boulders and of Permian boulders also points to a Permian age but this lack can also be explained on the assumption of a Pleistocene age with a source in the West Coast Range just east of Strahan where neither Permian sediments nor dolerite are known. However, if the source was in this area the lack of Owen Conglomerate boulders is very difficult to understand. The slickensiding and movement implied by it are in keeping with slickensides and movements in the Permian near Firewood Siding. Thus the bulk of evidence suggests a Permian rather than Pleistocene age but no Permian fossils were found in it. This, however, is common in the glacial beds near the base of the Permian System in Tasmania.

The poor sorting of the bulk of the material together with faceting and striation of some boulders indicate some glacial transport. Increase in percentage of smaller boulders and clay and silt grades indicates some sorting, although of a low order, which is confirmed by crude bedding and sandstone layers. On the whole the deposit indicates the possibility of deposition in aqueous conditions of some of the sediment. Possibly these deposits were laid down by an ice sheet which was not thick enough all the time to remain grounded but when the ice sheet was grounded the meltwater lenses may have been deposited whereas when floating, the tillitic conglomerate was formed. Lithologically, these beds resemble those between 65 and 115 feet above the base of the section on Mount Sedgwick (see fig. 9) and beds near the top of the Stockers Tillite and the base of the Quamby Mudstone in the Deloraine area.

SECTION AT POINT HIBBS.

The only previous work on Permian rocks at Point Hibbs is that of Hills (1914) who noted the presence of fossiliferous mudstone conglomerate which he regarded as equivalent to the basal beds of the Permian System in other parts of Tasmania. His work was later quoted by Viosey (1938). The authors have examined the Permian section both north and south of Point Hibbs (see map, fig. 10).

On the northern shore the Permian is faulted against a Devonian limestone at the eastern end. Near the contact the limestone is sheared but the Permian is affected by the fault only to the extent of a shearing trending north-westerly in some of the finer beds near the contact. The Permian at the contact dips 275° at 85° and maintains this steep westerly dip for nearly a thousand feet. At this point it is affected by another fault and after a belt of variable strikes and dips some 20 yards wide maintains a dip of 38° to the south-west (237° to 255°) for about a hundred yards before dipping under dolerite. Almost at the dolerite contact the dip is 255° at 38° and the contact although irregular in detail, trends 318° over the length of its exposure on the shoreline. This trend would carry the contact west of Hibbs Pyramid, which is reported to be dolerite, so that there is probably either a marked swing in the trend on a fault. The dolerite has produced intense contact metamorphism in the Permian sediments for a hundred yards from the contact.

Because of the faulted contact with the Devonian limestone, the lower part of the Permian section may be missing. The lowest bed exposed is a conglomerate about two feet thick composed of numerous small angular rock fragments in a matrix of angular, coarse sand. The grains in the matrix are equant. There is no bedding within the unit but there is a north-west trending fissility, probably due to shearing. The rock is medium-grey in

![Map of the area around Point Hibbs showing the Permian section and the contact with the Devonian limestone.](image-url)
colour. Some of the boulders in it are striated and reach a length of one foot. One remarkable feature noticed was the lack of boulders of the adjacent limestone. This bed is overlain by 11 feet of conglomerate, interpreted as an outwash, which is relatively well sorted and contains somewhat rounded pebbles and boulders up to a foot long and lenses of tillitic material. The boulders include many of granite, some of a feldspar porphyry and quartzite including a green quartzite.

The outwash conglomerate is followed by 93 feet of tillite containing several thin beds of outwash conglomerate near the base. After a gap of 30 feet, siltstone outcrops for a thickness of 85 feet. This contains a lense of pyritic limestone twelve feet above the base and pyrite nodules at higher levels. It is a dark-grey, somewhat fissile rock with wavy laminations in places. A few pebbles which tend to be rounded occur near the base. A thinly-beded siltstone unit 84 feet thick follows. The bedding is usually less than an inch thick but may reach two inches in thickness. Some of the siltstone is calcareous and there are a few cross-beded sandy bands. Erratics are rare but pyrite nodules are common. The only fossils present are some worm burrows.

The next unit is 205 feet thick and consists of twenty alternations of fine-grained sandstone (or coarse siltstone) and “erratic”-rich sandstone in which the fine-grained sandstone is dominant as far as thickness is concerned. The fine-grained sandstone consists of angular, equant fragments of quartz, feldspar, rare white mica and carbonaceous material with a few erratics. It is medium-grey in colour and bedding planes are four inches to eight feet apart. It is brittle rather than fissile. Fossils are absent or rare in this rock type in the lower part of the unit but a little more common higher up. They include Stenopora, Fenestrella, Siphonodonta, Strophalosia, Eurydesma cordatum, aviculopectinids, a euomphalid gastropod and crinoid columnals. Cross-beded sets up to eight inches thick are present and the currents came from a southerly direction. One sandstone band about 10 feet thick occurs at the base. There are a few cross-beds with an angle of 340° when restored and cross-bedding formed by a current flowing from 225°. This sandstone contains plant fragments. Associated with the fine sandstone are at least twenty-one beds of “erratic”-rich sandstone which stands up several inches to two feet above the platform cut in the fine sandstone. These bands vary from six inches to nine feet thick. They are composed of the same minerals as the fine sandstone but they are perhaps a little coarser. In places the cement is calcareous. Bedding varies in thickness from six inches up to several feet. Their characteristic feature is that they contain numerous “erratics” up to four feet long which are angular to sub-angular and include granites, porphyries, quartzites, quartz, quartz schist, gneiss, green quartzite and rarely limestone like that immediately to the east. These “erratic”-rich bands are not tillites as they appear to contain little if any clay matrix and within any one band these beds are lenticular in shape and are not continuously parallel, nor do they appear to be deflated, or fragmented, the fragments lacking orientation. About 110 feet above the base the fine sandstone contains large limestone lenses with Stenopora, Fenestella, Strophalosia, spiriferids, Eurydesma, Aviculopecten and Calictorina.

This unit of alternating sandstone and “erratic”-rich bands is followed by fifty-six feet of siltstone with erratics up to six inches long and numerous fossils. It is very dark grey. The siltstone contains rare small calcareous concretions which contain Calictorina and numerous glendonites which are commonly single crystals up to six inches long and only rarely rosettes with up to three crystals. One glendonite grew around a specimen of Eurydesma. Fossils are very common and include numerous Stenopora tasmaniensis, fenestellids (very common in some bands), spiriferids including Grantonia, Neospirifer and Ingelarella, Eurydesma cordatum, Notomyia, aviculopectinids and Keeneia. The numerous extensive colonies of Stenopora tasmaniensis are preferentially oriented in many places suggesting currents from the north-west, north or north-east.

The next unit, which is 430 feet thick consists of four cycles, each cycle consisting of a basal member of banded conglomeratic siltstone and siltstone and the higher one of siltstone. The lowest cycle is 65 feet thick and of this 59 feet are conglomeratic siltstone and siltstone and six feet of siltstone. In the second cycle there are nine feet of siltstone and conglomeratic siltstone and then 37 feet of siltstone. The next cycle is 125 feet thick with the basal member 103 feet thick and the upper one 22 feet thick. The final cycle is 295 feet thick with a basal member only five feet thick. There is a further major cycle in that in the first and third cycles the basal member is the thicker one while in the second and fourth the upper member is the thicker.

The lowest cycle contains numerous fossils, especially in the pebbly bands, and these include Eurydesma cordatum, Keeneia platyshimoides, Stenopora tasmaniensis, spiriferids, Peruvispira and fenestellids. The siltstones have wavy laminations. In the basal member of the third cycle fossiliferous and the top member an 18-inch-thick limestone bed occurs. This is very impure and contains numerous “erratics”. Fossils are not common in the limestone but include worm burrows and a bilaminar Stenopora very like S. johnstoni. The higher member of the fourth cycle is fossiliferous and the fossils include Stenopora and Eurydesma. Erratics up to 18 inches long occur in the siltstone member and a band of “erratics” occurs 146 feet above the base of the member. Erratics again become common near the top of the formation.

The belt of shattering and variable strike interrupts the section at this level. Beyond it at least 200 feet of alternating sandstone and siltstone occur in which the beds are usually two to three feet thick and not more than 20 feet thick is present. Bands of pebbles are present in the sandstone and erratics are present in the siltstone. The erratics are dominantly quartzite and are up to six inches long. Fossils are abundant on some horizons. They include gastropods, fenestellids, Stenopora Aviculo-
FIGURE 11

SECTION OF PERMIAN ROCKS ON NORTH SIDE OF POINT HIBBS

- Fossiliferous siltstone with glendonites
- Alternating siltstone and erratic rich sandstone
- Thin-bedded siltstone
- Pyritic siltstone
- Tillite
- Conglomerate
- Fault
- Devonian limestone

- Dolerite contact
- Alternating sandstone and siltstone
- Fault
- Siltstone
- Conglomeratic siltstone
- Siltstone including 2 ft. of limestone
- Conglomeratic siltstone and siltstone
- Siltstone
- Conglomeratic siltstone and siltstone
- Alternating conglomeratic siltstone and siltstone
pecten subquinquelnearus, Eurydesma cordatum, E. cordatum var. sacculum and spiriferids including Ingelarella. The section is terminated by a dolerite intrusion.

The Permian section on the north shore of Point Hibbs is summarized here as fig. 11. It will be seen that at least 1,200 feet of clastic sediments are present. The lowest 106 feet of dominantly glacial origin, might be correlated with the Wynyard Tillite. The next major unit could be considered as composed dominantly of pyritic siltstone with some calcareous concretions and rare sandstone bands. It is at least 174 feet thick but there is a 20-feet gap between it and the underlying formation. This might be considered on lithological and stratigraphical grounds as equivalent to the lower part of the Quamby Group (= Quamby Mudstone of Wells, 1957) and the Woody Island Siltstone. The next major lithological break is at the top of the alternating sandstone and pebbly sandstone, 205 feet thick. Fossils become abundant in the next unit which contains the fossils of the Nelidella zone with glendonites. The fossils indicate a position low in the Permian sequence in Tasmania and the presence of glendonites strongly suggests correlation with part of the Woody Island Siltstone as these pseudomorphs are known from this formation and its correlates in eastern and northern Tasmania. The formation showing the four cycles follows this and is 430 feet thick. The thin limestone bed in the third member may be the Darlington Limestone as it is roughly in the correct stratigraphic position and contains some of the fossils from that formation. However, this cannot be regarded as established. It occurs within a unit 20 feet thick of siltstone much more richly fossiliferous than the adjacent beds and this strengthens the correlation with the Darlington Limestone. If the richly fossiliferous beds elsewhere are accepted as being at or near the base of the Golden Valley Group (= Formation of Wells, 1957), the base of the correlate of this group in the Point Hibbs area might well be considered as the base of the 20 feet of richly fossiliferous beds. The beds above this 20-feet unit consisting of at least 44 feet of alternating siltstone and conglomerate then sandstone and siltstone might then be considered equivalent to the higher units of the Golden Valley Group such as the Macrae Mudstone and Billop Sandstone of McKellar (1957) and the Bundella Mudstone of Banks and Hale (1957). The Mersey Group of fresh-water beds does not seem to be present but it is not impossible that they are represented here by marine sediments.

Permian tillite and fossiliferous siltstone occurs on the western end of Mount Read occupying depressions in a partly exhumed pre-Permian surface of Dundas Group rocks. The section is not clear but the Wynyard Tillite and Quamby Group are thought to be represented. At Mount Sedgwick the Permian rests on a striated surface of Dundas Group rocks. The striations indicate movement of ice from west to east. The section includes a basal tillite then rocks of the Quamby and Golden Valley Groups but these are considered thinner than in eastern and north-western Tasmania. Near the mouth of the Henty River Permian rocks are faulted against older Palaeozoic sediments. The oldest Permian rocks recognized are correlated with the Mersey Group and include some coal. These are followed by the "Woodbridge" Group, Perntree Group and Cygnet Coal Measures. All these groups are thinner than in south-eastern Tasmania and generally of coarser grainsize. Near Strahan a fluvi-glacial conglomerate occurs and is correlated with the top part of the Wynyard Tillite. At Point Hibbs a section from the Golden Valley Group is exposed. At least 430 feet of Wynyard Tillite up to at least into the Golden Valley Group is well exposed. The Quamby and Golden Valley Groups are comparable in thickness with their equivalents near Deloraine and Cressy and perhaps thicker than the sections in south-eastern Tasmania (see fig. 12).

Evaluation of these variations in thickness must await more regional data.

GEOLOGICAL HISTORY.

It would appear from the evidence quoted earlier (that early in the Permian Period, Western Tasmania was covered by an ice sheet which in places moved...
PERMIAN SECTIONS WESTERN TASMANIA

FIGURE 12.
from west to east over a surface with a relief of possibly a couple of hundred feet. On the evidence of the boulders present in the basal tillite and overlying fluvioglacial or paludal beds, these sands and pebbly sands were deposited in a cyclic fashion, the cycle representing perhaps minor retreats and advances of the glacial front or influx of turbidity currents into the area from time to time. At Point Hibbs at least these sands were marine. Erratics of quartz schists and gneisses of local Precambrian type occur at this level. Perhaps contemporaneous with the glacial advance at Point Hibbs was the deposition of pebbly silts. Perhaps contemporaneous with the glacial advance at Point Hibbs was the deposition of pebbly silts. Perhaps contemporaneous with the glacial advance at Point Hibbs was the deposition of pebbly silts. Perhaps contemporaneous with the glacial advance at Point Hibbs was the deposition of pebbly silts.

Further retreat of the ice front led to deposition of siltstones containing few erratics, calcareous concretions and glendonites. This type of rock is much thicker at Point Hibbs than at Mount Sedgwick, where it also lacks the glendonites, and concretions. These siltstones are marine and were probably formed under conditions of poor circulation. They contain no structures or fossils characteristic of deep water but at the same time contain no clear evidence of shallow water deposition.

There is a break in the record of Permian sedimentation in Western Tasmania in the next rocks exposed being the lacustrine and paludal beds of the Mersey Coal Measures. These terrestrial conditions were followed by an inundation of the land by the sea. Pebbly siltstone, sandstone and impure limestone were deposited and at times marine life was abundant. It was mainly of shallow water formistic forms. Some evidence suggests that this area was closer to the source and that the sea was shallower than at Hobart. After retreat of the sea erosion occurred before deposition of pebbly sands, silts and carbonaceous silts in lakes and swamps. There were several variations in the competency of the currents in the area of deposition. Plant life was abundant and included pteridosperms and equisetales.

References.


LOCALITY INDEX.

Badger River 
Strahan 
41° 59' 
145° 14'

Comstock Valley 
Strahan 
41° 59' 
145° 14'

Darling 
Lyell 
42° 02' 
145° 30'

Deborah 
Quamby 
41° 31' 
145° 22'

Derrinal, Victoria 
Zeehan 
41° 59' 
145° 16'

Derrimal Siding 
Zeehan 
41° 59' 
145° 16'

Geologists Creek 
Strahan 
42° 00' 
145° 16'

Henty River 
Strahan 
42° 39' 
145° 18'

Hobart 
145° 20'

Hobart 
42° 52' 
145° 30'

Malonna 
Zeehan 
41° 55' 
145° 15'

Maria Island 
Zeehan 
41° 55' 
145° 15'

Moore's Pimple 
Zeehan 
41° 02' 
145° 28'

Mount Dundas 
Zeehan 
41° 52' 
145° 29'

Mount Dunstan 
Murchison 
41° 54' 
145° 29'

Mount Mountyddall 
Zeehan 
41° 59' 
145° 30'

Mount Tyndall 
Murchison 
41° 57' 
145° 34'

Pieman River 
Pieman River 
41° 49' 
140° 02'

Point Hibbs 
Quamby 
41° 59' 
145° 15'

Strahan 
42° 19' 
145° 20'

Zeehan 
41° 53' 
145° 17'

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Issued under the Authority of
The Honourable ERIC ELLIOTT REECE, M.H.A.,
Minister for Mines of Tasmania

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TASMANIA
DEPARTMENT OF MINES

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Figure 1. Locality Map.
KING ISLAND

1. KING ISLAND-SMITHTON-DEVONPORT (LEADER, S.W.C.)

King Island (S.W.C., M.S.)

Between Naracoopa and Grassy, along the SE shores of King Island (Fig. 2), are excellent exposures of spilitic volcanics.

By comparison with rock types in other parts of West Tasmania the spilite is believed to be Cambrian and the underlying dolomite, breccia, sandstone and mudstone are tentatively correlated with the Success Creek phase (Lower Cambrian or Upper Precambrian). The volcanics comprise pillow lava, block breccia, pillow breccia, broken-pillow breccia and broken-flow breccia, similar to basic volcanics in British Columbia and Iceland. There are two petrologic types of lava—the olivine-rich, and the augite-rich, and these give rise to different types of volcanic product. The picritic lava, with high water content, rarely forms pillows (and these are of a distinctive type) but is invariably the component of the brecciated types of flow. The augite lava forms classic pillow (and also massive) flows with little evidence of disruption. The augite lava is fairly well crystallized, with albite and diopside and minor chlorite, epidote, hydrogrossular, &c. The albite and diopside commonly form intergrowths. The picritic lava is poorly crystallized and consists largely of olivine pseudomorphs in a felted, tremolitic groundmass. The tuff acting as matrix to the breccia is a micro-globular sideromelane vitrophyre that has undergone replacement by hydrogrossular and/or chlorite. Devitrification of the glass particles in the vitrophyre possibly occurred during the cooling of the volcanic succession.

Though Scott suggested all but the pillow lavas were subaerial, Solomon has suggested that most of the volcanics were subaqueous and that the breccia formed partly by intrusion of the flows and pillows into soggy, vitrophyric tuff. A feature of most pillows is the lack of chemical variation across their radius.

Underlying the volcanics (and in part interbedded with the basal volcanics) are dolomitic mudstone, agglomerate, dolomite, thick dolomitic breccia and at least one bed of pebbly conglomerate. This conglomerate was identified by Waterhouse as tillite and Carey also obtained numerous striated pebbles from it and tentatively gave it a Cambrian age.

A feature of the coastline is a pre-Wisconsin raised marine platform 20-30 feet (6-9 m) above sea level backed by degraded sea cliffs.

South of the volcanic exposures, at Grassy, is the King Island Scheelite Mine, which consists of an open-cut (mining about 500,000 tons of rock per annum) and mill (producing about 1,000 tons WO3 concentrates per annum). The open-cut lies north of a granodiorite stock in contact metamorphosed and metasomatized argillaceous and calcareous sediments probably similar in their unaltered state to those lying below the volcanics. The granodiorite is Lower Carboniferous (dating by I. McDougall) and the sediments may be Lower Cambrian or Upper Proterozoic. The gently dipping sediments have been metamorphosed at temperatures over 500°C to forsterite-phlogopite-spinel-tremolite hornfels, anthophyllite-cordierite hornfels, biotite and actinolite hornfels, grossularite-diopside skarn (calc-flinta), and marbles.
LOWER CARBONIFEROUS

Granite

CAMBRIAN (?)

Gabbro

Volcanics: undifferentiated
Massive lavas
Pillow lavas
Ropy lavas

PRECAMBRIAN (?)

Tillite, dolomite breccia, banded dolomite
Mudstones, sandstones greywackes, tuffs, dolomites

GRASSY

KING ISLAND SCHELITE OPEN CUT

YARRA CREEK

FIGURE 2. Geology of south-east King Island.

Geology by H.A. Bartlett
Later metasomatism converted the marble to scheelite-andradite skarn resulting in the occurrence of ore in well-defined beds.

The succession in the open-cut is as follows:

Bed A.—Hanging Wall actinolite hornfels, up to 70 ft thick.

Bed B.—Diopside-grossularite bed, 0-52 ft thick. This contains ovoid to angular patches up to 1 ft across of calcite, quartz, sulphides, &c., that may be relict pebbles in conglomerate.

Bed C.—Top Orebody, 0-36 ft thick, consisting mainly of andradite and relics of skarn rocks. Average grade 1.2% WO₃.

Bed D.—Marker Beds, 0-25 ft thick, consisting of distinctive biotite hornfels, grossularite-pyroxene rock and actinolite-biotite hornfels. Vesuvianite, clinohumite and brucite occur at this horizon.

Bed E.—Bottom Orebody: 50-110 ft thick, averaging 0.5% WO₃.

Bed F.—Transition Beds, 0-35 ft thick, alternating actinolite-biotite hornfels, grossularite-pyroxene hornfels, and marble.

Bed G.—Footwall actinolite-biotite hornfels, up to 150 ft thick.

Metamorphosed basic volcanics occur locally in this succession. The metasomatism was strictly volume-for-volume, leaving the sedimentary bedding undisturbed. Scheelite is associated with andradite skarn and is mainly disseminated as grains from 0.05 mm to 0.2 mm across. Some scheelite occurs with pyrrhotite, chalcopyrite and other sulphides and also in dilational quartz veins. Molybdenite is common in places. The temperature probably reached 600°C during mineralization.

**Smithton (A.B.G.)**

Between Black River and Montagu there is a low coastal plain cut by the Black River, Duck River and other minor streams. Coastal features such as spits are well developed and Stanley is situated on an isthmus, tied to the mainland by Cainozoic deposits.

Between Black River and Smithton the country rises inland to Tertiary basalt plateaux. At Smithton a Tertiary south-trending fault has resulted in a wide flat down-thrown area, now covered by Cainozoic deposits. Between this lowland and Montagu a low ridge of Cambrian rocks extends northwards from Christmas Hills. Montagu is situated on low-lying flats at the edge of an isolated basalt hill.

Stony Point, north of Montagu, consists of foreshore outcrops of Cambrian siltstone, greywacke and greywacke-conglomerate.

At Black River Upper Precambrian conglomerate, quartzite and dolomite form a syncline through which the river flows. Dolomite also underlies much of the Broadmeadows area and outcrops in the Duck River. A localized deposit of limestone occurs at Lower Scotchtown, its exact relation to the dolomite being undetermined. At Nabageena siltstone, lithologically like Cambrian siltstone, overlies dolomite with a probably unconformable contact.
The Cambrian succession contains a variety of greywacke, conglomerate and lava with siltstone, the age of which is proved by Middle Cambrian trilobites, found near Christmas Hills. Pillow lava occurs on the eastern shore of Duck Bay. Tertiary limestone unconformably overlies Cambrian rocks in the Duck and Montagu Rivers. Tertiary brown coal and siltstone underlie basalt near Alcomie and Edith Creek. Associated with the Tertiary basalt plug or neck at Stanley (The Nut) are contemporaneous tuff beds. Forest is situated on a Tertiary basalt plateau and another plateau extends south from Irishtown and Mengha.

A Quaternary paludinal deposit of peat with fresh water molluscs has formed a marl of good quality in an area 1½ miles north of Irishtown.

Wynyard-Devonport Region

There are five structural provinces in this area: the Rocky Cape Geanticline, Dial Range trough, Forth Nucleus, basement wedges and Mersey Graben.

ROCKY CAPE GEANTICLINE (R.D.G.)

In the unmetamorphosed Precambrian sediments in the North-West Coast two distinct lithological assemblages are recognized corresponding to different basins of deposition. East of Wynyard is the thick eugeosynclinal facies of greywacke, slate and minor pillow lavas. This assemblage extends eastwards to the older metamorphosed Precambrian basement at Ulverstone. To the west is the miogeosynclinal facies of laminated siltstone, thick ortho-quartzite and wide expanses of dolomite. As yet no fossils have been found in these rocks.

The eastern facies tectonically and possibly stratigraphically overlies the western facies but is now separated from the latter by a shear belt of low grade regionally metamorphosed pelitic sediment and basic intrusives. The shear belt separates not only different facies, but also structures of markedly different tectonic style. This belt of metamorphics, only four miles wide, is a fundamental tectonic structure in western Tasmania, extending from Wynyard to Granville Harbour.

Major tectonic movements were from NW to SE with the eugeosynclinal facies being squashed against the older basement on the eastern margin. This arrangement is unusual and a cratonic foreland is postulated well to the west. Large recumbent, asymmetric and reclined folds with belts of regional overturning were formed in the eastern facies. Detailed structural analysis reveals a complex picture of progressive deformation during the main phase of folding, and two later phases on different axes. Structures showing repeated deformation are abundant. Synorogenic dolerite sills, dykes and sheets are intruded and are especially common at Burnie and Cooee. The structure is simpler in the western facies, consisting of a series of anticlines and synclines trending parallel to the shear zone, tight and asymmetrical near the shear zone, and becoming progressively larger, more open and symmetrical to the west.
Cambrian succession in the Trough has lenticular formations, the position of maximum thickness being different in each. The average thickness of the pile (6000 feet) is thus about half the total of the maximum thickness of the formations (11,000 feet). The trough widens and deepens southwards to join the regional Dundas Trough.

The non-conformities in the succession are notable—for example, the units Cateena Group (near the bottom), Beecraft Megabreccia (at the top) and Dial Group (Ordovician) are all found in contact with basement.

The Cateena Group is predominantly laminites but there are turbidite intercalations which form macrograded units thought to result from failure of marine embankments. These units are associated with syndepositional deformation which probably was caused by a temporarily high rate of deposition in which loading rates exceeded consolidation rates in clay.

The Hardstaff Movement of the Middle Cambrian resulted in gentle folding and faulting and considerable erosion. The Jukesian Movement of the Upper Cambrian commenced with gravity downsizing of large masses from the flanks of the trough to form megabreccias, followed by folding, erosion of rising beds, further folding and termination of deposition, followed by intrusion of keratophyre and mineralization.

A traverse along the Penguin foreshore from west to east crosses the following units:

- **Rocky Cape Geanticline**
  - Quartzite of the Rocky Cape Group at Watcombe Beach.
  - Steeply-dipping unconformity.

- **Dial Range Trough**
  - Beecraft Megabreccia (Upper Cambrian) containing a stock of Cambrian keratophyre and several dykes.
  - Faulted contacts (faulted disconformity?).
  - Motton Spilite containing keratophyric dykes.
  - Fault.
  - Teatree Point Megabreccia at Teatree Point containing trachyte dykes.
  - Sedimentary contact (disconformity?).
  - Motton Spilite containing pillow lavas.
  - Conformable contact.
  - Barrington Chert of Lonah Point.

**Forth Nucleus (K.L.B.)**

The Forth Metamorphics is an association of garnet schist, amphibolite and quartzite. The Ulverstone Metamorphics is phyllite and schist with quartzite and conglomerate. The dominant foliation is a transposition surface so that the lithological layering is not a sedimentary feature and there is a “mechanical succession” in most areas. In contrast, in the Upper Division of the Precambrian the major lithological boundaries (sandstone against mudstone) are bedding. This structural feature, together with differences in lithology and grade, enable the two Precambrian divisions to be distinguished where in contact.
Along the western edge of the Forth Nucleus is a strip of Upper Division rocks. The boundary between the two divisions is a large discontinuity, the Singleton Thrust. This truncates foliations in each division and the sole is marked by a thin gouge or by chaotic breccia. The thrust is flat-lying and was folded in Devonian times.

The Precambrian rocks of the Forth Nucleus are overlain unconformably by Cambrian rocks on the west and by Ordovician rocks on the south side. The Ordovician Gordon Limestone at Eugenana is folded and is "overlain" unconformably by Upper Devonian cave sediments which date the principal Palaeozoic orogeny as Middle Devonian and thus equivalent to the Tabberabberan of Victoria.

The Tabberabberan consisted of a number of phases of movement, there being two principal periods of folding with north-trending "Eugenanan" folds followed by folds of the "Loonganan" phase which trend SW. The Gordon Limestone at Eugenana records both these episodes together with folds of an in-between or "intermediate" movement; however, structures of the intermediate phase are not common elsewhere.

BASEMENT WEDGES (K.L.B.)

The basement wedges of the Ulverstone foreshore are blocks of Precambrian "thrust up" through the Cambrian core. From Lonah Point on the west to Picnic Point on the east the rocks encountered in a traverse of the foreshore (two miles in length) are:

Cambrian of Dial Range Trough
(1) Barrington Chert of Lonah Point.
(2) Cateena Group mudstone largely concealed under basalt.
Steep unconformity (possibly faulted).

Goat Island Basement Wedge
(3) Rocky Cape Group (Precambrian Upper Division).
Singleton Thrust.
(4) Ulverstone Metamorphics (Precambrian Lower Division) of Goat Island.
Westbank Fault.
(5) Westbank Chaos (a sheared Cambrian megabreccia).
Unconformity (possibly faulted).

Ulverstone Basement Wedge
(6) Rocky Cape Group.
Singleton Thrust.
(7) Ulverstone Metamorphics of the "Central Outcrop". Ulverstone Fault.
(8) Sheared Cambrian rocks (probably Cateena Group)
containing limestone.
Unconformity (well exposed).

Gawler Basement Wedge
Chaotic breccia, probably sole of Singleton Thrust.
(9) Ulverstone Metamorphics of Picnic Point.
Movement on the Westbank Fault may have commenced in the Cambrian but the Westbank, Ulverstone and Gawler Faults all moved in the Devonian with accompanying folding of both mantle and basement.

Structures of the Ulverstone Metamorphics are assigned to the Frenchman Orogeny and consist of complex folds which appear to have developed during one major phase of orthorhombic three-dimensional strain with the principal component an elongation parallel to the long axes of deformed pebbles and the long axes of pebble-like tectonic fish or "tectons".

Frenchman structures accompanied metamorphism which may have consisted of two distinct episodes, $F_1$ and $F_2$. The observed mesoscopic structure is synchronous with $F_2$.

Post-Frenchman structures include Tabberabberan folds (two phases) and a minor crenulation cleavage at Goat Island which is termed $F_3$.

**MERSEY GRABEN (K.L.B.)**

The Mersey Graben extends NNW into Bass Strait for a considerable distance. In general terms it has two powerful boundary faults at the Don River and Port Sorell, about 10 miles apart, with the country between being downthrown and much broken up.

Two periods of faulting are known from the Illamatha Colliery but time relations are obscure and regional mapping suggests a third period.

The graben is of early Tertiary age and occupied by Permian glacigene sediments and Jurassic dolerite sills. Systems of master joints and small faults in the sills are probably early Tertiary while columnar and bowtie joints are cooling joints of Jurassic age.

The western boundary fault is a complex bundle with an irregular trace with members which reactivate Devonian faults in places. The tectonic scarp was reversed by the time of the first basalts (Oligocene) and the Oligocene fault-line scarp has been exhumed or reversed.

The centre of the graben is occupied by a deep trough of Oligocene lavas and sediments which are terrestrial and 1,000 feet below sea level (in the Northdown-Moriarty complex of deep leads.)

**2. MERSEY-FORTH POWER DEVELOPMENT (Leaders, S.J.P., G.E.A.H.)**

Mersey-Forth Power Development (Figure 5) is the biggest project yet undertaken by the Hydro-Electric Commission. It will utilize the whole of the economic power potential of the Mersey, Forth, Wilmot and Fisher River systems and will have an installed capacity of approximately 290 MW produced at a capital cost of about £51½ million.
Figure 5. Locality Map, Mersey-Forth Power Development.
Figure 6. Parangana Dam Site.
PLEISTOCENE
2nd Glacial Stage
- Laminated Carbonaceous Clay, Silt and Sand
- Periglacial Solifluction Material
- Gravely Tilt

1st Glacial Stage
- Varves, Mudstones, Siltstones and Tillite
- PRECAMBRIAN
- Dove Group
- pCd Schist

Drill Hole
Buried Channel

Figure 7. Lemonythme Penstock Line and Power Station Site.
The method of power development is controlled by:

(a) The fact that the River Forth is more deeply incised in its upper reaches that the Mersey and Wilmot Rivers.

(b) The flow available in each of the rivers is insufficient for economic power development independently, but the combined flow does permit satisfactory development.

The Mersey River will be diverted westward to the River Forth by construction of Parangana Dam, about ¼ mile below the junction of the Mersey and Fisher Rivers, and by a tunnel and a penstock leading to Lemonthyme Power Station on the River Forth upstream of Cethana Dam. The Wilmot River will be diverted eastward to the River Forth by construction of a dam near Moina, and by a tunnel and a penstock leading to a power station on a tributary creek of the River Forth upstream of Cethana Dam. The diverted waters will be further utilized at power stations situated at the foot of dams to be built at Cethana, Devils Gate and Paloooa. The Fisher River will be developed by a dam at Lake Mackenzie and a canal, tunnel and penstock connected to a power station on the lower Fisher River. The principal storage for the system will be provided by Rowallan Dam on the upper Mersey River.

The area of development lies in the youthfully dissected country adjacent to the NW boundary of the Central Plateau. It lies on the northern edge of the Precambrian Tyennan Block and on the site of the Lower Palaeozoic basins. The upper part of the area—Lemonthyme Scheme—was glaciated and glacierized during the Pleistocene.

Mersey Diversion-Lemonthyme Scheme (S.J.P.)

Parangana Dam site (Figure 6).

Parangana Dam (river level 1125) will be a 150 feet high rockfill dam with a clay core. It will have a crest length of 940 feet and a 70,000 cusec discharge side channel spillway. The scheme is scheduled for completion in 1969.

Geological investigation consisted of surface mapping, 38 diamond drill holes, varying in length from 30 to 196 feet and totalling 3,200 feet, one adit, and 15 seismic traverses.

The site is located on the Tyennan Block where the structural trend is E-W. At the site the Mersey River flows transverse to the structural trend through vertically to near vertically foliated Precambrian Fisher Group quartzite, schist, phyllite and slate. The lower part of the gorge is blanketed by Pleistocene and Recent deposits. The site has been glacierized rather than glaciated and has a broad upper profile and a narrow central river-cut channel. Up to 40 feet of talus overlies drift that has a maximum thickness of 50 feet. These deposits rest on periglacial solifluction material at an altitude of 1,070 to 1,100 feet. This material fills the central river-cut channel to a depth in excess of 180 feet below the base of the drift.
Figure 8. Cethana Dam Site.
The drift consists of a mixture of bouldery till, mostly derived from the dolerite of the Central Plateau, and fluvi-glacial sand and gravel. The underlying periglacial solifluction material consists of locally derived quartzite, schist and basalt in a clayey matrix.

The problems of settlement and permeability of the deposits are under investigation. It is proposed that decomposed granodiorite be used for the clay core and that quartzite from the spillway cut be used for rockfill and rip-rap.

Lemonthyme Tunnel, Penstock and Powerhouse (Figure 7)

The combined flow of the Mersey and Fisher Rivers will be diverted from above Parangana Dam by a 4 mile long 18 feet diameter unlined tunnel under maximum cover of 1,400 feet. This will connect to approximately 4,600 feet of steel penstock, with diameters of 12 feet 6 inches and 11 feet 8 inches, leading to a power station on the River Forth near the mouth of Lemonythyme Creek (river level 720). The installed capacity will be 50 MW under a static head of 530 feet (approx.).

The tunnel line has been investigated by surface mapping and two 1,350 feet diamond drill holes. The line passes beneath Emu Plains, a 2,500 feet high plateau formed of Precambrian Dove and Fisher Group schist and quartzite capped by Tertiary basalt, on which lies a thin discontinuous veneer of Pleistocene till. The tunnel line was chosen to pass through Dove Group schist and phyllite for the greater part of its length, thus avoiding the hard quartzite of the adjacent Fisher Group as much as possible. In the Dove Group good quality, moderately to closely jointed, coarse to fine-grained schist is expected to predominate. This should contain numerous quartz boudins and occasional bands of quartzite. Steep foliation should tend to produce a rhombic shape with overbreak at the junction of the walls and the back.

The penstock line and power station site were investigated by 29 diamond drill holes totalling 2,400 feet, 16 test pits and 12 seismic traverses. 800 feet of the line will lie on weathered Precambrian Dove Group schist, but the remainder will be sited on Pleistocene drift consisting of tillite, varves, mudstone, siltstone, till, sand and clay. The deposit is up to 175 feet thick and is thought to contain material deposited during two glacial stages. The power station will be sited on medium hard schist that contains some strongly jointed rock and clay seams. The engineering properties of the materials are under investigation.

Cethana Scheme (G.E.A.H.)

At Cethana (Figure 8) (river level 400) a double curvature thin arch concrete dam will be built. The dam will have a maximum height of about 350 feet and a crest length of 930 feet, and will contain about 200,000 cubic yards of concrete. The overall spillway will be 250 feet long and have a capacity of 87,000 cusecs. A high level intake will lead the water via a 16 feet diameter steel-lined shaft to an underground power station containing one machine with a 81 M.W. capacity under a maximum static head of 325 feet. This scheme is scheduled for completion in 1971.
FIGURE 9. Devils Gate Dam Site.
The geological investigation consisted of detailed mapping before and after clearing and sluicing of the abutments, trenching, 1,050 feet of exploratory adits and 6,000 feet of diamond drilling. The drilling was carried out in two parts—20 holes up to 450 feet depth to determine a suitable dam location and 21 holes up to 400 feet deep on the selected site. Determinations of rock properties have been carried out in the field and in the laboratory.

The site is located in a deep gorge cut through the Cockatoo Ridge Anticlinorium by the River Forth. This anticlinorium is a second order structure in the folded belt of Precambrian and Lower Palaeozoic rocks which trend in an E-W direction along the northern flank on the Tyennan Block. At the dam the structure strikes obliquely across the river, plunges to the west, and has been modified by normal and thrust faulting. It has been possible to place the dam foundation clear of the main faults but some faults which are nearly parallel to the bedding are unavoidable and will require special attention during construction.

The rocks in the foundation are quartzite and quartzite conglomerate of the Roland Conglomerate and quartzite, conglomerate, slate, &c., of the Moina Sandstone. Both formations are of Ordovician age. Cambrian metasediments were reached by the deeper drill holes. Thin talus, scree, and soil covered the flatter slopes and supported a heavy vegetation.

Jointing, particularly that related to the folding, dominates the other geological features. Some joints remain open to the greatest depths penetrated by drilling and water pressure testing indicates that grouting and drainage will be necessary to control leakage and uplift pressure. Most joints, however, become tight a few feet from the surface. Limonite, but little clay mineral, coats all joint surfaces near the surface. At depth fine platy aggregates of pyrite coat most joint faces. The faces of joints or minor faults approximately parallel to the bedding exhibit extensive slickensiding and when fresh often a coating of chlorite material.

Chemical weathering has had little effect but the weathering of fault and joint fillings and the removal of this from the near surface layers has allowed imperceptible rotation of large masses of rock. As a result of this the physical condition of the outcropping rocks appears to be rather better than is observed in the adits.

An examination of the dam site rocks for concrete aggregate revealed an unexpected reactivity with low heat cement, and it is possible that other sources of aggregate, e.g., basalt, may have to be explored. All the rocks at the dam have been mineralized to some extent and the reaction may be due to some of the introduced minerals reacting with the cement paste.

Devils Gate Scheme (S.J.P.)

A 270 feet high, double curvature, thin arch, concrete dam with a crest length of about 390 feet and an-overfall spillway of 90,000 cusec capacity will be built at Devils Gate (Figure 9). The structure will contain about 36,000 cu. yd. of concrete. A short length of tunnel and penstock will conduct water to a surface power station with an installed capacity of 59 M.W. under a static head of about 230 feet. The scheme is scheduled for completion in 1969.
FIGURE 10. Wilmot Dam Site.
The geological investigation consisted of detailed mapping, surface test pits, 2,700 feet of drilling (35 holes varying in length from 45 to 250 feet), 440 feet of adits (5), sluicing of abutments and seismic determination of rock properties in the abutment areas and sound rock velocities in the power station area.

The site lies in the gorge tract of the River Forth where it flows through a low, rolling basalt covered plateau. The gorge is cut in a sequence of chert, argillaceous chert and argillite of probable Cambrian age. The rocks are strongly deformed by a series of N-S wrench faults of small strike-slip displacement. The damsite has been chosen to lie immediately downstream of one of these faults, but minor associated faults cut both abutments. Joints of at least two ages are present. The older joints are filled with quartz veins, whereas the younger joints are open and have thinly brecciated or graphitic slickensided surfaces. Prominent joints follow the direction of thrust of the arch on the right abutment.

The chert is sound and values of Young's Modulus of between $1 \times 10^6$ and $3 \times 10^6$ p.s.i. were obtained by "in situ" and seismic tests. The rock is resistant to weathering but breaks down to small pebbles and sand under mechanical stresses and is thus not a satisfactory source of all grades of aggregate. It is also weakly reactive with cement. Basalt is the most suitable rock for aggregate in the area.

**Wilmot Scheme (S.J.P.)**

A 115 feet high, concrete-faced, rockfill dam (river level 1,470) will be built just downstream from the junction of the Iris and Lea Rivers (Figure 10). The dam will have a crest length of about 450 feet and a concrete-lined side channel spillway of 47,000 cusec capacity. An 8 feet 6 inches diameter concrete-lined tunnel approximately 13,700 feet long is proposed. It will discharge into a 1,400 feet long 5 feet 6 inches diameter steel penstock leading to a power station with an installed capacity of 29 M.W. under a maximum static head of 860 feet.

The damsite was investigated by drilling (29 diamond drill holes totalling 2,600 feet), by sluicing, and 6 seismic and 17 resistivity traverses. The site lies in Ordovician Moina Sandstone, consisting of interbedded sandstone, quartzite, slate and argillite, on the eastern limb of a minor N-S trending syncline. The left abutment is a narrow spur containing the synclinal axis, which is cut by a cross-fault. The damsite was chosen so that the cut-off will lie downstream of the fault. The hard quartzite is normally unweathered, but the sandstone is decomposed to weathered and porous. The rockfill will be obtained from the spillway cut on the right abutment. A buried Tertiary channel, filled with Tertiary lacustrine sand and clay passes from the reservoir to the Wilmot River below the damsite. The permeability of the deposit is under investigation.

The tunnel line was investigated by two 250 feet drill holes and by seismic and magnetic surveys. The line lies in Ordovician Moina Sandstone and passes beneath the site of the Bell Valley Tertiary lake. Seismic profiles suggest that lake sediments may extend to tunnel depth and further drilling is planned.
Figure 12. Geological Map and Section, Mt. Bischoff Area (Groves and Solomon, 1964).
3. WEST COAST (Leader M.S.) (See Figure 11)

Most of Tasmania's mineral wealth is derived from the West Coast, the ores occurring mainly in rocks of Upper Proterozoic to Lower Cambrian age.

During the Proterozoic much of the West Coast was covered by several thousand feet of sandstone and mudstone (the Younger Precambrian) which thinned out eastward onto the Tyennan Geanticline, composed of multiply-deformed schist, quartzite, amphibolite, &c., (the Older Precambrian). Overlying the Younger Precambrian, probably unconformably, are a few thousand feet of sandstone, mudstone and dolomite (the Success Creek phase) which contain spilite at Zeehan. These rocks overlapped onto the Tyennan Geanticline.

This miogeosynclinal sedimentation was followed by eugeosynclinal deposition of greywacke, mudstone, paraconglomerate and volcanics (the Crimson Creek Argillite and the Dundas Group) in basins limited by the Tyennan Geanticline and a new ridge of non-deposition in the NW, the Rocky Cape Geanticline. Cambrian igneous activity was typical of the ophiolitic suite, with early spilite, later serpentinite sills and gabbro and associated chert. Copper-nickel magmatic segregations and disseminated osmiridium were formed within serpentinite (Bald Hill, Trial Harbour, Zeehan) and magnetite lenses developed in amphibolite dykes (Savage River). During this eugeosynclinal phase, which lasted from probably early Cambrian to the Upper Cambrian, a volcanic arc (the Mt Read Arc) developed along the west side of the Tyennan Geanticline, accumulating several thousand feet of sodic and potassic keratophyre and quartz keratophyre (partly as ignimbrites) and some albite andesite, known as the Mt Read Volcanics.

A general uplift in the early Ordovician (the Jukesian Orogeny) was accompanied by development alongside the geanticlines of narrow troughs which were filled by Cambrian and Precambrian detritus (the Jukes and Owen Conglomerates respectively). Sedimentation gradually spread outside the troughs and the whole area was covered by several thousand feet of Ordovician and Silurian limestone, sandstone and mudstone. This was interrupted by the Tabberabberan Orogeny (Middle Devonian) which probably consisted of two phases of folding followed by intrusion of several granitic stocks (e.g. the Meredith and Heemskirk Granites) and minor quartz porphyries. The scheelite ores of King Island, the cassiterite-pyrrhotite ores of Mt Bischoff, Renison Bell and probably Mt Cleve-land, and the lead-silver ores of Zeehan and Magnet belong to this phase.

Tasmania's three producing base-metal mines (Mt Farrell, Rosebery-Hercules and Mt Lyell) all lie within the Mt Read Volcanic Arc and are the richest of numerous small showings along about 40 miles of the arc. Their occurrence within the volcanics and
the lack of any obvious granitic sources suggest a genetic relationship with the volcanics. Similar ore types and volcanics are common in other Palaeozoic eugeosynclines.

Both volcanics and ores may be related to magmatic and hydrothermal activity in deep-seated fractures that were active from at least the early Cambrian to the Devonian.

**Mt Bischoff and Renison Bell (M.S., R.S.)**

These two deposits show many similarities: they appear to be related to greisenized quartz porphyry dykes and sills; they consist mainly of pyrrhotite-cassiterite lenses, both concordant and discordant; the cassiterite is very fine grained and irregular in distribution; the concordant lenses are mainly replacements of dolomite beds within the Success Creek Group and lying a few hundred feet below the base of the Crimson Creek Formation; they are concentrated in broad anticlinal structures in which longitudinal and transverse faults are prominent; and small silver-lead prospects form haloes around the tin mineralization.

At *Mt Bischoff* a radial system of fractures were filled by quartz-orthoclase porphyry dykes which in the mine area were converted to tourmaline-muscovite-topaz-pyrite greisen. Near the centre of the radial system, the dolomite bed within the Success Creek Group sandstone was replaced by pyrrhotite and talc with cassiterite occurring as fine grains mainly in the talc. Chondrodite was formed near the Brown Face orebody.

The age relations of dyke intrusion and ore deposition are not clear though probably ore followed the dyke, pneumatolytic gases rising mainly along the dyke margins. Studies of pyrrhotite structure and sphalerite composition indicate that a temperature of 500°C was reached; lower-temperature deposits surrounding the dyke system contain sphalerite, galena and jamesonite.

The dyke system is believed to overlie a cupola of the Meredith Granite, which crops out about two miles SW of Waratah.

The deposit has yielded over 55,000 tons of tin, from ore averaging 1% Sn, but is not being worked at present.

At *Renison Bell* the shallow concordant and steeply-dipping discordant lodes lie to the west of a large tourmaline-quartz intrusion at Pine Hill, from which a few greisenized acid dykes penetrate into the mine area along longitudinal fractures. The three discordant orebodies ("sills") replace both dolomite and sandstone mainly within or close to an unusual suite of sediments comprising the "Red Rock". This consists of hematitic sandstone and chert, paraconglomerate, shale and dolomite and conformably underlies the Crimson Creek Formation.

The "sills" contain pyrrhotite, pyrite, cassiterite (80% less than 75 microns) and pistomesite, and the 25 feet thick No. 2 sill, the richest, averages 1.3% Sn.

The steeply dipping lodes occupy longitudinal fractures and consist mainly of pyrrhotite and quartz. Two parallel lodes, the Federal and Bassett, have been proved to continue for a strike length of 2,000 feet, a dip length of 1,500 feet, and have a maximum width of 100 feet.
Figure 14. Geological Map, Rosebery Area.
Sulphur isotope studies indicate a magmatic hydrothermal origin and the ores probably have a similar origin to the Mt Bischoff deposits.

At the Mt Cleveland mine, 10 miles west of Waratah, steeply dipping concordant pyrrhotitic lenses occur in mudstone, chert, greywacke and conglomerate of the Crimson Creek Formation. They have no obvious magmatic source, though acid dykes were reported by early workers.

Savage River (G.U.)

Magnetite forms irregular masses in concordant and discordant amphibolite dykes that cut quartz-mica schist and quartzite in the upper reaches of the Savage River. This river dissects a Tertiary surface at 1,200 feet.

The metamorphics, termed the Whyte Schist, trend NNE, dip steeply and are multiply folded. The amphibolite dykes and bodies are up to 4,500 feet wide and continue for several miles; they are brecciated and sheared in irregular zones in which magnetite deposition occurs. The amphibolite may be related to the nearby Bald Hill pyroxenite-serpentinite mass, of probable Cambrian age, or it may belong to a Precambrian phase of igneous activity.

Magnetite occurs in zones up to 700 feet wide with high grade (40% Fe), irregular, disconnected patches up to 100 feet wide. It is the dominant iron oxide and contains ilmenite-magnetite-hematite-rutile intergrowths. Pyrite is present along with traces of chalcopyrite, chalcocite, bornite, covellite and sphalerite (Fig. 13).

Gangue minerals include quartz, feldspar, calcite, dolomite, chlorite, apatite, epidote and talc and in places the western wall of the mineralized zone is converted to banded quartz-feldspar-carbonate schist.

The magnetite bodies appear to be related to the amphibolite. They probably could not have segregated in situ nor is there evidence of injection. Magnetite may have been segregated elsewhere prior to intrusion and subsequently shredded into irregular lenses during flowage or it may have been deposited with sulphides soon after intrusion during a late high-temperature hydrothermal phase of activity.

Rosebery and Hercules Mines (M.S.)

These two deposits are the only economic ones on a N-S line of mineralization (Fig. 14) running along the western margin of the Mt Read Volcanics between Silver Falls and Whip Spur (south of Hercules). This line is probably an old fault zone (the Rosebery Fault), active from Cambrian to Devonian times.

The sphalerite-pyrite-galena-chalcopyrite ores occur as lenticular or tabular bodies, in hydrothermally altered tuff and siltstone that form lenticular beds within the Mt. Read Volcanics and dip gently eastward. The tuffs at Rosebery and Hercules appear to be at much the same horizon and are underlain by fragmental, dominantly potassic, keratophyric volcanics (including ignimbrites), known as the Primrose Volcanics or Pyroclastics. The volcanics overlying the ore horizon are dominantly sodic and less
The successive change from early potassic, fragmental flows to later, sodic, non-fragmental flows applies to other parts of the Mt Read Arc.

The succession at Rosebery consists of cleaved sericite-quartz rock with augen structure, grading downwards to slightly altered potassic, fragmental, quartz keratophyre, and followed upwards by grey fine-grained tuff with coarser bands (Host Rock), followed in turn by dark grey, finely banded siltstone with fine-grained tuff. At the top are several thousand feet of quartz keratophyre.

The rocks dip east on the limb of an early, long-wavelength fold and are disturbed by superimposed, small-scale folds with slaty cleavage that trend west of the earlier fold. Both fold systems are probably of Devonian age. The mine geologists interpret the small folds as drag structures on a larger fold. They suggest the orebodies are syngenetic and represent a tightly folded, conformable ore horizon, thickening and thinning around the folds to give the impression of a series of separate lenses. The prominent banding in the ore is considered to be of sedimentary origin.

The Zeehan Field and the Heemskirk Granite (R.B., T.G., C.B.)

For many years the silver-lead deposits of Zeehan have been regarded as part of the mineralized aureole around the Heemskirk Granite though the discovery that the iron ores forming part of the aureole were actually derived from ultrabasics has cast doubt on the validity of the aureole. The Zeehan deposits consist of fissures filled by pyrite-sphalerite, galena-siderite, galena-siderite-boulangerite and pyrite-stannite ores, and occur in rocks ranging from Precambrian to Devonian. The bulk of the production, however, is from a few mines near Zeehan township which occur in Precambrian spilite and sandstone. The spilite belongs to the same phase of volcanism as the Mt Read Volcanics and may have had some influence over ore distribution.

The Heemskirk Granite is a cassiterite-rich stock admirably exposed at Trial Harbour where it intrudes Cambrian volcanics, dunite, and Precambrian and Silurian sediments. It is composed of grey, pink and white granites all with the same mineralogical composition (quartz, orthoclase dominant, plagioclase, biotite subordinate). The white granite commonly contains nodular tourmaline segregations. The pink and white granites are two distinct bodies but the grey granite is only a local marginal variation of the pink granite. Emplacement began with the pink and grey granites, followed closely by the white granite, and finally the intrusion of minor bodies (porphyritic aplite, microgranite, aplite, pegmatite, quartz-tourmaline dykes, pyroxene dyke). Tourmaline is abundant in the later intrusions and, where green, is locally accompanied by cassiterite. Cassiterite also occurs in greisen zones and pipes (such as the Federation pipe, NE of Trial Harbour).

Rubidium-strontium isotopic age results have shown that all phases of the granite complex are essentially the same age (350 to 360 million years). Unlike normal high-level intrusive granites, which have a Sr$^{87}$/Sr$^{86}$ ratio in the vicinity of 0.71, this complex has an unusually high ratio of 0.73 to 0.74, being considerably enriched in Sr$^{87}$. It could be interpreted from this that the granite
body did not have a normal primary magma source but represents melted intruded sediments, which in this case would be of Pre cambrian age.

The dunite contains small segregations of nickel minerals including pentlandite, heazlewoodite, shandite and millerite.

Metamorphism of the Precambrian sediments is slight, and an andalusite-bearing pelitic hornfels is the only characteristic product. The Cambrian (?) volcanics give rise to a variety of assemblages: (1) Lime and ferromagnesian rich (hypersthene-cummingtonite(?)-labradorite; diopside-actinolitic hornblende-labradorite), (2) Magnesian rich (cordierite-hypersthen; cordierite-anthophyllite), (3) Ultrabasic (olivine Fo₃ or Fo₅ and/or pleonaste). These assemblages belong to the pyroxene-hornfels, hornblende-hornfels or albite-epidote-hornfels facies of contact
metamorphism, but later retrograde metamorphism has produced non-equilibrium assemblages, confusing delineation of these facies in the metamorphic aureole.

The contact relations between the serpentinized dunite and the Cambrian(?) hornfels country rock are obscured by diopside-rich rocks, which occur along the northern contact between the hornfels and the dunite. These diopside rocks form a characteristic feature of the aureole and, in addition to the hornfels/dunite boundary type, also occur as veins intruding the granite and extending from the granite across the contact, into the hornfels, or as apparently intrusive masses into the sediments.

Mt Lyell Mines (R.G.E., M.S.)

These deposits occur at the northern end of a 20 mile line of small copper prospects extending south to Mt Darwin. This line is marked by the presence of potassic quartz keratophyre which, near Darwin, is intruded by Cambrian granite (the Darwin Granite) of similar composition. The northern end is clearly on an important structural zone (the Great Lyell Fault Zone), the history of which extends back at least into the early Ordovician.

The ores (largely pyrite, pyrite-chalcopyrite and pyrite-chalcopyrite-borneite lenses) occur in cleaved and hydrothermally altered Mt Read Volcanics which have been thrust against upturned Owen Conglomerate. As at Rosebery, two trends of deformation are recognizable, one N-S (mainly early) and one WNW-ESE. Folding of the latter trend was accompanied by cleavage, and ore deposition was essentially post-cleavage, the form of the disseminated low-grade lenses being controlled by the orientation of the cleavage. The temperature of ore deposition probably reached at least 500°C and the hydrothermal alteration of the volcanics (largely potassic quartz keratophyre and some spilite?) to quartz-sericite and chlorite-quartz “schist” probably took place between 350°C and 600°C at a pressure of about 800 atmospheres.

An unusual feature of the Cambrian vulcanism at Lyell was the production of large masses of cherty rock invaded by veins and veinlets of hematite, magnetite and barite. Weathering of these iron ores may have given rise to the large bodies of hematite and barite (e.g. the Iron Blow) found at the base of the overlying Owen Conglomerate. The areal coincidence of the chert and ferruginous bodies with the richest copper orebodies may indicate a Cambrian phase of mineralization. This indication is supported by the close correlation between distribution of certain volcanic rock types and ore deposits throughout the Mt Read Arc, and the lack of local Devonian granite sources.

8. East, Central, North-West and West Tasmania (Leader, M.R.B.)

First Day (a) Route if weather fine (M.R.B.)

Hobart to Orford by bus, boat to and from Maria Island, bus to Swansea.

Maria Island

Folded quartzite and argillite, intruded by granite, are overlain unconformably by Permian rocks on the eastern shore of Maria Island. The Permian rocks are folded into a gentle syncline seen
Rissoin Sandstone: 'X XXXXXx, I, EmEmBER 5I505 SANOSTONE, GRADED BEDDING---- GROOVES OR SLICERUSES ON BASE. MEmBER C, HALO/HA FORMATION. TREND 150° T. TOP MOVED NE. IS/ROO Is. TESSELLATED PAVEMENT ONE 180° Af JOINT AS REALLY SMALL II/LT WITH CONSISTENT DEXTRAL MOVEMENT. ONE 75° M JOINT SHOWS CLEAR SINISTRAL MOVEMENT. EAGLEHAWK NECK

Pirates Bay

Malbina Formation: MEMBER E 7 CONVOLUTA. MALBINA FORMATION MEMBER E 7 CONVOLUTA. TESSELLATED PAVEMENT. ONE 180° M JOINT IS REALLY SMALL FAULT WITH CONSISTENT DEXTRAL MOVEMENT. ONE 75° M JOINT SHOWS CLEAR SINISTRAL MOVEMENT.

Figure 17. Geological sketch map, Eaglehawk Neck Area.
in magnificent cliff exposures on the north end of the island, and are overlain by Triassic sandstone intruded by Jurassic dolerite and faulted to the west against dolerite intrusive into Triassic sandstone.

The route marked on the map (Fig. 16) crosses successively higher units as shown on the correlation chart (Fig. 18). The section is notable for richness in *Eurydesma* in the Darlington Limestone and in fossils in the correlate of the Berriedale Limestone.

(b) Route if weather poor (M.R.B., E.W.)

Hobart to Eaglehawk Neck, walk around shoreline, bus to Swansea.

**Eaglehawk Neck**

Permian siltstone and sandstone, exposed in shore platform and cliff sections at Eaglehawk Neck, belong to the Malbina Formation (Fig. 17). Member A is not exposed in the immediate vicinity. Member B, at least 12 m thick, contains siltstone with small-scale slump and current drag structures, large erratics, thin beds...
of sandstone with graded bedding, limestone concretions and rare fossils. The top of Member B is scoured in many places. Member C, 1.3 m thick, is pebbly, pyritic sandstone, with numerous worm burrows. The pebbles include vein quartz, quartzite, granite, porphyry and siltstone up to 50 cm long. Wood in the base of Member C is elongated 330°-350°. Member D is poorly fossiliferous siltstone and sandstone containing erratics and a few fossils, e.g. "Spirifer" avicula and is at least 15 m thick. Member E is richly fossiliferous siltstone containing Stenopora crinita, Terrakea, S. avicula, Myonia carinata and Chaenomya etheridgei. It is overlain by a pebbly feldspathic sandstone correlated with the Risdon Sandstone.

A continuous Permian section in cliffs north of Pirates Bay rests on granite. Thin, basal, arkosic breccia and conglomerate is overlain by Darlington Limestone and other units, all with a regional dip to the SE on which are superimposed gentle folds and faults with displacements up to one metre. The Permian rocks are intruded by dolerite along a meridional contact dipping steeply west and passing just west of the neck. Contact metamorphic effects are limited to a zone less than 20 m wide.

At the shoreline the variations in development, frequency and direction of the joints in the Permian beds can be noted. Conjugate joints occur and although the dihedral angle varies greatly the direction of the intersector remains constant from bed to bed. Lateral displacement along joints can be seen at some localities.

Second Day (M.R.B., E.W.) Piccaninny Point (E.W.)

At the point occur closely folded hornfelses in which the sedimentary structures, apart from current bedding, have been destroyed. A country rock/granodiorite contact can be observed. The granodiorite is crowded with xenoliths and thin veins penetrate the metamorphosed sedimentary rocks. Late aplite intrusions cut both granodiorite and country rock, which may be related to the Mathinna Beds.

Elephant Pass (M.R.B., E.W.)

At the base of the pass is a quarry in granodiorite in which occur pegmatitic variants and graphic granite. Fluting along dislocation planes within the igneous rock indicates wrench movement. The country rock adjacent to the granodiorite intrusion is indurated and spotted, and small discordant and concordant bodies of granodiorite are observed within the road sections of hornfelsed sedimentary rocks which are believed to be of the Mathinna Beds. Rare sedimentary sole markings on the sandstone layers may be observed. A number of small folds with axial fractures occur, and are best examined near an exposed unconformity with the overlying approximately flat-lying Permian beds towards the top of Elephant Pass.

The Mathinna Beds are overlain unconformably by a succession of Permian rocks summarized as Fig 18. The main interests of the succession are the presence of a basal conglomerate passing upwards and westwards into non-marine beds with thin coal seams, the presence of rare trilobite pygidia in the Gray Siltstone; the richly fossiliferous correlate of the Berriedale Limestone containing Lyroporella, Taeniothaerus, &c., and the thinness of the correlate of the Malbina Formation.
EAST, CENTRAL, NORTH-WEST, WEST

Rays Hill (M.R.B.)

This section is thin but is notable for the thinness or absence of Malbina Formation, the richly glauconitic character of the correlate of the Risdon Sandstone or Malbina and Ferntree Formations and the thinness or absence of the Ferntree Formation. The section extends up the gully west of the farmhouse (600.8E/880.8N) and then up a cart track to the NW ending at 600.5E/881N.

Third Day (M.R.B., E.W.) Fingal-Ormley

A fine view of high-level erosion surfaces may be seen from a point on the South Esk Highway just west of the bridge over the Break O' Day River. The road is on the Lower Coastal Surface at about 800 feet on the flood plain of the South Esk River. The Higher Coastal Surface on the hills NW of Fingal is at 1,100-1,300 feet and is locally an exhumed sub-Permian surface. The St Clair Surface is seen locally as the top of Fingal Tier, south of Fingal (about 2,400 feet), the top of the Mt Nicholas Range and a bench on Tower Hill. The Lower Plateau Surface (3,000-3,500 feet) is represented by the exhumed sub-Permian surface of Mathinna Plains and the top of St Pauls Dome and the Higher Plateau Surface by the top of the Ben Lomond Plateau at about 4,800 feet.

The least complicated of the folds affecting the Mathinna Beds, which are of interbedded competent mudstone and initially competent sandstone layers, are well exposed in road cuttings between Fingal and about a mile beyond Ormley.

Examination of the geometry of the folded confined incompetent beds indicates that the shearing stresses to which they were subjected by the movement of the competent sandstone layers during deformation did not affect the development of cleavage within the mudstone in which the flaky minerals are aligned. The cleavage converges on the fold cores and troughs and is considered to have formed in the laminar-type flow surfaces of the incompetent material whilst accommodating itself to the interspaces determined by the more competent layers.

Folded sandstone layers behaved initially competently but show later "flattening". Reconstruction of unflattened profiles reveals that the cleavage surfaces, which form fans diverging from the fold cores, were formed approximately at right angles to the boundary at the outer arc. Cleavage formation in the competent granular layers is related to the phenomenon of dilatancy where zones of open texture develop at approximately right angles to the outer boundary during folding.

Poatina (M.R.B.)

The Permian section at Poatina is summarized as Figure 18. Erratics occur throughout the succession (except in the non-marine Liffey Group and Jackey Shale). The origin of pebbly sandstone in the Billopp Conglomerate is uncertain. The rocks above the Liffey Group, fossiliferous mudstone, contain few limestone beds in contrast to the Cascades Group in SE Tasmania. The equivalents of the Malbina Formation (Dabool and Western Formations) are thinner than this unit near Hobart (Fig. 18).

The Triassic section is the best in the State. The Ross Sandstone at the base is 200 m of quartz sandstone with some finer beds. This is over lain by 140 m of quartz sandstone and siltstone containing amphibian (probably Lower Triassic) and other verte-
brate remains and rare plant fragments. The Tiers Shale (85 m) is predominantly siliceous, carbonaceous siltstone with plant fragments and the highest unit is the Brady Formation (165 m) of feldspathic sandstone (lithic arenite), mudstone, claystone and coal containing "Estheria", plants and spores of Rhaetic/Liassic age.

Fourth Day (M.R.B.)

Mole Creek-Liena-Cethana

Stop 1: Alum Cliffs (439E/885.5N)—gorge of the Mersey River in Caroline Creek Sandstone with some faulting, sandstone locally very rich in worm casting, and containing worm burrows, strongly costate brachiopods and euomphalids.

Stop 2: The Den (434.5E/884.5N)—the top of the Gordon Limestone in the axis of a syncline here contains numerous corals suggesting an Upper Ordovician age.

Stop 3: Grunter Hill (425.5E/883.5N)—the top beds of the Caroline Creek Sandstone contain Lecanospira and other fossils.

Stop 4: A. Howe's Farm (425E/882.5N)—Gordon Limestone about 100 m above the base with Maclurites-Girvanella assemblage; cross-bedding in limestone from the NW but truncated top and bottom.

Stop 5: Forestry Road, Liena (422.5E/881.5N)—siltstone between Gordon Limestone and Eldon Group, some fossils.

Stop 6: Fisher River (420.5E/872N)—ripple marked Precambrian quartzite.

Stop 7: Forestry Road, Liena (421E/878N)—Caroline Creek Sandstone resting on granite.

Stop 8: Forestry Road, Liena (421E/878N)—fossiliferous siltstone between Caroline Creek Sandstone and Gordon Limestone; contains pelecypods.

Stop 9: Forestry Road, Liena (422E/879N)—Gordon Limestone with a few corals.

Stop 10: Lorinna Road, Cethana (414E/892N)—faulted unconformity between Roland Conglomerate (with pebbles of sheared porphyry) and greywackes of the Minnow Keratophyre Formation (Cambrian).

Fifth Day (M.R.B.) Devonport, Caroline Creek, Railton, Eugenana, Palooa, Ulverstone, Gunns Plains, Burnie

Stop 1: Haines Brick Pit (436.5E/915.5N)—slightly fossiliferous, pyritic, Permian mudstone (Tasmanites oil shale may be exposed) lapping onto shore of Caroline Creek Sandstone (type area is railway cutting 200 yd from Haines Brick Pit). Caroline Creek Sandstone contains worm castings and burrows, brachiopods, gastropods and trilobites (Carolinites &c.).

Stop 2: Blenkhorns Quarry, Railton (439E/910N)—siltstone and sandstone with Tritoechia overlain by Gordon Limestone with Nybyoceras spp., and other fossils.

Stop 3: Goliath Cement Company Quarry, Railton (438E/909N)—Gordon Limestone with Maclurites (rare), sponges, Recpectaculites and cephalopods.
Stop 4.: Halletts Lime Quarry, Eugenana (428E/922N)—folded Gordon Limestone with *Maclurites*, *Girvanella*, and other fossils; containing unfolded cave deposits with *Spinozonotriletes*, "Radianpora" and other spores suggesting an Upper Middle Devonian age. This occurrence places an upper time limit on the Tabberabberan Orogeny in Tasmania.

Stop 5: Bridge over Forth River at Palooona (423.5E/917.5N)—Cambrian lava, tuff and chert overlying Precambrian graphitic schist to the north.

Stop 6: Gunns Plains Road, Leven Gorge (405.5E/917.5N)—Argillite of the Radfords Creek Formation containing *Lejopyge laevigata* and other agnostids (Upper Middle Cambrian).

Stop 7: Gully east of Gunns Plains Caves (400.6E/916N)—near the top of the Gordon Limestone; a richly coralline zone with *Favistella*, heliolitids, favositids, aulacoids and other fossils.

Stop 8: Shoreline at Grooms Slip (409.6E/935.5N—Mottan Spilite (Middle Cambrian) with pillow structure.

Stop 9: Penguin (406.5E/936N)—steep contact between Bee-craft Megabreccia and Rocky Cape Group (Precambrian); a contemporaneous escarpment.

**Sixth Day** (M.R.B.) Burnie to Fossil Bluff, Wynyard, Hellyer Gorge, Guildford, Valentines Peak, Rosebery, Zeehan, Queenstown

Stop 1: Just east of Doctors Rock, Wynyard (380.5E/948.3N)—Wynyard Tillite resting on striated and smoothed pavement of Precambrian rocks; glaciofluvial rocks in and on tillite showing currents from the SW; tillite unconformable on laminated shales and sandstone (Fig. 19).

Stop 2: Seabrook Creek (379.8E/949.3N)—conglomerate and sandstone within the Wynyard Tillite; cross-bedding from the SW (Fig. 19).

Stop 3: Point with pine trees (377.6E/950.8N)—tillite unconformable on gently folded laminated shale and sandstone; convoluted structures in the tillite.

Stop 4: Fossil Bluff (375.4E/952.6N)—richly fossiliferous Aquitanian sandstone and limestone rest unconformably on gently tilted tillite with interbedded laminated shale showing intrastratal folding.

Stop 5: Upper Seabrook Creek, Elliott (378E/940N)—fine exposures of glacial varved claystone in Wynyard Tillite.

Stop 6: Waratah Highway, Onah (363.5E/920.1N)—Quamby Mudstone with arenaceous foraminifera.

Stop 7: Waratah Highway, Onah (363.5E/920N)—"Tasmanites" oil shale with arenaceous foraminifera (*Ammodiscus onahensis*, &c.).

Stop 8: Bridge over Hellyer River (365E/917N)—road sections of Wynyard Tillite.

Stop 9: A.P.P.M. Road, Valentines Peak (376.2E/906.5N)—Cambrian siltstone with *Nepea* and other trilobites probably Upper Middle Cambrian.
Seventh Day (M.R.B.) Queenstown to Zeehan and return

Stop 1: Austral Flats, Zeehan (340.1E/839.2N)—Caroline Creek Sandstone with abundant worm burrows.

Stop 2: Smelters Quarry, Zeehan (340.8E/838.8N)—the Mount Zeehan Conglomerate underlies Caroline Creek Sandstone on the flanks of Mt Zeehan and the latter formation is below the Gordon Limestone. The limestone and interbedded siltstone at the Smelters Quarry are richly fossiliferous (Receptaculities, Tetradium and other corals, Stictopora and other polyzoans, brachiopods, pelecypods, gastropods, Hecatoceras, Tasmanoceras, Anaspicyoceras and other cephalopods, asaphid and illaenid trilobites, &c.

Beyond Austral Creek, Crotty Sandstone (Gill and Banks, 1950, loc. 20), Amber Slate with Gilliatia (ibid. loc. 21), Keel Quartzite (ibid. loc. 22), Austral Creek Siltstone and Florence Sandstone (ibid. loc. 23) outcrop, and will be examined

Stop 3: Silver Bell Siding (340.3E/840.1N)—Florence Sandstone rich in fossils especially Karpinskia; just to the south over a fault Crotty Sandstone (ibid. loc. 17) with abundant Camarotoecia synchoneua will be visited.

A track leading past the Silver Bell Mine leads to richly fossiliferous Bell Shale on the banks of the Little Henty River (ibid. loc. 16) where Pleurodictyum megastomum, Australocoelia polyspera, Meristella bellensis, Notanoplia pherista may be found.

Stop 4: Oceana Road, Zeehan (340.1E/841.8N) (ibid. loc. 6)—Bell Shale.

Stop 5: Quarry near Howards Timber Mill, Zeehan (340.3E/842.5N)—ibid. loc. 1—Bell Shale with Plectodonta bipartita, Notanoplia pherista.

Stop 6: Near Aerodrome, Queenstown (358.2E/820N)—Florence Sandstone with Karpinskia and many other fossils.

Stop 7: Pearl Creek, Queenstown, (358E/420.3N)—Bell Shale with Australocoelia polyspera, Notanoplia pherista, Pleurodictyum megastomum.

Stop 8: Smelters Quarry, Queenstown (359.8E/819.5N)—Gordon Limestone with Tetradium, Beloitoceras, Anaspicyoceras, &c.

Stop 9: Ridge near Sports Oval, Queenstown (359.9E/819.4N)—siltstone in Gordon Limestone with lichadids, harpids, Ceraurus and other fossils.

Stop 10.: Sandhill, Queenstown (359.5E/818.5N)—Crotty Quartzite with few fossils.

Stop 11: Near hospital, Queenstown (359.2E/818N)—Amber Slate with Tentaculites.

Eighth Day (M.R.B.) Queenstown, Lake St Clair, Gretna, National Park, Maydena.

Stop 1: Gormanston Gap (362.7E/819.3N)—Owen Conglomerate in contact with Lyell Schist; weather permitting, the party will visit an outcrop showing merostome tracks.

Stop 2: 12 mile post, Lyell Highway (374E/817N)—sandstone (possibly part of Florence Sandstone) with Pleurodictyum megastomum, Encrinurus, Leonaspis, Parmorthis, Eatonia, Strophonella, &c
SKETCH MAP OF WYNYARD - OONAH DISTRICT
SHOWING OCCURRENCE OF PERMIAN VARVES

FIGURE 19. Geological Sketch Map, Wynyard District. (Published by courtesy of Royal Society of Tasmania.)
Stop 3: 15 mile post, Lyell Highway (378E/815.5N)—Austral Creek Siltstone with dalmanitids and Monograptus colonus.

Stop 4: Top of Victoria Pass (379.5E/815N)—faulted Gordon Limestone with Eofletcheria ida, Tetradium and other fossils; good section of limestone on Bubbs Hill just to south.

Stop 5: Lyell Highway just east of King William Saddle (411E/802.8N)—basal tillite of Permian System overlies striated surface (ice from just north of west) of Precambrian quartzite.

Stop 6: Lake St Clair—a glacially overdeepened lake.

Stop 7: Road cuts on Dobson Highway, National Park (465.1E/745.5N)—folded and faulted erratic-bearing fossiliferous sandstone of the Malbina Formation; fine exposure.

Stop 8: Cut on Maydena Road at Arcadian Siding (463.1E/742.1N)—folded and faulted erratic-bearing fossiliferous Grange Mudstone and Malbina Formation. Magnificent exposure.


Stop 1: The Gap (443.5E/741.8N)—near top of Florentine Valley Mudstone; siltstone and calcareous siltstone with Didymograptus gracilis, Tritoecchia, Syntrtophopsis, Lecanospira, Asaphellus lewisi.

Stop 2: Tim Shea Quarry (442E/742.8N)—upper beds of the Tim Shea Quartzite and Conglomerate containing some chromite; some folding is shown in the quarry; along the track to the summit of Tim Shea cross bedding and worm burrows and castings are seen in this formation.

Stop 3: “9 ”Road (442.5E/746.2N)—calcareous siltstone, impure limestone and siltstone at junction of “9 ”Road with main road and on low ridges north and south of “9 ”Road, with Tritoecchia, Tasmanocephalus, agnostids, Phyllograptus anna, and many other fossils.

Stop 4: Westfield Road (443.8E/751.2N)—siltstone above Gordon Limestone grading up into fine sandstone and coarse sandstone; siltstone unit contains a cryptolithid and many other fossils.

Stop 5: Junction Lawrence Creek Road and Eden Creek Road (443.5E/755.3N)—limestone with Tetradium cf. cellulosum, Foerstephyllum cf. halli, Thamnobeatricea, Receptaculites, lying above limestone with Maculrites and Girvanella.

Stop 6: Lords Road (443.2E/757.1N)—Maculrites-Girvanella limestone.

Stop 7: “16 Road” (442.9E/758.2N)—limestone above Maculrites-Girvanella limestone; contains Tetradium, Foerstephyllum cf. halli, Thamnobeatricea, Receptaculites.

Stop 8: Florentine Road (440E/757.6N)—calcareous siltstone and fine sandstone member within Gordon Limestone; contains trilobites, ostracodes and other fossils.

Stop 9: Florentine Road (441.5E/756.7N)—richly coralline limestone near top of Gordon Limestone with Eofletcheria, Palaeophylum and many other corals.
7. NORTHEAST TASMANIA (Leader, E.W.)

During the early part of the excursion visits will be made to either Eaglehawk Neck or Maria Island, Elephant Pass and Fingal. Notes on these localities are given under the heading of the E-Central-NW and W Tasmania Excursion.

St Marys Pass (E.W.)

Porphyrite is well exposed in quarries along the roadside. It contains phenocrysts of quartz, plagioclase, biotite and hypersthene, sometimes with amphibole rims, set in a fine grained groundmass. The porphyrite is at least 500 feet thick and was emplaced as an intrusive sheet or flow after the regional folding of the Mathinna Beds.

Upper Seamanter (E.W.)

Near Upper Seamanter a well-exposed sequence of the Mathinna Beds some 177 metres thick occurs in road cuttings. The sequence is of interbedded mudstone and sandstone with coarse-grained siltstone. Sedimentary structures are lacking and no fossils have been recorded from the mudstone. Inspection with a hand lens indicates that most sandstone layers are graded and poorly sorted. Fossils are not common in the sandstone but a stunted marine fauna has been recovered and rare plant remains have been found.

A host of markings in mud have been preserved as casts on the soles of the sandstone and coarse siltstone layers. Small-scale current bedding is sometimes developed towards the top of a graded layer of sandstone and the direction of the current indicated is similar to that obtained from the flute casts. Post-depositional sedimentary structures within the sandstone are rare but convolute folds, believed to result from liquefaction, occur.

The fine silt and clay of the mudstone layers are believed to be the "normal" type of sediment in the area, whereas the sandstone and coarse-grained siltstone are considered to have been deposited by turbidity currents which imparted the current marking characteristics of the beds.

Dianas Basin (E.W., C.P.)

On the foreshore is a well-exposed sequence of indurated interbedded thin sandstone and mudstone horizons. Graded bedding and small scale current bedding has been noted in the metamorphosed sandstone, and interstratal disturbances believed to have formed in the unconsolidated sediments may be observed. The rocks have been affected by two early fold systems one of which is of concentric type and at one locality appears to die out both downward and upward. The other fold system is of "similar-type". A monzonite/country rock boundary is exposed. The monzonite has caused small dome and basin structures in the sedimentary rocks adjacent to the contact, and its emplacement was accompanied by feldspathization of the early fold cores.

St Helens-Blue Tier Region (M.J.L.)

Near St Helens the coastal plain with extensive beach and dune deposits shows well developed levels, and lagoons, bar and tied islands are features of the area.
I. GRANODIORITE PORPHYRY

1. HORNBLENDE GRANODIORITE

2. PORPHYRIC MICROCLINE ADAMELLITE

3. GRANODIORITE (EQUIGRANULAR)

4. DIORITE

5. PORPHYRIC MICROCLINE ADAMELLITE

6. GREISENIZED BIDITE GRANODIORITE, DOLERITE APLITE, PEGMATITE & PORPHYRIC ADAMELLITE

7. (HORNBLENDE GRANODIORITE) TACTITE

8. HORNBLende GRANODIORITE

FIGURE 20. Locality Map, St Helens Area.
Higher levels are evident inland and on the Blue Tier occurs the sub-Permian surface.

The drainage is by the George River and its tributaries which have been rejuvenated by Tertiary faulting and diverted NW of St Helens by Tertiary basalt flows.

The rocks of this area are sandstone and shale of the Mathinna Beds folded on a NNW axis and intruded by a granite suite of Devonian? age. Tertiary and Quaternary gravel, sand and clay, some tin-bearing, overlie these rocks. Basalt flows occur in Thureaus Deep Lead and north of Priory.

The granite suite consists of foliated hornblende granodiorite, biotite granodiorite, muscovite biotite granodiorite and muscovite granite emplaced in that order with associated basic, intermediate and acid differentiates. The biotite granodiorite has been influenced
by potash metasomatism forming a porphyritic microcline adamellite and the muscovite biotite granodiorite has been greisenized by late magmatic processes with the introduction of cassiterite.

Late intrusions include aplites, some containing garnet, pegmatites, quartz porphyry and dolerite but the relative ages cannot be determined.

Contact metamorphism is low grade with biotite and rarely cordierite developing adjacent to the granite, which has chilled margins. Tactite, composed of hedenbergite and grossularite, occurs indicating limestone beds within the Mathinna Beds.

The properties of the granite suite can be demonstrated on the Niggli diagram (Fig. 21). Note the linear arrangement of the analyses all falling on one line with two exceptions: the porphyritic microcline adamellite and the greisenized biotite granodiorite.

**Mt Cameron Region-Endurance Tin Mine (R.J.)**

The basement rocks consist of Mathinna Beds intruded by Devonian granite. Considerable erosion resulted in the exposure of the granite during early Tertiary times. Cassiterite occurs in greisen veins within the granite near its contact with the country rock, and may also have occurred in veins within the Mathinna
NORTH-EAST

49

Beds. By mid-Tertiary times further erosion resulted in concentrations of the heavy minerals, such as cassiterite, in gravel horizons in river deposits of up to 250 feet thick in the region. Later, basalt flows covered much of the area. At South Mt Cameron there is no evidence to suggest that there ever existed a basalt cap above the river deposits which contain gravels or leads, rich in cassiterite detritus (Fig. 22).

Some 400,000 cubic yards of these deposits are obtained for treatment annually by high pressure hydraulic sluicing with water pumped from the nearby Ringarooma River. On average a cubic yard of the alluvium contains approximately 0.5 lbs cassiterite, which is concentrated in a sluice box. Gold, which occurs in the heavy mineral concentrate, is extracted by passing over an amalgam plate.

Basalt extrusions and possibly middle to later Tertiary faulting disrupted many lead systems causing alteration of river courses, erosion and subsequent redeposition of sediment. This has resulted in the formation of Pleistocene to Recent leads along present river beds and accompanying older flood plains, which are worked by dredging.

Scottsdale-Pipers River-Bridport Region (B.M., C.M.B., D.J.J.)

The basement rocks of the region, the Mathinna Beds of a probable Siluro-Devonian age, are well exposed at Tunnel. Beds grade from sandstone through siltstone into slate, as indicated by the sympathetic variation of cleavage. Characteristic turbidite features are present and include intraformational slumping, flames and load-casts. Asymmetrical folds with NE facing short limbs overturned illustrate the variation in bedding-cleavage angle with competency. Clay pellets are co-planar with a bedding fissility in an open fold but are parallel to axial-plane cleavage in a soft-sediment condition allowing rotation of the clay fragments during deformation.

Devonian granodiorite is emplaced in the eastern portion of the area. Adjacent to the contact, which usually follows the bedding of the Mathinna rocks, the granodiorite contains numerous xenoliths which are co-planar with an incipient foliation developed sub-parallel to the bedding of the country rock. Late aplitic quartzofeldspathic veins occur. The contiguous Mathinna rocks have been extensively recrystallized, biotite being notable, with a preferential development of feldspar in certain horizons which are most probably at junctions of original rock-types.

A Permian sequence, overlain by Triassic sandstone with obvious disconformity, occurs in the SW of the region where the hills of Permo-Triassic rocks are capped by a Jurassic transgressive dolerite sill. The lowermost basal Permian may be examined NE of Lilydale where it consists of conglomeratic mudstone and sandstone. The poorly-sorted mudstone beds lack grading, contain a polygenetic assemblage of granules, pebbles, cobbles and boulders in varying proportion, and may exhibit rudimentary bedding. The sandstone beds show a poor to moderate sorting and may have pebble horizons at their bottoms and sporadically distributed granules, pebbles and small cobbles higher up. Fragmentary fossils indicate a marine environment of accumulation. The conglomeratic mudstone is considered to be partially tillitic having been deposited
directly from glaciers on a hummocky floor within a marine environment. It is believed that increasing water participation made lateral and vertical gradation from tillite to till-like rocks. The conglomeratic sandstone is similarly considered to have resulted from localized rewashing and slumping of glacial material followed by redeposition by a turbidity current mechanism.

Tertiary and Quaternary deposits with Tertiary basalts dominate the north and north-eastern part of the region. An exceptional occurrence of nepheline basalt and nephelinite is exposed near Scottsdale. In hand-specimens the fine grained basalt is characterized by large clots of predominantly olivine crystals and amygdales filled with zeolites. The rock comprises partially altered microphenocrysts of olivine and less commonly pyroxene in a groundmass of pyroxene, olivine nepheline, iron minerals and chloritic and serpentinitic decomposition products. The coarser grained nephelinite differs from the basalt in being non-porphyritic and lacking a fine grained groundmass, showing less alteration and being devoid of olivine. The nephelinite/basalt interface may be distinct and straight or diffuse and carious. Proximity to a vent is suggested by the limited distribution of these undersaturated rocks.

Launceston Region (M.J.L.)

The oldest rocks of the area are slate and interbedded mudstone, siltstone and sandstone called the Mathinna Beds which are folded on a 320° to 340° axis plunging up to 25° to the north and south. The older beds composed of slate conformably underlie the sandstone-mudstone sequence north of Patersonia.

Intruded into the Mathinna Beds is an equigranular hornblende biotite granodiorite with associated granodiorite porphyry, diorite and quartz feldspar porphyry. The contact zones develop cordierite and are up to 2 miles wide in the Lisle area.

Unconformably overlying the granodiorite and Mathinna Beds are Permian sediments striking about 330° and dipping to the SW at 10°-15°. The lowest beds are tillite?, conglomerate, sandstone. At Patersonia tillite rests upon glaciated surfaces of Mathinna siltstone and slate, the striations indicating ice movement towards the NE. Overlying the basal beds is grey to black mudstone containing rare fossil horizons, scattered erratics and minor sandstone beds varying in thickness from 50 feet at Burns Creek to 380 feet at Lilydale. Overlying this unit is limestone containing Calcitornella stephensii which has been correlated with Darlington Limestone on Maria Island, and interbedded mudstone, siltstone and conglomerate. Interbedded sandstone, carbonaceous shale and quartz conglomerate 100 to 150 feet thick forming the Liffey Group overlie the mudstone, siltstone and conglomerate and are in turn overlain by 650 feet of interbedded siltstone, mudstone and pebbly sandstone, the lower part poorly fossiliferous and more sandy, which is the upper unit of the Permian system in this area.

Overlying the Permian sediments, locally unconformably, is interbedded sandstone and shale of Triassic age, totalling 600 feet on Brown Mt.

Intruded into the Permian and Triassic sedimentary rocks and Mathinna Beds is Jurassic dolerite, 800 feet thick, with centres near Patersonia and Dilston.
The Tertiary sediments, originally 1,000 feet thick, occur in a NNW trending belt up to 8 miles wide about the Launceston area. They are composed of interbedded clay, sandstone, conglomerate and lignite and contain interbedded basalt flows.

The beds occupy narrow elongate basins formed by NW-SE trending, E side downthrown, step faulting and tilting of the underlying rocks probably during early Tertiary times.

Away from the Launceston area the Tertiary deposits are represented by gravels and sands, occasionally altered to quartzite immediately underlying basalt.

On the western slopes of Mts Barrow and Arthur there are well defined periglacial block streams composed of dolerite boulders aligned parallel to the slope with a gradient of 8°. Also extensive screen deposits occur on the slopes of Mts Barrow and Arthur.

21. MEADOWBANK DAM (Leader, R.P.M.) (Figure 23)

The Meadowbank Dam is a massive buttress structure 122 feet high, 870 feet long with a concrete-faced rockfill right abutment. Two spillway crest gates working automatically maintain a constant reservoir level at SL 240 feet except during major floods. The stability of the dam and foundation rock is increased by pre-stressing cables.

The power station is located in the base of the dam and has an installed capacity of 40,000 kilowatts. It is remotely controlled from the Liapootah Power Station near Wayatinah.

The foundation rocks are interbedded Triassic sandstone, siltstone and mudstone which are predominantly quartzose but contain varying amounts of mica, graphite and iron oxide.

The beds dip gently and are cut by three main sets of joints which have the following orientations: steep with SE strike (i.e. parallel to the river), steep with NE strike (i.e. normal to the river), and flat close to the dip of the beds. A steep fault normal to the river and 400 feet downstream from the dam has produced a zone of broken rock and clayey gouge varying in thickness from 2 to 40 feet.

Problems of stability and leakage have been created by the presence of flat-lying breccia zones at many levels in the foundation. Extensive grouting, pre-stressing and rock-fill on the right abutment have been used to overcome these difficulties.

These breccia zones contain rock fragments in a matrix of sand, silt and clay and vary from a fraction of an inch to 5 feet in thickness. Usually these zones follow the bedding but also cut across it at steep angles. The pattern of these breccias as exposed in the excavation is puzzling and difficult to fit into usual fault orientations. Engineering difficulties arise because although some of the breccia is dry, hard and compacted, some of it is soft and large water flows have been encountered associated with these breccias in many places.
TRIASSIC

- Sandstone
- Mudstone
- Fault
- Calyx Hole
- Drill Hole
- Shaft

Figure 23. Meadowbank Dam Site.
SANDY BAY

22. SANDY BAY (M.R.B.) (Leader, S.W.C.) (see Figure 27)

The road cutting on Sandy Bay Road at Long Beach reveals boulder beds containing unsorted boulders of Permian rocks overlain by bedded mudstone containing a few boulders and impressions of dicotyledonous leaves and inflorescences. The boulder bed is thought to be a mudflow or landslide deposit formed at the foot of a fault scarp as a result of earthquakes. The mudstone was probably formed in a fault trough lake during the Tertiary. Beds of boulders in the mudstone suggest recurrence of earthquakes during deposition.

Basaltic breccia with interbedded flows from a cone near Blinking Billy Point later covered the lacustrine sediments. A thin flow of basanite covered the breccia and was in turn overlain by tuff. The volcanic rocks overlap progressively to the NW with a general disconformity onto the lacustrine beds. Subsequently a thick basanite flow covered earlier rocks south of the Long Beach cutting. The basanite contains phenocrysts of iddingsite (after olivine) in a groundmass containing nepheline.

The volcanic rocks are intruded on the shoreline by veins of opal with chalcedony, quartz and calcite, and the breccias in this area are impregnated with calcite. The order of development of hydrothermal minerals was opal, calcite, opal, chalcedony, quartz.

Subsequent to the vulcanism and probably also to the fault in the Long Beach cutting a boulder bed was deposited containing boulders of dolerite.

The mudstone and volcanic rocks have been folded into anticlines and synclines more or less radial from a point SW of Alexandra Battery. The cause of the folding is not clear.

23, 27, 33, 38. GEOLOGICAL LOG OF A FLIGHT OVER TASMANIA (M.R.B.)

On your left

Mileage*

On your right

0 (Llanherne Airport)

On Quaternary sands on the Llanherne Level about 4 m above sea-level on a large mid-bay bar. To the NE and SW are hills mainly cut in dolerite, the tops of which are accordant and form part of the Late Tertiary Higher Coastal Surface. Frederick Henry Bay and Pittwater are part of the drowned valley of the Coal River which occupies downfaulted blocks on the NE side of the Derwent Graben. This graben is locally a series of ramps dipping SW interrupted by faults downthrowing ENE.

Dolerite ridges, trending NNW

5-10 Valley of Coal River occupying a deep, narrow graben

Over youthfully dissected remnants of the Lower and Higher Coastal Surfaces cut into Jurassic dolerite and Triassic sandstone.

* Estimated average speed of aircraft: 150 mph; i.e., about 10 mls/4 mins.
The Midlands Graben may be seen to the north between Ben Lomond to the east and Millers Bluff and Bradys Lookout to the west, graben initiated in Paleogene and partly filled with Tertiary non-marine sediments and basalts.

Over St Clair and Lower Plateau Surfaces, dissected dolerite plateaux.

Lake Echo

Lake Sorell; Lake of Islands and Woods Lake; Arthur Lakes; origin debated.

Over Great Lake, the origin of which is still being debated: glacial, periglacial, warping, fault trough, erosion of sediments surrounded by dolerite?

Plateau mainly in dolerite (Higher Plateau Surface).

Ice-eroded plateau surface with numerous lakes and erratics; like Canadian barrens; ice divide ran from Mountains of Jupiter in SW almost to Lake Meander in the NE.

Over Mersey River valley; glaciated.

Over Forth River valley; glaciated; in pre-basaltic time main stream flowed north between present positions of Mersey and Forth River; basalt flows caused twinning.

Glacial lakes (Dove and Crater) north of arête of Cradle Mt and Little Horn; mammillated surface in valley of Rodway Creek south of Cradle Mountain.

Barn Bluff; cirques and glacial lake (Lake Will); dolerite, intrusive into Permian resting unconformably on Precambrian quartzite, caps the mountains here; dolerite rises stratigraphically south and east from Cradle Mt.

Dolerite-capped mountains (high monadnocks) of Pelion Range to east and west; highest point is Mt Ossa (5,200 ft) (1,586 m) the highest point in Tasmania. Glaciers flowed west from the Central Plateau across headwaters of Mersey and Forth Rivers towards the Bluff River. Dolerite intruded generally near base of Triassic in this range and Permian rests unconformably on Precambrian.
Ice-cap glacier on plateau to east flowed through deep valleys in Travellers Rest Range and over edge of this range into deep glacial rock basin occupied by Lake St Clair

South of the King William Range Permian rests unconformably on Precambrian rocks which sweep as long ridges to the SSW; the Precambrian rocks are overlain unconformably by Ordovician and Cambrian rocks to the east

Over Lake St Clair; cirques in mountains to west (Gould, Manfred, Hugel, Gell), leading to valleys with recessional, lateral and ground moraine opening into till plain with roches moutonnées, and moraines to south and west

Over Lake King William (artificial, due to building of Clark Dam); King William Range has mammillated plateau cut into by deep cirques with fine lateral and terminal moraines. Some ice went through range and flowed west down Surprise Valley to terminal moraine south of Mt Arrowsmith

Cirques, lateral, terminal and recessional moraines along the Frankland Range (Precambrian quartzite)

Cirques, U-shaped valleys, horns, over-ridden divides, lateral moraines, terminal and recessional moraines along Western Arthurs

Mt Picton with cirques and moraine-dammed lakes on north and south sides

Mammillated surfaces, cirques, over-ridden divides, U-shaped valleys and lateral and terminal moraines in Eastern Arthurs and Federation Peak area
Mt WELLINGTON

Federation Peak, a partial horn with mammillated areas to the north, deep cirque on the SE (Hanging Lake) to the SW; all cut in Precambrian quartzite; look to west over Precambrian rocks to Bathurst Harbour. Precipitous Bluff (dolerite), over-looking New River Lagoon, cut in Ordovician limestone

Pinders Peak and Mt La Perouse; with fine cirques and U-shaped valleys on north and east sides

Adamsons Peak with small cirques on north side

Hartz Mountains; glaciated, dolerite-capped mountains and plateau

Huon River

Over Collins Cap can be seen the valley of the Derwent River above New Norfolk; occupies a complex graben

Bruny Island, a double island, tied by a tie-bar, and D'Entrecasteaux Channel, a drowned valley of North-West Bay Rivulet

Mt Wellington and Mt Dromedary—part of Mt Dromedary Horst

Storm Bay, drowned estuary of the Derwent and Coal Rivers

Llanherne Airport

26. Mt WELLINGTON (Leader, I.Mc.D.) (see Fig. 27)

The uppermost 1,200 feet of Mt Wellington consists of a thick sheet of mid-Jurassic tholeiitic dolerite above essentially horizontal Permian and Triassic sediments. The body is a somewhat discordant sheet intruded about 1,000 feet above the base of the Triassic succession. The roof sediments and approximately 100 feet of dolerite have been removed by erosion.

The dolerite sheets of Tasmania may be divided into several zones based on grain size and on the proportions of the main minerals. The dolerite adjacent to intrusive contacts is chilled to a fine grained,
sometimes glassy rock, containing microphenocrysts of orthopyroxene. The lower \( \frac{1}{2} \) to \( \frac{1}{4} \) of the sheets (about 300 feet for Mt Wellington) is termed the Lower Zone and is characterized by fine to medium grain size and by the presence of pyroxene in greater amount than plagioclase. A small amount of mesostasis occurs interstitially. This zone is the region in which pyroxene has accumulated. The Lower Zone normally passes upward gradually into the Central Zone, but in Mt Wellington the change is rapid. The dolerites of the Central Zone are coarser grained and lighter coloured than those of the Lower Zone; the proportion of mesostasis and plagioclase increases markedly at the expense of pyroxene. These dolerites are enriched in Fe relative to Mg, and alkalies and SiO\(_2\) gradually increase upward. The Central Zone passes upward into an irregular Pegmatitic Zone which lies immediately below a thin Upper Zone adjacent to the upper contact; the Upper Zone has been eroded from Mt Wellington. The Pegmatitic Zone dolerite is coarse, light coloured, irregularly textured and is banded in places. Rocks of this zone form the summit of Mt Wellington; they consist essentially of abundant mesostasis, plagioclase with a relatively small proportion of pyroxene. The composition approaches that of granophyre.

32. RED HILL INTRUSION (Leader, I.McD.)

In Tasmania during the Jurassic a large volume of tholeiitic magma was emplaced in the essentially flat-lying Permo-Triassic sedimentary sequence, commonly as large cone sheets, which locally can be mapped as sills, transgressive sheets, and dykes. After emplacement, marked differentiation occurred in these dolerite bodies.

To the south of Mt Wellington is the Red Hill Intrusion comprising a gently transgressive sheet approximately 1,300 feet thick out of the roof of which the Red Hill Dyke rises vertically for more than 1,000 feet (Fig. 24).

This dyke is up to 1 mile wide and was roofed by sedimentary rocks. Differentiation has taken place in the Red Hill Dyke. Within the highest structural parts of the dyke a large volume of silicic granophyre is associated with quartz dolerite. Because of the level of erosion only the more felsic rocks are exposed; above the floor of the underlying sheet must occur a thick zone of dolerite more mafic than the original magma. Detailed chemical, petrographic, mineralogical and field studies on the Red Hill Dyke show a complete graduation between dolerite and granophyre, and provide very strong evidence that the rock series has formed by differentiation.

Magnesian pyroxene and calcic plagioclase crystallized early, and both progressively changed composition with fractionation; the residual magma was continually enriched in less refractory components. Strong enrichment in Fe relative to Mg and moderate absolute Fe enrichment took place during the main stages of fractionation, followed by enrichment in silica and alkalies in the later stages. Differentiation resulted from fractional crystallization and relative movement of phases under gravity. The volume of
Figure 24. Red Hill Area.
granophyre in the Red Hill Dyke is larger than expected; some residuum from the associated sheet probably migrated into the Red Hill Dyke.

Chemical and micrometric analyses of rocks representative of the complete range in composition found in the Red Hill intrusion are available.

36. PERMIAN STRATIGRAPHY AT MT NASSAU (Leader, M.R.B.)

Sections of the Permian System on the eastern slopes of Mt Nassau, 13 miles up the Derwent River from Hobart, are the most complete in the Hobart area, although the base is missing. (Fig. 25). Lower formations are exposed along the Berriedale-Collinsvale and Berriedale-Glenlusk Roads a few miles to the south.

The first part of the excursion will consist of examination of Section II beginning at the Bundella Mudstone and working up to the Risdon Sandstone. Later, Section I will be examined starting with the Geiss Conglomerate at Stop 2 and working up to the base of the Malbina Formation.

The Bundella Mudstone, with some sandy bands, some pebble-rich bands and some large erratics, contains many marine fossils.

Two cyclothems are represented in the Faulkner Group which overlies the poorly fossiliferous upper part of the Bundella Mudstone. Each consists of a basal pebbly mudstone, a non-marine siliceous sandstone and siltstone unit, a pebbly mudstone, and a poorly fossiliferous and poorly sorted siltstone. The Faulkner Group and contiguous formations are interpreted as showing initial deposition in a cold sea, followed by shallowing due to fall in sea-level, or rise in the sea-floor due to tectonic uplift or to deposition, and to development of extensive coastal plains on and behind the delta. The coastal plain was flooded by another relative rise in sea-level, but a later fall in sea-level led to development of a second coastal plain, eventually flooded by a second rise in sea-level.

The Rayner Sandstone, feldspathic, with a few erratics and numerous marine fossils, marks a return to more-or-less normal marine conditions. The Cascades Group consists of fossiliferous to richly fossiliferous calcareous siltstone and limestone with erratics and rare meta-bentonite bands.

The poorly-fossiliferous Malbina Formation, which contains glacial erratics, includes a richly fossiliferous member at the top.

The Risdon Sandstone at the base of the Ferntree Formation follows it. The siltstone of the Ferntree Formation contains a few marine fossils and erratics. Deposition of silt was interrupted at least once and probably twice by deposition of thin beds of pebbly sand.

The Ferntree Formation is overlain at Claremont just to the south and elsewhere in the Hobart area by well-sorted siliceous and carbonaceous sandstone and siltstone of the Cygnet Coal Measures, the highest Permian formation in the area.
Figure 25 (b). Columnar Sections, Permian System, Mt Nassau Area.
37. THE ALKALI ROCKS OF PORT CYGNET (Leader, R.J.F.)

Port Cygnet is situated on the north bank of the Huon River approximately 30 miles south of Hobart. Alkaline rocks occur mainly as a series of dykes intrusive into Permian sediments having a domal or horst structure. No intrusions into Triassic rocks have been found here but dykes intruding the Jurassic dolerite can be seen in the Wattle Grove area. Small dykes of syenite occur in the Surges Bay-Police Point area. Thermal metamorphism and assimilation of the dolerite by the intrusive alkaline magma may be demonstrated on the foreshore at Regatta Point, Port Cygnet. Recent K-A dating indicated the age of the intrusion to be a minimum of 100 million years (Cretaceous).

Recent work indicates that the complex may be represented by dyke swarms and that the extent of stock-like intrusions is not as great as previously indicated. The more massive intrusions consist of syenite porphyry containing phenocrysts of plagioclase (Ab80 to Ab90), sanidine, hornblende and occasional pyroxene, this being apparently a lime-magnesia rich type containing titania. These are embedded in a ground mass consisting of orthoclase crystals (about 0.02 mm across) with a little interstitial quartz.

The main feature of the dyke rocks which have been called sanidine trachytes and tinguiates is the presence of large phenocrysts of sanidine which often delineate a flow structure and in places a swirl pattern similar to turbulent flow. The sanidine can contain over four per cent of soda. The ground mass consists of smaller feldspar crystals. Phenocrysts of garnet are often present which may reach 10 mm in diameter. The most common type is melanite which has been considered to be formed from a reaction of the ferromagnesian minerals with the residual magma. Grossular occurs in one dyke south of Regatta Point. Other minerals recorded from the dykes are aegirene augite, biotite, feldspathoids, apatite, sphene, magnetite, corundum and muscovite.

40. BLACKMANS BAY (M.R.B.) (Leader, I.McD.) (see Fig. 26)

Richly fossiliferous calcareous Grange Mudstone outcrops in cliff sections south of Blackmans Bay and is overlain by the lower part of the Malbina Formation of siltstone and sandstone. The highest Permian formation in the area, Ferntree Mudstone, is overlain, apparently concordantly, by siliceous, micaceous, graphitic Triassic sandstone in the bluff half way along Blackmans Bay Beach. The Ferntree Mudstone contains several conglomeratic bands of uncertain origin in the exposures at the southern end of the bay. Erratics occur in all Permian formations here and are well shown in the cliffs at Stop 1 (Fig. 26).

Well-sorted, siliceous Triassic sandstone with well-developed cross-bedding occurs in the area.

The sedimentary succession is intruded by dolerite as a sill within the Grange Mudstone at sea-level, rising as a dyke along two faults, penecontemporaneous with the dolerite, bounding the block of Grange and Malbina Formations, and as a sheet transgressing upwards from the south into the Triassic sandstone from a level within the Grange Mudstone. Narrow dykes and irregular apophyses rise from the top of the sill and at Stop 3c one of these can be traced northwards as a thin upper sill from which an irregular
Figure 26. Geological Map of Piersons Peninsula.
(almost "cedar-tree") dyke descends to the lower sill. The apophysis at Stop 3c is associated with a pair of small faults. Intrusion of the dolerite caused formation of calc-silicate hornfels by metamorphism of the calcareous mudstone.

Modern and older wave-cut platforms, tunnels, blow-holes, arches and stacks have been developed by marine erosion of the Permian sediments and dolerite.

Stop 1—blow-hole, wave-cut platforms, erratics, fossils.
Stop 2—wave-cut platform, concentric colour bands, conglomeratic bands, erratics, fossil wood and shells, stack.
Stop 3—crossing dolerite dyke to reach coast-line.
  3a—arch and cliffs to north, top of dolerite sill and small dykes to south.
  3b—sea-caves, top of sill with "swirl marks" to north, top of sill, deep chines and tunnel to south.
  3c—lower sill with apophysis, upper sill and descending dyke with drag dip to north; tunnel in dolerite to north.
Figure 28. Strip Map 1.
Figure 29. Strip Map 2.
Figure 30. Strip Map 3.
Figure 33. Strip Map 6.
FIGURE 34. Strip Map 7.
FIGURE 35. Strip Map 8.
Figure 36. Strip Map 9.
FIGURE 38. Strip Map 11.
FIGURE 39. Strip Map 12.
Figure 43. Strip Map 16.
FIGURE 44. Strip Map 17.
FIGURE 47. Strip Map 20.
FIGURE 54. Strip Map 27.
MAP 27

MAP 29

MAP 30

Figure 56. Strip Map 29.
REFERENCES.

A Selection of Useful References


SOME FORMATIONS CLOSE TO THE PERMO-TRIASSIC BOUNDARY IN TASMANIA

by

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ABSTRACT

The Cygnet Coal Measures is a unit of carbonaceous shale, coal and feldspathic sandstone in Tasmania of Upper Permian age. It is overlain gradationally or disconformably by the Springs Sandstone, the lower member of which, Barnetts Sandstone, is a thinly-bedded, fine-grained feldspathic to arkosic sandstone, and the upper, the Mountain Lodge Sandstone, a more thickly-bedded, medium-grained protoquartzite. The upper part of the Springs Sandstone is probably Otoceratan. The Permo-Triassic boundary lies within these gradational non-marine units and cannot yet be fixed accurately. The base of the Mountain Lodge Member is probably the most convenient boundary to use as the Permo-Triassic boundary in local field mapping.

INTRODUCTION

Milligan (1849 pp. 17-18) first described the coal measures at Southport subsequently correlated with the Cygnet Coal Measures. Thureau in 1881 mentioned the coal at Cygnet and his description of the section at the coal mines may still be the best. Subsequently Johnston (1887) described coal measures of similar age at Adventure Bay on Bruny Island and in 1888 described the section at Cygnet and correlated both successions with the Newcastle Coal Measures of New South Wales. Subsequently freshwater beds at this level have been recognised widely in Tasmania and sections measured in several places (eg. Mount La Perouse, Hobart, Zeehan, Lake St. Clair, Mole Creek). During 1965, a good succession near the nominal type area was established in detail by I. Naqvi and this led to a review of formations adjacent to the Permo-Triassic boundary.

Difficulty is experienced in many parts of Tasmania in delineating the Permo-Triassic boundary. There is a macrofloral change near the boundary from the Glossopteris to the Dicroidium flora but pinpointing this change in the field is very difficult because of the poorly fossiliferous character of the formations overlying the Cygnet Coal Measures and their correlates. The standard field convention has been to regard the base of the first thickly bedded quartz sandstone above carbonaceous shales (with or without a Glossopteris flora) of the Cygnet Coal Measures as a convenient place to use as the Permo-Triassic boundary elsewhere. Lewis (1940) recognised that the important palaeogeographic change occurred at the base not the top of the Cygnet Coal Measure but was not consistent (1946, pp. 22-3).

The difficulties are increased by lack of definition and reasonably precise knowledge of the so-called basal Triassic units. The Ross Sandstone of Bonwick (1870) and later authors is not properly defined in its type area and may be undefinable there. The outcrop is certainly not good in the Ross area. The Rhyndaston Sandstone (David 1932) is much better exposed at Rhyndaston than the Ross Sandstone at Ross, but its relationships to the Permian on the one hand and to younger units on the other are not yet clear. The Springs Sandstone (Lewis 1940) is moderately well-exposed in its basal portions and its relationship to underlying rocks in the type area determinable but not that to younger sedimentary rocks. No accurate section of this formation has been published. Recently the basal Triassic unit in the Lake St. Clair area has been called the Gould Formation (McLeod et al. 1961, p. 26), the relationships of which to underlying and overlying units are clear, if gradational, but of which no detailed section has been published. There are, in addition, innate difficulties in defining and correlating units such as the Springs, Ross, Rhyndaston and Gould Formations, because of their depositional environment, probably flood plains with braided channels.

In this paper, definitions and detailed sections of formations near the Permo-Triassic boundary in the Cygnet and Hobart Districts will be offered and the problem of the Permo-Triassic boundary discussed in some detail.

CYGNET COAL MEASURES

Stratigraphy

The nomenclature and synonymy of this formation have been dealt with by Smith (1959, pp. 47-8). The first significant report is that of Thureau (1881) who used the term "Mt. Cygnet measures" and recorded a sandstone floor, 3 ft. of coal, approximately 64 ft. of sandstone, a 5 ft. seam of coal within borders of carbonaceous clay, and a micaeous, laminated sandstone roof. His map and section clearly show two seams separated by sandstone but it is not quite certain that the thickness quoted for the inter-seam sandstone is not excessive due to faulting. Twelvetrees (1902) reported a slightly different section at the Mt.
A—Distribution and Thickness of Cygnet Coal Measures and Barnetts Member in Cygnet District

30 Thickness of Barnetts Member
5 Thickness of Cygnet Coal Mine
Thickness in Cradoc Area after Leaman (pers. comm.)

B—Sections in Cygnet and Hobart Area

C—Map of Springs Area, Mt. Wellington

Fig. 1. A. Map of the Cygnet area showing distribution and thickness of Cygnet Coal Measures and Barnetts Member. B. Columnar sections of Cygnet Coal Measures and Springs Sandstone, Cygnet and Mt. Wellington. C. Sketch map of part of Mt. Wellington showing positions of sections.
Cygnet Mines, a small 2 inch seam, another seam 1 ft. thick 12 feet above the first and the main seam 3 ft. thick, 25 ft. above the second. The main and two minor seams of which only one was bonaceous siltstone, the lower siltstone resting on dark sandstone and the upper with a roof of grey hard, glistening, quartzose sandstone with a conglomerate in places. Reid (in Hills et al. 1922) reported two main and two minor seams of which only one was being worked. At Berry's, north-west of the main working (fig. 1 A) a sandstone roof caps a seam 12"-14" thick resting on 12 inches of black shale. This shale rests on 8 feet of shale and 20 feet of sandstone which in turn overlies mudstone. Thus it would appear that in the nominal type area the coal measures are at least 6.8 m. thick and may be over 12 m. thick on Thureau’s figures. Recent coal measures are at least 6.8 m. thick and may be over 12 m. thick on Thureau’s figures. Recent investigations by the authors show that detailed information in the type area is not available because of thick vegetation and deep soil cover. The Cygnet Coal Measures appear to overlie Ferntree Mudstone, to be between 12 and 18 m. thick and to be overlain by quartz sandstone and thinly-bedded (beds about 1 cm. thick) micaceous sandstones and siltstones.

The best section now available is that in shore platforms at Coal Mine Bay and immediately south (summarised as fig. 1 B, 1). The Ferntree Mudstone with rare erratics and some marine fossils is overlain gradationally by fine-grained carbonaceous siltstone with some sets up to 1.5 cm. thick of interbedded very-fine-grained sandstone and carbonaceous siltstone. From 0.9 m. to about 1.1 m. above the base the carbonaceous siltstone contains flow folds ("pseudo-nodules") from 4 cm. x 4 cm. to 6 cm. x 3 cm. and about 0.5 cm. thick consisting of beds less than 1 mm. thick of very fine-grained, white sandstone or coarse siltstone interbedded with carbonaceous siltstone.

A little higher in the section and especially about 1.5 m. above the base larger-scale but otherwise similar structures occur. These structures are up to about 15 cm. long. At about 1.9 m. above the base such structures tend to be the core of concretionary bodies, with 0.6 cm. to 1 cm. thick, and underlie a formation of feldspathic sandstone, quartz and feldspar grains lie in a felted matrix of carbonaceous matter all held by a minor clay cement.

This section is thinner than that recorded from the Mount Cygnet Coal Mine area (fig. 1B, 2) and apparently differs from it in containing less sandstone. The section on Balfs Hill near Cradoc is even thinner (Leaman 1966). Facies change or subsequent erosion may explain the variations in thickness but the disconformity everywhere present in this area above the coal measures suggests that erosion was the more important factor controlling the thickness locally.

Johnston (1888, p. 203) recorded Vertebraria australis and Gangamopteris spathulata from shales below the coal at Mount Cygnet and Lewis (1940) amended the record of G. spathulata to Glosopteris sp. The Cygnet Coal Measures at Cygnet contain spores of the Dulhuntyispora Microflora (Balme 1964, pp. 63-4) and from Welling Creek, Cradoc, a number of spore types have been recorded by Dulhunty and Dulhunty (1949) (see Table I).

The Cygnet Coal Measures may thus be defined as that formation about six metres thick at Coal Mine Bay (497.6, 677.7) of carbonaceous sandstone, carbonaceous siltstone and coal which contains a Glosopteris flora and spores of the Dulhuntyispora Microflora, overlies the Ferntree Mudstone and underlies a formation of feldspathic sandstone, the Barnett’s Member of the Springs Sandstone. It is Upper Permian in age.

Carbonaceous shale occurs below Triassic sandstone south-west of Huonville (Mather 1955, p. 196) and may represent the Cygnet Coal Measures. A little further west Ford (1956, p. 150) was unable to find any definite Cygnet Coal Measures. South of Cygnet in the Police Point area the Ferntree Coal Measures are overlain with quartz pebbles and plant stems and these latter by carbonaceous, micaceous shales (Hale 1953, p. 114)
and at Dover the Cygnet Formation is represented by micaceous, carbonaceous siltstones with some cross-bedding (Hale 1953, p. 117). At Dover and Police Point the contact with overlying rocks is a disconformity, shown by undulatory contacts, increase in heavy mineral content and the presence of pieces of Firth Mudstone in the overlying rocks (Hale 1953, p. 117).

East of Cygnet, this formation occurs in the valley of Garden Island Creek, in the bed of Snug Rivulet, and at Gordon (Reid in Hills et al. 1922, pp. 145-6) where coal overlies about two metres of carbonaceous shale and underlies sandstone. Still further east the Cygnet Formation occurs at several places on South Bruny Island but the best exposure is that at Adventure Bay, just south-east of the neck, where a fine section is exposed in shore platforms and cliff faces and the coal measures apparently grade up into Triassic sandstones. This section has not yet been adequately studied. Johnston (1886) recorded and later figured (1888, pl. x) two species of Gangamopteris, a Glossopteris species and fruit and stems.

In the Hobart area Lewis (1946, pp. 35, 95) reported Cygnet Coal Measures from near Silver Falls Creek and in the headwaters of New Town Creek. The formation also occurs below the Springs Hotel where the section (fig. 1B, 3-5) was measured by Banks and Anand Alwar. In that section the Firth Mudstone is overlain by a poorly-sorted feldspathic sandstone passing up into interbedded fine-grained, feldspathic sandstone and carbonaceous siltstone both with fragmentary plant remains. Several gaps in outcrop break the successions which is capped by a medium-grained, thickly-bedded, light olive brown cliff-forming sandstone with an estimated feldspar content of 25-30%, thus suggesting that it is an arkose. This is followed after a gap of only 0.5 metres approximately by quartz sandstone, taken, for convenience, as the base of the Springs Sandstone. Carbonaceous shales up to about 10 metres thick were reported by Lewis from Silver Falls Creek and New Town Creek, in the latter area being pyritic and containing wood fragments. Read (1960) reported at least three metres of carbonaceous shale overlain by a bed of conglomerate occurring. An incomplete section is provided as fig. 3 (column d).

A very good section of the Cygnet Coal Measures is exposed on the northern face of Mount St. Perouse. Preliminary studies and measurements have been made by B. F. Glenister and Banks and an approximate section is provided as fig. 3 (G. Glossopteris and Vertebra). The contact with overlying rocks is gradational and the unit shown at the top of the Cygnet Coal Measures, thin-bedded micaeous sandstone, thickly-bedded, cross-bedded, feldspathic sandstone may be equivalent to the Barnetts Sandstone which overlies the Cygnet Coal Measures at Cygnet.

At Maydena carbonaceous shales 4.5 m. thick are overlain disconformably by 16 m. of feldspathic sandstone (Jago 1965) but on the flanks of the Misery Range about 30 k. north of Maydena the Cygnet Coal Measures are represented by about 30 m. of interbedded carbonaceous siltstone and sandstone lying beneath thickly-beded quartz sandstone (Corbett 1964).

The thickness of the Cygnet Coal Measures increases northwards to the Lake St. Clair and Pelion Range areas (Guilfoyle 1955, Read et al. 1961) where carbonaceous shale, thin coal seams, feldspathic sandstone, some quartz sandstone and a bed of conglomerate occur. An incomplete section on Mount Inglis is predominantly feldspathic sandstone (Gee 1964).

South-west of Zeehan a thickness of at least 45 m. of cross-beded, ripple-marked quartz sandstone interbedded with carbonaceous siltstone probably overlies Firth Mudstone disconformably (Banks and Ahmad 1962).

In northern Tasmania, Cygnet Coal Measures (or its correlates Jackey Shale and Clog Tom Sandstone) have been mapped near Mole Creek (Jennings 1963), along the Western Tiers to Beaconsfield (Green 1959) and near Lilydale (Longman 1966). These coal measures may also overlie the Kelcey Tier Beds on the western slope of Bonneys Tier as suggested by comparison of Twelvetrees' plate 2 (1911) with later maps (Burns 1964, p. 103), and Brill (pers. comm.) reported coal high on the flanks of Bonneys Tier in Coal Creek.
Rock Types

The Cygnet Coal Measures and its correlates consist of sandstone, predominantly feldspathic but siliceous in many places, carbonaceous and micaceous siltstone and thin seams of coal. Conglomeratic beds are rare but occur at Mount La Perouse, Zeehan and Launceston at the present limits of outcrop of this formation and at Hugel Creek near Lake St. Clair. The sandstones are commonly carbonaceous and in many places are cross-bedded and ripple-marked. No study has yet been made of current directions. The sandstones predominate in most sections especially on Bruny Island, at Mount La Perouse, Zeehan, the Du Cane Range, Mount Inglis, Beaconsfield and Lilydale, again areas close to the present limits of outcrop. Although insufficient sand-shale ratios are available for accurate depiction of variations there is a suggestion that the silt content of the formation is higher at Poatina, Mole Creek, the Pelion Range, some areas near Lake St. Clair, Maydena, Southport, Cygnet and Hobart than around the margins of present outcrop. This in turn suggests derivation from higher source areas not far outside the present limits of outcrop in the north-east, north, north-west, west and south.

The presence of feldspar as a common constituent of the sandstone is unusual. The non-marine sandstones of the Lower Permian Mersey Group do contain feldspar but not in significant amounts and the prominent sandstones of the Lower Triassic are quartz-rich sandstones. No detailed petrographic studies have been made and the type of feldspar not determined.

Coal occurs at Coal Hill near Lake St. Clair, Southport, and Kelceys Tier (probably a single seam at each place) and two or more seams occur on the Pelion Range, Mole Creek, Bruny Island and Cygnet, the thickest known being at Cygnet (1.5 m., Thureau 1881).

Flora

Johnston (1888, p. 143) recorded *Gangamopteris spatulata*, *G. obliqua*, *Glossopteris browniana* var. *praecursor* and other indefinite plant remains from Adventure Bay and *G. spatulata* and *Vertebraria australis* from Cygnet (ibid. p. 203). Subsequently Lewis (1940) suggested that the *Gangamopteris* from Cygnet should be referred to *Glossopteris* sp. and Johnston's determinations from Adventure Bay require revision. From Southport Johnston (1893) reported *Vertebraria australis*, McLeod et al. (1961, p. 25) reported *Glossopteris*, *Gangamopteris* and *Vertebraria* near Thetis saddle and Banks and Ahmad (1962, pp. 9-10) recorded these fossils from Phillip Island, and *Schizoneura* from the Malamna area, near Zeehan. *Glossopteris* and *Vertebraria* occur in the Mount La Perouse area.

Spores from the Cygnet Coal Measures and their correlates have been reported by Dulhunty and Dulhunty (1949), Balme and Hennelly (1955, 1956a, 1956b), Balme (in Jennings 1963) and Balme (1964), and their distribution is summarised below as Table I.

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<td>Thymospora cf. hamatus</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 = Cradoc (Welling Ck.)
2 = Mt. Pelion.
3 = Mole Creek.
4 = Western Bluff.

Taxonomic combinations after Hart (1965).

The spores listed indicate correlation of the coal measures at Cradoc, Mount Pelion, Mole Creek and Western Bluff with one another and with the Newcastle Coal Measures of New South Wales which are Kazanian or Tartarian. The Jockey Shale at Western Bluff in particular is probably equivalent to the upper part of the Newcastle Coal Measures. Balme (in litt.) reported that the coal measures at Cygnet, Sky Farm, Hobart and Malamna were of the same age. The Kazanian or Tartarian age is suggested because of the occurrence of the same Dulhuntyispora assemblage in the Condren Member of the Liveringa Formation of Western Australia, underlain by the Lightjacket Member with goniatites of Upper Artinskian or Lower Kungurian age (Glenister and Furnish 1961, p. 688) and overlain by the Hardman Member with *Aulostegites tungsens* and *Waagenaconcha imperfecta* which occur in the Basleo Beds of Timor and are similar to species in the Kazanian of Russia (Coleman 1957, p. 139) thus suggesting a Kazanian age. The spores from the Newcastle Coal Measures may however range beyond the limits of the Condren Member but are clearly pre-Scythian.

Stratigraphic Relationships

The stratigraphic relationships of the Cygnet Coal Measures as here used are summarised in fig. 2. In north-eastern and eastern Tasmania the formation is missing. A disconformity is found at the base of the formation in northern and western Tasmania whereas in the central and southern parts of the basin, where the formation is thickest, the basal contact is conformable. This, with the smaller grainsize in the central parts of the basin, suggests lower stream velocities, and probably grades) in those areas, indicating perhaps a low-lying, flattish central area bounded by low, rather distant hills.
The upper contact shows less systematic variation in its character although again gradation occurs in most of the thicker sections and disconformity in the thinner. Variation in thickness of the formation and type of upper contact in the area around Cygnet suggests considerable differential erosion and possibly uplift before deposition of the overlying Barnetts Sandstone (see fig. 1 A).

The thickness of the formation varies up to about 105 m. but measured sections are exposed too sporadically to make construction of useful isopach maps possible in view of the likely effects of disconformities and until detailed correlations between sections become feasible. A zone of thicker Cygnet Formation appears to extend from south of Zeehan through the Du Cane and Pelion Ranges to Mole Creek, Poatina and Beaconsfield but this has an area within it at Westmoreland Creek, just east of Mole Creek, where Triassic rocks rest directly on Ferntree Mudstone (Jennings 1963). Another zone of thicker sediments appears to extend from Mount La Perouse through Southport to Bruny Island and Hobart.
Fig. 3.—Columnar sections of the formations close to the Permo-Triassic boundary in Tasmania.
SPRINGS SANDSTONE

The name was first used, casually, by Lewis (1940) and explained more fully by Lewis (1946, pp. 23, 35) by whom the thickness on Mount Wellington was given as 800 feet, 200 feet more than the average elsewhere. Elsewhere in that publication (Ibid. p. 46) the thickness was given as 500 feet, or even, it would appear, 1,000 feet (p. 67). It was described as massive sandstone. Lewis did not define the term very stringently and it is not clear if he considered the Springs Sandstone as only the cliff-forming sandstone or as all the rock between the Ferntree Mudstone and the dolerite contact on the Pinnacle Road.

A section was measured from the top of the Ferntree Mudstone on the Pinnacle Road to the dolerite contact (fig. 1 C) by M. Anand Alwar and one of the authors (M.R.B.) some years ago and is recorded here as figs. 1 B, 3, 4, 5, and 6. The lower part of it is divided in fig. 3 A and in an Appendix. The cliff-forming, “massive” sandstones below the Springs Hotel (A-E on fig. 1 C) form a distinctive mappable unit above which the section is very discontinuous.

It is proposed therefore to define the Springs Sandstone as that unit of quartz sandstone with minor siltstone and clay-pellet conglomerate overlying the Cygnet Coal Measures and underlying a unit of sandstone and siltstone, probably equivalent to the Knocklofty Sandstone and Siltstone, in track, road and cliff sections below the Springs Hotel. It is about 92.5 m. thick in its type section, (511.45 E. 717.05 N. to 511.52 E. 717.63 N.). No fossils have been recorded in it from its type section but it is probably Lower Triassic.

In its type area it may be considered as consisting of two members, a lower one about 55 m. thick of sandstone, especially sandstone with beds of the order of 10 cm. to a few tens of centimetres thick and fissile sandstone, siltstone and rare clay-pellet conglomerate, the upper one about 37.5 m. thick of coarsely cross-bedded cliff-forming sandstone in beds mostly of the order of one metre thick. The lower member may be correlated with the Barnettts Sandstone, well-exposed in cliff and shore-platform sections south of Coal Mine Bay, Cygnet. The upper member may be taken as the base of the upper member in the track section “A” and “C” and unit j in the road section “D” and “C”. The lower member consists predominantly of well-sorted medium to fine-grained sandstones with minor developments of coarse-grained sandstone near the base, and some carbonaceous siltstone with plant fragments. The sandstones consist predominantly of quartz with minor quantities (<10%) of muscovite, graphite and feldspar. They are cross-bedded and have beds a few centimetres to about 75 cm. thick and some are fissile. The carbonaceous siltstone contains plant fragments (probably sphenopsid), sandy beds a few millimetres thick and some clay pellets. Outcrop of this member is somewhat subdued in contrast to the strong development of cliffs by the upper member.

The upper member, which may be called the Mountain Lodge Member, outcrops well in the cliffs beneath the Springs Hotel and at Sphinx Rock. It may be considered to include units G to Y in the road, track and cliff sections between “C” and “E” (fig. 1 C). The main rock type is a well-sorted, medium to coarse-grained quartz sandstone, cross-bedded and with beds generally more than 75 cm. thick but with some units more thinly bedded.

Current ripple marks occur on some bedding planes and suggest currents from the northerly quarter. The cross-bedding suggests currents from northerly, westerly or south-westerly areas. The cross-bedding commonly shows current drag effects at the top of the set. The predominant mineral is quartz, often with sparkling surfaces which are crystal faces resulting from authigenic outgrowth, with very minor amounts of muscovite, graphite and feldspar (<2%). Clay-pellet and quartz pebble conglomerates also occur. A few grains of pink garnet were seen by hand-lens in the basal unit.

The section above the Springs Sandstone, as here used, on the Pinnacle Road reveals sandstones and some siltstones, the sandstones finer-grained and more thinly-bedded on the whole than those in the Mountain Lodge Member. Some beds with 10%-20% feldspar occur and a green micaceous mineral, probably chlorite, occurs on several horizons. Cross-bedding is common and rippling-marking present. Dips of cross-bedding appear to be too variable to allow assessment of current directions without statistical analysis.

Fossils have not been found in any of the units in this section. The Mountain Lodge Member is like the lowest sandstone units in the Knocklofty Formation a few miles to the east and these sandstones are overlain by fossiliferous siltstones of Sceythian age. The most likely age for the Springs Sandstone is Sceythian but there is no reliable, direct evidence for this.

In the Coal Mine Bay area near Cygnet, the Cygnet Coal Measures are overlain by a sandstone formation, divisible into a lower member called the Barnettts Sandstone and an upper member, lithologically similar to the Sphinx Rock Member of the Hobart area.

The Barnettts Sandstone may be defined as the lower member of the Springs Sandstone conformably overlying Cygnet Coal Measures at Coal Mine Bay. It consists of 27 m. of feldspathic sandstone, and is named for Barnettts Trig. Point (498.20, 678.00) near Coal Mine Bay. It is probably Triassic or may be Upper Permian.

The section of the formation (see fig. 1 B and Leaman & Naqvi 1967) commences with a basal conglomeratic unit (plate 1, f. 1) about one metre thick, consisting of granule and pebble conglomerate, feldspathic sandstone and thin beds (1-2 mm.) of coal and carbonaceous siltstone. The granules and pebbles are composed of quartz, carbonaceous siltstone, a mudstone (probably Ferntree Mudstone), and rarely of schist. Most of the larger fragments are 3-4 cm. long but some of the angular fragments of carbonaceous matter lying across the bedding reach a length of 10 cm. The matrix consists of angular quartz fragments with a minor clay cement. Quartz comprises about 60% of the rock. Kaolinitised feldspar in the matrix comprises about 10% of the rock. Muscovite and graphite are common, and rutile, limonite and distinctive patchy patches of pink garnet are present. The conglomerate is disconformable on the Cygnet Coal Measures. The conglomerate is cross-bedded, the current having come from 50°.
Above the conglomerate is a bed of coal and carbonaceous shale nine cm. thick and at least three metres long (plate 1, f. 2, 3). In places just below the coal is a bed five cm. thick of interbedded sandstone and carbonaceous siltstone like that immediately beneath the basal conglomerate.

The sandstone and siltstone unit passes west into a unit of very fine-grained, carbonaceous siltstone and sandstone (plate 1, f. 9).

A fine to medium-grained, fairly well-sorted sandstone overlies the coal and, where coal is absent, the basal conglomerate. This is cross-bedded, the individual laminae being a few millimetres to a few centimetres thick, and in the top part ferruginous concretions form up to 2% of the rock. The sandstone (33624 in the University of Tasmania Geology Department collection) consists of angular and a few subangular grains of quartz (about 50%); kaolinitised plagioclase (about 30%) which is oligoclase where it is determinable, some microcline (1%), muscovite (5%) and a few quartz-zircon grains comprise this siltstone (plate 1, f. 4).

A thin section showed that the rock consists of quartz and rutile occur. The framework is closed. Many quartz grains have sutured contacts against one another whereas the boundaries of others appear to be sericitised. The ferruginous cement seems to have been emplaced before development of the sericite in most places but in a few the sericite appears to be earlier. The rock is an arkose.

This richly feldspathic sandstone is overlain by thinly-bedded (beds a few cm. thick) feldspathic sandstone (33623) with pieces of carbonaceous siltstone like that of the Cygnet Formation forming about 8% of the rock. At the top of this unit is a bed 17 cm. thick of conglomerate of which up to 75% comprises this siltstone (plate 1, f. 4). The rock is predominantly quartz (80%) with very little muscovite (2%) and plagioclase (2%) which is probably oligoclase. The clastic grains are predominantly in the fine sand grade, a few only in the medium sand grade, some in the very fine sand and silt, if any, in the coarse silt grade.

The quartz is predominantly clear and unstrained so common as in the Barnetts Member. The rock is medium-grained, well-sorted, finely laminated sandstone (33620) which consists of quartz (75%), feldspar (sericitised, 10%), muscovite (5%), graphite (2%) and an iron-rich argillaceous matrix.

This member differs significantly from other rock units in the abundance of feldspar, the good sorting, the thinly-bedded, cross-bedded units and the abundance of small, spheroidal ferruginous concretions. The abundance of clay pellets at Coal Mine Bay helps to differentiate it from the overlying member. The pellets are discoidal to elliptical in structure up to eight cm. long and although the majority are siltstone, some are of feldspathic sandstone, suggesting contemporaneous erosion. Graphite from this member was examined by X-ray diffraction methods and its identity established.

The quartz sandstone conformably and transitionally overlying the Barnett's Member at Coal Mine Bay (plate 1, f. 8) is at least 27 m. thick in this and the Randalls Bay area. It is medium-grained, well-sorted, cross-bedded with beds of the order of one metre or more in thickness. Limonitic concretions and clay pellets are present but not so common as in the Barnett's Member. The rock (33619) consists of angular and subangular quartz particles (80%), muscovite (5%) and fragments of siltstone, carbonaceous siltstone, and some fine-grained sandstone (10%) with common particles of zircon, rutile and tourmaline with a minor cement of felted sericite laths (about 5%). Many of the quartz particles showed sutured, almost stylolitic, contacts with other particles. Most of the quartz is equidimensional but a few particles up to four times as long as broad occur. The quartz grains are predominantly of clear, unstrained quartz but some strained quartz, some quartz with rutile needles and some with euhedral zircon crystals and lines of inclusions occur. A few grains may show signs of regrowth. The tourmaline in this
Some Formations Close to the Permo-Triassic Boundary in Tasmania

As in other thin sections from the Barnett Member it is green. The zircons are predominantly euhedral or broken and position to the Mountain Lodge Member is present in all the minor. The grains are mainly in the medium sand grade with some coarse, some fine and some very fine sand particles. Tourmaline, ilmenite, melanite and some zircon and magnetite were separated as heavy minerals and comprise in all about 0.3% of the rock. This member corresponds in character and position to the Knocklofty Formation in the Hobart section.

Rocks apparently similar in character to the Barnett Member and overlain by thickly-bedded, usually cliff-forming quartz sandstones have been reported by Mather (1955, pp. 96-7) from the Huonville area, and Hale (1953, p. 122) from Brooks Bay where they are 45 m. thick and overlain by cliff-forming quartz sandstone between 30 and 45 m. thick: from the Police Point area (Ibid. pp. 122-3) and from the eastern shore of Port Esperance (Ibid. p. 124). An outcrop on the Esperance River south-west of Geeveston (Ford, 1954, p. 155) may be a correlate of the Barnett Member. Further afield the top 40 m. of the section beneath the thickly-bedded sandstones of Mount La Perouse may correspond to the Barnett Member and 15 m. feldspathic sandstone overlies carbonaceous siltstone near Maydena and may be a correlate of the Barnett Member (Jago 1966).

Neither the Barnett Member nor the overlying member at Coal Mine Bay has yielded fossils. The Barnett Member in its type area has some unusual features. The second unit (33624) is an arkose with a high proportion of kaolinised plagioclase and very few rock fragments. Its composition and texture suggest relatively short transportation by water from a terrane of granitic and meta-morphic rocks. Higher units contain progressively less feldspar. Although in each case the modal grade is fine sand, the estimated mode decreases from about 0.2 mm. (33623, 33622) to 0.12 mm. (33621), and the range in grain sizes decreases in general from six grades (33624) to four (33623, 33621), and an impression of better sorting and longer transport emerges from this preliminary study. No change in terrane during deposition of this member is evident. The cementing material in all sections studied is sericite and ferruginous.

The upper member at Coal Mine Bay shows a marked increase in modal grain size (about 0.35 mm.) and in the size of the coarsest fragment present (1.1 mm.), with a continued decrease in the feldspar content. The current velocity of the depositing streams apparently increased but feldspar was no longer available in the source area due to deep weathering of quartzo-feldspathic rocks or to the earlier source of feldspar having become covered.

Correlations

Suggested correlations, based on lithological similarity and stratigraphic position are shown in fig. 3. The most significant point emerging from these correlations is that if correlation with the Ross Sandstone at Poatina is correct, the Springs Sandstone is Scythian and may be roughly correlated with the Knocklofty Formation which contains two spores of stratigraphic significance also present in the Ross Sandstone. Thus at Cygnet and Hobart the Permo-Triassic boundary lies within the range of the Cygnet and Springs Formations.

The Permo-Triassic Boundary in Tasmania

Evidence has been presented earlier that the Cygnet Coal Measures are Upper Permian, contain the Dulhuntyispora Microflora, and at Western Bluff at least may be correlated with the upper part of the Newcastle Coal Measures of New South Wales. A siltstone 85 m. above the base of the Ross Sandstone at Poatina contains Lundbladispora brevicula and Densosporites playfordi (Playford 1965) and a siltstone at Crisp and Gunn's Quarry, Knocklofty, in the Knocklofty Formation also contains these spores (G. Playford pers. comm.). The presence of these spores suggests correlation with the Collaroy Claystone of the Narrabeen Group of New South Wales (Evans 1966) and with the Kockatea Shale of Western Australia (Playford 1965). The presence of these spores further suggests correlation with two lower spore assemblages (Tr Ia, Tr Ib) reported from New South Wales and Queensland (Evans 1966) have not yet been found in Tasmania. In New South Wales the thickness of sediment separating the Collaroy Claystone from the Newcastle Coal Measures is nearly 400 m. (Hanlon et al. 1953) considerably more than that between the Lundbladispora horizon and the Jackey Shale. At this stage it is impossible to fix with any precision the boundary in Tasmania corresponding to the base of the Narrabeen Group in New South Wales, and, of course, to divide the Tasmanian succession accurately in terms of a world standard Permo-Triassic boundary (top of the Cycloolobus Zone).

For local convenience in field mapping this boundary has been taken at the base of the first thickly-bedded sandstone above the highest carbonaceous siltstone. This may well correspond to the base of the Sphinx Rock Member as both on Mount Wellington and at Cygnet the Barnett Member contains carbonaceous siltstone, is relatively thinly-bedded above this siltstone and has a subdued outcrop whereas the Sphinx Rock Member outcrops boldly and the obvious place for a field mapping boundary is at the base of this member. The entry of cross-bedded, feldspathic sandstones is probably not a suitable horizon for distinguishing the Cygnet from the Springs Formation as the Cygnet contains feldspathic sandstones in many places although at others, e.g., Malanna, it does not seem to have significant quantities of feldspar. The base of the Barnett Member is a convenient boundary as, in some places at least, there is a conformity and a thin conglomerate at this level. However, in the type areas and elsewhere the conditions of deposition did not change significantly at this horizon; coal and feldspathic sandstone occur both above and below the contact. In addition, disconformities, even those overlain by thin conglomerates, within fresh-water successions may well be of very local extent and short duration. Angular unconformities between the Drumstone and Springs-type sandstone have been reported by Wooley (1959) and Alwar (1960) but the evidence is not incontrovertible. Attempts to
determine the age of this boundary at Cygnet and Southport by palynological studies failed because of poor preservation of spores. Disappearance or virtual disappearance of feldspar from the section does not appear to be a good criterion for separating Barnetts and Mountain Lodge Members as this seems to have occurred at different levels in different sections. In some of the sandstones above the Mountain Lodge Member on Mount Wellington appear to contain considerable quantities of feldspar. The appearance and disappearance of feldspar is probably related to uncovering and covering of different source areas at different times. At Cygnet and elsewhere the contact between Barnetts and Mountain Lodge Members appears to be gradational and the main objective criteria for distinguishing them are bedding thickness, grain size and outcrop behaviour.

Finally, delineating formations in a persistent fluvial environment is very difficult just because of the environment and no less difficult if the fluvial environment changes slowly with time as may be suggested for the interval from Cygnet to Mountain Lodge.

Thus no a priori case can be established for preferring the base of the Barnetts to the top of the Barnetts as a system boundary and neither may correspond to the top of the *Cycloculus* Zone. A floral change occurred at about the time of deposition of the Barnetts Member and establishment of the position of this change in different sections may eventually provide a better time marker than is now available. As is widely realized by Australian palaeontologists this change itself may not correspond to the system boundary elsewhere.

**CONCLUSIONS**

The Cygnet Coal Measures of Upper Permian age are followed disconformably or gradationally by the Springs Sandstone, the basal member of which, Barnetts Sandstone, is thinly-beded, fine-grained and in places arkosic and the upper member, Mountain Lodge Member, a more thickly-beded, coarser-grained protoclastite. The Springs Sandstone has few identified fossils but by correlation with the Ross Sandstone is probably basal Triassic (Otoceratan). The most convenient horizon to take as the Permo-Triassic boundary in Tasmania is probably the base of the Mountain Lodge Sandstone but this is debatable and certainly may not correspond temporally to the Permo-Triassic boundary elsewhere.

**REFERENCES.**


APPENDIX I

Section from Dolerite Contact on Pinnacle Road to Cygnet Coal Measures

TOP—dolerite contact, “F” on fig 1 C

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2</td>
<td>1.20 m. fiss., fine-gnd ss and coarse sltst, 10 Y R 6/6.</td>
</tr>
<tr>
<td>G2</td>
<td>1.21 m. coarse-gnd sltst, beds 7.5 to 25 cm. thick; non-fiss; 5 Y 6/4.</td>
</tr>
<tr>
<td>H2</td>
<td>0.61 m. ss, beds order of few cm. thick.</td>
</tr>
<tr>
<td>I1</td>
<td>2.74 m. med to fine-gnd ss, qz, musc, feld (&lt;5%); graph uncommon, green biot or chlor; beds 7.5 cm. to 1 m. thick; 10 YR 4/2.</td>
</tr>
<tr>
<td>J1</td>
<td>0.75 m. med-gnd ss, musc, feld (&gt;5%); c.b. sets 2.5-5 cm. thick, c.b. dipping 130° at 12°; 10 YR 6/6.</td>
</tr>
<tr>
<td>K1</td>
<td>0.75 m. clay-pellet conglomerate.</td>
</tr>
<tr>
<td>L1</td>
<td>1.06 m. ss, qz, feld, graph, clay pell up to 5 cm. long 5 Y 5/2; beds up to 2.5 m. thick.</td>
</tr>
<tr>
<td>M1</td>
<td>1.06 m. ss with beds of order of 30 cm. thick.</td>
</tr>
<tr>
<td>N1</td>
<td>0.76 m. fine-med-gnd ss, qz, musc, feld rare, single bed, friable; 10 YR 7/4.</td>
</tr>
<tr>
<td>O1</td>
<td>0.35 m. coarse to med-gnd sltst, qz, musc, graph, very fiss.</td>
</tr>
<tr>
<td>P1</td>
<td>3.50 m. f to med-gnd ss, qz, feld (5%), musc, clay pellets, bedding up to 1.25 m. thick; 10 YR 6/6.</td>
</tr>
<tr>
<td>Q1</td>
<td>0.60 m. med to coarse-gnd ss, qz, feld (abt 10% some fresh), beds 22-40 cm. thick.</td>
</tr>
<tr>
<td>R1</td>
<td>2.25 m. friable med to coarse-gnd ss.</td>
</tr>
<tr>
<td>S1</td>
<td>0.30 m. ss, beds 0.5 to 2.5 cm. thick.</td>
</tr>
<tr>
<td>T1</td>
<td>0.46 m. fine-gnd fiss ss, beds approx 1 cm. thick; qz, musc, graph.</td>
</tr>
</tbody>
</table>

Second road to chalet above Mountain Lodge.

Gap of 17.22 m. including first road to chalet above Mountain Lodge.

“E” on fig 1.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>0.45 m. med-gnd ss, qz, feld (&lt;5%); graph; contains large rounded frags up to 5 cm. long which look like Fern-tree Mudstone and garnetiferous ? phyllite; bedding up to 2.5 cm. thick; c.b., 10 YR 8/2.</td>
</tr>
<tr>
<td>D1</td>
<td>5.50 m. ss, beds up to 1 m. thick.</td>
</tr>
<tr>
<td>C1</td>
<td>0.07 m. 6 beds, each less than 0.5 cm. thick of clay pellet conglomerate; pebbles up to 1 cm. long in arenite (gns up to 1 mm.) matrix, qz, feld (5-10%); (some bands up to 20% feld and in these gns are more angular than in others), musc, rare graph, chlor; beds of conglomeratic lenticular, 10 YR 4/2.</td>
</tr>
<tr>
<td>B1</td>
<td>2.40 m. ss.</td>
</tr>
<tr>
<td>A1</td>
<td>0.60 m. med-gnd ss, qz, feld (5-10%), musc, graph (rare), beds 45-15 cm. thick, 10 YR 6/6.</td>
</tr>
<tr>
<td>Z1</td>
<td>1.20 m. fiss., fine-gnd ss with qz, musc, feld, graph uncommon, green biot or chlor; beds 0.5 to 6 cm. thick, 10 YR 6/6.</td>
</tr>
<tr>
<td>Y1</td>
<td>0.61 m. med-gnd ss with qz, musc, graph, feld (&lt;5%); c.b.; bedding 15 cm. to 20 cm. thick.</td>
</tr>
<tr>
<td>X1</td>
<td>3.02 m. s with beds of order of few cm. thick.</td>
</tr>
<tr>
<td>W1</td>
<td>1.06 m. med to fine-gnd, c.b. ss, containing qz, feld, musc; c.b. sets 10-12 cm. thick; c.b. dips 170° at 12°; 5 BG 6/2.</td>
</tr>
<tr>
<td>V1</td>
<td>1.06 m. c.b. ss with discoidal ferruginous clay concretions up to 2.5 cm. long; c.b. sets 0.5 to 2.5 cm. thick, thinner near base; thicker near top.</td>
</tr>
<tr>
<td>U1</td>
<td>0.91 m. thick bedded ss.</td>
</tr>
<tr>
<td>T1</td>
<td>2.74 m. med-gnd ss; qz, musc, feld uncommon; beds 30 cm. to 1.25 m. near base, 2.5 to 5 cm. thick near top; 10 Y 6/2 or 5 BG 5/2.</td>
</tr>
<tr>
<td>S1</td>
<td>0.61 m. med-gnd ss with qz, musc, graph, feld (&lt;5%); c.b.; bedding 15 cm. to 20 cm. thick.</td>
</tr>
<tr>
<td>R1</td>
<td>2.25 m. friable med to coarse-gnd ss.</td>
</tr>
<tr>
<td>Q1</td>
<td>0.60 m. med to coarse-gnd ss, qz, feld (abt 10% some fresh), beds 22-40 cm. thick.</td>
</tr>
<tr>
<td>P1</td>
<td>0.35 m. coarse to med-gnd sltst, qz, musc, graph, very fiss.</td>
</tr>
<tr>
<td>O1</td>
<td>3.50 m. f to med-gnd ss, qz, feld (5%), musc, clay pellets, bedding up to 1.25 m. thick; 10 YR 6/6.</td>
</tr>
<tr>
<td>N1</td>
<td>0.76 m. fine-med-gnd ss, qz, musc, feld rare, single bed, friable; 10 YR 7/4.</td>
</tr>
<tr>
<td>M1</td>
<td>2.29 m. c.b. ss; basal part with sets 0.5 to 1 cm. thick, overlain by ss with eroded current ripples, clay pellets and current drag; c.b. dips 310° at 16°; overlain by c.b. ss sets 7.5 to 10 cm. thick.</td>
</tr>
<tr>
<td>L1</td>
<td>0.46 m. one bed ss.</td>
</tr>
</tbody>
</table>
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Unit

R 1.60 m. med-gnd ss, qz, musc (rare), feld (rare) clay pell (rare), c.b. beds 0.5 to 1 cm. up to 60 cm.; 10 YR 5/4.

Gap of 0.4 m.

Q 0.50 m. one bed ss.

P 0.15 m. ss, qz, musc, graph; beds <0.5 cm. thick.

Gap of 1.2 m.

O 1.80 m. fine-gnd ss, qz, musc, graph; bedding 2.5 cm. thick.

N 1.60 m. fine to med-gnd ss, qz, musc, graph, feld (<5%); beds 0.5-1 cm.; c.b. with dip 90° at 13°, 10 YR 6/6.

Gap of 1 m.

M 4.60 m. med-gnd ss, qz, musc, graph; beds 15-60 cm. thick, c.b.; cliff forming, 10 YR 6/6.

L 0.20 m. friable white ss.

K 0.20 m. c.b. fiss ss, fine-gnd, qz, graph, musc, one set.

Third step on track above road at “C” (fig. 1 C).

“C”-“D”

l 1.80 m. ss, qz, musc, graph, clay pell, beds 7.5 to 15 cm. thick.

k 0.15 m. c.b. ss, qz, graph, musc.

j 1.70 m. med-coarse-gnd ss, beds 0.8-1 m. thick; with qz, graph, clay pell near top; near base sets 7.5 to 30 cm., c.b. with current drag; 10 YR 6/6; ss.

i 1.50 m. fine-gnd ss, musc, qz, beds 0.5-2.5 cm.

h 0.30 m. c.b. ss, sets 1-2.5 cm. thick.

g 0.45 m. one set c.b. ss.

f 0.30 m. fine-gnd ss, qz, musc, graph, beds 1.0-2.5 cm.

Gap of 0.75 m.

e 0.60 m. med-fine gnd ss, qz, musc, graph, 10 YR 6/4.

Gap of 0.30 m.

d 0.15 m. c.b. ss; sets 1-2 cm. thick.

c 2.25 m. ss, beds 75 cm. thick.

b 0.60 m. ss.

Gap of 3.5 m.

Unit

a 2.59 m. med-fine gnd slst, qz, musc, feld, rare plant frags, non-fiss; irregular blocky fracture.

“D”

“C”-“A”

J 0.90 m. ss, beds more than 30 cm. thick.

Road (approx 2.45 m. gap).

I 1.25 m. med to coarse-gnd ss, with clay pell, c.b., qz, feld (<5%), musc (rare), graph (rare), beds 10 cm. or more thick.

H 0.50 m. fine-gnd qz, clay pell conglom.

G 1.50 m. med to coarse-gnd ss, qz, feld (<5%), musc (rare), graph (rare), pink garnet (very rare), beds 10 cm. or more thick; some conglom bands 10 YR 6/6.

Gap of 10.36 m.

F 10.67 m. fine-gnd ss, qz, musc, beds less than 1 cm. thick, very fiss near base, less so near top 5 Y 5/2.

E 1.50 m. med to coarse-gnd, carb slst with qz, musc, feld, plant frags (? sphenopsid), some beds fine-gnd ss and clay pell conglom, somewhat fiss, N4-N5.

D 6.40 m. very fiss, micaceous, fine-gnd ss, beds less than 1 cm. thick, 5 Y 5/2.

C 1.20 m. ss, beds 1-1.5 mm. thick, 5 Y 7/2.

B 1.70 m. ss, beds 1-2.5 cm. thick; otherwise as A.

A 14.60 m. med. to coarse-gnd ss, qz: feld (<10%); musc, graph, 10 YR 8/4.

Base of Springs Sandstone on track from “C” to “A” on Pinnacle Road (Pillinger Drive).

Thicknesses by abney levelling or by measurement on outcrop by steel tape.

Abbreviations.–biot–biotite; c.b.–cross-bedded or cross-bedding; chlor–chlorite; conglom–conglomerate; feld–feldspar; ferrug–ferruginous; fiss–fissile; frags–fragments; gnd–grained; graph–graphite; med–medium; musc–muscovite; pell–pell; qz–quartz; rned-rounded–slst–siltstone; ss–sandstone.

Colour symbols quoted are from Rock Colour Chart, Goddard et al.
EXPLANATION OF PLATES.

1. Basal conglomerate with cross-bedding, Barnetts Member in type section; note coal lense immediately above it in right-hand side of photograph.

2. Coal lense between basal conglomerate and second unit of Barnetts Member.

3. Second unit of Barnetts Member in type section shown basal conglomerate at lower left passing up and right in interbedded feldspathic sandstone, carbonaceous siltstone and coal; second unit at top of photograph.

4. Clay pellet conglomerate, Barnetts Member, Coal Mine Bay.

5. Cross-bedding and ferruginous concretions, Barnetts Member, Coal Mine Bay.

6. Thinly-bedded sandstone showing diffusion rings and weathering pattern, Barnetts Member, Coal Mine Bay.

7. Thinly-bedded sandstone, Barnetts Member, Coal Mine Bay.

8. Contact between Barnetts Member below and thickly-bedded, cross-bedded sandstone above as seen in cliff section at Coal Mine Bay 493.3, 677.42. Hammer lying immediately below contact.

[Photos by A. Goede for I. H. Naqvi.]
AGE AND RELATIONSHIP OF TASMANIAN FOSSIL FAUNAS AND FLORAS

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1961
INTRODUCTION

Only about 750 fossil species have been listed from Tasmania and of these less than two hundred have been studied by methods now considered adequate. Marine invertebrates are found in the Precambrian, Cambrian, Ordovician, Silurian, Lower Devonian, Permian, Tertiary and Quaternary; vertebrate fossils are rare except in the Pleistocene but occur in the Permian, Triassic and Tertiary; small Ordovician, Silurian and Lower Devonian floras are known with richer floras in the Permian, Triassic, Tertiary and Quaternary. No Carboniferous, Jurassic or Cretaceous fossils are known. The remarks which follow could best be described as forming a progress report and it should be appreciated that they are based on very few fossils.

PRECAMBRIAN

Groups of schists and gneisses intruded by metamorphosed basic rocks are overlain unconformably by groups of sediments containing quartzites, siltstones, dolomites, rare conglomerates and tillite. These latter are themselves intruded by basic dykes and sills. The older schists and gneisses represent regionally metamorphosed sediments of the ortho-quartzite suite. Some details of the stratigraphy of the Precambrian are set out in Table I. Worm tubes and casts have been recorded from quartzites in the higher Precambrian rocks at three places, Mount Balfour, Port Davey and Sisters Beach. The exact age of these is unknown. At Dundas rocks correlated with these are overlain with an angular unconformity by rocks containing trilobites of the Ptychagnostus gibus Zone of the Middle Cambrian.

CAMBRIAN

Middle and Upper Cambrian rocks overlie older rocks unconformably and are themselves overlain unconformably by rocks high in the Upper Cambrian or low in the Ordovician. The Middle and Upper Cambrian rocks consist of more than 10,000 feet of conglomerates, sand-
CORRECTIONS

As there was no opportunity for correction of galley proofs a number of errors occur in the text. These are as follows:-

1. "Opik" should read "Öpik" throughout.

2. Two trivial names on p. 329 E. johnstoi and Syntrophopsis karmbergi are capitalised incorrectly.

3. On p. 329 column 2, 1. 42 for 1853 read 1953.

4. On p. 330 for Milthia in fauna column read Miltha. Some commas have been omitted; the only serious one is that between captorhinid and fish. For Thinnfeldia in flora column read Dicroidium.

5. on p. 332 column 1, 1. 3 for Billingsarea read Billingsaria
   13 "tasmaniens" tasmaniensis
   26 "Nytopora" Nyctopora
   27 "Plasmoporela" Plasmoporella
   34 "Gastonsoceras" Gasconsoceras
334 column 2, 1. 5 "fusu" fusus
335 "1, "Thinnfeldia" Dicroidium
337 "2, 1.2 "Cupressinocylon" Cupressinoxylon
338 "2, 1.44 "Palaont." Palaeont.
Pacific (sense of Opik, 1956, p. 268) and Acado-Baltic elements. The dendroid fauna is specifically similar to that found in Victoria. The Blackwelderia and Leiopyge associations are dominantly Acado-Baltic with some Pacific (especially East Asian) affinities. The Lower Dresbachian faunas are Appalachian and the highest one Acado-Baltic again.

Thus deposition occurred in Tasmania from the time of the Middle Cambrian Ptychagnostus gibbus Zone to that of the Upper Cambrian Glyptagnostus reticulatus Zone and during this time the faunas were dominantly Acado-Baltic with some Pacific elements allied to both East Asian and Appalachian forms.

ORDOVICIAN

The Ordovician System comprises a major cycle of sedimentation. It begins with greywacke and sub-greywacke breccias and conglomerates, followed by conglomerates, sandstones, siltstones and limestones in that order. These higher rocks are of the orthoquartzite suite. This cycle is referred to as the Juene Group and reaches a maximum thickness in any one section of over 6,000 feet (Table I.). In some places the limestone passes up into siltstone and this into sandstone but elsewhere the boundary between limestone and sandstone is sharp with the possibility of normal faulting and erosion before deposition of the succeeding bed in one place.

The lowest formation, Jukes Breccia, contains trilobites, orthid and inarticulate brachiopods, and a gastropod tentatively identified as Scaevogyra in one area. None of these fossils have yet been studied in detail so that the age and relationship of the fauna remains obscure. The succeeding Owen Conglomerate contains only tubicular worm casts. A better known assemblage occurs in the Caroline Creek Sandstone (=Tubicolar Sandstone of Owen Conglomerate) and includes the alga Lirophyccus tasmanicus, the gastropods Opileta and Cryptolites, the worms Scolithus aff. canadiensis and S. tasmanicus, and the trilobites Asaphellus lewisi, Carolinites bulbosa, C. quadrata, C. tasmaniensis, Etheridgaspis carolinensis, E. Johnstoni, Prospiscus subquadratus and Tasmanocephalus stephensi. Kobayashi (1940) considered this fauna to be early Ordovician in age, and to show marked East Asian affinities. The subsequent discovery of Carolinites in Central Australia and the Garden City Fauna in Utah and Nevada (Ross, 1951) and in the British Isles (Stubblefield, 1950) is palaeogographically significant. Stratigraphically above the Caroline Creek Sandstone is the Florentine Valley Mudstone which also contains a rich fauna. This includes the brachiopods Synthropsis Karmbergi, ?Tritoechia careyi, T. lewisi (Brown, 1947) and Orausta (?), the gastropods Lecanospira tasmaniensis, Simopea, Roubidouxia and Tentaculites (Kobayashi, 1940a; Etheridge, 1904), and the trilobites Asaphopsis florentinensis, A., Juneensis, A. (?) gracioso-status, Tasmanaspis lewisi and T. longus. Kobayashi (1940a, p. 62) considered the trilobites to show a Lower Ordovician age and remarked on their East Asian affinities. He noted also a North American element, in the gastropods. Brown (1947) showed that the brachiopods indicated a Middle Canadian age and affinities with North America. Browne (1952) remarked on the similarity between the brachiopods and some from a limestone at Bowan Park, New South Wales. Graptolites occur in this formation but have not yet been described.

The Florentine Valley Mudstone is overlain by the Gordon Limestone which contains a rich marine assemblage but only corals, cephalopods, and a few gastropods and algae have been figured to date. At the base of the formation is a fauna of cephalopods with some sponges. The cephalopods include Allocotoceras insignis, Endoceras, Manchuroceras excavatum, M. steanei, Piloceras tasmaniensis, Suecoceras robustum and Utoceras? (Teichert and Glenister, 1953) which show an Upper Canadian age and marked East Asian affinities with western North American and Baltic elements. Also considered as probably Upper Canadian is an horizon with Mysterioceras australis and Trocholitoceras idaense from Ida Bay in south-eastern Tasmania. At Railton in northern Tasmania beds with Nybyoceras puncubiculatum, N. multicubiculatum, Ormoceras and Anaspyroceras occur just above the base of the limestone. Teichert and Glenister (1853) consider these to be Chazyan or Mohawkian. Several hundred feet above the base of the formation in several places Maclurites florentinensis, Maclurites sp., Girvanella grandis, G. problematica and G. tasmaniensis occur either individually or in association. This horizon is thought to be Chazyan (Banks and Johnson, 1957) and it overlies the cephalopod beds at Railton. Hill (1955) recorded Acidolites, Billingsaria banksi, Coccoseris ramosa, Eofletcheria ida, Lichenaria ramosa, Tetradium compactum, Tryplasma cero-ides and Streptelasma cf. aequisulcatum from Ida Bay and suggested that horizons from oldest Blackriveran to Trentonian age at least were
Table I.
Summary of Succession of Tasmanian Faunas and Floras.

<table>
<thead>
<tr>
<th>System</th>
<th>Series Local Group</th>
<th>Rock Types</th>
<th>Faunas</th>
<th>Floras</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Pleistocene</td>
<td>Swamp and cave deposits</td>
<td>Nototherium, Thylacoleo</td>
<td>Eucalyptus, Acacia Conifers, etc.</td>
<td>Australian</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Pliocene</td>
<td>Marine sands, lacustrine deposits</td>
<td>Milthia, etc.</td>
<td>Eucalyptus, Acacia Podocarp conifers</td>
<td>Bassian</td>
</tr>
<tr>
<td></td>
<td>Miocene</td>
<td>Marine limestones and sands</td>
<td>Trybliolepidea</td>
<td></td>
<td>Bassian</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Table Cape Group</td>
<td>sandstone, limestone marine</td>
<td>Sherbornina, Aturia australis, Prosqualodon, Wynyardia.</td>
<td>Trisaccites, Ephedra and native conifers etc.</td>
<td>Australian and South American</td>
</tr>
<tr>
<td>Eocene</td>
<td>Launceston Beds</td>
<td>gravels, sands, clays, lignite</td>
<td>fresh-water pelecypods</td>
<td></td>
<td>Australian</td>
</tr>
<tr>
<td>Cretaceous</td>
<td></td>
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<td>Jurassic</td>
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<td>Triassic</td>
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<tr>
<td>Permian</td>
<td>Tartarian</td>
<td>sandstone, siltstone, coal, tuffaceous sandstone</td>
<td>captorhinid fish</td>
<td>Thinnfeldia, Cladophlebis, Johnstonia, Phoenicopsis</td>
<td>East Australian, South Africa, South American</td>
</tr>
<tr>
<td></td>
<td>Cynet Formation</td>
<td>siltstone, marine sandstone</td>
<td>spiriferids</td>
<td>Glossopteris, Gangamopteris, Vertebraria indica</td>
<td>Gondwanaland</td>
</tr>
<tr>
<td></td>
<td>Kungurian</td>
<td>siltstone sandstone</td>
<td>spiriferids, Chaenomya, Stenopora crinita</td>
<td>Gondwanaland</td>
<td>East Australia</td>
</tr>
<tr>
<td></td>
<td>“Woodbridge Group”</td>
<td>marine</td>
<td>Taeniothaerus subquadratus, Calceolisporgia, Lyroporella, Pterotoblastus.</td>
<td>East Australia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Artinskian</td>
<td>limestones, siltstones</td>
<td>Glossopteris, Gangamopteris, Noeggerathithanis hislopi</td>
<td>Gondwanaland</td>
<td>East Australia, West Australia, Gondwanaland</td>
</tr>
<tr>
<td></td>
<td>Cascades Group</td>
<td>sandstones, siltstones, coal, oil shale</td>
<td>Calcitornella Geinitzina Eurydesma cordatum Keeneia platyschismoides</td>
<td>Gondwanaland</td>
<td>East Australia, West Australia, Gondwanaland</td>
</tr>
<tr>
<td></td>
<td>Golden Valley Group</td>
<td>sandstones, siltstones, limestones</td>
<td>Forams, Keeneia twelvetreesi, Eurydesma, Calceolisporgia “Streblascopora” marmionensis</td>
<td>Gondwanaland</td>
<td>East Australia, West Australia, Gondwanaland</td>
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<td></td>
<td>Sakmarian</td>
<td>siltstones, oil shale</td>
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<td></td>
<td>Quamby Group</td>
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<td>Wyndyard Tillite</td>
<td>tillite, varved claystones etc.</td>
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<td>Carboniferous</td>
<td>Lower</td>
<td>siltstone and sandstone</td>
<td>Pleurodictyum megastomum, Australoecia polypera, Maoristrophia, Plecotodonta,</td>
<td>South-east Australia, New Zealand, Europe, North America, South America, South Africa</td>
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<td>Devonian</td>
<td>Eldon Group</td>
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<td>Bell Shale</td>
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<td>System</td>
<td>Series</td>
<td>Local Group</td>
<td>Rock Types</td>
<td>Faunas</td>
<td>Floras</td>
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<td>calcareous sandstone</td>
<td><em>Pleurodictyum megastomum, Notoconchidium, Protoleptostrophia</em></td>
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<td>Amber Slate</td>
<td>siltstone and sandstone</td>
<td><em>Cyrtograptus, Tentaculites, Gillia</em></td>
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<td>Crotty Sandstone</td>
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<td><em>Camarotoechia synchoneua, Monograptus</em></td>
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<td>“Fenestella Shale”</td>
<td>siltstone</td>
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<td>Ludlovian</td>
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<td>Wenlockian</td>
<td>Amber Slate</td>
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<td>Keel Quartzite</td>
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<td>Amber Slate</td>
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<td>Gordon Limestone</td>
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<td>Cambrian</td>
<td>Upper</td>
<td>Florentine Valley</td>
<td>calcareous mudstone</td>
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<td><em>Esotactites</em></td>
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<td><em>Maclurites</em></td>
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<td>Jukes Breccia</td>
<td>greywacke, breccia and conglomerate</td>
<td><em>Girvanella</em></td>
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<td></td>
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<td>Dundas Group</td>
<td>sub-greywacke, siltstone conglomerate</td>
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<td></td>
<td>Middle</td>
<td></td>
<td>acid and basic lavas, cherts</td>
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<td>Lower</td>
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<td>basic intrusions quartzites siltstones conglomerates dolomites</td>
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<td>basic intrusions schists, gneisses</td>
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present. A Trentonian age has been suggested for a coralline horizon at the Oceana Mine, Zeehan, where Hill (1955) noted Billingsarea? banksi, Eofletcheria contigua, ? Lichenaria, Lycoporaf cf. javosa, L. ramosa, Nyctopora zeehanensis, Tetradium ? compactum, T. dendroides, T. petaliforme, and T. ? tasmaniense. Also probably Trentonian and/or Upper Ordovician is the fauna from the Smelthers Quarry and Despatch Mine, Zeehan, from which the following fossils have been recorded: ?Lichenaria? ramosa, ?Nyctopora, ?Protararea, Tetradium conjugatum, T. dendroides and T. tasmaniens (Hill, 1955), Leptodomus? nuciformis, Trochonema montgomeryi, (Etheridge, 1896), Anaspicyra pora anzaas, Hecatoceras longinquum, H. obliquum and Tasmanoceras zeehanense (Teichert and Glenister, 1953), Illaenus johnstoni, Asaphus and Pliomera brevispinus (Etheridge, 1896). Possibly equivalent or a little higher are the beds at the Smelthers Quarry, Queenstown with Acidolites, Alveolites, Protarareae cf. richmondensis, Tetradium conjugatum, T. dendroides, T. syringoporoides, T. tasmaniense (Hill, 1955), and Beloitoceras kirtoni (Teichert and Glenister, 1953). Limestone at Bubbs Hill includes Eofletcheria ida, Nyctopora and Plasmoporela and is Upper Ordovician (Hill, 1955). A limestone at Liena contains Favistella cerioideae, Pavosites marginatius, Halysites ?chillagoensis and Plasmoporela cf. convexotabulata (Hill, 1943) and is probably Upper Ordovician. Finally from the Gordon River Entelophyllum, Phaulactis shearsbyi (Hill, 1943), Anaspicyraceras, Gastonsoceras insuperatum, Gordonoceras bondi, Ehippiourhoceras decorum, Stromatoceras extinum and Tasmanoceras zeehanii (Teichert and Glenister, 1953) have been recorded. These probably come from many horizons but Silurian rocks may be present based on the corals and Gasconsoceras. Affinities of the faunas are East Asian and Appalachian (Teichert and Glenister, 1953), and not at all with contemporaneous north-western Australian faunas. Some affinities with the Baltic Province are also shown by the cephalopods. The corals similarly show affinities with the Appalachian and Baltic Provinces and with a fauna from central New South Wales. At least one of the gastropods shows Appalachian affinities.

The Gordon Limestone is in places overlain by a richly fossiliferous calcareous siltstone first called the "Fenestella Shale", a name derived from the presence of fenestrate bryozoa which on preliminary examination appear to be trepostomes. No fossils from this formation have yet been described. Thus what little is known of the Ordovician fauna of Tasmania suggests affinities with New South Wales, East Asia, Western North America, the Appalachian province and the Baltic province. The East Asian influences are strongest early in the period and later influences appear to be mainly North American.

SILURIAN AND DEVONIAN

It is convenient to deal with these together as in Tasmania they form a single major cycle of sedimentation lasting from early in the Silurian to high in the Lower Devonian. This major cycle is called the Eldon Group. There is an overall decrease in grain size upwards through the major cycle, on which there are superimposed three smaller cycles each consisting of an alternation of sandstone and siltstone. The Eldon Group is conformable in some places and perhaps disconformable in others on the Junee Group. It was folded, probably in the Devonian, and with all older rocks is overlain unconformably by Cas Lower Permian sediments. Of comparable age in north-eastern Tasmania is a group of sandstones, sub-greywackes and siltstones from which only primitive vascular plants, Hostimella sp. and Hedeia, have been figured. Unidentifiable trilobites, brachiopods, corals, and cnidaria also occur in it in one place. This group, the Mathinna Group, might well be the off-shore equivalent of the on-shore association of the Eldon Group.

The lowest formation of the Eldon Group is the Crotty Quartzite which is richly fossiliferous on some horizons. The fossils include tabulates, rhyynchonellid brachiopods, pelecypods, gastropods, cephalopods, worm tubes and casts, crinoid plates and algal markings. Of these one brachiopod Camarotoechia synchoneua is the only adequately described fossil for which the stratigraphic horizon is known. Rocks correlated with the Crotty Quartzite also contain Monograptus but this has not yet been described. From the overlying Amber Slate no fossil has yet been described and figured. Tetaculites is common on some horizons associated with brachiopods. Ostracodes are also common, and include Gillatia (Opik, 1951) which occurs in the Upper Llandovery in Victoria and at Canberra. Monograptus occurs in rocks equated to the Amber Slate. No fossils have been described from the overlying Keel Quartzite and an unnamed siltstone above it. However, from the Florence Quartzite, the next formation, twenty species have so far been figured (Gill, 1949; 1950). From its type area
Pleurodictyum megastomum, Notoconchidium florencencis, Eatonia pleonecta and Protoleptostrophia plateia have been described (Gill, 1950), and indicate a Lower Devonian age, at least for the top part of the formation. The affinities are with Victoria and New Zealand. From east of Queenstown, in a sandstone correlated with the Florence Quartzite, Gill (1949; 1952) has recorded Pleurodictyum megastomum, "Lindstroemia," Pararetonia euclepta, Cyrtia tasmaniensis, "Spirifer," Nucleospira megahypha, Strophonella australiensis, S. lyellensis, Protoleptostrophia plateia, Parmorthis vandiemeni, Maoristrophia banksi and M. careyi, Cheirurus sp., Dalmanites aff. wandongensis, Encrinus aff. silverdalenensis, Graftonmorella australis and Odontopleura aff. rattei. This fauna occurs near the top of the formation and contains a number of species from the Lower Devonian of Victoria, New South Wales and New Zealand. Hill (1957) notes that Pleurodictyum appears in the Upper Gedinnian so that much of the Florence Quartzite may be Devonian although the base may be Silurian. The topmost formation of the Eldon Group, the Bell Shale, is richly fossiliferous, Pleurodictyum megastomum, Australocoelia polyspera, Chonetes aff. ruddockensis, Eospirifer parahentius, Meristella bellensis, Maoristrophia banksi, M. careyi, Notanoplia pherista, Notoleptaena, Parmorthis aff. allani, Plectodonta bipartita, Cypricardinia, Proe. turus euryceps and Trimerus zeehanensis having been recorded. This is a Lower Devonian fauna and has dominantly Victorian and New Zealand affinities, with the exception of Australocoelia polyspera which as Boucot and Gill (1956, p. 1178) have pointed out, is the first Malvinocaffric element so far recorded in Australasia. Gill (1953) has dealt with the relationship of the Australasian Lower Devonian faunas with those of other parts of the world and has remarked on the European affinities of many of the species. Hill (1957, p. 49) has also remarked on the "Eurasaustralian fauna" in the Lower Devonian.

Thus the Eldon Group contains rocks of Silurian and Lower Devonian age. Faunal affinities are unclear until the Lower Devonian when they are strongly with Victoria, New South Wales and New Zealand with one Malvinocaffric species.

At Point Hibbs a richly fossiliferous limestone occurs from which Favosites? bryani, F. goldfussi and Heliophyllum? chillagoense have been described (Hill, 1943). Although this limestone has in the past been regarded as Gordon Limestone, new work established clearly that this is not so, it is probably Lower Devonian.

Over two hundred species have been recorded from the Permian System in Tasmania but most of these are in need of revision. The Permian System consists of about 2,500 feet of sediments of the sub-greywacke suite with some orthoquartzite suite sediments whenever conditions became terrestrial. The impurity and poor sorting of the sub-greywacke suite sediments is attributed to the effects of glaciation on the near-by land surface and to the presence of numerous icebergs in the sea. Vulcanism is represented by bands of meta-bentonite in one formation. The succession (Table I) represents two alternations of marine and fresh-water conditions with other cycles superimposed on the main ones. Banding of the sediments is common. One cyclothem has so far been recognized (Banks and Hale, 1957). Evidences of local glaciation are abundant in the Sakmarians (and perhaps Upper Carboniferous) and glacial erratics occur in marine sediments at least as young as Khungarian.

The oldest Permian fauna is that of the oil shale of the Quamby Group. This oil shale contains the spore Tasmanites punctatus, the foraminifera Ammodiscus multicinctus, Hyperammonoides acicula, Critichonia teicherti, Pelosina hemiphatica, Ammobaculites woolnoughi and Digitina recurvata, the pelecypods Eurydesma hobartense, Aviculopecten sprentii, the gastropod Keeneia twelvetreesi, and the astrozoan Etherid gastcr cf. clarkei. Somewhat higher in the Quamby Group on Woody Island, Banks, Hale and Yaxley (1955) have recorded Stenopora tasmaniensis, Fenestella dispersa, ?Streblospora marmonensis, Calceolospingia, Jimbacrinus, Calcitornella stephens and Eurydesma cordatum. The Darlington Limestone of the overlying Golden Valley Group is richly fossiliferous with Calcitornella stephens, Geinitzina triangularis, Stenopora tasmaniensis, S. johnstoni, Eurydesma cordatum, Keeneia platyschismoides and many other fossils including Calceolospingia spp. If correlation with the Callytharra Limestone in Western Australia on the basis of Calcitornella, Geinitzina and other foraminifera is correct, the Darlington Limestone is Lower Artinskian (Teichert, 1941—for correlation of Callytharra Limestone). Other formations of the Golden Valley Group contain rich faunas including at least some of those species mentioned above.

The flora of the Mersey Group contains Glossopteris ampla, G. browniana, G. indica, G.
The fauna of the Cascades Group is very rich. It includes Cladochonus, Thamnopora, Euryphyllum, Stenopora pustulosa, S. crinita Stenodiscus moniliformis, Polypora woodsi, Fenestella granulifera, Lyroporella, Tæniothaerus subquadatus, Strophalosia jukses, S. typica, Anidanthus springsurenensis, Trigonotreta stokesii, Cancrinella farleysensis, Eurydesma cordatum var. succulentum, Ancylopecten squamuliferus, Calcitornella novelti, Pteroblastus and Conularia derwentensis. Calcitornella also occurs at least in the lower part of the group. This fauna indicates correlation with the Maitland Group of New South Wales and the Cattle Creek and/or Ingelara Formations in Queensland (Banks, 1957 a) which are thought to be Artinskian. The fauna is dominantly eastern Australian but Western Australian elements such as Lyroporella, Tæniothaerus subquadatus, Calcitornella novelti, and Pteroblastus also occur in it. Recently Crockford (1957) has recorded Stenodiscus, a genus first described from Tasmania, from Western Australia. Also in the Cascades Group is a bryozoan which externally resembles Strebloscopora marmionensis (Crockford, 1957) from Western Australia.

The fauna of the “Woodbridge” Group is neither so rich nor so well known as that of the Cascades Group. It includes Stenopora crinita, Chaenomya etheridgei, Eurydesma cordatum var. succulentum, Warthia micromphala, Hyolithes lanceolata, and Trichroycinus tasmaniensis. In general a correlation with the middle and upper parts of the Maitland Group of New South Wales is indicated and the fauna is entirely Eastern Australia.

The fauna of the Femtree Group is very poor but enough to indicate marine deposition. The flora of the Cygnet Formation contains Glossopteris angustifolia, G. browniana, Gangamopteris angustifolia, G. cyclopteroides and Vertebraria australis as well as the sporomorphs Acanthotriletes tereteangulatus and Lueckisporites fusus. The former sporomorph occurs only in the Newcastle Coal Measures in New South Wales and the latter in only the Newcastle and Tomago Coal Measures. Other plants and sporomorphs also occur. The known flora is entirely a Gondwanaland one. Balme and Hennelly (1956) have suggested a correlation between the Newcastle Coal Measures and the Liveringa Formations, the top of which contains plant remains and is considered by Thomas and Dickens (1954) to be Tartarian.

The faunas of the Tasmanian Permian are dominantly eastern Australian in affinity but there are similarities with Western Australia and Timor at least from some time in the Sakmarian (Quamby Group) until the end of the Artinskian (Cascades Group). In the three topmost groups no Westralian elements are known. The Westralian elements in the Tasmanian Permian are lacking in New South Wales and Queensland and this suggests a marine connection south of the present continent of Australia. In conjunction with the evidence of different Westralian elements in the Queensland Permian, this suggests that at times in the Permian the Australian continent was entirely surrounded by sea (see also Teichert 1951, p. 87). Some Gondwanata elements are also present.

**TRIASSIC**

The stratigraphy of the Triassic rocks of Tasmania is poorly known. At the base is a quartz sandstone and higher up are quartz sandstones and siltstones, followed by coal seams associated with claystones and feldspathic sandstones which are possibly partly of pyroclastic origin (see Banks, 1952).

Three vertebrates only are known from the Triassic. Two captorhinid femora of Lower Triassic aspect occur in quartz sandstone isolated in a fault block and two fish Acrolepis hamiltoni and A. tasmanicus occur in quartz siltstones of unknown stratigraphic position.

The flora is quite a rich one especially in the coal measures. There are unidentified lycopods in the sandstone and siltstone units in several places, and a lycopod strobilus, Lepidostrobus muelleri, has been recorded, but must be considered doubtful. Three sphenopsids, Neocalamites
feldia acuta, T. feistmanteli, dosperms are very common and include are known. Ferns are common, the main one carrerei, N. hoerensis and Phyllotheta australis are known. Ferns are common, the main one being Cladophlebis australis but C. johnstoni and C. tasmanica, Chiropteris tasmanica, Asterotheca cf. hillae and Gleichenia dubia also occur. Pteridosperms are very common and include Thynnfeldia acuta, T. feistmantelli, T. odontopteroides, T. cf. talbragarensis, Johnstonia dentata, J. coriacea, J. trilobita, Sphenopteris lobifolia and S. morrisiana. Other fern-like fronds include Cardiopteris tasmanica, "Pecopteris" luumensis and ?Phlebopteris aethopteroides. Cycads are very common and include Doratophyllum tenisonwoodsii, Linguifolium diemenense, L. lilleanum, Sphenozamites feistmantelli, Otozamites mandeslohi, ?Pseudocenis, Pterophyllum inconstans, P. ridosonin, P. strahani, Taeniopteris carruthersi, T. morrisiana and T. polymorpha. Ginkgoales are present and common on some horizons. They include Ginkgo digitata, G. hobartensis, G. salisburoidea, Ginkgoites bidens, G. australis, Czekanowskia tenuifolia, Pterichus annularoides and Phoenicopsis elongatus. Sagenopteris moribunda and S. tasmanica complete the known flora. All Tasmanian identifications are based on leaf form and venation. As pointed out by Jones and de Jersey (1947, p. 81) there are many species in common between the Tasmania flora and that of the Ipswich Coal Measures of Queensland. Of the forty-five species known in Tasmania, eighteen occur in that formation and some of them have a restricted stratigraphic distribution within it. Five species occur in Tasmania and the Wianamatta Group in New South Wales, five in the Narrabeen Group, four in New Zealand, five in the Upper Beaufort Beds, nine in the Molteno Beds in South Africa and seven in Argentina. There are six species common to the Tasmanian Triassic and that of Bald Hill, near Bacchus Marsh, Victoria and six with the Lower Jurassic flora of Victoria.

Thus the Triassic of Tasmania can in part at least be correlated with the Ipswich Coal Measures of Queensland which is considered by Jones and de Jersey (1947) to be equivalent to the Upper Narrabeen, Hawkesbury and Wianamatta Groups in New South Wales. Browne (David, 1950, p. 431) considered the Lower Wianamatta to be basal Upper Triassic on evidence of the vertebrates so that the Tasmanian floras might be considered as more or less Middle Triassic with both Lower and Upper Triassic beds possibly present. The flora shows strong relationship at the specific level with Eastern Australia, with some relationship to floras in New Zealand, South Africa and Argentina. South African affinities are strengthened by the presence of the captorhinid femora. The Argentinian relationship is of considerable interest in view of the discovery (Harrington, 1955) of a strongly Eastern Australian fauna in the Permian south of Buenos Aires.

TERTIARY

The Tertiary flora of Tasmania was large. Numerous forms have been differentiated on leaf form and venation but few cuticle studies have been made. Silicified wood is common but little has been described. Coniferous twigs and cones have recently been re-examined. Fruits and seeds are common but few have been critically examined. Within the last ten years palynological studies by Cookson and others have given more exact information on the flora than was previously available. The plant remains are mainly found in lacustrine, fluviatile, paludal and spring deposits of sands, clays and lignite but some also occur in marine deposits. Most of the freshwater beds were deposited in large fault trough lowlands.

The oldest flora known is that occurring in linites near Launceston and Ouse. These contain the pollens Trisaccites micropterpus, Ephedra notenosis, Microcachrydites antarcticus, Araucariacites australis, Phyllocladus palaeogenicus, Dacrydiumites florinii, Banksiaedites, Beaufriedites verrucosus, Casuarinidites cainoizocics, Dacrycarpites australiensis, Myrtaceadites eugenioides, M. mesonesus, and M. parvus, Podocarpus precupresinus, Proteacidites cf. crassus, P. parvus, Triorites harrisi and Nothofagus. The first two of these pollens are present in beds older than the Oligocene brown coals of Victoria but not in those coals (Gill and Banks, 1956, p. 12). For this reason this flora is considered as of Lower Tertiary age. At Geilston Bay Araucaria derwentensis and A. johnstonii occur as cones and twigs and Arthrotaxis tasmanica as cones. Leaves of Podocarpus (Dacrycarpus) and Podocarpus (Polypodiospis) brownii (Selling, 1950) are associated with basalt at Burnie and podocarpaceous wood (Cupressinoxylon hookeri Arber, 1904) occurs between basalt flows at Macquarie Plains. Araucaria imbricatiformis is based on cones from Macquarie Harbour in beds from which Johnston (1888) recorded Acacia meiringii and Eucalyptus milligani, based on leaf impressions. The only other place where Johnston recorded either Eucalyptus or Acacia was Mt. Bischoff where he recorded E. kayseri. If Johnston's determinations are correct and the range of these two
genera as known in Australia (Cookson, 1954) apply to Tasmania the Macquarie Harbour beds may be late Pliocene or later in age. Thus throughout the Tertiary in Tasmania the flora was dominantly of native conifers, proteaceans and myrtaceans with other species related to those now living further north and in New Guinea and New Caledonia (Cookson, 1953).

Tertiary vertebrates are rare but the oldest marsupial in Australia, *Wynyardia bassiana*, occurs in Upper Oligocene beds near Wynyard, where it is associated with *Prosqualodon davidi*, a whale of South American affinities, and shark's teeth.

Nearly three hundred species of marine invertebrates have been described from the Tasmanian Tertiary. Most of these are in need of revision. Marine beds mainly sandstones and calcarenites, occur as a coastal fringe around the north-west coast and on the Bass Strait islands. The oldest beds contain *Sherbornina atkinsoni*, *Euerassatella oblonga* and many other species. These are overlain by beds with numerous *Turritella* spp., *Cellepora gamborense*, *Lovenia forbesi*, *Prosqualodon*, *Wynyardia* and *Aturia australis*. Younger beds with *Lepidocyclina* (*Trybiolipidina*) occur elsewhere, and are probably late Lower Miocene. No further marine beds occur until the Upper Pliocene or Pleistocene beds of Flinders Island with *Milthia grandis*. The invertebrate faunas are distinctly Bassian in character.

QUATERNARY

The fauna and flora of these superficial deposits are essentially modern and Tasmanian. The only group that justifies comment is that of the marsupials. These included *Diprotodon australis*, *Nototherium victoriae*, *N. mitchelli*, *Thylacoleon*, *Thylacinus*, *Phascolonus* and other extinct forms. Many of these were of considerable size. The only fossil bird from Tasmania is an emu from Pleistocene swamp deposits.

SUMMARY

Worm tubes and casts occur in a pre-Middle Cambrian sequence of quartzites, siltstones, dolomites, conglomerates and basic dykes and sills which overlie unconformably a sequence of schists, quartzites, sheared conglomerates and amphibolites.

Rocks of the *Ptychagnostus gibbus* Zone of the Middle Cambrian unconformably overlie older rocks. They form part of a thick sequence of rocks of the sub-greywacke and greywacke suites associated with volcanic and pyroclastic rocks, cherts and rare dolomites and limestones which extend into the Upper Cambrian at least up to the *Glyptagnostus reticulatus* Zone. This sequence consists of at least eleven cycles of sedimentation. It is intruded by slightly transgressive sheets of pyroxeneite, now largely serpentinized. The faunas show affinities with those of Victoria, Queensland and the Acado-Baltic province with some Appalachian and East Asian elements especially late in the Middle Cambrian and early in the Upper Cambrian.

Ordovician rocks rest unconformably on older rocks and form a single cycle of sedimentation over 6,000 feet thick in parts. They belong dominantly to the orthoquartzite suite. The oldest known fauna is Middle Canadian in age and the youngest possibly Richmondian. In the Lower Ordovician affinities are with East Asia and North America with some similarity to faunas in New South Wales, Central Australia and Great Britain. During the Middle and Upper Ordovician the affinities are with North America and the Baltic province.

The Silurian and Lower Devonian rocks form a single major cycle with three minor cycles superimposed on it. The sequence is over 6,000 feet thick and consists of sandstones, siltstones, limestones and rare conglomerates of the orthoquartzite suite. The Silurian fauna is poorly known but the Lower Devonian fauna is very rich and shows strong affinities with that of Victoria and New Zealand, less with New South Wales, some with Europe, a little with North America and there is one species of the Malvinocaffric province. The change in affinity from dominant North American in the Ordovician to the dominant south-east Australasian in the Silurian (?) and Lower Devonian may be at least partly due to the changes in the palaeogeography of eastern Australia resulting from the Benambran Orogeny in the late Ordovician or early Silurian.

The Precambrian, Lower and Middle Palaeozoic rocks were folded, faulted and intruded by granite, probably in the Devonian. Unconformably on these were deposited Permian rocks. The Permian System consists of two alternations of marine sediments of the sub-greywacke suite and fresh-water sediments of the orthoquartzite suite resting in many places on a basal tillite. The total thickness is probably about 2,500 feet. The oldest fauna is probably Sakmarian and the youngest Kungurian or Kazanian. The fresh-
water intervals occurred in the Middle Artinskian and Tartarian approximately and are roughly contemporaneous with those in New South Wales. The flora contains nothing but Gondwanaland elements. The fauna is dominantly eastern Australian with some Westralian-Timor elements and some Gondwanaland elements. The Westralian-Timor elements are present from Sakmarian to Artinskian but no later. This exclusion of the Westralian elements coincides with the beginning of a new cycle of sedimentation in Tasmania and this may be correlated with the changes in palaeogeography consequent upon fold movements near the end of the Artinskian in New South Wales or to lowering of sea level associated with the renewed onset of glaciation which could well have broken the earlier marine connection south of Australia.

The Triassic System consists of several thousand feet of quartz sandstone, and siltstones, coal seams and tuffaceous (?) sandstones. The fauna is very poor but includes two captorhinid femora of South African affinities. The flora of the coal measures indicates an approximately Middle Triassic age but may extend down into the Lower Triassic and up into the Upper Triassic. Strongest affinities are with Queensland South Africa and Argentina.

The Triassic and older sediments were intruded by sheets and dykes of dolerite. A surface including dolerite was bauxitized and later faulted. In the fault troughs freshwater sediments including lignite accumulated. The lignite contains pollen considered to indicate a Lower Tertiary age. The flora of the Tertiary consisted dominantly of native conifers, with myrtaceans, proteaceans and other plants, some of which show a relationship to those growing in northern Australia, New Guinea and New Caledonia now.

In the Upper Oligocene and Lower Miocene several hundred feet of marine sands and calcarenites were deposited as a fringe around parts of the Bass Strait coast. The faunas are dominantly southeast Australian and include the oldest marsupial from Australia in the Upper Oligocene. This appears to have been related to the present brush possum. Upper Pliocene or Lower Pleistocene marine sediments are also known from some of the Bass Strait islands. Basalts in Tasmania are pre-Upper Oligocene and post-Lower Miocene, probably Pliocene.

Glaciation affected Tasmania in the Pleistocene when the flora was more or less as at present. The fauna included extinct giant marsupials and emus as well as living species.

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A DARWIN MANUSCRIPT ON HOBART TOWN

by

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Read before the Society, 4th August, 1970

ABSTRACT

The collection of Darwin's papers in the Library of Cambridge University includes a 22-page manuscript on the Geology of Hobart Town. Consideration of the manuscript suggests that Darwin's collection of fossils described in 'Geological Observations' came from the Bundella Mudstone at Porter Hill, the Cascades Group near Barossa Road, Glenorchy, and the Malbina Formation at Eaglehawk Neck. The manuscript further demonstrates his assiduity and acuteness as a geological observer, and suggests a considerable fund of geological knowledge of Van Diemen's Land in 1836.

INTRODUCTION

During consideration of a manuscript by the late Edith Smith dealing with the fossil polyzoa described by Lonsdale in Darwin's 'Geological Observations' (1844), the question arose as to the most likely places from which Darwin had collected his specimens. In following this up, contact was made with the Librarian, Cambridge University, where Darwin's papers are lodged, and the Librarian made available a microfilm of a manuscript memorandum on the geology of Hobart Town. Because of the importance to palaeontological taxonomists of this memorandum in revealing Darwin's collecting spots and because of the additional light it throws on Darwin's activities while in the area as well as on his geological ability, the manuscript has been deciphered and is reproduced here with Darwin's original notations. Plate 1, a copy of p. 8 of his manuscript, is reproduced by permission of the Syndics of Cambridge University Library.

I would like to acknowledge the help of the staff of the State Archives, Morris Miller Library at the University of Tasmania, the Under-Librarian of Cambridge University Library, the Curator of the Darwin Collection at Down House, and Miss E. Geddes, Librarian to the Royal Society of Tasmania.

Mr R. F. Wise, British Museum of Natural History, kindly made available fragments of the matrix of some important Tasmanian fossils held therein and rubber moulds of some of these fossils. I would also like to acknowledge helpful criticism from Professor S. W. Carey, Mr D. E. Leaman and my wife.

Memo on Hobart Town by Charles Darwin, transcribed by Maxwell R. & Doris M. Banks.

1836 February Hobart Town 837 (1

In the neighbourhood of Hobart town, two\(^3\) distinct formations occur, both accompanied by rocks of igneous origin.

I will begin by the most modern of the two. In this formation the prevalent rock is white, fine grained Sandstone, composed of minute grains of Quartz\(^1\) with a little white cementing matter. Within the town it is associated, with reddish laminated Aluminous Sandstones, other ferruginous ones and some Clay Shales. On a hill close behind the town, there are strata of a very impure Coal, carbonaceous Shale, and white Sandstone banded with the finest lines, stained black, by a similar substance. Here such layers are penetrated (crossed out is 'with all at a high angle and being disturbed') by a great mass or dyke (a hundred yards wide) of a decomposing Greenstone; on one side the strata dip away at an angle of 60° or 70° and fragments\(^2\) of Porcelain rock and indurated sandstone, lying in the lines of function, point out the effect of an igneous mass — on the other side, the confusion is even greater; layers of impure Coal, being now in a nearly vertical position.

Footnotes:

The following comments occur in the margin of the manuscript at the place indicated:

i. 'R.N. p. 120; Granite on E. coast

ii. Examine flints in 'Flo' formation for Infusoria

iii. Dr Scot's paper on Van Diemen's Land

Comments:

A. This probably refers to dolerite dyke which cuts and indurates the Upper Triassic succession between Clare St Oval and Waverley Ave, and is cut by Augusta Road at 516.25 E. 722.55 N. The dimensions of the dyke and the lithology of the intruded rocks fit the description; the tilting of the strata is considerable but the vertical strata mentioned are no longer visible if this is the locality described. Another, less likely, possibility is that it refers to a Tertiary basaltic dyke which intrudes, bakes and disturbs the Triassic sediments which include carbonaceous siltstone at the top of Arthur St, West Hobart, in the eastern abutment of the former Crisp and Gunns Quarry (516.55 E. 720.9 N). However the width of this dyke is only 10 to 20 yards, not a hundred as stated by Darwin.

B. 'R.N.' refers to one of Darwin's notebooks so marked on front and back cover. Page 120 contains the pencilled comment 'Bailly talks of much granite on all East side of Van Diemen's Land' (Miss J. Dobson, Curator of Down House, pers. comm.) Bailly was one
of the naturalists with Baudin during his exploration of Van Diemen's Land in 1802 (Péron 1807).

C. Presumably a reference to a paper by the Rev. Archdeacon T. H. Scott in Annals of Philosophy, Vol. 7, p. 462 for June 1824. This very brief paper commented on the similarity in geology of 'New Holland' and 'Van Diemen's Land.' It noted the presence of rocks of the 'coal formation' at Hobart and Georgetown, of fossiliferous limestone between Hobart and New Norfolk and near Georgetown, of a rock like 'the Millstone Grit' and salt in the Midlands and 'elevated primitive ridges' on both sides of the Midlands valleys.

1836 February Hobart town 838 (2 In the Government domain and in other places I saw the Sandstones and Greenstones abutting against each other in straight lines. In all parts of the hill, on which the town stands dykes of Trappan rock and those of aqueous origin alternately appear; and I am doubtful which class is most abundant—the Stratification in some places, as has been shown, is exceedingly disturbed and inclined strata generally are common; in many cases however, this is the result of the manner of deposition, as has been described near Sydney, and hence the two classes are not easy to be distinguished. Following the coast down to the South of the town frequent patches of this formation are met with. I found a coarse ferruginous Sandstone containing numerous thin strata of Clay and highly ferruginous matter reposing in layers, inclined apparently from original deposition, on a mass of coarse greenstone; the lower

Footnote:
The following comment was made on the back of page 1—On a yellow substance in Cavities in Trap. Daubrisson vol. 2, p. G 569.

Comments:
D. Such a straight line abutment of dolerite against Triassic sandstone may be seen along the shoreline near the Naval Depot (co-ordinates 519.3 E. 721.8 N to 519.4 E. 721.4 N) and was revealed by the excavations for the Olympic Pool (co-ordinates 519 E. 721.25 N).

E. Dykes of dolerite are common in the Triassic sandstone of the City area (see Lewis 1946, pp. 116, 120; Banks et al. 1965).

F. This probably refers to Tertiary sands and clays resting on dolerite at Battery Point near Quayle Street (519 E. 719.2 N) and steeply tilted near Sayer Crescent (518.9 E. 718.6 N). Dolerite boulder beds were exposed in excavation for blocks of flats at the back of Maryville Esplanade near Sayer Crescent (co-ordinates 518.9 E. 718.55 N) (fig. 1 B). The steeply tilted beds are no longer exposed but were referred to by Johnston (1888, p. 282) and illustrated by him (1888, plate opposite p. 280).

G. Presumably a reference to a book by D'Aubisson de Voisins. 'Traité de Géonosie' published in Strasbourg and Paris in 1819. D'Aubisson was one of Werner's pupils who became a Plutonist (Zittel 1901, p. 61).

1836 Febru. Hobart town 839 (3 parts passed into a Conglomerate, from containing so many pebbles of the underlying Greenstone and a white flinty rock, bearing peculiar Organic impressions and Sandstone, all which belong to the older formation and will be subsequently mentioned.—Again further onwards, a H coarse Sandstone containing some indurated clay is covered by some thicknesses of strata of a white soft alumino-sandstone, somewhat like the substance of Huepilacuy at Chile. These are capped by a stratum of basalt, a few feet thick, compact with scarcely even a minute vesicle and abounding with very small crystals of red Olivine 3(?) This is separated from a superior and exactly similar stratum of Basalt by one, which has an irregular outline, contains masses of hard basalt, but is itself partly decomposed and resembles Wacke.—By tracing its graduations I found this new comparatively compact substance once to have been Scoria which without doubt divided two distinct streams.

Comments:
H. This can refer only to the Tertiary sands and clays overlain by basalt forming parts of a volcanic centre at and just south of the southern end of Long Beach and extending to the point south of Blinking Billy Point (i.e. from 521.25 E. 716.7 N to 521.4 E. 716.4 N) (fig. 1 D); this section was subsequently described and figured by Johnston (1888, pp. 279-81) and intensively studied by Spry (1955).

3468 1836 Hobart town 840 (4 of subaqueous Lava. The whole of this mass has been tilted at an angle of 30° to the South.—Following the Basaltic beach for a few hundred yards, there is a cliff, composed of a very compact mass of highly vesicular stone mingled with some compact kinds.—parts have been broken and apparently reunited by heat, others clearly by the agency of water, as shown by containing two or three rounded pebbles. The cells of the Vesicular Lava, are generally linear, the lines being not infrequently parts of curves and the internal surfaces are lined with sulphur (?).—I can feel no doubt that this little projecting cliff although at present showing(1) no trace of a Crater, was the point, from which the Basalt flowed. In close proximity we have the older greenstone bearing almost the appearance of a syenite and through this rock the former Volcano must have burst its way.—This is the only spot where I examined any Basalt but in all the South part of both sides of the

Footnote:
(i) 'yellow substance or stains' in margin at this point.
soft chalk; it is at a little remarkable that such a substance should be included between their stratigraphic limits. On the shore, a few miles south of Hobart town, I found the following varieties blending into each other, alternately: 1. A white, sandy, rock with grains of quartz; a thin, slightly calcareous shelly, compact clay slate of a greenish- brown. 2. A dark green or blackish, fine-grained, compact clay slate. The occurrence of a very few fossils in the slate of this formation is generally common. Such happens in the limestone + forming cases. On the west of Wellington, noticed, a similar species, a pale brown-coloured clay slate (which people cannot be called greensand). 3. White, compact, variegated, containing alumina, clay, the smaller, 1. The opposite shore to Blaxs.
3466 or red colour, hard, siliceous, and contains Bay. 

...ficial similarity of the columns to basaltic columns as 'Beagle' would have had to pass in coming up Storm K. This is probably close to Cape Raoul which the to the top of Mt Wellington did not realise that the J. Darwin, like Flinders (1801) and many other early navigators and naturalists, regarded the great cliffs of columnar dolerite around the Derwent Estuary as volcanic in origin. By many the cliffs were stated as composed of 'basaltes', probably because of the superficial similarity of the columns to basaltic columns as in Auvergne. It is a little surprising that Darwin who voluntary mine of Coal (not of very good quality) is worked in Sandstone. I suppose of course these Carboniferous strata are of the same age, with those at Hobart Town and if so the great Basaltic Plat- 

forms and the 2 little streams of lava which I have described, belong likewise to one class of events. This whole formation occurs as a fringe, at the base of older series, around the estuary; it likewise extends inland and partly comprises the lower grounds of the fertile valley of the Derwent. I do not think its elevation exceeds a few hundred f.—We now come to the older ...perfect; but the greater part is of an intermediate nature. 

...in character between compact hard blue Clay-Slates, white Cherty or Flinty rocks; they may be described as gradu-

ating in character between compact hard blue Clay-Slates, white Cherty or Flinty rocks, white aluminous fine Sandstones (or Claystones) and Limestones; each kind is occasionally met distinct and tolerably perfect; but the greater part is of an intermediate nature. 

J. Darwin, like Flinders (1801) and many other early navigators and naturalists, regarded the great cliffs of columnar dolerite around the Derwent Estuary as volcanic in origin. By many the cliffs were stated as composed of 'basaltes', probably because of the superficial similarity of the columns to basaltic columns as in Auvergne. It is a little surprising that Darwin who ...in one of the quarries south of the upper part of Barossa Road. 

...the boulders are like Grange Mudstone. The only other occurrence of Carboniferous strata is in one of the quarries south of the upper part of Barossa Road, Tolosa Street, Collinsvale, Granton and else-

where (see also comment on N). 

N. This locality 'Beyond New Town,' combined with the occurrence of travertine ('Snow white, soft ... pure Calcareous substance') between 'strata of hard crystalline Limestone' makes it likely that the area was that at Barossa Road (513.3 E. 724.4 N) where even as late as the 1940s the quarries had just that appear-

ance. The 'flinty beds' occur abundantly in this neighbour- 

hood as Grange Mudstone. A less likely locality is in one of the quarries south of the upper part of Tolosa Street (512.2 E. 724.25 N) (fig. 1 C). The only...
Fig. 1.—Maps illustrating some of the areas visited by Charles Darwin, February 6-16, 1836. Numbers in margins of maps refer to co-ordinates in State Grid System.

A. General map of the Hobart area showing some of the areas visited and the course of the track to Huonville.
B. Sandy Bay area showing some of the localities mentioned in the text.
C. Geological sketch map of the Barossa Road—Tolosa Street area; no geology is shown north of Tolosa Street; the quarry visited by Darwin is that marked (1) or one close to it.
D. Geological sketch map of the Lower Sandy Bay—Taroona area showing localities mentioned in the text.

Puzzling feature is the presence of 'a few parts almost composed of a small Oyster' and might refer to a small outcrop of *Eurydesma*—rich limestone on the Glenlusk Road (508.25 E. 728.1 N) which was certainly worked as a source of lime in the early days of the colony as shown by the presence, size and style of the remains of a small kiln nearby. However, this last possibility is not considered very likely as (a) Darwin would probably have referred to this locality as beyond Humphrey's Rivulet which was already named (Frankland's map 1839), (b) 'flinty beds' are not at all close (see Sutherland 1964 maps), (c) there is no present evidence of travertine there, (d) the *Eurydesma* would hardly be referred to as small, (e) in his published description Darwin referred to this being 'near New Town' (1884, p. 155), and (f) on a chart (Dept of Lands, Buckingham Plan 17 A,
dated Nov. 1832) a lime kiln is shown at the Barossa Road locality but nowhere else north of New Town to the limits of the map near Granton.

1836 Hobart town 844 (8 soft chalk; it is not a little remarkable that such a substance should be included between strata of hard crystalline Lime-
stone.—

On the shore, a few miles South of Hobart town I found the following O varieties blending into each other and alternating. (i) a white Cherty rock with grains of quartz; a blue slightly cal-carceous, siliceous compact Clay-Slate and a greenish brown rather softer, coarser Clay-Slate. The whole abounds with impressions; in it are scattered a very few rounded pebbles of pure Quartz, Quartz rock and some of a Micaceous Clay-
Slate.—

The occurrence of a very few pebbles in the strata of this formation is generally common.—Such happens in the Limestone and following cases.—On the flank of Mount Wellington I noticed amongst similar kinds, first a pale blue coarse speckled clay Slate which perhaps would be called Greywacke), a white compact-uneven fracture aluminous Sandstone (perhaps with an uneven fracture, which in parts becomes more sandy in other passes into a Porcelain rock with conchoidal fracture; the whole series graduates into an underlying blue stone partaking of the characters of Clay Slate.—In both are found rarely casts of Terebratula and pebbles.—(a) Near New Norfok a similar white stone, passes into a very hard brittle s., one with straight fracture—whose grains of quartz are blended and almost dissolved in a siliceous paste.

Here pebbles of pure quartz were more frequent than elsewhere. Mr Frankland, the Surveyor-General, gave me specimens of the white Aluminous stone, abounding with impressions of Shells from the Huon River and likewise, a blackish Limestone almost composed of parts of Bivalves from the island of Maria.—(B) We thus see this formation extends over the whole SE extremity of Van Diemen's land.—With respect to its connection with the first formation

Footnote:
(a) and (B) appear in the margin at the places indicated and refer to the following notes which appear on the back of page 9.

(a) also all the strata are crossed by fissures the sides of which are penetrated with ferruginous matter, so as, from being harder, to project upwards.—

(B) I have also Terebratula from the neck of the Peninsula (where the gards is kept) of the penal Settlement (3630:31:32).

Q. There are too many outcrops meeting this description near New Norfolk to allow specification of a locality. However it is likely that the coach on which Darwin travelled to and from New Norfolk (Barlow 1933, p. 389) stopped at the Black Snake Inn near the present western end of the Bridgewater Causeway.

At this locality Ferntree Mudstone occurs which meets the description.

R. There is insufficient detail given to allow recognition of a locality or formation.

S. This reference is certainly to the Darlington Lime-
stone from the cliffs and shore platforms north of Darlington, Maria Island. This limestone has long been known for its richness in Eurydesma (see also comment HH).
1836 Hobart town 846 (10) I was not fortunate enough to find an actual junction; but as in this latter, pebbles from the second and older series are found, the two formations must be quite distinct. In a like manner neither did I see the inferior junction; the white flinty Slates, being the lowest stratified rocks which are visible. The pebbles however of Quartz rock and Micaceous Slate, show that a third and older formation must be not very far distant.—

Yet in this immediate neighbourhood I believe the lower strata of the second series generally rest on a coarse greenstone which (i) has burst through them when in a fluid state. I think this, from the entire absence of pebbles of Green-distant from this rock; and from its close juxtaposition on either hand of masses of the stratified slates, which would appear to be the effect of violence.—I confess however, I saw no cases, where the Stratifications pointed out this relation, in a satisfactory manner. The strata are seldom horizontal but are gently inclined and as far as I can ascertain in

(i) this is the manner in which Darwin presumably indicated the insertion at the point shown of the phrase 'when in a fluid state.'

U. This correct ordering of the dolerite with respect to the Permian rocks represents the earliest correct attempt to do this. It was unfortunately not published.

1936 Hobart town 847 (11) no particular direction. Almost all the hills, even those of quite secondary height, consist of Greenstones. Fringed with these strata.—On the opposite side of the water to Hobart town, a hill composed of ordinary, granular, and fine grained ferruginous Greenstones was skirted in the upper parts of its sides by gently inclined strata, which appeared (but I do not feel at all sure) to have undergone some alteration; there were bluish siliceous - Aluminous stones with minute grains of Quartz and white ones of a similar nature, which are indurated and fractured.—

Mount Wellington, the most conspicuous feature in this neighbourhood rising close behind the town to the height of (i) 3,100 ft is similarly constituted.—Passing over the low ground at its foot composed of the first series, we first reach in the ascent the anomalous flinty and slaty rocks, then come to the Sandstones; these strata extend to a height perhaps of 1200 ft, above which there is nothing but Greenstone.—As the strata on the sides are not very much disturbed,

(i) 'Anguln. M. Beagle' is written in the margin at this point.

V. This locality is a little difficult to identify with certainty but is probably Flagstaff Hill (523.7 E. 726.1 N) on which ‘Ferntree Mudstone (bluish siliceous-Aluminous stones ...') outcrops almost to the top on the eastern side. The top is occupied by dolerite ('Greenstone'), part of a wide dyke forming most of the western face of the hill.

W. See comment L. Darwin did not see the faults which greatly disturb the section between Hobart and the summit of Mt Wellington (see Banks et al. 1965).

1836 Hobart town 849 (12) perhaps this height nearly expresses the thickness of this formation.—All the Greenstone which crowns this mountain is of a very uniform character; it is rather coarse and contains (i) crystals of Horn-blaende; it strongly affects the Magnetic needle; one side of the summit shows (ii) a large columnar structure; generally there is a grand accumulation of immense loose fragments.—I have as yet only mentioned the Trappean rocks incidentally, some as belonging to the former group, others to the second series of strata. From my limited observations I have not been able to ascertain any difference in these Trappean rocks of two ages.—Indiscriminately over the country, we find ordinary Greenstone graduating into a granular kind which assumes a Syenitic appearance. These probably belong to the older set, and are generally found in the higher hills; there are however numberless exceptions; on the coast some miles South of the town, there is a continued mass of a Greenstone composed of

(i) '& yellow cryst.' is written in the margin at this point.

(ii) 'heavy' is written in the margin at this point.

X. It is interesting to see that Darwin recognised that most of the higher hills were capped by dolerite. His 'granular kind which assumes a Syenitic appearance' refers to the coarsest variety of dolerite, perhaps pegmatitic or granophyric differentiates) which are widespread. Professor Carey points out (pers. comm.) that in places (on sea shores) weathering causes the dolerite to become paler and this may be the origin of the 'syenitic appearance.' I have examined the pale weathered dolerite and the colour is due to the fact that within the zone of wave washing or splash the feldspar weathers to clay, thus changing from transparent or translucent to white and chalky looking, before the ferromagnesian minerals oxidise and hydrolyse to red iron hydroxides. Where the feldspar is translucent, the rock is dark but where the feldspar is chalky, the rock is mottled and looks syenitic.

Y. This is most likely to refer to the dolerite between Porter Hill and Cartwright Point (521.4 E. 714.4 N) where schlieren and masses of pegmatitic feldspar-rich dolerite occur. Somewhat similar rocks occur at Crayfish Point (520.9 E. 712.2 N) and at the western end of Taroona Beach (520.3 E. 711.9 N) but it is unlikely that Darwin travelled down the coast as far as Crayfish
Point or he would have seen and commented on the unusual boulder beds between Cartwright and Crayfish Points.

1836 Hobart Town 849 (13 numerous Crystals of Feldspar and Hornblende (and Mica ?) mingled in patches with a compact Feldspar. This rock in mass, had the aspect of a Granite. These Trappean formations (including in that name ancient Lava streams) prevail most extensively over the whole Island.—I hear everywhere of cascades of Columns and detached conical hills.—The summit of Mount Wellington is broad, level and of considerable extent; looking to the W. and N.W. numberless mountains of the same form and height are seen; these in parts are said almost to unite into an elevated central plateau. I may here mention some facts obligingly communicated to me by Mr Frankland, which will give a general outline of the Geology of the Island.—The central mountains which occupy a large space; and of which Mount Wellington may be considered as the termination in one direction entirely consists of Greenstone.—On their Northern boundary (20 to 30 miles SW of Launceston) there is an extensive formation of Limestone, Conglomerate, and Clay. Slate.—From Quamby Bluff I have specimens of this latter rock marked with impressions of the Corallines and Terebratulate, so frequently mentioned.—Hence it is every- AA. The 'great formation of white Quartz' must refer to the ranges of Precambrian quartzites and quartz schists which characterise south-western Tasmania. This passage is an almost direct transcription from Flinders' (1801) description in his report on the first circumnavigation of V.D.L.

1836 Hobart town 850 (14 boundary (20 to 30 miles SW of Launceston) there is an extensive formation of Limestone, Conglomerate, and Clay. Slate.—From Quamby Bluff I have specimens of this latter rock marked with impressions of the Corallines and Terebratulate, so frequently mentioned.—Hence there can be little doubt concerning the age of the day Slate; and when we consider the variable nature of the Flinty Slate and Limestone beds, containing pebbles near Hobart town; it is highly probable that the whole formation of the North belongs to the same one of which the SE extremity is composed. We shall thus see one continuous series sweeping around the central nucleus of Greenstone.—On the NE coast Granite is extensively found; and on the opposite extremity, the SW, there is a great formation of white Quartz; so conspicuous is this from its brilliant appearance, that Navigators noticing it from a distance, have thought it to be Snow.—The level district at the sources of the Derwent and Tamar BB. The conjunction of 'level district', 'silicified wood', 'beds of agate pebbles' and 'salt' indicate that this area is that between Antill Ponds and about Conara, perhaps especially between Tunbridge and Ross.

1836 Hobart town 851 (15 are remarkable by the large quantities of silicified wood found there; in the same district are found beds of Agate pebbles. Salt likewise is procured from some ponds which periodically in the dry season leave an incrustation of this substance.—Perhaps these latter circumstances indicate another and distinct formation.—Within the outskirts of Hobart town, there is a Quarry in Limestone, which I have delayed mentioning because I am entirely ignorant in which class it ought to be arranged. The limestone is of a pale yellow colour, not very compact, of a minute Crystalline structure; its strata are inclined at an angle of 45°. It is everywhere traversed by a very small linear CC cavities, which resemble those found in some Freshwater Limestones, to which stones this bears much resemblance.—Contains occasional layers and nodules of ordinary flint and still more occasionally a few small pebbles.—Those which I saw were about twice as large as beans, and consisted of pure Quartz and Quartz rock.—Some of the lower strata, abound with distinct impressions of various leaves, which are said to differ from those now existing.—Very many Shells have been found.—The Limestone is covered by a mass of Alluvium, several feet deep, by a rather stony nature. Fragments of some Trappean rock, by their decomposition, now appear
as balls imbedded in a Wacke; the interstices however and in parts, masses, consist of a quite white soft Calcareo-Aluminous powder. — This resembles a substance which was found under very similar circumstances at St Jago in Chili. This singular mixture of rubbish has also filled up a vertical fissure after the manner of a dyke in the Limestone, DD and until I found in it a rounded pebble, I was uncertain of its nature.— I suppose, the Limestone, after the displacement of its strata, but yet whilst beneath the Water, bearing lime in solution, was covered, by some subterranean violence with the fragments of Volcanic rocks.— This kind of Limestone has only been found on the side of a small hill; as from the purity

DD. Probably the first record of a Neptunian dyke from Australia.

1836 Hobart town 854 (17 of the Lime, which is produced¹ from it it is an object of value, it has been searched for with some care.— It is probable that this very limited formation was deposited either in a lake or small creek; the nature of the pebbles would lead me to class it with the older formation; but on the other hand its unconsolidated nature and the impressions of leaves connect it with the more modern series. I now come to a subject which I have so frequently discussed in my Geological Memoranda; viz recent movements in the level of the land. On both sides of the Bay and along nearly the whole line of coast broken shells are found on the land to the height of 30 to 40 ft in quantities which render it rather difficult to believe they have all been carried there by the Aborigines. Amongst these shells are found many rounded pebbles and individuals too small to be brought for purpose of eating; the coast moreover in a few places, by its outline, obscurely shows a small

(i) 'Examine for bones' is written obliquely across the top of the line here

of land, which the tides might have heaped up, and before this had happened, a higher surf might have thrown up the beach.— Again on the banks of the Derwent River where the water is fresh or so brackish that marine shells will not live even for some miles lower down, the same layers of shells, intermingled with masses of shingle are found on the banks, elevated from 6 to 10 ft above the present highest tides. When the bay was less filled with the

Footnote:
The following notes appear on the reverse of p. 18.
(a) N.B.: That changes are still in progress in this little cove is certain from the fact that oysters which two years previously were abundant, have entirely ceased to exist.
(b) I may mention also that some of the little side valleys have that peculiar flat-bottomed structure which indicate that they formerly were occupied by the water as small coves

EE. There appears to be a page missing here.

Hobart town 855 (20 Australian caves.—Mr Frankland has determined to investigate this subject and likewise the recent rise of the land; there can be little doubt he will make some interesting discoveries. Before concluding I will give a summary of the history of the formations; but, when it is considered that this Island nearly equals Ireland in extent it will be manifest what a shadowy outline such must be. At a very early period the great Quartz formation in the SW extremity probably existed as one or more island; as likewise perhaps did the Granite of the NE (a).—In the surrounding or intervening ocean, thick mass of strata were accumulated, which compose the second series; Hence we have the pebbles of pure quartz and Quartz rock.

In this sea Corallines abounded, and amongst them numerous Terebratula and beds of oysters.—During this epoch, the subterranean forces propelled upwards large masses of Greenstones; this propulsion appears to have taken place

Footnote:
The following appears on the reverse of p. 20.
(a) for some other rocks v. Lesson's Zoologie FF FF.
R. P. Lesson was naturalist on the French survey ship La Coquille which visited Australia in the period 1822-1825. The ship did not visit Hobart but while in Sydney (Jan. 17-Mar. 22, 1824) the naturalist "procured about 30 specimens of rocks from Van Diemen's Land: pegmatites, rocks of a tertiary terrain, spirifers, serpentine, asbestos, an intermediate" (¹transition) "limestone" (Duperrey 1830, Zool. II, p. 144).

1836 Hobart town 856 (21 in mass, and as the superincumbent strata are not much displaced, without much partial violence.—In this state we either
have an Archipelago crowded with Islands or a land deeply indented by arms of the Sea; in such spaces our first or most modern formation was deposited from the wear and tear of the older\(^{(a)}\).—During this period igneous rocks were both poured out as Lava streams and injected masses violently ruptured the strata. We believe lastly the land attained its present position after some considerable oscillations of level.—

In attempting to compare the Geology of this country with that of the Colony of New South Wales, a considerable resemblance may be observed in the Carboniferous series, which in both places forms the upper formation. At the distance of 600 (Geograph:) miles it appears very doubtful how much confidence may be given to such resemblances in ascertaining their coeval origin. I think

Footnote:

On the reverse of p. 21.

(a) I should observe in such newer patches of strata, many probably belong to rather distant periods of time but its first rough classification they come into the formation.—

and also

'Macc. Class of Rocks p. 471 on Hypersthene appearing at passage (?) from greenstone to syenite. GG GG. Probably a reference to a publication by John Macculloch, the Scottish mineralogist and geologist, 'A Geological Classification of Rocks, with Descriptive Synopses, comprising the Elements of Practical Geology. London 1821.

1836 Hobart town 857 (22 however it is not improbable, that on an extended examination, a considerable degree of parallelism in the formations of the two countries would be discovered. The Limestones of Argyle with Organic remains, might correspond with the second series of this place, and the Quartziferous Granites of Australia, with the Quartz rock of Van Diemen's land.—On first examining the country, from the preponderance of Trappean and ancient Volcanic rock I was struck with the resemblance of it to New Zealand. There also I believed there were two distinct formations; the older containing Lime-stones and Cherty beds, and the more modern Lignites and Sandstones.—

With respect to the absolute age of the second series of this place, I fear the fossils are far too scanty even to offer a conjecture. The subject remains a field open to the examination of the rising Geologists of Tasmania.—

Footnote:

On the reverse of p. 22.

May 25, 1836, Memoir of Van Diemen's Land. of Mr Frankland HH 3468 vesicular lava; locality as 3467

HH. This refers to a paper by Frankland on Maria Island (Proc. Geol. Soc. 1836, ii, p. 415), read on May 25, 1836.

The microfilm on which this transcription is based was supplied by The Librarian, Cambridge University and was marked Darwin Ms, 38 (1) ff 837-857; original pages of ms. about 8.1" × 10". Pages are numbered 1 to 22 (19 is missing) in Darwin's script; numbers 837-857 are not in Darwin's script.

A Catalogue of Darwin's Specimens from Tasmania compiled from his manuscript.

For this purpose it is assumed that the numbers in the margins of the manuscript refer to specimen numbers collected at the sites mentioned or of the rocks etc. mentioned in the immediately subjacent text. The numbers are in Darwin's script. Quotes from Darwin's text are in italics.

3445 greenstone (dolerite); coast south of Hobart town (Half Moon Bay, Lower Sandy Bay 521.4 E. 716.3 N) (see Spry 1955)

3447 fine grained aluminous sandstone (Ferntree Mudstone); opposite shore to Hobart town (Bellerive-Kangaroo Bluff foreshore)

3448 Porcelain rock with conchoidal fracture (Ferntree Mudstone); locality as 3447

3449 bluish siliceous-Aluminous stones (probably Ferntree Mudstone); opposite side of the water to Hobart town (near Bellerive, possibly Flagstaff Hill, Gordons Hill or Grasstree Hill)

3450 white ones (stones) of a similar nature (to 3449) (probably Ferntree Mudstone); locality as 3449

3451, 53, 54 ferruginous greenstone (p. 11 of manuscript) (dolerite or weathered dolerite); locality as 3449

3455 greenstone (dolerite, perhaps pegmatitic or granophyric); on the coast some miles south of the town (possibly Porter Hill (521.52 E. 715.55 N) to Cartwright Point or Crayfish Point, Tarona)

3456 greenstone (dolerite); locality uncertain

3457 white cherty rock . . . with impressions (? Grange Mudstone or top of Bundella Mudstone); shore a few miles south of Hobart (Porter Hill or cliffs south of Blackmans Bay)

3458 blue slightly calcareous siliceous compact Clay-Slate . . . with impressions (Bundella Mudstone); locality as 3457 (must be Porter Hill)

3459 greenish brown rather softer, coarser Clay-Slate . . . with impressions (Bundella Mudstone); locality as 3457, 8

3460-65 impressions from area of 3457-59 (fossils as moulds); locality as 3458

3466 sandstone (Springs Sandstone); (Locality not certain, could be Mt Wellington; see p. 6 of ms.)

3467 basalt with red olivine (?) (basalt with olivine altered to iddingsite); coast south of the town (Long Beach, Sandy Bay; see Spry 1955)
It may be deduced that Darwin was not aware that the 'Beagle' had been originally scheduled to visit Tasmania depending on the season (Narrative, 2, p. 33; instructions to FitzRoy) and one may suspect that this part of the itinerary became known to him only in Sydney. Thus, during the evening of Friday, 5th March 1836, a blustery wet day (Narrative, 2, p. 624), Charles Darwin reached Hobart Town in the 'Beagle' (Narrative of the Surveying Voyages of H.M.S. Adventure and Beagle, vol. III, p. 532). Darwin records in his narrative that he walked around the streets of Hobart during the morning of the sixth (ibid., vol. III, p. 532) and subsequently made 'several pleasant little excursions.' From the Narrative and his diary (Barlow 1933, pp. 388-9) it is clear that one of these was to what is now Bellerive which he reached by steam boat. During the interval Feb. 7 to Feb. 10 he not only visited Bellerive but also made two attempts to climb Mt Wellington. The first attempt was foiled by '. . . the thickness of the wood,' and the second, though successful, was rather strenuous as the guide '. . . conducted us to the damp southern side of the mountain.' From the summit he noticed 'to northward . . . wooded mountains of about the same elevation and tame outline as the one on which we stood.' (Barlow 1933). Between the 12th and the 15th he went riding ('several pleasant rides') with Mr Frankland, the Surveyor-General, one of these being to Ralph's Bay ('Geological Observations . . . p. 141), From 'Geological Observations . . .' it may be further deduced that he visited limestone quarries 'near New Town,' revealed by this new memorandum to be most probably the quarries at the northern end of Barossa Road. It is also confidently deducible ('Geological Observations . . . p. 139) that he examined the volcanic centre just south of Long Beach, Sandy Bay. The new memorandum casts further light on his 'pleasant little excursions.' His 'long walk on the side of the bay opposite the town,' almost certainly included an ascent of Flagstaff Hill. He seems likely to have seen the dolerite dyke now cut by Augusta Road near Waverley Ave (memorandum, p. 1, Note A). His 'excursion' along the shore of the town took in the Tertiary sediments behind what is now Maryville Esplanade, at that time probably a sandy beach backed by cliffs of Tertiary, and extended to Long Beach, to Porter Hill where he collected Permain fossils, and probably beyond this to Cartwrights Point, near which he saw the dolerite which 'has the aspect of a granite.' (memo, p. 13). He also visited the lime quarry in Burnett Street (see comment CC). In his diary he noted that on 16th February 'the weather was cloudy and prolonged the stay beyond what was expected.' The cloudiness prevented observations of the sun and calculation of the latitude and longitude therefore involving the use of the many chronometers carried by the 'Beagle'. As such observations were a critical part of the ship's task in circumnavigating the globe, the ship stayed in port until such observations could be made. On 16th February, Darwin went by stage coach to New Norfolk, probably taking the opportunity to collect a specimen when the coach stopped at the inn at Black Snake Gully. Taking all these statements and deductions about his activities together, about eight of the 11 complete days spent in Hobart Town can be accounted for (Mount Wellington 2 days; Hobart streets 4 days; Bellerive 1 day; Ralphs Bay 1 day; Barossa Road 1 day; New Norfolk 1 day; Sandy Bay at least 1 day; Burnett

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3469 scoria; locality as 3467
3470-71 Clay Slate with impressions of . . . Corallines and Terebratulace (Permain fossiliferous mudstone, probably Golden Valley Group); Quamby Bluff (several richly fossiliferous localities occur in this area); ('2470' and '2471' may be a slip of the pen and may have been intended to be 3470 and 3471 as all of Darwin's other numbers for Tasmanian material commence with '3'; and there are no numbers 3470 and 3471 in the margins)

3472 greenstone (dolerite); top of Mt Wellington
3473 pale blue coarse speckled clay slate (? Ferntree Mudstone); flanks of Mt Wellington
3474 white compact uneven fracture aluminous stone (?Ferntree Mudstone or siltstone in Malbina Formation); flanks of Mt Wellington
3475 Mottled blue and yellow aluminous stone (probably Ferntree Mudstone); flanks of Mt Wellington
3476-80 compact crystalline blackish brown stone containing Terebratulace etc. (Berriedale Limestone); beyond New Town (probably quarry at Barossa Road, 513.3 E. 724.3 N; possibly quarry near Tolosa Street, 512.2 E. 724.3 N)
3481 snow white, soft . . . pure calcareous substance (travertine); beyond New Town (locality as 3476-80)
3482 white stone . . quartz . . in a siliceous paste (Ferntree Mudstone); near New Norfolk; probably near Black Snake Inn.
3483-88 silicified wood; the level district at the source of the Derwent and Tamar (Campbell Town-Tunbridge region)
3489-94 impressions of leaves (fossil dicotyledons); quarry of limestone . . . within Hobart Town (top of Burnett Street; approx. 517.4 E. 721.4 N; probably quarry at the northern end of Barossa Road. It is also confidently deducible ('Geological Observations . . . p. 139) that he examined the volcanic centre just south of Long Beach, Sandy Bay. The new memorandum casts further light on his 'pleasant little excursions.' His 'long walk on the side of the bay opposite the town,' almost certainly included an ascent of Flagstaff Hill. He seems likely to have seen the dolerite dyke now cut by Augusta Road near Waverley Ave (memorandum, p. 1, Note A). His 'excursion' along the shore of the town took in the Tertiary sediments behind what is now Maryville Esplanade, at that time probably a sandy beach backed by cliffs of Tertiary, and extended to Long Beach, to Porter Hill where he collected Permain fossils, and probably beyond this to Cartwrights Point, near which he saw the dolerite which 'has the aspect of a granite.' (memo, p. 13). He also visited the lime quarry in Burnett Street (see comment CC). In his diary he noted that on 16th February 'the weather was cloudy and prolonged the stay beyond what was expected.' The cloudiness prevented observations of the sun and calculation of the latitude and longitude therefore involving the use of the many chronometers carried by the 'Beagle'. As such observations were a critical part of the ship's task in circumnavigating the globe, the ship stayed in port until such observations could be made. On 16th February, Darwin went by stage coach to New Norfolk, probably taking the opportunity to collect a specimen when the coach stopped at the inn at Black Snake Gully. Taking all these statements and deductions about his activities together, about eight of the 11 complete days spent in Hobart Town can be accounted for (Mount Wellington 2 days; Hobart streets 4 days; Bellerive 1 day; Ralphs Bay 1 day; Barossa Road 1 day; New Norfolk 1 day; Sandy Bay at least 1 day; Burnett
Street quarry \(\frac{1}{2}\) day. As at least two of the 11 days were sabbaths, and likely to be observed as days of rest and letter writing (see below re letter to Katherine) almost all his time in Hobart can be accounted for. The 'Beagle' sailed from Hobart on 17th February, having been 11 days in port (Darwin in the Narrative, p. 534, apparently erroneously gave the figure as 10 days).

Darwin wrote in his journal (pp. 532, 533, 536), . . . first aspect of the place (Hobart) . . . very inferior to that of Sydney . . . latter a city this only a town . . . streets fine and broad . . . shops appeared good . . . Mount Wellington of little picturesque beauty . . . if I emigrate choose this rather than Sydney . . . climate and aspect of country . . . society on a pleasanter footing . . .

Mount Wellington of little picturesque beauty . . . if I emigrate choose this rather than Sydney . . . climate and aspect of country . . . society on a pleasant footing . . . no specimen numbers are given and if the inference made (comment L) that he saw these near the Turnip Fields during ascent of or descent from Mount Wellington is correct, it is perhaps not surprising that he did not collect any, being wise about not carrying extra weight up the mountain and being too exhausted or too late on the way down to worry about collecting specimens. They did not reach the ship till 8 o'clock 'after a severe day's work (J. Res. 1839, p. 530). Near Barossa Road quarry, he accepted the 'smallest stony corals' (ibid. p. 14) Terebratula, a small oyster, Pecten and corallines and apparently collected five specimens. He also apparently collected six specimens of 'impressions' from the Porter Hill area (memo p. 8). He noted Terebratula from Bellerive but did not collect any and included donated specimens of Terebratula from Quamby Bluff and Eaglehawk Neck and corallines (Stenopora) from Quamby Bluff in his collections.

Subsequent work by Sowerby reported in 'Geological Observations' (pp. 158-160) led to replacement of the term Terebratula by the terms Producta and Spirifer and Lonsdale (ibid. pp. 161, 169) named the 'corallines' Stenopora, and the 'Retepora' Fenestella. Three specimens of Producta brachytihaeraeus are quoted by Sowerby; one, the only one of which he was certain, in grey limestone (presumably Berriedale Limestone from Barossa Road where T. brachytihaeraeae (Morris) is common); another, an internal mould of the brachial valve, in a 'light rusty-brown' stone; and a third, an internal mould of the pedicle valve, in a 'nearly similar stone.' Of these only the second is extant and recognisable in the B.M.N.H. (B.M. 1929) and is Strophalosia (Hill 1950, p. 19). Hill (1950, p. 19) noted that it bears the printed number '498' in the type of script used by Darwin. In this case, assuming that the label has not been displaced, the specimen is one of those given to Darwin by Frankland from the Huon. I have seen the specimen in the British Museum and it is an internal mould with a ferruginous coating and the block also contains a Neospirifer sp., Stenopora, ostracodes and productid spines. My diagnosis of its locale at the time (1956) was that it most probably came from the Rayner Sandstone which outcrops above the Channel Highway at Porter Hill, but similar rocks occur in the Huon area, e.g. near Cygnet. The brachial valve most resembles that of S. jukesii which occurs in the Cascades Group near Hobart, and its correlates elsewhere. By the courtesy of the B.M.N.H. I have been able to obtain pieces of the matrix and rubber casts of the Strophalosia and associated fossils. These show that the matrix consists of finely mottled pink and white siltstone with angular sand-grade clasts of quartz and larger clasts of (?) chlorite schist and moulds.
of fossils, mainly polyzoa, coated with limonitic encrustation. Comparison with specimens of Rayner Sandstone from Port Arthur suggest that the provenance was elsewhere. The rubber casts show the presence of a ramose Stenopora and Peruvipira alliandensis Fletcher.

The specimen on which the diagnosis of Spirifer subradiata Sowerby is based was apparently the original shell of a brachiual valve. This is most likely to have come from the Barossa Road area, based on the range of this species in Tasmania and mode of preservation, but an origin from Eaglehawk Neck is not impossible. The provenance of the specimens of Spirifer trapezoidalis Sowerby is not clear although the description of the matrix a 'dark, rusty, grey limestone' suggests some of the limestone within the Bundella Mudstone on the shoreline at Porter Hill. No light is cast on the provenance of Spirifer pavicostata Sowerby but the internal moulds on which Spirifer vespertilio and S. avicula were based almost certainly came from Eaglehawk Neck where such moulds are known in the Malbina Formation. The specimen, B10858, in the B.M.N.H. is recorded as 'said to be Spirifer vespertilio... Charles Darwin collection.' The specimen, a medium-grey siltstone, contains external moulds of both the normal (Strzelecki 1845, pl. XVII, f. 1) and short variety (ibid., pl. XVII, f. 3), the former referred to as Sulcipilica transversa by Waterhouse (1968, p. 27), the latter as ?Licharewia phalaena (ibid., p. 24) associated with Ingelarella angulata Campbell and crinoid columns in a matrix characteristic of the Malbina Formation. The lithology and associated fossils taken in conjunction with Darwin's memo strongly suggest an origin from Eaglehawk Neck. No extant internal moulds assignable to Darwin's collection are known.

The origin of the polyzoa described by Lonsdale from Darwin's collection can also be ascertained with some confidence as a result of access to this memo. Stenopora tasmaniensis is embedded in a 'coarse calcareous shale, ... or a grey limestone' (Geological Observations, p. 162), and is associated with Fenestella internata which also occurs in a 'coarse grey calcareous shale, ... splintery limestone ... hard-ferruginous or light-coloured claystone' (ibid., p. 166). This association of fossils and rock types is best met in the limestones and siltstones of the Bundella Mudstone at Porter Hill, and, before the existence of Darwin's memo was known, the late Edith Smith had chosen this area on the basis of the associations as the locality from which neotypes should be set up. Not only are these fossils abundant at Porter Hill, but so also is Fenestella ampla; Fenestella fossula also occurs there. The matrix of F. ampla as noted by Lonsdale ('Geological Observations', p. 165) can also be matched at Porter Hill. This leaves only S. ovata and Hemispira sexangula of those species described by Lonsdale unlocated, but Lonsdale's description of the matrix leaves no doubt that Porter Hill was the site. Stenopora ovata occurs there but is less common than S. tasmaniensis at that locality. H. sexangula has not been recognised subsequently. Strzelecki also collected Permian fossils from Tasmania, which were described and illustrated by Lonsdale (polyzoa) and Morris (molluscs and brachiopods). These included a Stenopora ovata from Norfolk Plains (B.M.N.H. PD 4604), and Stenopora informis (B.M.N.H. PD 4605). Lonsdale took this opportunity to figure some of Darwin's specimens as, Hemispira sexangula, F. fossula and F. ampla (Strzelecki, pl. ix, f. 4a, 1a, 3) were stated to be from Darwin's collection (Strzelecki 1844, p. xvii), Morris also figured some Darwin material, e.g. Spirifer tasmaniensis Morris var. (Strzelecki, pl. xv. f. 4), Morris further stated (ibid., p. 280) that he had seen Darwin's specimens assigned to Spirifer rotundata and Spirifera trapezoidalis var. by Sowerby and he grouped them as Spirifer tasmaniensis.

Of the species based on Darwin's collections, specimens of only two are now available (Productus brachythæra, B.M.N.H. B 12998, which is a Stenopora avicula, and Spirifera vespertilio, B.M.N.H. B 10858). A neotype has been established by Crockford (1941) for F. fossula from near the top of the Cascades Group on Huon Road not far from the Turnip Fields and a specimen (B.M.N.H. PD 4603-5) exists of Stenopora ovata which was used and figured by Lonsdale in his work of Strzelecki's collection. It does not, however, come from the type area as deducible from Darwin's published and unpublished work.

Maxwell (1956) successfully suggested suppression of Productus brachythæra Sowerby (G.B.) 1844 in favour of Peruvispira allandalensis and from the type of Terrakea Booker 1930, the type specimen of which was designated as B.M.N.H. BB 9466 from Illawarra. We thus now have the interesting situation that Terrakea brachythæra (Morris) occurs in the likely type area for P. brachythæra Sowerby.

Establishment of neotypes, where necessary, should be based on specimens from the Barossa Road area for Spirifera subradiata, at Eaglehawk Neck for S. avicula and from Porter Hill for the polyzoans, as suggested by the late Edith Smith in her manuscript on fossil polyzoa.

DARWIN'S CONTRIBUTION

Darwin recognised 'two distinct formations' near Hobart and a third further afield. The younger of the two 'formations' near Hobart contained rocks now known to be Triassic (memo p. 1 and top of p. 2) as well as Tertiary rocks (memo bottom of p. 2 and p. 3). He correctly (memo p. 5) correlated the coal-bearing Upper Triassic rocks of the Saltwater River area near Port Arthur with those of New Town. Some of the 'disturbances' in the Triassic on the Domain were correctly identified as cross-bedding.

The older 'formation' had 'hard sandstone' at the top (memo p. 6) which is now known to be Triassic and correlatable with the sandstones of Knocklofty and the Domain. Darwin himself almost made this correlation (central part of memo p. 6). The rock types beneath this sandstone, now regarded as Permian, were recognisably described by Darwin who also placed them in approximately correct superpositional order. He did not display any extraordinary virtuosity in noticing the great variety of fossils in the Permian rocks but perhaps this is not unexpected as he had only a hand lens and a simple microscope (up to about 30; made by Bancks & Son, 191 New Bond Street; J. Dobson pers. comm.) with him and the state of palaeontology at the time was such that discrimination of the great variety of fossil forms was just beginning (the name 'palaeontology')
was used for the first time only in 1834 (Zittel 1901, p. 363) and it is doubtful if Darwin saw it before he reached England late in 1836. One might be amazed that a biologist and palaeontologist as good as Darwin could not provide better names than 'corallines,' 'Retepora,' 'Terebratula,' 'Pecten,' 'oysters' for the abundant Permian invertebrates he must have seen. However, it was only two years before Darwin left England in the 'Beagle' that the Polyzoa were recognised as fundamentally different from corals. As late as 1818 Lamarck recognised only three brachiopod genera, Orbicula, Terebratula and Lingula, and it was only in 1834, two years after Darwin left England, that von Buch published the first significant treatise on brachiopods (Zittel 1901, pp. 397, 399). Darwin did use the fossils and rock types to correlate correctly Permian rocks at Quamby Bluff with those at Hobart and elsewhere in south-eastern Tasmania.

He used the pebbles of Permian fossiliferous mudstone and Jurassic dolerite in the 'Tertiary beds at Sandy Bay to infer the correct order of deposition of his 'modern' and 'older' formations. The pebbles in the Permian he also used correctly to suggest the presence of older formations including the Precambrian quartzites with quartz veins in south-western Tasmania (memo, p. 10, p. 20). Darwin noted (in his notebook marked 'R.N.'), on p. 21; a zerox of which was kindly made available by Miss Dobson, Curator of the Darwin Collection) 'There is a resemblance at Hobart Town between the older strata and the bottom of the sea near T. del Fuego'. In 'Observations on South America' Darwin commented (Darwin 1846) on the occurrence of pebbles on the sea-floor off the coast of southernmost South America and explained them as due to ice transport. Thus he seems to have realised the possibility that the pebbles in the Permian (older strata) were ice-berg rafted. His reconstruction of the Permian ('second series') palaeogeography (middle part of p. 20 of memo) is remarkably close to much more recent attempts (e.g. Banks 1962).

Darwin's comments on the igneous rocks he saw were astute. He had an eye for unusual minerals and remarked on the red (?) olivine at Sandy Bay, subsequently recognised as iddingsite. He was probably the first observer to notice the pegmatitic or granophyric differentiates of the dolerite which he referred to as 'syenite', 'syenitic' and having 'aspects of a Granite' (memo, p. 4, p. 12, p. 13), and to notice the syenitic appearance of dolerite weathered in some conditions. His identifications of minerals in the dolerite would not gain him a pass in a modern examination but must again be taken in the context of contemporary knowledge. Thus his identification as hornblende (instead of augite) of the dark component in the greenstone (memo, p. 13) reflects the common idea of the time that augite occurred only in volcanic rocks (after Haüy) and that hornblende occurred in 'compound and aggregated rocks' (Bakewell 1819, pp. 292, 301, 302).

On one important point Darwin's memo and his report on Van Diemen's Land published in 'Geological Observations' differ. In his memo Darwin correctly deduced that the 'greenstone' (dolerite) was younger than the 'second series' (Permian and basal Triassic) on the basis of lack of dolerite pebbles in sediments immediately adjacent to the dolerite and the disturbance of the stratification close to the dolerite (memo, p. 10). Had he elaborated this argument in the published work, the debate which developed later on the age of the dolerite might well have been avoided.

Darwin saw or understood few of the many faults which affect the Hobart area (see map, Banks et al. 1965) but this perhaps is not surprising in view of the shortness of his stay and the probable lack of outcrop at the time.

On matters of geomorphology, Darwin noticed incidentally but did not interpret the accordance of summit heights (memo, p. 13) and gave much of his attention to recent changes in sea-levels (memo pp. 17-20). His observations on this matter were accurate but his argument confused and weak and one almost gets the impression that his interest in the subject developed so strongly and well in South America had overruled his discretion.

From his own observations and from discussions with Frankland and perhaps by judicious reading of the available literature on the geology of Tasmania, Darwin deduced a reasonably accurate geological history (memo pp. 20, 21) and some accurate palaeogeographic reconstructions. His suggestion of parallelism in history with New South Wales was perspicacious, that with New Zealand poorly founded.

When the statement on Van Diemen's Land in 'Geological Observations' is compared with the memo, it is seen to be much less detailed and in places, e.g. where dealing with the 'modern formation', the condensation leads to confusion. Localities cannot be established with confidence. The locality for the leaves seen by Robert Brown had not been given in as much detail and led Johnston to infer incorrectly that they came from Geilston. Much of the material on the dolerite was reduced or eliminated although a new mineral identification, that of Hypersthene was added, presumably as a result of testing before the blowpipe, as fusibility is one of the tests given by Bakewell (1819) for distinguishing hypersthene from hornblende. Identification of the fossils he collected allowed Lonsdale and Sowerby to suggest affinities with the Mountain Limestone (Carboniferous) of Great Britain, a remarkably good correlation at that time. The published treatment of movements in sea-level was better organised and gives less impression of special pleading than does the memo. Thus, on the whole, the published work is less informative than the memo and it is regrettable that the latter was not published.

There remains the question of what Darwin, by his publication on Van Diemen's Land, added to knowledge of the geology. Before his visit scattered observations, especially about the coastline, had been made by early French and English exploratory maritime surveys, with a limited number of observations inland by early surveyors such as Humphrey, Laycock and Hellyer. Granite, basalt, sandstone, shale, coal and limestone, quartzite and slate had been recognised and minerals such as jasper, cornelian, quartz, hematite, silver lead, asbestos and feldspar recorded. Some comments on rock and mineral distribution were given by Bischoff (1832), a work certainly sighted by Darwin as he cited it in the Journal (p. 533). With minor exceptions, no relation-
ships had been established and no ages were known. A geological map of Van Diemen's Land drawn in 1836 would have been a mineral and rock-type distribution map. All earlier observations seem to have been made through Werneri'an eyes; Darwin was the first Huttonian to do any geology here.

Darwin provided a more detailed description of the rocks within a small area in Tasmania than had earlier authors. He described for the first time variations within the dolerite. He also described, probably for the first time in Australia a structure of the type later called a 'Neptunian dyke.' His analytical techniques, though primitive, were better than those generally used earlier on Tasmanian rocks. But his work went beyond description and analysis. He concerned himself with relationships, a thing few if any earlier workers had done. He tried to establish a sequence as can be gathered from his published statement and even better from his unpublished memo. He collected fossils, not as curios but as means of correlating strata with those in Europe. His initial age determinations (see Journal and Narrative) were fair first approximations improved by more detailed work on the fossils by Lonsdale and Sowerby. Darwin inferred on relationships near Half Moon Bay that it had been the site of a volcanic crater, thus going beyond Péron who may earlier (1907, p. 247) have seen the basalt and scoria there. He would appear to have been the earliest author to note accordance of levels in Van Diemen's Land.

Thus Darwin's published work marked a considerable advance on any earlier, work here and was a distinct contribution, but was overshadowed, unjustly, almost as soon as it was published by Strzelecki's monumental 'Physical Description . . .'. Publication of Darwin's manuscript on Hobart would have been an even greater step forward than that provided by published material.

The reason or reasons for lack of publication of the manuscript is unknown. The published version is much abridged when compared to the manuscript and pressure of space may be surmised as one reason.

SUMMARY AND CONCLUSIONS

As a result of the location of the unpublished manuscript by Charles Darwin on the geology near Hobart, it has been possible to account for much of his stay of 13 days at Hobart in February 1836. The manuscript with associated specimen numbers allows localisation of his collection with considerable confidence. Polyzoa collected by Darwin and described by Lonsdale almost certainly came from the mudstone and limestone of the Bundella Mudstone on the shoreline at Porter Hill, Lower Sandy Bay, and the brachiopods described by Sowerby from the Darwin collection probably came from limestones of the Cascade Group near Barossa Road, Glenorchy, and from siltstones of the Malbina Formation at Eaglehawk Neck. Darwin's observations were acute enough to allow recognition of the rocks and localities he described, but he, perhaps naturally enough, did not see or deduce any of the many faults which affect the Hobart area. His identifications of minerals, rocks and fossils were good in terms of the very limited instruments available at the time and considering the state of the science. He was the first to recognise the relative ages of the dolerite and associated sediments and to describe a volcanic neck (and recognise it as such) from Tasmania. His correct deduction of the geological history of the island, at least in broad outline, indicates his own acuteness and some fund of geological knowledge of Tasmania prior to his visit. He seems to have been the first Huttonian to publish on Tasmanian geology; all earlier writers appear to have been Werneri'ans.

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Some Permian trilobites from eastern Australia

BY

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SOME PERMIAN TRILOBITES FROM
EASTERN AUSTRALIA

by ROBIN E. WASS and MAXWELL R. BANKS

ABSTRACT. A new genus of proetid trilobite, Doublatia, occurs in the Permian of eastern Australia. It is represented by the type species, Doublatia infiata gen. et sp. nov., in the Artinskian Branxton Formation of New South Wales and by two species, D. pyriforme sp. nov. and Doublatia sp., in slightly older beds, the Enstone Park Limestone in north-eastern Tasmania. The new genus is more closely related to Ditomopyge than to other proetids. Two pygidial forms not referable to Doublatia also occur in the Permian of eastern Australia.

The Permian faunas of eastern Australia have been studied since the early nineteenth century, many detailed collections have been made and from them monographs on various groups have resulted. During the past decade there have been many studies of a revisionary nature but trilobites have received little attention because they are rare and their remains fragmentary.

Whereas Teichert (1944) has described Ditomopyge meridionalis and D. sp. from Western Australian Permian strata, the only trilobite named specifically from the eastern Australian Permian is ‘Griffithides’ dubius Etheridge (1872, p. 338, pl. 18, fig. 7), described and figured from a single pygidium and thorax joined to a damaged cranidium from the ‘Don River, Queensland’ in strata then stated to be of Carboniferous age. The inferred number of thoracic segments was within the range 10–12. Jack and Etheridge Jr. (1892, pl. 7, fig. 12) refigured this specimen, referring its horizon to the Permo-Carboniferous Gympie Beds; they located the Don River (p. 215) as a tributary of the Dawson River and not as might have been supposed the Don River, near Bowen. They erroneously referred the species dubius to the genus Philhpsia from evidence derived from trilobites they believed to be conspecific in the Star Beds of the Great Star River, Queensland, and another unspecified horizon in the Rockhampton area.

Mitchell (1918) restricted the name dubius to the Etheridge (1872) type specimen which he was unable to locate and redescribed the Jack and Etheridge Jr. (1892) material as P. stanvellensis Mitchell and P. rockhamptonensis Mitchell. He also transferred Etheridge Jr.’s (1892) P. dubia from New South Wales to P. elongata Mitchell. All these species are of Carboniferous age and will not be considered further.

Voisey (1939, p. 401; 1950, p. 67) recorded ‘Phillipsia’ from the Permian of the Manning–Macleay province, north of Newcastle, New South Wales; they are indeterminate fragmentary pygidia, AM F38133–4, and were probably collected from the Cedar Party Limestone. Banks (1962, p. 207) records rare trilobites from Permian strata at Elephant Pass and Ray’s Hill, near St. Mary’s in north-eastern Tasmania.

The specimens described herein come from the following localities shown in text-fig. 1. They are:

1. In a quarry, 1 mile west-north-west of Mulbring, 16 miles west of Newcastle, New South Wales, at 475336 Cessnock 1:63,360 military map: Fenestella Shale, Branxton Formation.

2. In the creek bed, Sawpit Gully, 1-9 miles east of ‘Boorook’, New South Wales, at 374426 Drake 1:63,360 military map: Cataract River Formation.

3. Above (2) and separated from it by a thin pyroclastic flow.


5. At Ray’s Hill, near St. Mary’s, 60068807 State Grid, Tasmania: basal beds of the Enstone Park Limestone.

Trilobites from Elephant Pass and Ray’s Hill were not found in situ. Stratigraphic horizons for these localities have been deduced using palaeontological and petrological similarities.

Stratigraphic units discussed are shown in Table 1. Further information is available in Banks (1962) and Runnegar (1967, 1969).

ASSOCIATED FAUNAS

The fauna associated with Doublatia inflata gen. et sp. nov. near Mulbring includes Anidanthus solitus (Waterhouse), Ingarella branxtonensis (Etheridge), Strophalosia cf. clarkei (Etheridge), Fletcherithyris parkesi Campbell, brachiopod cf. Notospirifer, Deliopecten squamuliferus (Morris), Pleurikodonta sp., Atomodesma (Aphanaia) sp., Myonia cf. corrugata Fletcher, Stutchburia costata (Morris), Stenopora crinita? Lonsdale, Protoretepora ampla (Lonsdale), Fenestella bituberculata Crockford, and blastoid fragments, indicative of the Ulladulla fauna (Runnegar 1969). The Fenestella Shale stratigraphically above strata containing Neocrimites meridionalis (Teichert and Fletcher) is considered to be middle to upper Artinskian in age, agreeing with Runnegar’s interpretation.

Associated with the Sawpit Gully specimens is a definite Fauna IV assemblage listed by Runnegar (1970). Its probable age is early Upper Permian although there is little published information on this assessment.

The Elephant Pass trilobite occurs in a fine-grained dark yellowish-orange (10YR 6/6) dense siltstone (UT 55297) which also contains Euryphyllum sp., Stenopora spp., Strelioscopora marmorinensis (Bretnall), fenestellids, Strophalosia sp. nov., S. preovalis Maxwell, Anidanthus springsunsensis (Booker), Cancrinella farleyensis (Etheridge and Dun), Taeniothaerus subquadratus (Morris), Terrakea sp., Spirigerella sp., ‘Spirifer’ tasmaniensis (Morris), Granthonia hobartensis Brown, Ingarella sp., Notospirifer darwini (Morris), Spiriferellina australis Maxwell, Fletcherithyris farleyensis Campbell, F. reidi Campbell, Aviculopecten tenuicollis (Dana), A. fittoni (Morris), and Streblochondria sp. nov. Taeniothaerus subquadtratus occurs in a thin zone about the middle of the Berriedale Limestone; Cancrinella farleyensis occurs above T. subquadratus in the Berriedale Limestone or Grange Mudstone at Mt. Nassau. Thus correlation with the Berriedale Limestone is established. Index species and other characteristic fossils enable the fauna to be identified as Fauna II (Runnegar 1969), thus suggesting correlation with the Farley or Greta Formations or possibly the lowest part of the Branxton Formation, New South Wales, an interval considered by Runnegar (1969, p. 88) to span the Sakmarian–Artinskian boundary.
TEXT-FIG. 1. Map of eastern Australia showing localities of trilobites discussed.
The Ray’s Hill trilobite fragments occur in blocks of greyish-orange (10YR 7/4) or pale greyish-orange (10YR 8/3) friable and decalcified silty limestone. The fauna in the same block as the holotype of *Doublatia pyriforme* gen. et sp. nov. includes *Calcitornella stephensi* Howchin, *Frondicularia aulax* Crespin, *Stenopora* spp., *Streblascopora marmionensis*, *fenestellids*, *Schuchertella* sp., *Spirigerella* sp. nov., *Licharewia* sp., *Pterospirifer* sp., *‘Spirifer’ tasmaniensis*, *Grantonia hobartensis*, *Ingelella* cf. *angulata*

**TABLE 1.** Stratigraphic table for portion of the eastern Australian Permian succession; based primarily on information in Runnegar (1969) and McNeil (1965).

<table>
<thead>
<tr>
<th>Hunter Valley</th>
<th>Northern New South Wales</th>
<th>Eastern Australia Permian Faunas</th>
<th>Hobart Tasmania</th>
<th>Mt. Elephant Tasmania</th>
<th>Russian Stages</th>
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<tr>
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<td>Kazanian</td>
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<tr>
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<td>Gilgurry</td>
<td>IV</td>
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<td>Ferntree</td>
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<td>Risdon-Malbina</td>
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<td>Kungurian correlate</td>
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<td>Drake</td>
<td>III; U</td>
<td>Grange</td>
<td>Berriedale-Enstone</td>
<td>Artinskian</td>
</tr>
<tr>
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<td></td>
<td></td>
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<tr>
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<td>Nassau</td>
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</tr>
<tr>
<td>Rutherford</td>
<td></td>
<td></td>
<td>Mersey</td>
<td></td>
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</tr>
</tbody>
</table>

Campbell, I. *?inglearensis* Campbell, *Notospirifer darwini*, *Spiriferellina australis*, *Fletcherithyris reidi*, *Peruvispira* cf. *elegans* (Fletcher), *Pseudomyalina* sp., *?Atomodesma* sp., *Streblochondria* sp. nov., and *?Astartila* sp., as well as numerous worm castings, ostracodes, and crinoid columnals. Other specimens containing fragments assigned to *D. pyriforme* include, in addition, *Euryphyllum* sp., *Protoretepora ampla* and *Aviculopecten temunicollis*. The fauna in the block containing *Doublatia* sp. includes *Stenopora* sp., *Polypora* sp., *Fenestella* sp., *Strophalosia* sp. nov., *Terrakea* sp., *Spiriferellina* sp., *Peruvispira* sp., and a myalinid. The associated fauna at Ray’s Hill also has characteristic Fauna II species, suggesting approximate correlation with the Elephant Pass horizon.

Therefore, the occurrences of trilobites in the Permian of Tasmania is likely to be a little older than the beds containing *D. inflata*, the *Fenestella* Shale, in New South Wales.

**Acknowledgements.** It is a pleasure to acknowledge the continual guidance of Dr. K. S. W. Campbell, Australian National University, Canberra. Dr. R. E. Grant, United States National Museum, Washington, compared the holotype of *Doublatia inflata* with specimens available in the U.S.A. and perused literature unavailable in Australia. For assistance in obtaining information on specimens, their localities and associated faunas, we thank Drs. J. S. Jell and J. D. Armstrong, Mr. F. S. Colliver and Mr. P. Telford of the University of Queensland, and the Director of the Australian Museum, Sydney. We wish to thank Mrs. M. R. Banks for assistance with typing and technical aspects and Mr. G. Z. Foldvary for photography.
One of us (R. E. W.) acknowledges facilities made available by the British Museum (Natural History) during a visit to London. Financial support received from an Eleanor Sophia Wood Travelling Fellowship and University of Sydney Research Grants is gratefully acknowledged.

Specimens from the University of Queensland were collected by Banks, Dr. B. N. Runnegar, and P. Telford. Tasmanian specimens were collected by Banks, together with W. D. Palfreyman, J. B. Jago, and R. F. McShane.

Abbreviations used throughout the text are: AM—Australian Museum Collection, Sydney; SUP—Sydney University Palaeontological Collection, Department of Geology and Geophysics, University of Sydney; UQ—Department of Geology Collection, University of Queensland, Brisbane; UT—Department of Geology Collection, University of Tasmania, Hobart.

SYSTEMATIC DESCRIPTIONS

Class TRILOBITA
Order PTYCHOPARIIDA
Suborder ILLAENINA
Superfamily PROETACEA
Family PROETIDAE

The Carboniferous and Permian trilobites have been grouped in different ways by different authors over the last twenty years (compare Hupe 1953, Moore, 1959, Hahn and Hahn, 1967). Hahn and Hahn (1967) and Hessler (1963) suppressed Phillipsiidae as a family name and treated genera formerly placed therein as members of subfamilies of the Proetidae. This treatment will be followed here.

Subfamily GRIFFITHIDINAE Hupe 1953 emend. Hahn and Hahn 1967

Characterized by the forward extension of the frontal lobe of the glabella, the upwardly inflated glabella and the development of a median preoccipital lobe.

The new genus, Doublatia, clearly falls within this subfamily as emended by Hahn and Hahn. Hahn and Hahn (1967) recognized three groups within this subfamily and brief diagnoses of each group compiled from their text (mainly pp. 343, 345) and figs. 4 and 5 follow:

Griffithides group: cephalon more-or-less triangular in outline, glabella highly inflated, furrows 2p and 3p lacking, generally 13 or fewer rings in pygidial axis (except Exochops, 16).

Cyphinoides group: cephalon rounded in outline, glabellar furrow 2p always and 3p usually present; generally 11 or fewer rings in pygidial axis.

Paladin group: cephalon rounded in outline, glabellar furrows 2p and 3p present; 13 or more rings in pygidial axis.

The placing of Doublatia within one of these groups is difficult and will be dealt with later.

Morphology used in the following discussion is used in the sense adopted in Moore (1959), except for points on the facial suture, for which see Hupe (1953, p. 48).

In the descriptions, long or length refer to the measurements parallel to the axial line and wide or width refer to measurements transverse to the axial line.
Genus Doublatia gen. nov.

Type species. Doublatia inflata gen. et sp. nov.

Diagnosis. Cephalon semicircular to parabolic in outline with narrow border; glabella strongly inflated anteriorly; glabellar furrows 2p and 3p weakly developed, lateral preoccipital lobes and occipital ring strongly developed, median preoccipital lobe developed; palpebral region opposite posterior half of the glabella; well-developed marginal crest on free cheeks; genal spines short; thorax of ? nine or ? ten segments; pygidium with axis extending only two-thirds of the pygidal length and with small number, eight or nine, axial rings, a postaxial ridge, and fewer pleurae than axial rings; no pygidial border; wide pygidial doublure; surface finely granulose.

Discussion. It is a combination of morphological features that enables this species to be placed in a new generic category. These are: the narrow border on the cephalon which is extended posteriorly to form a short, flat genal spine, the swollen glabella, the absence of a border on the pygidium, the pygidal pleurae which are clearly visible on the posterior region of the pygidium, and the wide pygidal doublure.

Doublatia inflata gen. et sp. nov.
Plate 36, figs. 1–4

Material. One nearly complete specimen and pygidium.

Holotype. SUP 12929A, B, from near Mulbring, N.S.W.

Diagnosis. Doublatia with semicircular cephalic outline, almost circular main glabella lobe and nine axial rings and eight pleurae in the pygidium.

Description. Greatest dimensions 26.2 mm long and 20.0 mm wide. Outline of the cranium semicircular to semi-elliptical; in plan it is waisted adjacent to the palpebral lobes. The posterior margin is very slightly convex anteriorly. The glabella is slightly waisted and increases in width posteriorly from the anterior margin to the lateral preoccipital lobes. Posterior to this point it decreases in width. The glabella border furrow is deep with the greatest depth at its mid-width. It is U-shaped anterolaterally and semi-elliptical anteriorly. It possesses a sharp, upturned border which is round and, from what is preserved, increases gradually in height from the anterior portion of the glabella. The anterior border furrow is 1.0 mm (sag.) and 1.6 mm (exsag.), measured normal to the periphery. The furrow begins to shallow opposite the eye and opposite the posterior glabellar margin it is almost unrecognizable. The median preoccipital glabellar furrow is very shallow and gently convex anteriorly. It joins the lateral preoccipital lobes at their mid-length. The greatest convexity of the median preoccipital lobe is in the central portion. This lobe is depressed below the anterior region of the glabella but elevated above the occipital ring. The occipital furrow which is convex anteriorly does not vary greatly in depth; it appears deeper laterally due to the bulbous nature of the lateral preoccipital lobes. Shape of the occipital ring is difficult to determine due to preservation but is close to a semi-ellipse with only very slight curvature posteriorly. Lateral preoccipital lobes are very bulbous and are more coarsely ornamented than the rest of the glabella.
Furrows surrounding the lobes are deepest anteriorly. The frontal glabellar lobe is inflated as shown by the great convexity of the anterior and antero-lateral margins. Its central portion is relatively flat and the convexity adjacent to the lateral preoccipital lobes is not as great as in the anterior and antero-lateral regions.

The antero-lateral outline of the librigenae is gently curved. Along the facial suture, α is situated lateral to the forward projection of the axial furrow, β in the sub-marginal furrow just inside the marginal crest. The anterior limbs β-γ are sigmoidal and slightly convergent posteriorly. Point γ is situated close to the axial furrow in front of the junction of lp with the axial furrow. The palpebral lobe is a semi-ellipse, the long axis of which is directed antero-axially. Point δ is situated posteriorly on the palpebral lobe, approximately opposite the mid-length of the lateral preoccipital lobe. Point ε lies a little outside the axial furrow and approximately opposite the transglabellar, pre-occipital furrow. From ε the facial suture runs postero-laterally at about 10° to the axial line for a short distance before turning laterally through about 135°. From this turning point it continues straight to the posterior margin which it meets at an angle of about 20°. The area of greatest convexity on the librigenae is the most antero-lateral region. The genal spine extends to about the second or third thoracic segment and slopes on both sides from a low ridge which bisects the spine. The ridge runs axially parallel to the posterior margin of the cephalon until reaching the facial suture where it changes curvature posterior to the palpebral lobe. There is a marked depression adjacent to the posterior end of the facial suture. Essentially, the librigenae rise gradually towards the periphery and then slope sharply in most regions to the lateral border.

Nine or ten thoracic segments are present. The axis expands to the seventh or eighth axial ring where it is approximately one-third the thoracic width; posteriorly it narrows. The greatest height of the axis is at the sixth or seventh ring, where it is elevated above the pleurae; at the most posterior ring, axis and pleurae are on a similar elevation. The greatest height of the axial rings is along their mid-width. Interaxial furrows are concave anteriorly. The junction between pleurae is normal to the axis until the fulcral lobe is reached approximately one-quarter of the distance along the pleural length. The interpleural furrow then curves posteriorly, being gently concave anteriorly. The same applies for most of the pleural furrows. In one or two cases, however, they are gently concave anteriorly and converge towards the interpleural furrows. Lateral extremities of pleurae become more posteriorly directed near the pygidial junction. The greatest height of pleurae is approximately at their mid-width adjacent to the fulcral lobe.

The pygidium is semicircular in outline. There is no border. The axis, containing nine rings, extends only two-thirds of its length. The posterior end of the axis is very steep and is extended as a faint postaxial ridge. The axis narrows from 6.0 mm at the thoracic junction to 2.9 mm at the junction of the seventh and eighth axial rings. The height of the axis decreases posteriorly to the junction of the seventh and eighth rings.

**Explanation of Plate 36**

Figs. 1-4. *Doublatia inflata* gen. et sp. nov. 1, holotype, SUP 12929A, × 3. 2, SUP 12929a, × 3. 3, SUP 12929A, before removal of part of pygidium, × 5. 4, SUP 12929A, after removal of part of pygidium to reveal free cheek and facial suture, × 5.

Fig. 5. Pygidium indet., Type A. UQ F44458, × 4.

Fig. 6. Pygidium indet., Type B. UQ F44457, × 4.
WASS and BANKS, *Doublatia* gen. nov.
and then increases slightly to the ninth ring. The greatest convexity is at the mid-point of all axial rings. The posterior side of the interaxial furrow is very steep and the anterior side slopes sharply to the ring. Adjacent and parallel to the axial furrow on rings one to six, and possibly seven, is a furrow which results in the formation of a small tubercle at the ends of these rings. There are seven well-defined pleurae with an eighth poorly defined. The pleural length decreases posteriorly. The greatest height of pleurae is anteriorly. Interpleural furrows between anterior pleurae curve most in a posterior direction and the sixth pleura approximately parallels the axis. Interpleural furrows are deeper than pleural furrows; the pleural furrow separates two regions of convexity in the pleurae with the posterior part always having the greater convexity. All furrows are well defined except for some in the posterior region. The doublure is wide, extending at least as far as the posterior culmination of the axis. It is ornamented by many fine ‘semiconcentric’ grooves.

**Doublatia pyriforme** gen. et sp. nov.

Plate 37, figs. 1–12, 14, 15; text-fig. 2

**Material.** The material on which this description is based consists of two cranidia, five free cheeks, other cephalic fragments, thoracic fragments, four complete pygidia, and two partial pygidia. One pygidium includes both the internal and external moulds and two other pygidia and one of the free cheeks are partly decorticated to reveal part of the doublure. Only UT 55297 is from Elephant Pass; all other specimens are from Ray’s Hill, Tasmania.

**Holotype.** UT 90142, a cranidium from Ray’s Hill.

**Paratypes.** UT 90113, 90144, 90155, free cheeks; UT 90094a, b, 90115, 90121, pygidia; all from Ray’s Hill.

**Diagnosis.** Doublatia with pyriform main glabellar lobe, short genal spine, eight axial rings and seven pleurae in the pygidium.

**Description.** The holotype cranidium (a partly decalcified original skeleton, Pl. 37, figs. 1, 2, 4) is 6.5 mm long and 5.0 mm wide from β₁–β₂ and about 7.0 mm from ω₁–ω₂ (subscript refers to the side of the animal, left or right, on which point occurs). The anterior border (α₁–α₂) is arcuate in plan and subtends an angle of about 95° at the centre of curvature (approximately the centre point of the glabella). The facial suture rises steeply and obliquely abaxially to β on the crest of the marginal ridge whence it passes as a straight line to γ at the waist of the cranidium just over half the distance from anterior to posterior of the cranidium. The line β–γ makes an angle of about 30° with the axial line. The distance from γ₁ to γ₂ is about 3.4 mm. The facial suture at γ has a small radius of curvature. From γ to ε the suture describes a semi-elliptical path with a major diameter of about 1.5 mm. Point δ is situated about 4.0 mm behind the anterior margin and about 2.8 mm from the axis. Points γ and ε are both close to the axial furrow and approximately equidistant from the axial line. From ε the suture passes backwards for a short distance and then posteriorly and laterally to ω. The line ε–ω₁ is about 45° to the axis. The line ω₁–ω₂ is about 5.8 mm from the anterior margin. The posterior margin of the cranidium is crossbow shaped in plan with the convexity to the posterior. The anterior border, horizontal in front view (Pl. 37, fig. 2), is turned up sharply to form a rounded ridge about 0.3 mm across. Behind this is a deep, narrow, rather angular,
preglabellar border furrow which expands laterally to form the anterior part of the fixigenae. The glabella is also waisted, the narrowest portion being at the intersection of the preoccipital (lp) and the axial furrows and a little posterior of γ. At its narrowest point the glabella is about 3.0 mm wide. From this waist the glabella widens in a gentle curve around the preoccipital lobes. The glabella is about 4.6 mm long. The main (frontal) lobe of the glabella is pyriform, the posterior margins being defined by deep preoccipital furrows (lp) which converge posteriorly from the waist of the glabella towards the axis and make an angle of about 50° with the axis. Slight shearing (top and front to the left) has made accurate measurement of the convexity of the glabella difficult. The highest point is situated half-way along the glabella and the glabella is distinctly

**TEXT-FIG. 2. Reconstructions of Doublatia pyriforme** sp. nov. × 5. A, dorsal view of cephalon with partially decorticated free cheek to show connective suture and part of the doublure. B, dorsal view of pygidium with decorticated left pleural area showing doublure. C, hypothetical reconstruction of front view of cephalon showing inflated glabella, high palpebral lobes, and inferred position of free cheeks; doublure shown as dotted line. D, cephalon viewed from the right side. E, section of several pygidial pleurae as seen from the right-hand side. IPF = interpleural furrows. PF = pleural furrows.

**EXPLANATION OF PLATE 37**

All numbers refer to the UT Collection; all specimens except 55297a, b, come from Ray's Hill.

Figs. 1–12. *Doublatia pyriforme* sp. nov. 1, Holotype cranidium from the right side, 90142, × 5. 2, Holotype cranidium from the front, × 5. 3, Left free cheek, 90113, × 5. 4, Dorsal view of internal mould of holotype cranidium, × 5. 5, Partly decorticated left free cheek (reverse printed), 90155, × 5. 6, 7, Internal mould and rubber cast of external mould of pygidium, 55297a, b, × 5. 8, Left free cheek, internal mould, 90144, × 5. 9, Rubber cast of external mould of pygidium, 90094a, × 5. 10, Partly decorticated pygidium, 90094b, × 5. 11, Partly decorticated pygidium viewed from left hand side to show profile, 90094b, × 5. 12, Dorsal view of large cranidium, 90153, × 5. Fig. 13. *Doublatia sp.*, dorsal view of external mould of cranidium, 90143, × 10.

Figs. 14–15. *Doublatia pyriforme* sp. nov. 14, Large left free cheek, 90161, × 3. 15, Partly decorticated left free cheek (reverse printed) showing connective suture, terrace lines and genal spine, 90155, × 8.
but rather uniformly convex upwards (text-fig. 2d; Pl. 37, fig. 1). The frontal lobe is either unsegmented or may show two short, faint, lateral furrows directed posteriorly and axially and rising close to the waist. Shearing and preservation preclude a definite statement on this point. The frontal lobe is terminated posteriorly by a shallow translabellar preoccipital furrow joining the most axial points on lp, and approximately in the line $\epsilon_l - \epsilon_r$. The preoccipital segment is broken by two shallow grooves, posterior branches of lp parallel to the axis, into a more-or-less rectangular median preoccipital lobe (about 0·05 mm long and 0·15 mm wide) and two lateral preoccipital lobes which are almost trapezoidal. Before shearing and the accidents of preservation, collection, and preparation these were probably quite bulbous (Pl. 37, fig. 13). The occipital furrow is straight from the lateral edge of the cranidium to the axial furrow where it curves gently posteriorly to outline the lateral preoccipital lobes and then continues in a straight line across the axis. The occipital furrow is deep and is asymmetrical in sagittal section, (Pl. 37, fig. 1, text-fig. 2d), the anterior slope being very steep, the posterior gently curved and rising on to the almost flat occipital ring. The partially decorticated free cheek (UT 90155) shows that before reaching the axis the facial suture passes onto the ventral surface at a position corresponding approximately to the forward projection of the axial furrow (Pl. 37, figs. 5, 15). At the anterior margin the suture turns axially at about 90° to the margin and runs for a short distance before turning abaxially at about 100° to become a connective suture and join the inner edge of the doublure.

Five free cheeks occur in the same type of matrix as the cranidium, are of similar size and show a facial suture which matches that of the cranidium. The closest match in size occurs in specimen UT 90144 which is 3·6 mm long and 4·2 mm wide (these and other measurements are tabulated as Table 2). The outer margin is evenly curved and the axial and posterior margins almost perpendicular to each other so that the free cheeks approximate one quadrant of an ellipse. The free cheek has considerable relief. The posterior margin is straight or at most very gently curved. The lateral border is marked by a high, sharply rounded crest (up to 0·6 mm wide) which persists almost to the point of the genal spine but declines sharply near the spine. A rounded ridge rises rapidly from near the genal spine and runs just inside the occipital border, reaching a culmination about half-way from the spine to the facial suture, before descending towards the dorsal furrow. A broad shallow furrow lies inside the marginal ridge both laterally and posteriorly and the occipital part of this deepens to a pit just outside the facial suture. The palpebral lobe rises steeply from the sub-marginal and occipital furrows. The genal spine is a short, rather blunt posterolateral prolongation of the genal angle. Partial decortication of one free cheek (UT 90155) revealed the doublure marked by terrace lines (Pl. 37, fig. 15) and showed that the inner edge of the doublure lay under the axis of the broad, shallow sub-marginal furrow, at least anteriorly. The cross-section of the free cheek shows a narrow, high, rounded marginal ridge, a broad shallow furrow, and the steeply rising slopes of the palpebral lobes (text-fig. 2c, d).

Combining the shapes of the cranidium and free cheeks suggests that the cephalon was arched transversely, the free cheeks probably lying at a considerable angle to the horizontal during life (text-fig. 2c). It was probably approximately parabolic in plan with the genal angles projecting downwards and backwards as short, blunt spines (text-fig. 2d). A distinctive feature is the high ridge or crest which borders the cephalon except at the genal angles and along the axial part of the occipital ring.
Isolated fragments of cephalon and thorax show clearly the finely granulose surface of the trilobite. The isolated thoracic segments suggest that the axis was wide and the pleural regions rather narrow. Fragments of the pleurae (e.g. UT 90159) suggest a width (6.5 mm) about double the length (3.2 mm) and the shape in outline of a parallelogram. The pleural furrow is directed towards the postero-lateral corner in most specimens but is almost parallel to the posterior margin in others. In crushed external moulds it is represented by a high, sharply crested, oblique ridge.

Several pygidia occur in the same type of matrix as the holotype cranidium. They have axes of approximately the same width as that of the cranidium and have the same type of ornament. On the basis of mutual and exclusive association, axis width, and ornament the pygidia (Table 2b, less UT 55297) are considered as belonging to the same species as the cranidium.

The anterior and posterior margin of the pygidia are both arcuate in plan, the radius of curvature of the anterior (8.2 mm in UT 90094a) being greater than that of the posterior (6.5 mm in UT 90094a). The anterior margin is smooth across the axis. From the axial furrows the front margin of the pleural articulating half-segments runs forward to a point situated about a quarter of the distance from the axial furrow to the lateral margin. From this point the border of the half-ring continues in a gentle curve to the antero-lateral point of the articulating facet whence it runs almost parallel to the axis and posterolaterally to the widest point of the pygidium. The pygidia are about 0.5 to 0.6 times as long as they are wide (Table 2b). The axis is widest anteriorly and its maximum width varies from about 0.32 to 0.43 of the maximum width of the pygidium. The axis tapers very gently backwards (axial furrows at 12° to 16° approximately to the axial line) to about the seventh ring posterior to which it narrows rapidly and slopes down to a low postaxial ridge. The axis is 0.66 to 0.77 of the length of the pygidium. In sagittal section the top of the axis is horizontal (Pl. 37, fig. 11) or slopes gently down and back from the anterior ring. In transverse section the axial rings, except the terminal one, are not uniformly curved but tend to rise steeply from the axial furrows, flatten out, or even fall a little before arching evenly over the axial line. In effect there are two furrows within the axis, parallel and close to the axial furrows and these produce a faint tubercle at the pleural ends of each axial ring. The axis contains eight rings in addition to the anterior articulating half-ring. The rings appear to be or to have been (prior to slight deformation) uniformly curved in sagittal section and to be separated by sharp furrows.

The pleural regions are very nearly uniformly convex upwards (Type A of Weller 1937, p. 342) and the axis rises only a little above the projection of the curve of the pleural regions. There is no border. Segmentation of the pleural region does not match that of the axis. There are only seven pleurae on each side in addition to the postaxial ridge. The pleurae decrease successively and gradually in height from anterior to posterior. They consist of two sections of different heights and convexities separated from one another by pleural furrows. The anterior part is low and very gently convex upwards, whereas the posterior is high and more convex (text-fig. 2e). The interpleural furrows are rather more distinct than the pleural, due to slightly greater depth but both sets of furrows become shallower and therefore more indistinct posteriorly. The interpleural furrows meet the axial furrows at approximately the same point as do the inter-ring furrows on the axis and the pleural furrows meet the axial furrow at points
approximately half-way along each axial ring. The interpleural furrows are gently convex antero-laterally, the convexity decreasing from anterior to posterior within the pleural field and the anterior angle between the axial line and the interpleural furrows increasing from just over 90° for the most anterior segment to just over 180° for the seventh. The interpleural and pleural furrows are almost parallel (or concentric). Several specimens show that the surface was finely granulose.

Table 2. Cephalic and pygidial measurements of *Doublatia inflata* sp. nov., *D. pyriforme* sp. nov., and *D. sp.*

<table>
<thead>
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<th>A. CEPHALIC MEASUREMENTS</th>
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<td>(i) Glabella, in front of transglabellar, preoccipital furrow</td>
<td>L</td>
<td>W</td>
<td>L/W</td>
</tr>
<tr>
<td><em>D. inflata</em> (SUP 12929A)</td>
<td>6.5</td>
<td>7.5</td>
<td>0.87</td>
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<tr>
<td><em>D. pyriforme</em> (UT 90142)</td>
<td>4.1</td>
<td>3.2</td>
<td>1.28</td>
</tr>
<tr>
<td><em>D. pyriforme</em> (UT 90153)</td>
<td>&gt; 9.3</td>
<td>5.0</td>
<td>&gt; 1.86</td>
</tr>
<tr>
<td><em>Doublatia</em> sp. (UT 90143)</td>
<td>&gt; 5.4</td>
<td>5.0</td>
<td>&gt; 1.08</td>
</tr>
</tbody>
</table>

(ii) Free cheeks

<table>
<thead>
<tr>
<th>L</th>
<th>W</th>
<th>L/W</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>D. inflata</em> (SUP 12929A)</td>
<td>11.0</td>
<td>7.7</td>
</tr>
<tr>
<td><em>D. pyriforme</em> (UT 90161)</td>
<td>7.8</td>
<td>6.2</td>
</tr>
<tr>
<td><em>D. pyriforme</em> (UT 90113, 90144, 90155, 90284)</td>
<td>&gt; 9.8</td>
<td>&gt; 5.0</td>
</tr>
</tbody>
</table>

Range: > 3.2-5.0 3.0-4.4 > 1.07-1.25

L measured exsagittally, W transversely

<table>
<thead>
<tr>
<th>B. PYGIDIUM</th>
<th>Lp</th>
<th>Wp</th>
<th>La</th>
<th>Wa</th>
<th>Lp/Wp</th>
<th>La/Wa</th>
<th>Lp/La</th>
<th>Wp/Wa</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>D. inflata</em> (SUP 12929A)</td>
<td>9.0</td>
<td>19.4</td>
<td>6.0</td>
<td>6.5</td>
<td>0.46</td>
<td>0.92</td>
<td>1.50</td>
<td>3.0</td>
</tr>
<tr>
<td><em>D. pyriforme</em> (UT 90094a, b, 90121, 90230-1, 55297)</td>
<td>3.1-7.0</td>
<td>5.6-12.4</td>
<td>2.3-4.0</td>
<td>2.3-4.0</td>
<td>0.52-0.65</td>
<td>0.52-0.65</td>
<td>1.0-1.2</td>
<td>1.3-1.5</td>
</tr>
</tbody>
</table>

Range: 3.1-7.0 5.6-12.4 2.3-4.0 0.52-0.65 1.0-1.2 1.3-1.5 2.3-4.0

All measurements in millimetres. L = length, W = width, Lp = length of pygidium, La = length of axis, Wp = width of pygidium, Wa = width of axis.

The internal moulds show that the doublure was wide. Anteriorly it extended from the outer margin about halfway to the axial furrow and it maintained this width throughout so that in the plane of symmetry it extended forward to the posterior end of the axis. It is prominently marked by numerous fine concentric grooves (terrace lines).

The dimensions and relative proportions of the pygidium of *D. pyriforme* are shown in Table 2b which includes those of *D. inflata* for comparison.

Other material. Other material probably of the same species includes a rather larger partial cranidium (UT 90153) from the same type of matrix at Ray's Hill, a larger free cheek (UT 90161) and the pygidium (UT 55297) from Elephant Pass. The cranidium is an internal mould of the part of the dorsal surface of the glabella and fixed cheeks. It has been sheared, the length of the preserved part being 9.3 mm, the width 5.0 mm. The anterior border comes to an obtuse point just to the right of the axis but this may be due to shearing. The border is marked by a high, rounded ridge only 2.0 mm across.
The preglabellar furrow is similar to that in the holotype and expands in the same way to a fixed cheek, the preserved portions of which have the same shape as the holotype. The frontal lobe of the glabella is pyriform and strongly convex upwards, the highest point being about 6 mm behind the anterior border and almost 2 mm above the general level of the base of the glabella. The anterior part of the glabella has been partly crushed.

Although this partial cranidium is approximately twice the size of the holotype, the frontal lobe of the glabella is pyriform and on this basis it is included in *D. pyriforme*. The proportions of the frontal lobe are even further from those of *D. inflata* than they are from *D. pyriforme*.

Another large specimen is the free cheek (UT 90161) preserved as an internal mould. The specimen has a length to width ratio very close to that of other specimens assigned to *D. pyriforme* and very different from that of *D. inflata*. There is a narrow (0.4 mm) ridge around the lateral margin which is lower (only 0.5 mm high) than in smaller specimens but similarly decreases in height near the genal angle. The occipital ring is similar to that in the smaller specimens, in that it rises to a culmination about half-way between the genal angle and the posterior limit of the facial suture. The occipital furrow shallows towards the genal angle. A broad shallow furrow lies inside the marginal ridge and the cheek rises steeply from this to the palpebral lobe. The top of the palpebral lobe is about 1.8 mm above the plane of the lateral margin of the free cheek. The facial suture has a similar shape in plan to those of the smaller specimens.

Although the pygidium from Elephant Pass (UT 55297, Pl. 37, figs. 6, 7) comes from a different place and lithology, it shows the same characters as the pygidia from Ray's Hill and is placed in the same species.

**Discussion.** The Tasmanian species is generally only about half the size of that from Mulbring. The cephalic outline which has to be reconstructed in both species described here, is semicircular in *D. inflata* and in *D. pyriforme* is a parabola approximating to the curve $y = \frac{x^2}{4.5}$, where $y, x$ are Cartesian co-ordinates in millimetres of a point on the outline relative to the front of the cephalon as origin and the long axis of the cephalon as the $y$ axis. The cranium of *D. pyriforme* is proportionally longer ($L:W = 1.5$) than that from Mulbring ($L:W = 1.14$). Both have a glabella waisted just in front of the preoccipital lobes but in *D. inflata* the frontal lobe is almost circular as against pyriform in *D. pyriforme*, the depth of the waist indentation is less in *D. inflata*, and the lateral preoccipital lobes are more circular in *D. inflata* than in *D. pyriforme*. The occipital region is similar in both. The preglabellar furrow is narrower and the border more upturned and higher than in *D. inflata*. In addition the border ridge is higher and the submarginal lateral furrow wider and deeper than in *D. inflata*. Shape of the facial suture is very similar but $\beta - \gamma$ is straight in *D. pyriforme*, sigmoidal in *D. inflata*. The ornament is similar in both. Thoracic segments are similar in shape as far as can be judged. The pygidium of *D. pyriforme* is about the same shape (but half the size) as that of *D. inflata* and the relative proportions of length and width of axis and pygidium show approximately the same range (Table 2h). *D. pyriforme* does, however, differ from *D. inflata* in that it has eight axial and seven pleural segments as against nine and eight respectively in *D. inflata*. The difference in segmentation may be specific or related to a stage in holaspid development. In this latter case all the Tasmanian pygidia would represent the one holaspid stage, being earlier than that represented by the Mulbring.
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specimens (cf. Weller 1937). While this is possible, it is rather unlikely that the only specimens collected belong to the same, and not final, holaspis stage. It is more likely that this difference is specific. The angle made by the axial furrows with the axial line is a little higher (18°) in *D. inflata* than in *D. pyriforme* (12–16°).

*Doublatia* sp.

Plate 37, fig. 13

A third cranidium (UT 90143) was found as an almost complete external mould in white silicified limestone at Ray’s Hill. The preglabellar region and the fixed cheek on one side are missing.

*Description.* The glabella is 3.7 mm long and a little over 4 mm wide, and it is waisted as in *D. pyriforme*. The frontal lobe, although incomplete anteriorly, appears to be almost circular and is highly inflated, the highest point lying on the axis about 2.0 mm in front of the preoccipital furrow and at least 0.9 mm above the base of the glabella. The left-hand side of the frontal lobe shows two faint but distinct furrows arising at equal intervals of about 0.3 mm in front of the preoccipital furrow and extending inwards and backwards to about two-thirds of the way to the axis. The more posterior of these parallels the preoccipital furrow, the more anterior being more directly transverse. The preoccipital furrows run towards the axis making an angle of about 60° with it before turning back almost parallel to the axis to meet the occipital furrow. A shallow indistinct furrow joins these furrows to delineate a third, almost rectangular, median preoccipital lobe. The lateral preoccipital lobes are trigonal to trapezoidal. The occipital furrow is deep and more-or-less symmetrical in sagittal section. The occipital furrow is laterally straight but inside the dorsal furrow curves sigmoidally forward from each side. The occipital ring is very convex in both sagittal and transverse section, producing an almost bulbous appearance. The posterior margin is disrupted but appears to have been gently convex backwards. The high, arcuate palpebral lobe is preserved on the left hand side. The facial suture appears to be slightly divergent anteriorly (*γ–β*) and curves smoothly at the front towards the axial line (*β* towards *α*). Behind the palpebral lobe it diverges at about 60° to the axial line to just in front of the occipital ring; at this point it flattens to 45° to the axial line at which angle it meets the occipital ring which it crosses at about 75° to the axis. The pleural part of the occipital ring is still rising where it is cut by the facial suture. The whole surface of the cranidium is both coarsely and finely granulose.

*Discussion.* This cranidium is considered to belong to *Doublatia* on the basis of similar waisting of the glabella, glabellar segmentation, and ornamentation. The frontal lobe of the glabella is almost circular, more similar to *D. inflata* than to *D. pyriforme* (Table 2A (i)), but the lateral preoccipital lobes are closer in shape to those of *D. pyriforme* than those of *D. inflata*. The frontal limb of the facial suture (*γ–β*) is sigmoidally curved as in *D. inflata*. The occipital region differs only a little from *D. pyriforme* in sagittal section.

It is likely that this specimen represents a new species or perhaps is *D. inflata* but it is not complete enough to allow proper decision.
Generic affinities of Doublatia

Relationships within the Griffithidinae have recently been considered by Hahn and Hahn (1967) who used cephalic outline, degree of glabella inflation, presence of furrows 2p and 3p in the glabella, and the degree of segmentation of the axis of the pygidium as the main criteria linking genera into groups as outlined earlier. Some doubts must be expressed about the validity of these features in showing phylogenetic relationship.

Cephalic outline varies considerably within a genus. In Ditomopyge decurtata (Gheyselinck) and D. fatmii Grant (both illustrated by Grant 1966, pl. 13) the outline is parabolic but the equations of the parabolae in the two species are different. D. scitula (Meek and Worthen) (Weller in Moore 1959, p. 0403, fig. 307, 5a) had an almost semicircular cephalic outline whereas D. meridionalis Teichert had an outline which was probably trigonal. The type species of Doublatia had an outline which was probably almost semicircular but the other species assigned here to the genus had an outline which was parabolic. It might be expected that similarity in cephalic outline would have been selected in separate lineages as an adaptation to similar habitats.

Both Cyphinoides and Eocyphinium (Reed 1942, pls. 8, 9) have glabellar inflation at least as great as some of the Griffithides group, for example, Permoproetus, although probably not as great as Neoproetus and Kathwaia. On the whole the degree of glabellar inflation seems to support the grouping adopted by Hahn and Hahn.

Glabellar segmentation, reflecting some locomotory or alimentary structures of the soft anatomy might be expected to be more conservative than cephalic outline, at least, and therefore be a better criterion for establishing relationships. Hahn and Hahn (1967) considered that the median preoccipital lobe developed independently, presumably as parallel evolutionary regressions to some early Ordovician or Cambrian precursor of the Proetidae, in at least three lineages, Kaskia—Ditomopyge, Thigriffides to the Cyphinoides group, and Bollandia—Permoproetus. They further postulated redevelopment of glabellar furrows in front of 1p in the Paladin—Kaskia—Ditomopyge—Anisopyge lineage, in the Thigriffides—Cyphinoides group lineage and in the Bollandia—Paraphillipsia lineage. Suppression of 1p and 2p glabellar furrows in Griffithidella doris (Hall) leading through Bollandia to Neoproetus and Kathwaia might suggest, on the other hand, that such suppression could also affect the other groups. However, the over-all trend was towards increasing segmentation leading to the formation of a median preoccipital lobe and as many as three other pairs of glabellar furrows as in Anisopyge. In neither the Griffithides nor the Paladin group did rectilinear evolution of this feature occur, judging from the text and figures of Hahn and Hahn. In the Griffithides group Permoproetus developed a median preoccipital lobe from ancestors without one and in the Paladin group Kaskia, lacking 3p, intervened between forms with this pair of furrows. The lineage suggested by Hessler (1965, pp. 258–9) in the Cumminglellinae, i.e. Moschoglossis—Cumminglella—Richterella—Ameura, demonstrates gradually increasing suppression of glabellar furrows from anterior to posterior. It would be superficially simpler to group all genera with 1p forked or with a median preoccipital lobe and postulate derivation by increase in strength, length, and number of glabellar furrows from a genus in the Lower Devonian with unforked 1p and some furrows in front of 1p. Such a derivation might proceed through a species like Schizoproetus celechovicensis (Smycka) or Cyrtosymbole escoti (Koenen) to Eocyphinium and Cyphinoides or a similar genus
and on to genera with a median preoccipital lobe and one or more furrows in front of 1p. Hupé (1953) made almost such a grouping in erecting the Ditomopyginae. However, this rectilinear increase in glabellar furrowing is not without exception, and reversal of trend would have to be postulated to accommodate *Permoproetus* and *Paraphillipsia* at least.

Another potentially useful taxonomic character is the glabellar outline which helps to characterize the Phillipsinae and Cummingellinae and to connect such genera as *Moschoglossis* and *Ameura* (Hessler 1965, pp. 258–9). Gradual lateral and forward expansion of the anterior lobe of the glabella and progressive suppression of glabellar furrows from anterior to posterior as shown by this lineage, may, if continued, have led to *Paraphillosia*. The authors have attempted to construct a phylogenetic system based on conservation of glabellar shape or on modification of glabellar shape by anterior or later expansion but with no retrogression and taking particular note of the position of the waist or waists. However, this scheme also contains anomalies such as one species of *Ditomopyge* having only one waist at 2p and related therefore to *Cyphinoides* and *Eocyphinium* whereas others may have a second, smaller waist about midway along the length of the lateral preoccipital lobes, suggesting relationship to *Kaskia*. Another anomaly in such a scheme is the placement of species of *Griffithides* in two lineages, one with waists at the mid-length of the lateral preoccipital lobe and 1p (*G. longiceps* Portlock), the other waists at 1p and within the frontal lobe in front of 1p (*G. (Meta-philipsia) seminiferus* Phillips)).

Yet another trend used in classification is increase in segmentation of the axis of the pygidium. However, no phylogenetic scheme yet published, nor the one mentioned earlier as having been tried by the authors, maintains this as a rectilinear trend in all lineages.

It would appear that the Proetidae, or at least the genera grouped by Hahn and Hahn (1967) as Griffithidinae, were subject to mosaic and reversible evolution, leading to difficulty in establishment of clear phylogenetic lines. Such lines may emerge when more intermediate forms are described especially from the Upper Devonian, Upper Carboniferous, and Lower Permian and make possible tracing, through small steps, evolutionary and migratory patterns. It is likely, from what is already known of the derivation of eastern Australian Permian fossils generally (Teichert 1951), that the precursor of *Doublatia* was a Carboniferous form from eastern Australia or perhaps an earlier Permian form from Western Australia.

At the present stage of knowledge and in view of the likelihood of mosaic evolution within the Griffithidinae, all that can usefully be done to establish the generic relationship of *Doublatia* is to compare it feature by feature with other genera and so assess the genus to which it is most similar. Such an assessment may reveal a real phylogenetic relationship or a distantly related genus at about the same stage in a number of evolutionary trends.

Little is to be gained by comparisons of the cephalic outlines of the *Doublatia* species. The glabella has a single waist at 1p, as have *Neoproetus*, *Kathwaia*, *Paladin*, *Bollandia*, and some species of *Ditomopyge*. The waist is about as narrow as in *Paladin*, *Bollandia*, and *Ditomopyge* but not as narrow as in *Neoproetus* or *Kathwaia*. Some species of *Ditomopyge* have a second waist, as mentioned earlier, but there is no sign of this in *Doublatia*. The widest part of the glabella in *Doublatia* is across the preoccipital lobes.
Bollandia and Paraphillipsia are the only other griffithidines (and Paraphillipsia may be a cummingelline) to show this and it may be considered a primitive feature. Other genera such as Ditomopyge, Exochops, Neoproetus, and Permoproetus approach this condition but of these only Ditomopyge and Neoproetus have similar waisting to Doublatia. In both these genera the frontal part of the glabella is as wide as or slightly wider than the posterior. In this feature Doublatia shows more resemblance to some of the earlier members of other superfamilies than to most other griffithidines. Of those genera with similar waisting only Ditomopyge is at all like Doublatia in possessing a median preoccipital lobe and glabellar furrows 2p and 3p. The degree of inflation of the frontal lobe of the glabella of D. pyriforme is comparable with that in some Ditomopyge species and Timoraspis whereas that of D. inflata is more comparable with that of Neoproetus indicus Tesch but less than that in Kaskia. The degree of forward expansion of the glabella is most similar to that of some species of Ditomopyge, for example, D. sylvense Weber, D. fatmii, and some specimens of D. meridionalis from the Lower Permian of Western Australia which had a frontal brim (Teichert 1944). Microphillipsia shows about the same degree of forward development of the glabella. There is considerable resemblance of the front part of the cephalon of D. pyriforme with the fragment figured as ?Conophillipsia by Campbell and Engel (1963, pl. 8, fig. 4) from the Tournaisian of New South Wales.

The occipital ring is close in shape to that of Ditomopyge sp. (Teichert, 1944) from the Lower Permian Fossil Cliff Limestone of Western Australia, of Neoproetus indicus and ‘Griffithides’ trigonoceps Ghey selinck from Timor.

Comparison of the shape of the facial suture of Doublatia with that of other proetids shows that the palpebral lobe is situated comparatively far back on the cranidium (γ approximately opposite 2p, ε approximately opposite the transglabellar, preoccipital furrow). The position compares most closely with that in Kathwaia, Permoproetus, and Ditomopyge. The frontal limbs (γ–β) are slightly more divergent than in Kathwaia and much more divergent than in Permoproetus and notably straight, both features seen also in Weania goldringi Campbell and Engel 1963. In shape of this limb Doublatia is closest to Kathwaia but shows similarities also to some Lower Carboniferous genera (e.g. Weania and Metaphillipsia) and lesser similarities to Paladin and Ditomopyge. The posterior limbs (ε–ω) are similar in plan to those of Kathwaia with lesser resemblances to those of Ditomopyge, Metaphillipsia, Ameura and a number of other genera. The connective sutures are long and divergent, different in both respects from those of Proetus cuvieri (Struve in Moore 1959, p. O385, fig. 292) and P. bohemicus (Hupe 1953, p. 51, fig. 5d) and in their divergence they differ from those of Carbonocoryphe binde mannii (Struve in Moore 1959, p. O393, fig. 299, 6a).

The free cheeks of Doublatia pyriforme show a marked resemblance to those assigned by Campbell and Engel (1963, pl. 6, figs. 10–13) to Weania goldringi especially in the angular nature of β, the wide divergence and straightness of γ–β, and the shape of the genal spine but W. goldringi is closer to D. inflata in flatness. The genal spines in Doublatia are short and most closely resemble those of Neoproetus in both length and in the structure of the border and adjacent furrow in the immediate vicinity of the genal angle. There are lesser resemblances to Eocyphinium, Bollandia, Weania goldringi, Microphillipsia, and Timoraspis breviceps (Gheyselinck) in these respects.

In the majority of cranidial characters, then, Doublatia is closest to Ditomopyge and
derivation from an early *Ditomopyge* species, in which the glabella did not reach the anterior margin of the cephalon and was rather narrow anteriorly, might be suggested. From such an ancestor *Doublatia* could have evolved by slight weakening of the anterior fork of Ip and by shortening of the genal spine. A collateral relationship with *Neoproetus* and *Kathwaia* is suggested by the similar waisting of the glabella, similar position of the palpebral lobe, similar genal spine (*Neoproetus* only), and somewhat similar ornament. Another genus with fairly close collateral relationship is *Microphillipsia*, as shown by similarity in glabellar extension, shape, and segmentation, and in the development of the genal spine.

Although the cephalon of *Doublatia* is essentially that of a *Ditomopyge* with a short genal spine, the pygidium is very different from that of *Ditomopyge*. The pygidium of *Doublatia* is strikingly reminiscent of some cornuproetines (*Pribylia, Cornuproetus*), some cyrtosymbolines (*Cyrtosymbole, Calybole, Waribole*, and *Weania*) and some tropidocoryphines (*Decoroproetus*). With these it agrees in many, but not all, of the following characters—outline, shortness of axis, lack of border, small number of segments, presence of pleural as well as interpleural furrows, presence of postaxial ridge. In almost all the characters listed and in the width of the doublure it is remarkably close to the pygidia assigned by Campbell and Engel (1963, pl. 6, figs. 1–4) to *Weania goldringi* from the Tournaisian of New South Wales. The outline, transverse profile, segmentation, presence of interpleural furrows and a postaxial ridge are similar to those in *Kathwaia* but the anterior part of each pleura was much more convex in *Kathwaia* than in *Doublatia*. The pygidium of *Doublatia* also shows many similarities to that of *Griffithidella doris* (Hessler 1965, pl. 37, figs. 1, 5, 6). The conservatism of the pygidial structure of *Doublatia* is reflected in its very close similarity to *Weania* from the Tournaisian and similarity to Devonian genera especially *Pribylia*.

Thus *Doublatia* had a cephalon moderately advanced in terms of glabellar expansion and inflation compared to many other proetids but not as advanced as many others. Development of lobation of the glabella was at an intermediate evolutionary stage and several genera had more lobes. The free cheek was advanced in terms of length of the genal spine. The most primitive feature was the pygidium. *Doublatia* was at about the same general stage of evolution as some *Ditomopyge* species but has a more primitive pygidium than any species of *Ditomopyge*. Thus it may be phylogenetically related to a primitive *Ditomopyge* from which it developed mainly by shortening of the genal spine or perhaps also by retrogressive shortening of the pygidium associated with reduction in number of pygidial segments and loss of border. Alternatively it may have arisen independently from another stock with cephalic changes parallel to *Ditomopyge*.

From general considerations of the nature of Upper Carboniferous and Permian faunas in eastern Australia (Campbell 1961; Teichert 1951) it is likely that *Doublatia* arose either from Lower Carboniferous Eastern Australian stock, protected by a barrier, probably climatic, from competition in the Upper Carboniferous with stock migrating from outside Australia, or from Lower Permian Western Australian stock which migrated around the continental block of Australia late in the Lower Permian. The similarity of the front end of the cranidium of *?Conophilipsia* to that of *Doublatia pyriforme* and the similarity of the free cheeks and pygidia assigned to *Weania goldringi* to those of *Doublatia* support the possibility of a long eastern Australian history for
Doublatia. On the other hand, derivation from Ditomopyge described by Teichert (1944) from the Fossil Cliff Formation, Western Australia, cannot be rejected as the cranidia are rather similar and the age relationships are those required for such a derivation.

Trilobites are generally represented in the Permian of eastern Australia by isolated pygidia. The following descriptions are of two common forms of pygidia found in this region.

Pygidium indet., Type A
Plate 36, fig. 5

Description. The specimen, UQ F44458, is a pygidium. There are at least seven axial rings and eight pleurae with the latter being parallel to the axis at the posterior extremity. The pygidial axis is very pointed posteriorly and extends for three-quarters of the pygidial length. At the anterior end the axis occupies about one-third of the pygidial width. It increases in height until about the fourth axial segment and then slopes gradually to the posterior extremity. An extremely narrow pygidial border is present resulting in a change of slope along the ends of the pleurae.

Locality. The specimen was found in Sawpit Gully (Locality 2). Three other specimens, UQ F58160–1 from this locality and 58306 from Locality 3 appear to be closely related to the specimen described above.

Pygidium indet., Type B
Plate 36, fig. 6

Description. The specimen, UQ F44457, is also a pygidium. At least ten axial rings are preserved with small tubercles developed at the junction of the axial rings and pleurae. The axis is about one-third the pygidial width at the anterior end but it gradually decreases in width posteriorly. The posterior extremity of the axis, at three-quarters of the pygidial length, is rounded.

Locality. The specimen was found in Sawpit Gully (Locality 2). Another specimen, UQ 58305, is similar to UQ F44457 and was found at Locality 3.

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Reconstruction of a Scene near Hobart in the Triassic Period
THE FOSSIL REPTILE FROM CRISP AND GUNN'S QUARRY, WEST HOBART

Maxwell R. Banks
University of Tasmania

During the afternoon of Wednesday, 28th September, 1960, Dr. J.A. Townrow, Research Fellow in Palaeobotany, and the author were looking for fossil plants in the Triassic shales on the upper bench of Crisp and Gunn's Quarry, Arthur Street, West Hobart, when the author found a jaw bone with teeth in a loose block. The following day he returned with assistance and with the help of a couple of quarrymen uncovered and collected quite a number of bones, all from the one horizon in the block. The bones were identified as belonging to a reptile related to *Chasmatosaurus*. The excavation and piecing together of the bones began with the help of A.J. Harrison, a third year student in Geology and Zoology. In August, prior to the discovery of the reptile, Professor Camp of the University of California, Berkeley, who was undertaking a tour of the Triassic rocks of Australia looking for fossil vertebrate animals, had written from Western Australia to arrange the Tasmanian part of his tour. Arrangements were made but we were not sanguine of his success as few discoveries had been made here despite some search. Early in October he arrived and after seeing the specimen offered his expert assistance in preparing and studying the fossil. This was accepted and a prolongation of his stay made possible by the University. The directors of Crisp and Gunn Pty. Ltd. then donated the specimen to the University. Professor Camp spent the next six weeks carefully preparing and mounting the fossil and making a detailed study of it. The coincidence of Professor Camp's visit and the discovery were very fortunate as he is an acknowledged authority on Triassic reptiles. The specimen (Number 54655 in the collection of the Geology Department) is now mounted in plaster in a large wooden, glass-covered box and plaster and specimen have been sprayed with a very thin film of lacquer to prevent disintegration of the bones by air. This unique specimen is in the fireproof vault at the Tasmanian Museum where it will remain until adequate fireproof facilities are available at the University. At one stage it was hoped that plaster casts of the specimen could be prepared but the bones are too delicate to permit this to be done with safety.

This is not the first discovery of vertebrate fossils in Triassic rocks in Tasmania. In 1856 workmen found the thigh bone of an amphibian (a salamander-like creature) in one of the sandstone quarries near Government House in Triassic rocks (about 200 million years old) and this bone is still in the Tasmanian Museum. In 1889 quarrymen found fish in sandstones at the southern end of Knocklofty. One of the fish is in the Tasmanian Museum but others were lost. In 1890 a well-preserved fish was found in Triassic rocks near Tinderbox Bay and this also is in the Tasmanian Museum. In about 1949 a small fish was found by a student on an excursion in the shale quarry at Poets Road. Fossil reptiles are relatively abundant in rocks younger than Triassic on the mainland of Australia but the only one possibly Triassic comes from an unknown locality in Queensland. In about 1900 W.G. Thureau found a specimen, alleged to be a fossil reptile, in rocks on a coal mine dump at Tarleton near Devonport in Permian rocks (220–230 million years old). The specimen was sent to the National Museum of Victoria but cannot now be found. Fortun
ately a plaster cast was taken and is now in the Tasmanian Museum. The cast cannot be positively identified as that of a fossil reptile. Thus, as matters stand, the reptile discovered in 1960 is the oldest reptile known with certainty from Australia.

The fossil from Crisp and Gunn's quarry consists of upper and lower jaws, the roof of the skull and some of the bones from the back of the skull, some bones of the forelimb and the series of bones connecting the limb to the backbone, some ribs, some vertebrae from the chest, lumbar and tail region and many bones of the hind limbs. Although the bones are a little scattered on the rock surface, they occur more-or-less in their correct position, the skull and lower jaws at one end and the tail at the other, (see photograph on next page). The bones have been partly converted into a carbon compound which makes them rather fragile. The bones belonged to a lizard like animal, about three feet long, which had a rather long snout with many sharp backwardly-pointing teeth (see tentative reconstruction on cover). From these it is clear that it was a flesh eater and it may not be entirely fortuitous that the bone of a small amphibian occurs on the same bed of rock
in the position of the lizard's gullet. The forelimbs are weaker than the hind limbs and this suggests that the animal could walk on its hind limbs but it probably used all four legs most of the time.

The lizard apparently died in a swamp and after the flesh had rotted away the bones were scattered a little by the swamp waters. Seed ferns, pines and other plants grew in or near the swamp in which silt and rotting vegetation were accumulating. In the swamp were living tiny water fleas, small fish and salamander-like amphibians, and on the fish and amphibians the reptile probably preyed.

The reptile which will be given a name meaning "the Tasmanian Triassic lizard", is related to reptiles from South Africa and other parts of the world but belongs to a new genus in the sub-order Proterosuchia of the order Thecodontia, an order ancestral to the crocodiles on the one hand and to the dinosaurs on the other.

The discovery is significant in several ways. Firstly it will excite, in fact already has excited greater interest in the vertebrate fossils in Triassic rocks in Tasmania, will result in discovery of more such fossils and will provide a means of correlating these rocks with those in other parts of Tasmania, other parts of Australia and overseas. Already fish, amphibian and other reptilian bones have been found in the quarry, fish, amphibians and reptiles found at Granton, amphibians at Pittwater and Campania, and fish and amphibians found at Poatina. Secondly it is the oldest known reptile from Australia by some tens of millions of years. Thirdly it will add a little to the understanding of the evolution of the reptiles. Finally it will provide food for thought on the distribution of the continents in the earlier part of the Triassic Period and the routes taken by land animals in moving from one continent to others now separated from it by deep ocean.
CORRELATION CHARTS FOR THE CARBONIFEROUS, PERMIAN, TRIASSIC AND JURASSIC SYSTEMS IN AUSTRALIA

by


ABSTRACT

New correlation charts for the Carboniferous, Permian, Triassic and Jurassic Systems in Australia are presented.

The base of the Carboniferous is taken as the base of the Gattendorfia Zone of the European section. In Eastern Australia nine zones based on marine invertebrates (goniatites and brachiopods) and two microfloral zones are recognized.

The base of the Permian System is taken as the base of the Eurydesma Fauna or of the Glossopteris Flora, but this may be too high relative to the European and Russian type sections. Correlations of the Western Australian Permian with sections outside Australia are based on marine invertebrates (goniatites, brachiopods and pelecypods) and with Eastern Australia on brachiopods and pelecypods. Within Eastern Australia four invertebrate faunas (assemblage zones) are recognizable.

The base of the Triassic System is taken as the base of the Otocerasatan Stage in Western Australia and at the level in Eastern Australia best correlated microflorally with this level in Western Australia. This is taken provisionally as the base of the Narrabeen Group in New South Wales, but palynological evidence suggests that this level may be too low with reference to the base of the Alpine Triassic. Correlations within the Triassic System depend on marine invertebrates, and non-marine vertebrates within the Lower Triassic and on macroflora and microflora in these and younger rocks.

The entry of Classopollis is taken as the base of the Jurassic System. Marine invertebrates in Western Australia and microfauna and microflora generally are used for correlation within the system. The beginning of the Cretaceous Period is taken as the time of entry of Cicatricosisporites australiensis.

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INTRODUCTION

Following a request from Dr. Van Leckwijck, Secretary General, I.U.C.S., for a brief review and bibliography of the "Gondwana" Systems in Australia, Dr. Campbell, Dr. Dickins and the author, as Australian Representative on the Sub-Commission on Gondwana Stratigraphy, met briefly during a meeting of the Australian and New Zealand Association for the Advancement of Science in Melbourne in January to consider the feasibility of this and of completing this by the end of May 1967. It was considered feasible and it was decided to hold a meeting during April to complete the review in the form of correlation charts and a list of contributors or participants compiled. Owing to other pressures the author was unable to convene the meeting until 30th May. Stratigraphers and palaeontologists from all States were able to meet in Canberra over two days, 30th and 31st May, to finalise compilation of the correlation charts. This meeting allowed ready discussion of points of debate and resolution of some outstanding problems and shortened appreciably the time needed to prepare the charts. Drafting of the charts and preparation of the bibliographies then occupied two months.

Those invited to attend this meeting were Mr. B.E. Balme, Dr. P. Coleman (Univ. of W.A.), Dr. N.H. Ludbrook (Geol. Survey of S.A.), Dr. J. Dear, Dr. N.J. de Jersey and Mr. A. Williams (Geological Survey of Queensland), Dr. J. Rattigan and Dr. H.C. Hoelle (University of Newcastle), Dr. C.T. McElroy (University of N.S.W.), Dr. R.E. Hoss and Mr. R. Helby (University of Sydney), Dr. J.M. Dickins, Mr. E.C. Druce, Dr. P.H. Evans, Dr. J. Roberts, Dr. M.S. Skwarko (Bureau of Mineral Resources), Dr. K.S.W. Campbell (Australian National University); and Dr. J.A. Townrow and the author (University of Tasmania). In addition, the opinions or work of Dr. P.C. McKellar (Geological Survey of Queensland, Dr. B. Runnegar (University of Queensland), Drs. D.J. Belford, B.L. Mamet and P.J. Jones (Bureau of Mineral Resources) and Dr. G.A. Thomas (University of Melbourne) were sought and incorporated on some aspects of the correlations. Financial support from the Australian Academy of Science, University of Western Australia, Geological Survey of Queensland, University of Queensland, University of Newcastle, University of Sydney and University of Tasmania, cooperation of the Bureau of Mineral Resources and the hospitality of the Department of Geology, Australian National University, made the meeting possible.

The main responsibility for compilation of the charts fell as follows: Carboniferous – Dr. K.S.W. Campbell; Permian – Dr. J.M. Dickins; Triassic – M.R. Banks; Jurassic – Dr. N.J. de Jersey and A. Williams.
SEDIMENTARY BASINS
of
Australia & New Guinea
CARBONIFEROUS TO JURASSIC

Amended from Bureau of Mineral Resources Rec. 1983/159
Brief notes accompany each chart to clarify particular points or provide for minority views. The relationship of the notes to each chart is indicated by a number, e.g. 2, at the head of the relevant column on the chart. The latest information on radiometric dates is given in a paper by Evernden and Richards (1962, J. Geol. Soc. Aust., 9 (1), 1-49).

A map showing the sedimentary basin and state boundaries within Australia is included (Fig. 1) for ease in reference.

Within each chart the columns are arranged from left to right in the order north to south in Western Australia, South and Northern Australia then north to south in eastern Australia. Within each column the maximum thickness (in metres) of each formation is shown within the space allotted to that formation. Boundaries accurately delimited in time are shown as full lines, boundaries approximately located in time are shown as dashed lines (i.e. the overall position of the formation is clear but the boundaries are not clearly dateable) and the boundaries of formations of which both the general position and the age of the boundaries of which are unclear are shown as dashes alternating with question marks (i.e. -?-?-?-). Diachronous and interdigitating boundaries are shown in the usual diagrammatic fashions. No attempt is made to show angular relationships between superposed formations. Absence of rocks of a particular age is shown by vertical lines within the column. At the foot of each column is shown the bibliographic source or sources upon which the column is based, the numbers referring to numbered references in the appropriate bibliography.

Some formalisation of the biostratigraphy has been incorporated in the Carboniferous and Permian charts but the subcommittee considered any formalisation in the Triassic and Jurassic charts premature.
The more important Triassic sections are shown for each basin. Several minor occurrences are dealt with in the notes which follow.

1. A summary of the Triassic succession in the Carnarvon Basin based on three or four wells in the northern part of the Basin and one of the offshore wells was provided by B.E. Belme. "Locker Shale: This has a maximum known thickness of 520 m. although it has been completely penetrated in only one well. It is marine and of Scythian age, correlating with the Rockalera Shale in the Perth Basin and the Blina Shale in the Canning Basin. Hungaroo Beds: This formation has a maximum known thickness of 90 m. and consists of alternating sandstone and shale, with a rich microflora. The lower part of the unit appears to be marine as it contains abundant spinose acritarchs... The Hungaroo Beds probably range in age from late Lower to Upper Triassic."

2. Beds similar to those of the Leigh Creek Coal Measures and of approximately the same age occur in the Springfield Basin where they are about 260 m. thick. The Springfield Basin is about 320 km. north of Adelaide (Johnson 1960).

3. Triassic rocks have been recognised on microfossil evidence in the Coopers Creek Basin (= Cooper Basin) and in the Innamincka Basin (Deli-Frome-Santos 1961). Microfloras indicating correlation with the Rezen Formation, Clematis Sandstone and Koolayember Formation of the Bowen and Galilee Basins have been recorded (Evans 1966c).

4. The Warang Sandstone is the name used for Triassic sandstones at the northern end of the Galilee Basin (de Bretizel 1966) and was used on the preliminary edition of the Galilee 1:250,000 Sheet (1965).

5. In the northernmost part of the Bowen Basin the Garborough Sandstone occurs and is correlated with the Clematis Sandstone. The
overlying Teviot Formation is correlated with the Woolayember Formation. (J. M. Dickins pers. comm.)

6. Some confusion exists about the nomenclature of Triassic formations in the Bowen and Surat Basins. The Gabawin Formation has been used to cover the Woolayember, Clematis and Rewan Formations (Mack 1963) but in its type area is a correlate of only the Rewan Formation (P. R. Evans pers. comm. and 1964).

The Wandoan Formation has been used to include the lower member of the Bundamba Formation in the old, wide sense, a unit now referred to as the Precipice Sandstone and Evergreen Formation, both of Jurassic age (see Jurassic Chart). In the type area the Wandoan Formation consists of correlatives of the Clematis Sandstone and Woolayember Formation (Bastian and Arman 1965, Union Oil 1965b).

7. The Callide Coal Measures which occur in the northern end of the Yarrol Basin, are correlated with the Ipswich Coal Measures.

8. "The Lower and Middle Triassic Brooweena Formation consists of an estimated thickness of 1850 m. of quartzose sandstone, subgraywacke, feldspathic graywacke, siltstone, mudstone, conglomerate and minor developments of acid tuff in the type area. The thickness reaches 3350 m. northwest of Childers." (P. Ellis, Geological Survey of Queensland).

9. The Tarong Beds from the Nanango area on the northerly extension of the Esk Rift (Cribb 1960) are correlated with the Bundamba Group (sensu stricto).

10. The Ipswich Coal Measures contain, from the base upwards, the Kholo Sub-group (including the Mt. Crosby Insect Bed), the Tivoli, Booneena and Blackstone Formations (Allen 1961; Allen and Staines 1959).

11. A small basin, the Lorrie Basin, on the north coast of New South Wales contains conglomerate, sandstone, shale and some coal, forming the Camden Haven "Series" (Voisey, Proc. Linn. Soc. N.S.W., 1939) which is of the order of 100 m. thick and, on palaeobotanical evidence, Triassic.

12. The Triassic section in the Oxley Basin contains the Gunnee Beds considered to be equivalent to the Woolayember Formation. In other parts of this basin the Triassic is represented by the Wollar Sandstone and equivalent beds which are correlated on microfloral grounds with the Harrabeen Group, Hawksbury Sandstone and Wianamatta Group of the Sydney Basin." (R. Helby, pers. comm.).
13. The Narrabeen Group contains, from the base upwards, the Hun- 
morah Conglomerate, the Tuggerah Formation, Collaroy Claystone 
and Cosford Formation. The Wianamatta Group consists of the Liverpool 
Sub-group (with the Ashfield Shale, containing Faracyclotosaurus, etc. 
at the base) overlain by the Camden Sub-group.

The base of the Triassic System in the Sydney and Bowen Basins 
has been taken for the purpose of the correlation chart as the base of 
the Hunmorah Conglomerate and the base of the Rewan Formation respect-
ively. Helby (pers. comm.), however, considers that the "shaley lower 
portion of the Hunmorah Conglomerate, the Coalcliff Sandstone, Wombarra 
Shale, the lower part of the Scarborough Sandstone and most of the Caley 
Formation may be Upper Permian. These contain a Glossopteris Flora 
in places and a microflora with Dulhuntyisoora parvithola, Densoisporites 
fibulatus, Quadrisporites horridus and other spores. This microflora 
'shows a strong similarity with one occurring in the Upper Permian Ch-
hidru Formation of the Salt Range Succession in Pakistan (B.E. Balme 
pers. comm.).'"

14. Correlated broadly with the Brady Formation on lithological and 
palaeontological grounds are the feldspathic sandstones and coal 
measures at Norwich (Longford), Avoca, Merrywood, Bingal, Mt. Nicholas, 
Cornew, Dalmayne, Douglas River, Coles Bay, Little Swanport, Colebrook, 
Richmond, Saltwater River, New Town, Sendfly, Catamaran, Mt. Lloyd, 
Plenty, Langloh and elsewhere.
### Correlation Table for the Triassic System in Australia

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<td>Fitzroy</td>
<td>Carnarvon</td>
<td>Perth</td>
<td>Leigh Creek</td>
<td>Cooper</td>
<td>Bowen &amp; Galilee</td>
<td>Mary-Borough</td>
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| 304 | 54 | 98 | 14 | 114 | 238 | 290 | 253 |
| 323 | 81 | 123 | 56 | 123 | 130 | 192 | 194 | 85 |
A CORRELATION CHART FOR THE
TRIASSIC SYSTEM IN AUSTRALIA.

by Maxwell R. Banks,
University of Tasmania.

for correlation chart see pocket
ABSTRACT

A correlation chart for the Triassic System in Australia is presented. The base of the System in Australia is taken as the earliest occurrence of the Lunatisporites pellucidus Assemblage Zone in a section of the Rewan Formation in the Bowen Basin, Queensland, and the base of the Jurassic System as the occurrence of Ceratosporites helidonensis with Classopolis and Retitriletes austroclavatitides in the Upper Woogaroo Subgroup in a section near Ipswich in the Moreton Basin. Correlations within Australia are based predominantly on microfloral evidence with supporting evidence from fossil vertebrates and, to a minor degree, on macroflora. Correlation of Australian units with those in other continents depends on ammonites, bivalves, conodonts, vertebrates and microflora in Lower Triassic units and on vertebrates and microflora for higher units.

A cross-indexed bibliography of the Triassic System in Australia covering 21 years to the end of 1973 is also provided.

INTRODUCTION

The Triassic System in Australia consists predominantly of continental deposits up to about 2.5 km thick but with estuarine, deltaic or shallow marine sediments within the present land areas only in the Fitzroy, Perth and Maryborough Basins (see map, fig. 1). Marine sections have been reported off-shore along the North-west Shelf and in the Bonaparte Gulf Basin (Laws and Kraus 1974). Sections in the Carnarvon (Thomas and Smith 1974), Perth and Tasmania Basins span or almost span the Period but sections in other basins represent only parts of the Period or are very discontinuous. Continuity of even the long sections is not yet demonstrated.

Correlations made prior to about the last decade depended heavily on the lithostratigraphical and biostratigraphical successions in the Sydney Basin. Discovery of marine Triassic rocks in the Perth and Gympie Basins and the extensive use of palynological evidence especially in the Bowen, Moreton, Sydney and
Perth Basins now provide much broader bases for correlation.

The microfloral succession known in Queensland is the most complete yet published but is thought to have gaps in it. An apparently continuous section in the Tasmania Basin has not yet been adequately sampled palynologically and few details are yet published on the palynology of the apparently complete section in the Perth Basin. Species within the succession which are useful for intra- or intercontinental correlation are shown on the chart.

Correlations implied on the chart depend on published information as shown on the chart and in the reference list. The correlations are based predominantly on palynological evidence with support from macroflora, invertebrates, especially ammonoids, and vertebrates. Several people have been kind enough to criticise a preliminary chart and their help is acknowledged elsewhere. The author must, however, accept responsibility for the chart as presented. Correlations implied on the chart are similar to those implied by Anderson and Anderson (1970) probably because both sets are based on essentially the same data.

The evidence for the correlations adopted is shown in the form of italic numbers placed in the space provided for each formation, the numbers referring to the taxa listed below the chart, taxa the range of which is shown in the column entitled "Australian Biostratigraphy". The ranges shown are based particularly on ranges known in the Bowen and Clarence-Moreton Basins.

The numbers in the top row of the chart refer to localities shown on the accompanying map (fig. 1), and in the bottom row to numbered references in the bibliography herewith. Wherever information is available, the thicknesses shown are known maxima in metres.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge helpful criticism from Mr. Wayne Harris, Geological Survey of South Australia, Dr. Robin Helby, formerly Geological Survey of New South Wales, Dr. Noel de Jersey, Geological Survey of Queensland and especially Dr. Rob. McTavish and Dr. G. Dolby of West Australian Petroleum Pty. Ltd. Mr. S.M. Forsyth, Geological Survey of Tasmania, helped from time to time.

LIMITS OF THE TRIASSIC SYSTEM AS USED IN AUSTRALIA

If time is defined as a dense set of events (Whitrow 1961, p. 161, 164),
any duration (such as a geological Period) consists of all those events which include and occur after some initial instant (a set of events any two of which are simultaneous and such that there is no event not contained in the set which is simultaneous with them all), and before the instant which initiates the next duration. Thus the Triassic Period may be defined as a duration between and including some initial instant and some other instant which initiates the Jurassic Period. In the interests of clarity, reproducibility, usefulness and stability the initial instant should have the following characteristics:

(a) be clearly definable (especially from the preceding instant),
(b) be readily recognisable,
(c) be amenable to far-reaching correlation, preferably by several methods,
(d) be one of a dense set of events recorded within the one geological section (i.e. preferably be within a section with "continuous" deposition),
(e) be recorded by a rock at a particular level ("marker point") in a specified rock section ("stratotype"), the marker point and stratotype meeting the other conditions listed,
(f) be widely (preferably internationally) recognised as the initial instant.

These conditions are listed by or follow from conditions enumerated by Ager (1964), George et al. (1967, 1969).

Most successions likely to include the base of the Triassic System fail on one or other of the conditions listed above, a situation which has resulted in difficulties and disagreements concerning the boundary. Only sections in the Armenia-Iran area, Kashmir and the Himalayas and East Greenland seem to satisfy them. Sections at Kuh-e-Ali Bashi in north-western Iran include, limestone with Paratirolites and other limestones with ammonoids of Dorashamian Age (Rostovtsev and Azaryan 1973), the former overlain by the Early Triassic Elikah Formation (Teichert et al. 1973) correlated with the Kathwai Member on the Salt Range and containing Claraia and conodonts. Apart from other considerations placement of the base of the Triassic
at the base of the Elikah Formation would not be particularly wise because of lack of ammonoids in that formation although presence of *Anchignathodus isarcicus* provides means of correlation with the Kathwai Member and the lower part of the Werfen Formation.

The section in the Kap Stosch area, East Greenland has been recently investigated by Teichert and Kummel (1973) who inferred a break "equivalent to at least the Dzhulfian Stage". In many places the "base of the Triassic" is represented by a marked change in lithology. This section fails then on lack of continuity.

Lack of continuity as shown by Kummel and Teichert (1970) also precludes use of the section in the Salt Range as a reference section.

There remain sections in Kashmir and the Himalayas. Of these, those in Kashmir are to be preferred as they are thicker and thus less likely to be condensed or have gaps in them. Attention must then be focussed on the Guryul Ravine section described recently by Nakazawa et al. (1970). Deposition appears to be continuous and fossils such as *Claraia* occur in beds below that in which *Otoceras* enters the section. Thus on present indications it appears best to define the beginning of the Triassic Period as the time of beginning of deposition of the lowest bed (Bed 52a) containing *Otoceras* in the Guryul Ravine near Srinagar, Kashmir. This may not be precisely contemporaneous with the beginning of deposition of the lowest bed containing *Otoceras* in the section at Lilang, Spiti, in the Himalayas, an horizon commonly used as the base of the Triassic Standard System (Tozer 1971, 1972). At Lilang the *Otoceras woodwardi* Zone overlies beds with *Cyclolobus insignis* (Diener 1912, p. 142) suggesting the presence of a break in continuity. Both sections suffer the disadvantage that no beds of Changhsingian (part of Dorashamian) Age have yet been discovered in them (Waterhouse 1973, p. 310). Thus it seems that there is at present no known completely satisfactory section for the emplacement of the "marker point" marking the base of the Triassic System. One solution might be to follow Waterhouse (1973) in making the base of the Smithian Stage, the base of the Triassic System. This would have considerable practical advantage in that the "point" could be placed
within a continuous fossiliferous section in Smith Creek, Ellesmere Island. However, despite Waterhouse's arguments (1973), this would appear as a major departure from customary understanding and introduce, at least initially, great confusion. Use of the base of the Otoceras Zone in Kashmir (Bed 52a; Guryul Ravine) or in Spiti, preferably the former, seems for the time being the best solution.

Emplacement of a "marker point" in either of the Guryul Ravine or Lilang successions at the first appearance of Otoceras does not help particularly in determining the position of the base of the Triassic System in Australia. Ammonoids are known only in the Gympie-Maryborough and Perth Basins, those from the Perth Basin being the older. Evidence on the age of these has been re-assessed recently by McTavish and Dickins (1974) and Skwarko and Kummel (1974). The lowest "Triassic" marine beds, Kockatea Shale, in the Beagle Ridge Bore contain Claraia stachei and another species of Claraia and are probably Early Griesbachian but, if the point is established at the base of bed 52a in the Guryul Gorge, could be very late Permian. At the same level as Claraia occur Kraeuselisporites cuspidus, K. saeptatus, Lundbladispora playfordi, L. willmotti, L. brevicula, Lunatisporites pellucidus and L. obex. The presence of Claraia, Ophiceras and L. pellucidus suggest correlation with the Kathwai Member in the Salt Range and in turn with part of the Otoceras Zone in the Himalayas. L. pellucidus enters the section in the Salt Range in the Kathwai Member (Balme 1970). Higher beds with qualitatively essentially the same microflora are regarded by McTavish and Dickins (1974) as Late Griesbachian to possibly early Spathian in age. The Kockatea Shale rests unconformably on the Permian Carynginia Formation and the Beagle Ridge section is thus not suitable as one in which to designate the base of the Triassic System in Australia. More continuous deposition apparently occurred in the Tasmania, Sydney and Bowen Basins. Too little is known of the palynology of the Tasmania Basin to permit establishment of a base within it. In the Sydney Basin the base of the Lunatisporites pellucidus Assemblage (i.e. the assemblage zone corresponding to that in the Beagle Ridge Bore) has been widely recognised (Helby 1973, p. 147) but the detailed palynological biostratigraphy in relation
to the lithostratigraphy has not been published so that a suitable horizon and locality for the Australian "marker point" at the base of the Triassic System cannot be specified with confidence within the Sydney Basin. A position within the thicker part of the section, i.e. in the sections penetrated by the Balmain Shaft, Cremorne No. 2 bore or the Windeyer Bore, would appear to be most appropriate.

The section about which most palynological information has been published is that in the Bowen Basin (de Jersey 1970a) but _L. pellucidus_ does not occur in the lowest Triassic unit, the Rewan Group, and most of the other components of the microflora in the Perth Basin enter well above the base of the formation (between 89.6 m and 69.9 m in D.R.D. 28), with a few even higher. The basal portion of the Rewan "is tentatively regarded as Lower Triassic" (de Jersey 1970a, p. 27) whereas higher portions are regarded as clearly Triassic. On the basis that the assemblage rather than a particular species thereof is used for correlation, the section beginning between 89.6 m and 69.9 m in D.R.D. 28 might be taken as a correlate of the lower part of the section in the Beagle Ridge Bore and the first convenient horizon below it taken as the base of the Triassic System. In fact, following Balme (1969b, p. 111), Helby (1969c, p. 405; 1973, p. 145) and Anderson and Anderson (1970, chart 6) and on the basis of the horizon of entry of _L. pellucidus_ into the Salt Range section (Balme 1970, p. 426), the base of this assemblage is probably the position most likely to correspond to the base of the Triassic System. One could thus establish an Australian "marker point" between the two levels quoted in D.R.D. 28. For the sake of later clarity and precision the exact positioning of the spike would need closer palynological control than is now available, preferably within a continuously fossiliferous succession.

The base of the Jurassic Standard System may be taken as the base of the Blue Lias in the Watchet area, Somerset, United Kingdom (George _et al._ 1969, pp. 159-160). Lack of marine Jurassic beds of this age in Australia precludes direct correlation. In the correlation chart presented at the First Gondwana Symposium (Banks _et al._ 1969) the entry of _Classopollis classoides_ was taken.
as the base of the Jurassic System in Australia. Even at that time the use of
this convention was of doubtful validity in view of the record of this species
in the Rhaetian of Britain (Chaloner and Clarke 1962). The situation is now
complicated by the reassignment of specimens previously assigned to *C. classoides*
to several other species and of the species previously called *Glis copollis meyeriana* to *Classopollis* (de Jersey 1973c). Several possibilities warrant
examination.

The first of these possibilities is to place the boundary at the entry of
*Classopollis simplex* in G.S.Q. Ipswich 4, sited near Lowood just north of Ipswich
in the Moreton Basin (de Jersey 1971a pp. 2, 41-3; p. 24). This has the advantage
that, of the local species of *Classopollis*, only *simplex* is restricted to the
Jurassic System overseas (de Jersey, 1973c, p. 132). However, in the bore hole
cited the Helidon Sandstone rests with a paraconformity on the Raceview Formation
and all the Upper Woogaroo Subgroup is thought to be missing. As it is desirable
that the base of a System be within a conformable sequence this bore-hole does
not provide a suitable type area for establishment of a "marker point".

Bore hole G.S.Q. Ipswich 1, drilled just south of Ipswich (de Jersey 1971a,
pp. 20, 40) has more potential from this point of view but palynological information
is lacking on the upper part of the section. However, between 147.4 m (483ft. 7ins.
and 117.15 m (384ft. 6ins.) *Ceratosporites helidonensis* enters the section in small
numbers and is associated with rare *Classopollis meyeriana*. Higher in the section
(at 58.5 m) these species are more abundant and are associated with *Retitriletes
austroclavatitides* in a microflora closely comparable to that in the basal part
of the Helidon Sandstone in which *C. simplex* occurs (de Jersey 1971a, p. 23).
Thus on present evidence a convenient boundary might be taken as the entry of
*Ceratosporites helidonensis* in the drill hole G.S.Q. Ipswich 1, but a more compelling
case could be advanced for a higher level, i.e. between 117.15 and 58.5 m, on the
basis of significant numbers of *C. helidonensis*, *Classopollis* and *R. austroclav-
atitides*. De Jersey (1975, pp. 163, 170-71) also placed the boundary at about
this position and from fig. 14.3 (p. 163) would appear to favour the higher of
the two positions.

However, even this position might be too low. Thus Geiger and Hopping (1968, p. 7) noted that *C. meyeriana* first appears in Middle Keuper rocks and that while *C. torosus* occurs first in outcrop in basal Jurassic rocks, it occurs in cores in rocks just older than Rhaetic. Warrington (1974, p. 143) went further and reported both species in the Red (Keuper) Marls and that *Retitriletes austroclavatitides* (Cookson) occurs in the Upper Rhaetic beds in north Somerset. De Jersey (1971a, p. 9) noted that *R. austroclavatitides* has also been reported from the Middle Rhaetic in Germany. Morbey and Neves (1974, p. 162) took as the base of the Rhaetic in Austria the first appearance together of *Classopollis torosus*, *Granuloperculatipollis rudis*, in association with *Classopollis meyeriana* and *Ovalipollis ovalis*. Orbell (1973) examined the palynology of the British Rhaet-Liassic and it is clear from his work that the use of *Classopollis torosus*, *C. meyeriana* and *R. austroclavatitides* to mark the base of the Jurassic is invalid as their entry, mutual occurrence and abundance predate this boundary. He showed pictorially in Table 4 that the boundary lies within the *Heliosporites* Zone which, together with the underlying *Rhaetipollis* Zone contains the above-mentioned spores. Even if the boundary was taken as suggested by Orbell (1973, p. 33) at the base of the *Heliosporites* Zone, the two Australian horizons are likely to predate this, although the higher one may approximate to it. The base of the *Trisaccites variabilis* Zone (de Jersey 1975) is clearly younger than the beginning of the Jurassic. One must, with de Jersey (1975, pp. 170-171), place the base of the Jurassic within the *Polycingulatisporites crenulatus* Zone and probably within the *Ceratosporites helidonensis* Subzone, but the exact position is not yet clear. The situation needs more clarification, perhaps by more intense palynological work on cores in the Ipswich area or by work on off-shore Western Australian sections.

For the present the Triassic System in Australia may be taken approximately as the rocks deposited between the time of entry of the *Lunatisporites pellucidus* assemblage into the Rewan Group in D.R.D. 28 in the Bowen Basin and the time of formation of the rock containing significant numbers of *C. helidonensis*, *Classopollis*
and *R. austroclavatitides* at 58.5 m in drill hole G.S.Q. Ipswich No. 1 in the Moreton Basin. An even higher horizon may well be more valid but resolution of the question must await further work, possibly on Western Australian sections.

**AUSTRALIAN MICROFLORAL ZONES**

Balme (1964, p. 65-8) recognised two microfloras in the Triassic System in Australia, an older *Taeniaesporites* Microflora, only certainly known in Western Australia at the time, and a younger and more widespread *Pteruchipollenites* Microflora. Evans (1966) recognised eight sub-units which he assigned to three units, Tr 1, 2 and 3. The lowest sub-unit, one with abundant *Quadrisporites horridus*, is now generally regarded as Permian. Unit Tr 1b begins with the entry of *Taeniaesporites*, Unit Tr 2a with the entry of *Lundbladispora*, Unit Tr 2b with the entry of *Aratrisporites*. In Unit Tr 3 *Falcisporites* spp occur in great abundance. Within this unit Unit Tr 3b commences with the appearance of *Aratrisporites fischeri*, Unit Tr 3c contains neither
Aratrisporites nor Duplexisporites gyratus, entry of the latter of which marks the base of Unit Tr 3d. Evans' system has had to be somewhat modified. Helby (1969c, pp. 404-5) recognised as Early Triassic a microflora with Lunatisporites pellucidus, several species of Striomenosaccites and several large species of Protohaploxypinus. This is followed by a microflora with Densoisporites, Lundbladispora, Kraeuselisporites and Lunatisporites. Subsequently Aratrisporites enters the section. Later assemblages are dominated by Alisporites and Osmundacidites (Helby 1969d, p. 417) with Duplexisporites entering the section within this assemblage but about half way through it. At an even higher level Cadargasporites enters (Helby 1969d, p. 423). Anderson and Anderson (1970, Chart 6, following Helby) recognised a "Lunatisporites" pellucidus Zone, followed by the Protohaploxypinus samoilovichii Zone and then a Falcisporites Zone with four sub-zones, A, B, C and D.

A recent work, that of Helby (1973), recognised four assemblage zones of Triassic age in New South Wales. In order from the base upwards these are the Lunatisporites pellucidus, Protohaploxypinus samoilovichii, Aratrisporites tenuispinosus and A. parvispinosus Assemblage Zones. He also showed in tabular form the relationship between earlier biostratigraphic schemes (his fig. 2).

Despite some lacunae, the sections in south-eastern Queensland not only span more of the Triassic Period than others in Australia but more palynological work has been published on them (by de Jersey and his co-workers). Unfortunately no succinct statement on the complete microfloral succession is available but a paper by Dr. Jersey (1975) made formal definitions of some biostratigraphic units covering the upper parts of the Triassic System in Queensland. By considering papers by de Jersey and others published between 1964 and 1973, a biostratigraphic system based on first appearances, sharp increases in abundance or microfloral assemblage can be deduced as follows:

Top
27. Entry of Classopolis simplex (in Helidon Sandstone).
26. Entry of Ceratosporites helidonensis in the Ripley Road Formation.
Rhaetian

25. Entry of *Foveosporites moretonensis* and *Polycingulatisporites moeniensis* (in the Raceview Formation).


Norian to Karnian

23. Presence of *Osmundacidites parvus* (high in the Blackstone Formation).

22. Entry of *Semiretisporis antiquus* (low in the Blackstone Formation).

21. Presence of *Semiretisporis denmeadi* (Tivoli Formation to lower Blackstone Formation).

20. Entry of *Lycoespora pallida* (Tivoli Formation).


18. Entry of *Cycadopites tivoliensis* (Mt. Crosby Formation).

17. Entry of *Craterisporites rotundus* (Mt. Crosby Formation).

Ladinian

16. Presence of *Cadargasporites senectus* (Moolayember Formation).

Anisian

15. Presence of *Protohaploxypinus jacobii* (low in Moolayember Formation).


13. Entry of *Rugulatisporites trisinus* (Clematis Formation).

Scythian

12. Entry of *Triadispora crassa* (high in Rewan Formation).

11. Entry of *Aratrisporites tenutispinosus*.

10. Entry of *Tigrisporites playfordi*.

9. Entry of *Lophotriletes novicus*.

8. Increase in abundance of *Falcisporites* and *Aratrisporites* (in upper part of Rewan Formation).

7. Entry of *Aratrisporites rugulatus* and *Voltziaceaesporites heteromorpha*.

6. Entry of *Aratrisporites wollariensis* and *Kraeuselisporites cuspidus* (in middle part of the Rewan Formation).
5. Entry of **Lundbladispora willmotti** (in middle part of Rewan Formation).

4. Entry of **Densoisporites playfordi**, **Lunatisporites obex** and **Kraeuselisporites saeptatus** (in lower part of the Rewan Formation).

Permian


2. Entry of **Cyathidites breviradiatus** and **Osmundacidites senectus**.

1. Entry of **Dictyophyllidites mortoni** and **Discisporites psilatus** (base of Rewan Formation).

Base of Rewan Group

0. Entry of **Lunatisporites novimundus** (Late Permian).

The Rewan also contains many species found in older rocks. The characteristically Triassic genus **FaZcisporites** entered the record in the Permian System but did not become abundant until the later part of the Scythian.

Because of lack of microfloral assemblage overlap between the Moolayember Formation and Ipswich Coal Measures and between these Coal Measures and the Bundamba Group and because of ages of these units derived by correlation with overseas sections, de Jersey has in numerous publications shown gaps in the sequence between them.

De Jersey (1975, pp. 164-170) defined three zones and a subzone. The lowest of these, the **Duplexisporites problematicus** Zone is based on a section of the Esk Formation and would cover Events 14 to 16 inclusive in the above list. Above this but not continuous with it is the **Craterisporites rotundus** Zone, corresponding to Events 17 to 23. Higher still and again not continuous is the **Polycingulatisporites crenulatus** Zone which extends from Event 24 well into the Liassic and which includes the **Ceratisporites helidonensis** Subzone beginning with Event 26 and also extending into the Liassic.

From range charts published by Balme (1970) and comments by Helby (1973), it is clear that the biostratigraphic scheme based on known Queensland ranges does not have general application. Thus **Osmundacidites senectus** (Event 2) occurs in the Permian Chhidru Formation in the Salt Range where **Muskiosporites radiatus** (Event 3) enters even earlier (in the Amb Formation). The latter species also
occurs in the Permian *P. reticulatus* Assemblage in New South Wales. *Densoisporite playfordi* (Event 4) enters the Salt Range section about half way up the Chhidru Formation as also does *Kraeuselisporites cuspidus* (Event 6). *Aratrisporites* enters the Queensland section at Event 6 after which *Lophotriletes novicus* (Event 9) enters. The latter species occurs in the *Aratrisporites tenuispinosus* Assemblage in New South Wales but is known as early as the Amb Formation in the Salt Range. *Tigrisporites playfordi* (Event 10) occurs first in the *P. reticulatus* Assemblage of the Late Permian of New South Wales and ranges from the Chhidru Formation of the Salt Range into the Mesial Triassic. The palynomorphs noted from the *Aratrisporites parvispinosus* Assemblage in New South Wales enter the Queensland succession within the interval of Events 14 to 19 inclusive. *Lunatisporites pellucidus* used as name species for the earliest Triassic assemblage in New South Wales does not enter the Queensland succession until much later (in the Esk Formation (Events 14-16)). Brief mention has already been made of the occurrence of a few taxa in sections outside Australia and ranges of some taxa are shown on the correlation chart. De Jersey (1970a, pp. 26-27) pointed out that although *Lunatisporites (=Striatisaccus) novimundus* enters sections in Central Europe at the base of the Triassic, it has also been recorded in Permian rocks in Great Britain and occurs in rocks as young as Keuper (de Jersey 1970a, p. 16).

In the Queensland section *O. senectus* does not range above about the middle of the Rewan Formation but has been recorded from the Late Triassic Leigh Creek Coal Measures (Playford and Dettman 1965, p. 135). *Calamospora tener*, reported by de Jersey (1970a, p. 4, fig. 3), from within the Rewan Group makes its first appearance in European sections at the base of the Muschelkalk (de Jersey and Hamilton 1967, p. 24). The specimen figured by de Jersey (1970a) came from almost the top of the Rewan, above the entry of *Triadispora crassa* (event 12).

*Grebespora concentrica* occurs elsewhere in Scythian and Anisian microfloras but not Permian ones (de Jersey 1970a, p. 27). *Voltsiaceassporites heteromorpha* enters the European sections in the Middle Bunter (de Jersey 1970a, p. 26; 1972a) and continues into the Keuper (Warrington 1970, p. 196). *Lundbladiispora brevicula* enters the Salt Range section at the base of the Mittiwali Member (Balme 1970) which is Gyronitan (Kummel 1966) (Late Griesbachian, Tozer 1965). *Triadispora crassa*, noted by de Jersey (1970a, p. 15, p. 26) as first occurring in the Upper
Scythian and continuing to the Karnian, has been reported by Warrington (1970, p. 194) from the Röt, Upper Bunter and Keuper. The type of *Accinctisporites ligatus* has recently (Scheuring 1974, pp. 207-209) been shown to be identical with *Lunatisporites acutus*. It is known to range from the Basal Muschelkalk to Upper Karnian and Upper Keuper (de Jersey and Hamilton 1967, p. 14; Warrington 1970, p. 192). *Triadispora falcoa* is known in Europe from Röt to Keuper (Warrington 1970, p. 194). *Protohaploxypinus jacobii* which occurs low in the Moolayember Formation is recorded elsewhere in rocks ranging from Permian to Anisian in age (de Jersey and Hamilton 1967, p. 17; Geiger and Hopping 1968). *Annullispora folliculosa* has been recorded from the Rhaetian of Svalbard (Smith 1974, p. 177) and New Zealand (Dickson 1972) and from the Liassic of Poland (de Jersey 1970b, p. 9). *Stereisporites perforatus*, which enters the Queensland section in the Mt. Crosby Formation first appears in European sections in the Karnian (de Jersey 1971b). *Baculatisporites commaensii*, which enters the Queensland section a little higher than *S. perforatus*, enters the European section a little lower, in the upper Muschelkalk (de Jersey 1970b, p. 7). *Apiculatisporis globosus* which occurs in the higher parts of the Ipswich Coal Measures also enters the European section in the Karnian. *Polycingulatisporis crenulatus* occurs first in Middle Rhaetic rocks in Germany and also occurs in Liassic rocks (de Jersey 1970b, p. 10).

Although in a general way taxa enter the Queensland succession in the same order as their first appearances overseas, there are many anomalies in detail which may be due to ecological factors, different rates of migration or inadequate sampling. The anomalies do, however, render the methods of correlation by first appearance or by overlap at least suspect and probably inapplicable. Correlation by similarity of microfloral assemblage would appear to be the only useful method.

Development of a generally applicable biostratigraphic scheme for the Triassic System in Australia will have to await publication of palynological work on rocks in the Sydney Basin, perhaps work on the Poatina Section in Tasmania and more particularly work on the sections in the Carnarvon and perhaps offshore Bonaparte Gulf Basin.

**ACRITARCHS**

Acritarchs, commonly interpreted as indicating some marine influence in
deposition have been reported from the Rewan, Moolayember and Esk Formations in Queensland (de Jersey 1968, 1970a, 1972a; Evans 1966), the Wianamatta Group and Tuggerah Formation in the Sydney Basin (Helby 1969a; Mayne et al. 1974, p. 207), the Kockatea Shale (Balme 1963) and Woodada Formation (Balme 1969a) in the Perth Basin, the Locker Shale in the Carnarvon Basin (Balme 1969a) and the Blina Shale (Evans 1966).

MACROFLORA

Although macroscopic plant remains are very common on some horizons in some places and have been known at least since 1845 (Strzelecki), their value for correlation still appears somewhat limited. Ranges of a few forms which seem useful are shown on the chart, the range being based on correlations using microfossils.

In the Sydney Basin, Schizoneura australis occurs in the Munmorah Conglomerate and Schizoneura gondwanensis and Dicroidium narrabeenense in higher formations and then Cylostrobus sydneyensis in the Gosford Formation (Raggatt, p. 407 in McElroy 1969). Schizoneura also occurs low in the Triassic System in southern Tasmania and Cylostrobus higher up, in the Knocklofty Formation which also contains a microflora with Densoisporites playfordi and Lundbladispora brevicula. Lepidopteris madagascariensis from the Narrabeen Group, the Hawkesbury Sandstone, the Esk Beds and the Nymboida Coal Measures (Flint and Gould 1975) suggests correlation with the Early Triassic Sakamena Group of Madagascar and the Cynognathus Zone of South Africa.

Flint and Gould (1975) listed other plants which occur in the Esk Beds but not in the Ipswich Coal Measures. These include Asterotheca hillae, Dictyophyllum davidii, Cladophlebis lobifolia, Lepidopteris madagascariensis, Dicroidium eskenense, Anthrophyopsis grandis, Pterophyllum nathanii, Nilsonia cf. princeps, Pseudoctenis eathensis and Taeniopteris crassinervis. However A. hillae occurs in the Tingulpa Formation correlated by de Jersey and Hamilton (1965a) with the Ipswich Coal Measures on palynological grounds and in the "Feldspathic Sandstone" at Mt. Nicholas in Tasmania also correlated with the Ipswich Coal Measures.

The Ipswich Coal Measures contain a rich flora including Neocalamites carrerei, Asterotheca fuchsii, Cladophlebis concinna, Dicroidium dentatum, Yabeiella brakbuschiana, Y. mareyesciaca, Pterophyllum multilineatum and Linguifolium demmeadi.
(Flint and Gould 1975). Similar floras occur in the Red Cliff Coal Measures in northern New South Wales (ibid.) and in the Late Triassic coal measures of Tasmania. Within the Tasmania Basin Townrow (1966) has suggested that a zone with *Dioicidium odontopteroides* is followed by one with *D. obtusifolium*.

Calcareaous algae have been reported from the Bald Hill Claystone and Wianamatta Group in the Sydney Basin.

**INVERTEBRATES**

Foraminifera have been reported from the Liverpool Sub-group of the Sydney Basin (Lovering 1954a), perhaps more authentically from the Tuggerah Formation and Bald Hill Claystone (Mayne *et al.* 1974) and from the Early Triassic rocks of Western Australia (McTavish 1973) but are of no stratigraphic significance.

Mayne *et al.* (1974) recorded sponge spicules from the Tuggerah Formation. The "Tarlton Formation" of the Huckitta area in the Northern Territory also contains sponge spicules but may not be Triassic.

A worm (*Spirorbis*) occurs in the Kockatea Shale (Dickins and McTavish 1963) and a worm burrow (*Diplocraterion*) in the Blina Formation (Veevers and Wells 1961, p. 110). These too lack stratigraphic significance but are palaeoecologically interesting.

Inarticulate brachiopods (*Lingula*) have long been known in the Blina Shale (see Veevers and Wells 1961, p. 110) and also occur in other Early Triassic sediments in Western Australia with other undescribed brachiopods (McTavish 1973, p. 279). Again these are of palaeoecological rather than stratigraphic interest.

Many years ago Etheridge described a gasteropod *Tremonotus maideni* from the Hawkesbury Sandstone (see Mayne *et al.* 1974). The bellerophontid gasteropod *Stachella* was noted by Runnegar (1969) from near Woondum (Gympie-Maryborough Basin) associated with ammonites. Standard (1964, ref. quoted by Branagan 1969) listed a gasteropod from the Hawkesbury Sandstone (Sydney Basin) and McTavish (1973, p. 279) noted minute gasteropods in the Lower Triassic of Western Australia.

Both marine and non-marine Pelecypoda have been described and the former have some stratigraphical significance. Marine pelecypods include *Bakevilia* sp., *Trigononucula* sp., *Claraia perthensis*, *C. stachei* and "*Anodontophora*" cf. *griesbachii*
from the Kockatea Shale (Perth Basin) for which they indicate an Early Triassic age (Dickins and McTavish 1963; McTavish and Dickins 1974). The significance of *Claraia stachei* has been noted earlier. *Pseudomonotis* sp. has been noted in the Blina Shale (Vevers and Wells 1961, p. 110). The Brooweena Formation in the Gympie-Maryborough Basin contains *Nuculopsis* sp., *Nuculanella* sp., *Schizodus*, *Myalina* sp., *Neoschizodus teres*, "Ctenodonta" *cordalbae* and *Bakevellia capricorni* a fauna suggesting a younger Triassic horizon than the bivalves in the Kockatea Shale but still an Early Triassic one. Fleming (1966b) considered that it was probably not older than Flemingitan (Late Dienerian).

Non-marine units contain pelecypods at Leigh Creek (*Unio eyrensis, Protovirgus jaensehi*), in the Springfield Basin (*Unio springfieldensis*), at Waterloo near Sydney (*Unionella wianamattensis*), in other parts of the Sydney Basin (*Unionella carnei, U. bowralensis, Protovirgus dunstani*), in the upper part of the Gosford Sub-group (Mayne et al. 1974), at and near Ipswich in the Moreton Basin (*Unio eyrensis, Mesohydridella ivesiensi*) (Ludbrook 1961) and in the Tingalpa Formation near Slacks Creek (*Unio eyrensis; Gould 1967*).

Ammonites have been described from the Kockatea Shale (*Glyptophiceras* sp., *Ophiceras* (*Discophiceras*) cf. *subkyotkicum*, *Subinyotes kashmiricus*) for which they suggest a Late Griesbachian to Smithian age (McTavish and Dickins 1974). Runnegar (1969) has described other ammonites (*Latisageceras woondumense, Dienero- ceras woondumense, Flemingites* sp., *Anaflemingites armstrongi, Paranorites queenslandicus, P. hillae, Pseudohedenstroemia* sp. and *Aratoceras* ? Sp.) from the Traveston Formation in the Gympie-Maryborough Basin and assigned a Late Dienerian or Early Smithian age to the horizon. Skwarko and Kummel (1974) have recorded further ammonites (*Proptychites* sp., ? *Koninokites*, ? *Paranorites* and *Gyronites*) from the Kockatea Shale in Dongara No. 4 borehole and suggest a Dienerian age for the occurrence. An outcrop of the Kockatea Shale near Mount Minchin has yielded *Aratoceras* spp., *Prionites* sp., *Hemiprionites* sp. and *Anasibirites kingianus* and was regarded by Skwarko and Kummel (1974, pp. 113, 117) as Smithian. Marine strata, from a bore hole in the Sahul Shelf were recognised as probably Early
Anisian by these same authors (op.cit., pp. 113, 115) on the basis of a ammonite, probably *Nicoledites*. This core also contained halobiid bivalve pieces.

Ostracodes have been found in the Wianamatta Group (Lovering 1954a) and Bald Hill Claystone (Mayne *et al.* 1974) in the Sydney Basin, and described from the Kockatea Shale (Jones 1970).

Conchostracans have long been known from the Wianamatta Group (*Euestheria cf. coghlanii, E. gienleensis, Palaeolimnadia wianamattensis*), lower units in the Sydney Basin (*E. coghlanii*) and from the Blackstone Formation in the Moreton Basin (*E. coghlanii, E. ipoviciensis*). They occur in the Knocklofty and Brady Formations in Tasmania (Tasch 1975). *Isaura* occurs as coquinas in the Blina Shale in the Canning Basin (Veevers and Wells 1961, p. 110). Conchostracans have also been noted in the Kockatea Shale (Dickins and McTavish 1963).

Of considerable biological interest are a small number of arthropods from the Triassic rocks of the Sydney Basin. These include a syncarid crustacean, *Anaspidites antiquus* (Chilton), an anostracan crustacean, *Synaustrus brookvalensis* Riek, and a xiphosuran, *Austrolimulus fletcheri* Riek from the Hawkesbury Sandstone at Brookvale and a phreatoicid crustacean, *Protoamphisopus wianamattensis* (Chilton) from the Ashfield Shale at Newtown.

Insects are abundant on several horizons, the main ones being the Hawkesbury Sandstone (Brookvale near Sydney), Ashfield Shale of the Wianamatta Group (St. Peters near Sydney), the Mt. Crosby Formation of the Kholo Sub-group and the Blackstone Formation near Ipswich in the Moreton Basin. Evans (1956a, b) and Riek (1954a 1955a, b) have been the main recent students of this group but Fleming (1966a) has also made a contribution. Other localities with fewer insects are Balmain, near Sydney, in the lower part of the Narrabeen Group, and Fingal and New Town in the Tasmania Basin (Riek 1962, 1967). Riek (1968) has also reported a beetle from the Hill River area in the Perth Basin and regarded it as Triassic. This group is no longer of any stratigraphic interest but is of considerable biological interest in revealing some facets of the evolution of the group.
The only records of echinoderms in Triassic rocks in Australia are of an ophiuroid from near Woondum in the Gympie-Maryborough Basin (Runnegar 1969), crinoid fragments from the Early Triassic of Western Australia (McTavish 1973, p. 279) and holothurian spicules in the Grose Sub-group in the Sydney Basin (Mayne et al. 1974). Invertebrate tracks and other trace fossils have been recorded from the Kockatea Shale (Dickins and McTavish 1963), from the Gosford Sub-group and from the Hawkesbury Sandstone, *Brookvalichnus obliquus* (Webby 1970).

**VERTEBRATES**

Vertebrates have long been known from Triassic rocks in the environs of Sydney and Hobart (Tasmania Basin) but have been recognised more recently in the Leigh Creek area of South Australia, in the Perth and Canning Basins, in other parts of the Tasmania Basin and in the Clarence-Moreton and Bowen Basins in Queensland.

The oldest adequately dated vertebrate in the Triassic System in Australia is the rhytidosteid amphibian *Deltasaurus pustulatus* from the Early Scythian (probably Dienerian) Kockatea Shale in the Perth Basin (Cosgriff 1965). The amphibian is within a sequence containing the *Lunatisporites pellucidus* microfloral assemblage, ammonites and bivalves of Late Griesbachian and Dienerian age. Fish have been noted in the Kockatea Shale by Dickins and McTavish. A second species of *Deltasaurus* *D. kimberleyensis*, occurs in the Blina Shale in the Canning Basin (Cosgriff 1965) and in the Cluan Formation in Tasmania (Cosgriff 1974). The Blina Shale also contains the brachyopid amphibian *Blinasaurus henwoodi*, and the trematosaurid *Erythrobrachachus noonkanbahensis*, as well as fish such as *Saurichthys* and dipnoans (Cosgriff 1965, 1969; Cosgriff and Garbutt 1972). On the basis of similarity of *Deltasaurus* to *Rhytidosteus* and *Peltostega*, of *Blinasaurus* to *Batrachosuchus*, *Boreosaurus* and *Brachyops* and of *Erythrobrachachus* to *Aphaneramma* Cosgriff (opera cit. has suggested correlation of the Blina and Kockatea with the *Cynognathus* Zone of South Africa, the Mangli Beds in India and the Sticky Keep Formation of Spitzbergen, the age of the latter being given by Tozer (1967, p. 20) as of the *Romunderi* Zone of the Smithian. On the evidence therefore, the vertebrate bearing part of the Blina Shale may be slightly younger than that of the Kockatea Shale.
Blinasaurus (as *B. townrowi*) has also been recorded in several localities in Tasmania (Cosgriff 1974) associated with the dipnoan *Ceratodus, Cleithrolepis, Saurichthys, Deltasaurus kimberleyensis*, another rhytidosteid *Derwentia warreni*, a lydekkerinid *Chomatobatrachus halei*, and a proterosuchian reptile close to *Proterosuchus vanhoepeni*. The brachyopid and rhytidosteid amphibia suggest correlation with the Blina Shale and the overseas correlates noted above. Cosgriff (1974, p. 94) noted, however, that *Chomatobatrachus* shows similarities with the Lydekkerina and Limnoketes from the *Lystrosaurus* Zone and the resemblance of the reptile to one also from the *Lystrosaurus* Zone has been noted above. The reptile also bears some resemblance, however, to *Euparkeria* from the *Cynognathus* Zone and on the combined evidence of the amphibia and the reptile Cosgriff (1974, p. 95) suggested an age for the Tasmanian vertebrate assemblage intermediate between that of the *Lystrosaurus* and that of the *Cynognathus* Zones. The vertebrates in the Tasmania Basin are associated with elements of the *Lunatisporites pellucidus* microfloral assemblage. On the evidence available the Tasmanian vertebrate faunas may be a little older than the Blina fauna.

The Rewan Formation contains dipnoan and actinopterygian fish, the brachyopid, *Brachyops allos* Howie, the unusual amphibian *Rewana quadricuneata* Howie, and reptiles including probable eosuchians and thecodonts (Howie 1972a, 1972b; Bartholomai and Howie 1970). Romer (1971, p. 114) suggested that the reptile figured by Bartholomai and Howie was *Procolophon*, an element in the *Lystrosaurus* Zone of South Africa. The vertebrates may suggest correlation with the Mangli Beds of India.

The oldest vertebrates in the Triassic System in the Sydney Basin occur in the Gosford Sub-group. This sub-group contains a rich fish fauna including a cestraciont shark, a dipnoan, palaeoniscid, captopterid, perleidid, cleithrolepid and saurichthyid forms (Hills 1958). The unit also contains *Blinasaurus wilkinsoni* and the capitosaurid amphibian *Parotosaurus wadei*, the closest relative of which is *P. nasutus* from the Middle Buntsandstein. Cosgriff (1965, p. 89) correlated
the vertebrate horizon of the Gosford Sub-group with the Cynognathus Zone, and (1974, p. 95) placed it a little younger than the Tasmanian vertebrate faunas. The Gosford Sub-group contains the plant Lepidopteris madagascariensis (Townrow 1966) known also from the Cynognathus Zone in South Africa and the Sakamena Group of Madagascar. A little higher in the Sydney Basin, the Hawkesbury Sandstone contains a rich fish fauna-dipnoan, palaeoniscid, captopterid, perleidid, cleithrolepid, saurichthyid, pholidophorid, pholidopleurid and promecosominid, as well as the capitosaur Parotosaurus brookvalensis. This formation contains Lepidopteris stormbergensis as well as L. madagascariensis indicative of correlation with the Molteno Group of South Africa (Townrow 1966).

The highest vertebrate fauna in the Sydney Basin is that in the Wianamatta Group (mainly in the Ashfield Shale). The fauna includes fish - a very late pleuracanth shark, a dipnoan, palaeoniscids, semionotids, a platysomid, a cleithrolepid and a promecosominid (Hills 1958) - as well as a brachyopid Notobrachyops picketti (Cosgriff 1973) and the large capitosaurid Paracyclotosaurus daviid (Watson 1958). The latter was regarded by Watson as probably Early Keuper on its evolutionary position but the bulk of palynological evidence in New South Wales and Queensland does not support an allocation as late as this.

Later vertebrates include footprints, probably of a bipedal theropod, in the Blackstone Formation near Ipswich in the Moreton Basin (Staines and Woods 1964), a stereosponyol footprint from the Tingalpa Formation at Albion near Brisbane (Hill et al. 1965, p. 26), and a fish scale from Leigh Creek in South Australia (Hills 1958). Austropeol wadleyi, a labyrinthodont amphibian from the Jurassic Marburg Sandstone near Brisbane, may be a reworked Triassic specimen (Colbert 1967).

Present evidence is consistent with a vertebrate sequence starting with brachyopids, rhytidosteid, lydekkerinid proterosuchid assemblage, followed by a similar one lacking the last two groups but with a trematosaurid, then by a brachyopid-capitosaurid fauna with more abundant fish. This sequence cannot, however, be regarded as at all well established.

**CONODONTS**

Although conodonts had been noted earlier, the first descriptions were published only late in 1973 (McTavish). Thirteen species were described and
figured and indicate correlations of sections in the Perth and Carnarvon Basins with Dienerian, Smithian and Spathian Stages.

**RADIOMETRIC DATING**

The beginning of the Triassic was placed by Smith (1964) at 225 million years ago on evidence from eastern Australia (Evernden and Richards 1962; Cooper et al. 1963). Later results favoured an age of about 235 m.y. based on a K/Ar age of biotite in a tuff in the Gyranda Formation (Webb and McDougall 1967). This tuff is, however, well below the horizon in the Rewan Formation suggested as the local base of the Triassic System. If the local base is even only approximately contemporaneous with the base in Guryul Ravine, the age of 235 m.y. seems somewhat too high. On the other hand, Green and Webb (1974), using new constants for the calculation, suggested 240 million years (and re-calculated Smith's figure to 230 m.y.).

Although many granitic bodies in eastern Queensland and north-eastern New South Wales have been shown by radiometric dating in the last decade or so to be Triassic, few of them can be accurately placed stratigraphically and therefore add nothing to stratigraphic understanding. Such granites will not be considered further. A few radiometrically dated rocks, do, however, add stratigraphic information.

The oldest, and least informative of these is the Crows Nest Granite, the biotite in which is dated at 237 (242 using new constants) m.y. by the \(^{40}\text{Ar}/^{39}\text{Ar}\) method (Green and Webb 1974). This granite is overlain unconformably by rocks of the Bundamba Group (Rhaetian) which must therefore be younger. A K/Ar dating on the Djuan Tonalite gave an age of 230 m.y. (Day et al. 1974, p. 362) and it is overlain unconformably by the Tarong Beds correlated by de Jersey (1970c) with part of the Ipswich Coal Measures and thus probably Karnian. Hornblende in a dyke (one of the Brisbane Valley Porphyrites) gave an age by the K/Ar method of 218 or 219 m.y. (Webb and McDougall 1967). These dykes intrude folded beds of the Esk Formation considered to be as young as Early Ladinian and are overlain unconformably by the Early Jurassic Wivenhoe Sandstone. Rocks of the Somerset Dam Igneous Complex have been dated by Webb and McDougall (1967) by the K/Ar method using hornblende (213, 215 m.y.) and plagioclase (207, 208 m.y.). These rocks
intrude the Neara Volcanics which underlie the Esk Formation and are probably Anisian. Cranfield and Schwarzbock (1974) noted that the Mount Byron Volcanics which overlie the Esk Formation and other units of the Toogoolawah Group unconformably and are themselves intruded by dolerite and microgabbro possibly related to the Somerset Dam Igneous Complex. These authors also noted the possibility that rhyolitic cobbles in the Kholo Sub-group may have been derived from the Mount Byron Volcanics. The Early Jurassic Wivenhoe Sandstone overlies the Somerset Dam Igneous Complex.

In the Nambour Basin, the North Arm Volcanics have recently (Green and Webb 1974) yielded an age of 208 (213 new constant) million years. They are overlain by the Landsborough Sandstone (Stevens 1971) thought to be Jurassic.

In or close to the Gympie-Maryborough Basin a number of intrusive rocks have been dated radiometrically and show some relationship with Triassic (or Early Jurassic) rocks. They intrude the Brooweena Formation and in one case a younger Triassic unit. The Neurum Tonalite (K/Ar, biotite, 223 m.y. using old constants) intrudes the Early or early-middle Triassic Brooweena Formation and is overlain by the Landsborough Sandstone. Many of the granites in the basin have ages (K/Ar using old constants) averaging 218 m.y. and are unconformably overlain by the Myrtle Creek Sandstone correlated tentatively by Day et al. 1974 (fig. 7, p. 340, p. 349) with the Woogaroo Sub-group of the Bundamba Group. One of the granites intruding the Brooweena Formation has been dated (see Ellis 1968, p. 24) at 218 m.y. and is overlain by the Aranbanga Beds (Ellis 1968, p. 20). The Aranbanga Beds are themselves intruded by the Toonahra Granite dated at 210 m.y. (Whitaker et al., 1974).

These relationships are shown in the appropriate columns.

P.O.Banks (1973), quoting Armstrong and Besancon (1970) and others, placed the end of the Triassic Period at 200-205 m.y. Green and Webb (1974) using new decay constants place the boundary at 205 m.y. None of the evidence for this age derives from Australia.

The Garrawilla Volcanics which occur along the eastern edge of the Great Artesian Basin in New South Wales have been dated as from 201 to 171 m.y. in age.
(Dulhunty 1973a). They rest on the Saxa Member of the "Talbragar" Formation correlated (Hind and Helby 1969) with the Wianamatta Group considered by Helby (1973) as older than the Ipswich Coal Measures which are probably Karnian, and probably Late Anisian and Early Ladinian. The volcanics are overlain by the Purlawlaugh Formation and are associated with the Ballimore Formation (Dulhunty 1973, pp. 323-4). The Purlawlaugh Formation contains Early and Middle Jurassic spores (Hind and Helby 1969, pp. 490-491) and the Butcheroo Shale Member (base of the Purlawlaugh Formation) which overlies the volcanics directly, a basal Jurassic microflora (Dulhunty 1973b). If the end of the Jurassic Period was 200-205 m.y. ago as suggested by Banks (1973) these lavas may well be Early Jurassic rather than spanning the Triassic-Jurassic boundary as suggested by Dulhunty. Because of the potential value of this section in determining the age of the base of the Jurassic, it would probably repay much closer stratigraphic, palynological and radiometric work.

NOTES ON THE COLUMNS

Column 1:-

Stage names are standard stage names. Subdivisions of the Scythian are those of Tozer (1965). Widespread use of subdivisions of the Scythian, the Mesial and Late Triassic within Australia is unjustified as yet because of difficulties of correlation with standard sections. They are included here to provide an approximate yardstick for the position of formations in columns 3 to 20. The evidence for such positioning is shown in column 2, by the fossils listed with each formation and in the fossil list at the foot of the chart. Heights assigned in this column to the major subdivisions of the Triassic System are roughly proportional to the thicknesses of the appropriate units in the Dolomite Alps and North Eastern Alps where the Triassic is essentially of the one rock type.

Column 2:- Australian Biostratigraphy.

Ranges of microflora illustrated in this column are based on ranges established in Queensland sections and on ages assigned to formations within those sections, mainly by de Jersey. This is done because there is more published
information on the palynology of these than on that of other sections. It is clear, however, that the succession is not complete so that the ranges must be regarded as somewhat tentative.

Macrofloral ranges are derived from correlations based on microflora. Invertebrate and conodont ranges are derived from marine sections in other parts of the world. Vertebrate ranges given are related to palynological ranges within Australia.

Column 3:—Bonaparte Gulf Basin

Little has been published about the Triassic rocks of the Bonaparte Gulf Basin. A complete Triassic section is apparently present (Laws and Kraus 1974, which see for earlier references) but little has been published on detailed litho- or biostratigraphy. Detailed study of marine Triassic sections in the Ashmore Block and mixed marine and non-marine sections in the Bonaparte Gulf Basin should provide good control biostratigraphy for use elsewhere in Australia and better correlations of Australian sections with those elsewhere.

Column 4:—Canning Basin; Fitzroy Trough.

Balme (1969a) correlated part of the Blina Shale with the Mianwali Formation in the Salt Range. He also dealt with the correlation of the Erskine Sandstone which contains Dicroidium, Pfeuromeia, Gleiuchenites, Aratrisporites and Falcispores. Aratrisporites suggests a late Early Triassic or early Middle Triassic age.

The Culvida Sandstone contains Dicroidium odontopteroides, D. feistmanteli, Equisetites woodsi, Linguifolium dermeadi, Ginkgoites antarctica, Danaeopsis hughu, Xylopteris elongata and Lepidopteris stormbergensis, a flora which led White (in Veevers and Wells 1961, p. 295) to consider it equivalent to the Ipswich Coal Measures now considered to be probably Karnian. Such an age makes difficult the correlation of the overlying sandstone and shale unit containing Iseura with the Blina Shale as suggested by some authors.

The Cronin Sandstone (Veevers and Wells 1961, p. 128, 296) is doubtfully included as the macroflora identified by White contains plants such as Ptilophyllipecten not known elsewhere in Australia in the Triassic but known in the Jurassic
either in Australia or overseas.

In the off-shore section of this basin there are thick Middle to Late Triassic successions (Challinor 1970).

Column 5: Carnarvon Basin.

Thomas and Smith (1974) summarised the petroleum geology of this basin and commented briefly on the Triassic sequence. Although the Triassic section is apparently not complete, it should provide valuable biostratigraphic data for improvement of correlations between Australian sections and those elsewhere. Some indication of this is given in McTavish's (1973) work on conodonts from the Locker Shale. The most detailed statements yet published on the Triassic rocks of this basin are those of Balme (1969, 1969a).

Balme reported *Aratrisporites* from the Locker Formation suggesting thereby that part of it was Spathian or younger on the basis of the first appearance of *Aratrisporites* in the Narmia Member in the Salt Range and at comparable horizons elsewhere. He noted also that pelecypods listed in an unpublished report may show that part of the Locker Shale is Late Triassic.

The Mungaroo Beds contain *Aratrisporites* not known in Eastern Australia in beds younger than the Ipswich Coal Measures, and two species which allow correlation with the Late Triassic (Isaloi) of Madagascar (Balme 1969a).

Column 6: Perth Basin.

Because of interdigitation of marine and non-marine fossils including microflora and vertebrates in the Kockatea Shale, the section in the Perth Basin is very important for correlations of Early Triassic rocks throughout Australia. In several places there are basal sandstone members of the Kockatea Shale (Hosemann 1971) and these have been given different names in different places, e.g. Dongara Sandstone, Yardarino Sandstone.

The Woodada Formation contains a microflora including *Aratrisporites* indicating a late Early Triassic or younger age and some acritarchs (Balme 1969a).

*Aratrisporites* and other plant microfossils in the Lesueur Sandstone suggest a Middle or Late Triassic age (Balme 1969a, p. 76).
Column 7: South Australia.

Several basins of Triassic deposition are recognised, the more important being the Leigh Creek Basin and the Springfield Basin which contains more than 335 m of Triassic sediments. The Leigh Creek Coal Measures include Liassic units. Triassic sediments also occur in the Boolcunda Basin just south of the Springfield Basin and about 60 m of Late Triassic sediments are known in the sub-surface near Goyder's Lagoon in far north-eastern South Australia.

Column 8: Cooper Basin.

Triassic rocks in this basin are entirely sub-surface and are apparently conformable with the Late Permian Gidgealpa Formation.

Column 9: Victoria.

Triassic rocks occur in only two places in Victoria, at Bald Hill and at Yandoit Hill. The exact placement of these rocks within the Triassic is difficult but Douglas (1969, p. 279) noted some floral resemblance of the Yandoit Hill beds with the Ipswich Coal Measures and wrote of the difficulty of giving any age more precise than Mesozoic to the Bald Hill occurrence. Syenite of Late Triassic age is reported by Talent (1969) from east Gippsland.

Column 10: Poatina Section.

This section which rests gradationally on Permian rocks is the most complete known in the basin but only reconnaissance biostratigraphy has been done. The Triassic rocks together with the Late Permian Jackey Shale constitute the upper freshwater division of the Parmeener Super-group (M.R. Banks 1973).

Column 11: The exact stratigraphic relationships between the formations shown in this column and in the Poatina section are unclear. Lithic arenites become noticeable components of the two sections at the base of the Tiers Formation and the New Town Coal Measures respectively. Drilling in the type section of the Cygnet Coal Measures has shown that the Barnetts Member of the Springs Sandstone is part of the Cygnet Coal Measures (Clarke and Banks 1975). Coal is present in and in many places has been mined from the upper part of the succession. Many local names have been given but macro- and microfloral evidence indicates approximate contemporaneity.
The type sections of the Springs Sandstone, Knocklofty Formation and the New Town Coal Measures are isolated by doleritic intrusions or faulting.

Columns 12-14:— Sydney Basin.

Stratigraphic nomenclature within the Triassic rocks of the Sydney Basin is very complex as also are the stratigraphic relationships. No attempt is made on these columns to express all relationships or show all named stratigraphic units. Relevant papers are noted below each column and in the Bibliography. Particular attention is drawn to a recent paper by Helby (1973).

Both Helby (1969c, 1973) and Grebe (1970) regarded the lower part of the Narrabeen Group and its correlates as Late Permian as did Balme (1969b).

Column 15:— Great Artesian Basin.

Triassic sediments occur only within the Coonamble Lobe of the Surat Basin in New South Wales. This lobe includes a small structural basin, the Oxley Basin. As in the Sydney Basin a multiplicity of stratigraphic names have been used (see Hind and Helby 1969; Dulhunty 1973), and no attempt is made to detail them here. In beds now correlated with the "Talbragar" Formation, Hind and Helby (1969) and Helby (1973) noted microfossils of the *Aratrisporites parvispinosus* Assemblage Zone, characteristic of the Hawkesbury Sandstone and Wianamatta Group in the Sydney Basin. The use of the term "Talbragar" in this context is subject to controversy (Ward 1975).

Column 16:— Clarence District of Clarence Moreton Basin.

The Nymboida Coal Measures consists of four formations — Cloughers Creek Formation, Bardool Conglomerate, Copes Creek Tuff and Basin Creek Formation, the last of which is the most significant in terms of coal. Other coal measures — Red Cliff Coal Measures and Evans Head Coal Measures — also occur along the east side of the basin. The Basin Creek Formation contains a macroflora indicating correlation with the Esk Beds, the Red Cliff Coal Measures a macroflora indicating correlation with the Ipswich Coal Measures (Flint and Gould 1975). No palaeontological evidence is available on the age of the "Bundamba Formation" of the Clarence part of the basin.
Column 16a:- Lorne Basin.

The Camden Haven Group consists of the Camden Head Claystone at the base, the Laurieton Conglomerate and the Grants Head Formation at the top. Correlations with the Sydney Basin are based on the occurrence of *Lunatisporites noviaulensis*, *Protohaploxypinus samoilovichii* and *Aratrisporites coryliseminis* (Helby 1973).

Column 17:- Moreton District, Clarence Moreton Basin.

Within the Ipswich Coal Measures the upper three formations are now grouped as the Brassal Sub-group, which, therefore, with the Kholo Sub-group constitutes the Coal Measures. Within the Bundamba Group the Triassic members shown have been joined as the Woogaroo Sub-group which with the Jurassic Marburg Formation constitutes the Group. These nomenclatural changes were introduced by Cranfield and Schwarzbock (1972). Elsewhere within the Clarence Moreton Basin, Triassic rocks are also known near Mt. Barney (Stephenson in Hill and Denmead 1960) and around, north and south-east of Brisbane.

In the Brisbane area the Brisbane Tuff, a prominent local rock and a unit which includes welded tuffs, is overlain disconformably by the Tingalpa Formation which is in turn overlain disconformably by the Moorooka Formation (Houston 1965b). All three units contain a macroflora and were correlated by Houston with different units within the Ipswich Coal Measures. This correlation was confirmed by de Jersey and Hamilton (1965a) on palynological evidence.

A Triassic volcanic unit, the Chillingham Volcanics, occurs in the Mt. Warning area on the New South Wales-Queensland border (Ewart et al. 1971) and is considered equivalent to the Ipswich Coal Measures.

Column 18:- Esk Trough.

The Bryden, Neara and Esk Formations have recently been grouped as the Toogoolawah Group (Cranfield and Schwarzbock 1972). Some other local names for Triassic formations and members are not shown on the chart. The most important of these in the south and extreme south-west of the Trough, is the Wivenhoe Sandstone which overlies the Esk Formation unconformably. It is correlated by Hill, Playford and Woods (1965) with the Tarong Beds which occur west of Nanango which is itself
somewhat west of the northern part of the Esk Trough and may not properly be included therein. de Jersey (1971a, p. 3) showed the equivalence of the Wivenhoe Sandstone with the Early Jurassic Helidon Sandstone.

The relationship shown between the Triassic formations near Ipswich and those in the Esk Trough is based on palynological and macrofloral evidence and appears to conflict with photogeological correlations (Jorgenson and Barton 1966). Column 19: Gympie, Maryborough Basin.

As noted earlier, this basin is important in that it contains Early Triassic marine fossils. Unfortunately no work has yet been published on the microfloral stratigraphy. The stratigraphic relationships of the Kin Kin Phyllite is unclear but it may include rocks of Triassic age (Runnegar and Ferguson 1969). The age of the Myrtle Creek Sandstone is unclear. Ellis (1968, p. 29) regarded it tentatively as Jurassic and it also appeared on the Jurassic Correlation Chart (de Jersey and Williams in Banks et al. 1967). Triassic volcanic rocks occur at Agnes Water, 80 km north-west of Bundaberg (Stevens 1968).

Column 20: Bowen, Galilee Basin.

Malone et al. (1969) combined the Rewan, Clematis and Moolayember Formations to form the Mimosa Group. Subsequently Jensen (1975) elevated the Rewan and Clematis Formations to Group status on the basis of wide distribution of the units, formerly members, within those formations. The Rewan Group contains the Sagittarius Sandstone and the Arcadia Formation, the Clematis Group, the Glenidal Formation and Expedition Sandstone.

Several local and informal names have been applied to the Clematis Sandstone or part thereof. These include Wandoan and Showground, the former of which also includes equivalents of the Moolayember Formation (de Jersey and Hamilton 1969).

The Dunda Beds which rest on the Rewan along the north-eastern edge of the Eromanga Basin may be lateral equivalents of the Rewan Group in the Denison Trough of the Bowen Basin (Casey 1970; Olgers 1972). At or near the base of the Rewan Group occurs the Brumby Sandstone Member (Exon 1968, p. 10).
The Carborough Sandstone of the northern end of the Bowen Basin (Allen et al. in Hill and Denmead 1960, p. 282) is considered equivalent to the Clematis Sandstone (Hill, Playford and Wood 1965, Olgers 1972).

In the Charters Towers area the Warang Sandstone, an Early Triassic unit, outcrops (Casey 1969, Clarke and Paine 1970) and formed near the north-eastern edge of the Galilee Basin. Olgers (1972, p. 59) showed the Warang Sandstone as correlative with the Dunda Beds and the Clematis Sandstone. The Collopy Formation of the Townsville area may also be Triassic on the basis of correlation with the Warang Sandstone (Wyatt et al. 1970).

Other Queensland Triassic Units.

On the western side of the Yarrol Basin a small basin of Triassic deposition, the Abercorn Trough, occurs just south of Monto. Volcanic rocks and sediments, the Cynthia Beds correlated with the Moolayember, Esk and Clematis Formations, have been recognised (Day et al. 1974). The authors also suggest likely correlation of some units with the Aranbanga Beds and the Muncon Volcanics.

The Callide Coal Measures from the northern end of the Yarrol Basin are considered as partly correlates of part of the Ipswich Coal Measures by Hill, Playford and Woods (1965) (see also Tweedale in Hill and Denmead 1960, p. 280) and partly of the Jurassic Precipice Sandstone (Day et al. 1974, p. 337).

In the Mossman area in far northern Queensland, the Pepper Pot Sandstone contains a macroflora of Triassic aspect (Amos and de Keyser 1964) and the Featherbed Volcanics may also be Triassic but are regarded by de Keyser and Lucas (1968) as probably older.

Triassic Rocks in Northern Territory.

Sandstone and siltstone with some pebble, boulder and cobble beds outcrop the area of the Tobermory and Hay River Sheets near the Queensland border. They have been named the Tarlton Formation and contain fossil plants determined by White in 1961 as being of Late Triassic age (Smith 1963a, 1965).

Just to the west in the Huckitta area conglomerate and silty sand outcrop and are correlated with the Tarlton Formation (Smith 1963b). They contain sponge spicules. The age of this unit must be regarded as doubtful.
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