PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 88

The Geology of the West Coast Range of Tasmania

PART I: STRATIGRAPHY AND METASOMATISM

By

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(WITH 4 TEXT FIGURES AND 9 PLATES)

ABSTRACT

The West Coast Range is a monadnock mountain chain of Tremadocian and older rocks. The Tremadoc strata were fault angle conglomerates which were crushed in Devonian times between a Cambrian geanticline and the Precambrian core of Tasmania. Cambrian rocks are of spilitic lavas and macigno facies greywackes. The Tremadocian strata are of Flysch and Molasse-like facies. Devonian movement was largely on the line of upthrust of the Cambrian geanticline and along this same line intense metasomatic metamorphism closely followed the Devonian orogeny. The juxtaposition of contemporaneous and later faulting with metamorphism and volcanic sedimentary and metamorphic breccias, provides interest. The two most interesting problems concern metamorphic contacts which resemble unconformities, and the tectonic history of the area. The phenomena observed can be welded into a consecutive story which is thought to be of world-wide application.

INTRODUCTION

This study is part of a wider programme of investigation into the mineral bearing region of Western Tasmania. The work, under the aegis of the University of Tasmania, has already resulted in descriptions of the stratigraphy and palaeontology of the Siluro-Devonian strata of the Zeehan district, by Gill and Banks (1950).

The Ordovician strata form the subject of another study; this article is concerned with the rocks and structures of the West Coast Range; with rocks which are in general of Cambrian age, unfossiliferous, metamorphosed, and cast in complex forms. In order to make a more complete picture of events, information has been supplied on districts outside the immediate area. This study is, unlike most petrological works, a field problem involving a high degree of structural interpretation. The results of field and structural studies are presented here, and at a later date a petrological and theoretical study of the porphyroid rocks and ore deposits will be given.

* This work was performed while the writer was a Research Fellow of the University of Tasmania

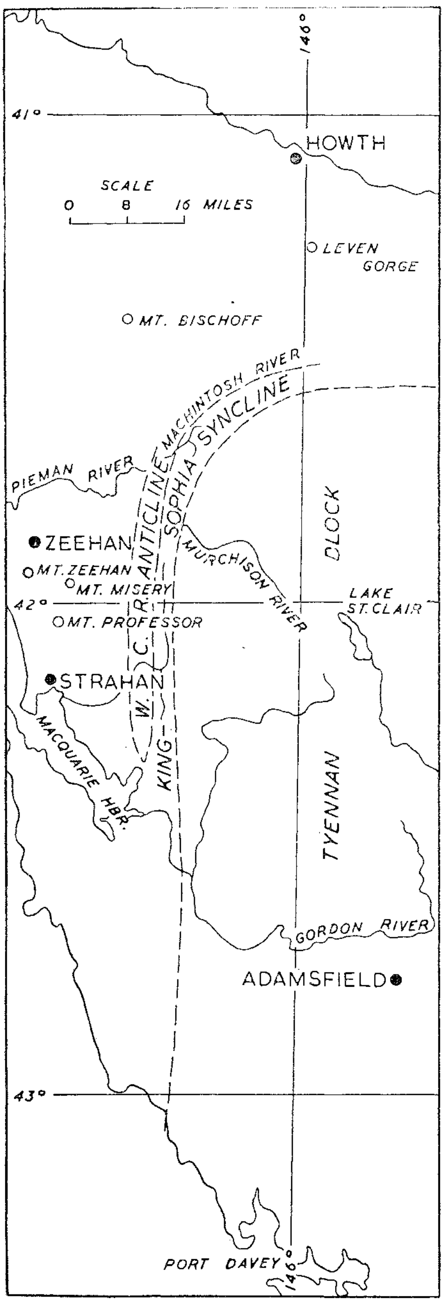

Fig. 1.—Locality map of part of Western Tasmania.

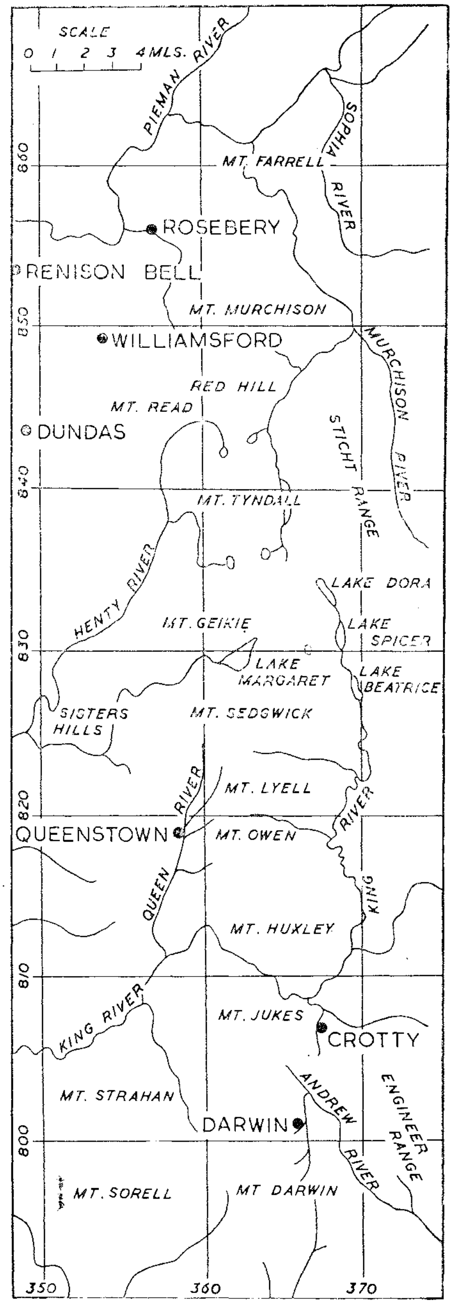

Fig. 2.—Index map of West Coast area.

LOCATION AND TOPOGRAPHY

The position of the West Coast Range is indicated in the maps, figs. 1 and 2, together with centres of mining and other localities mentioned in the text. The Range occupies a belt of country fringing the western margin of the Plateau of Central Tasmania. To the east the Range is separated from the plateau by a depression in which the major rivers run, while to the west the Range gives way to a broad low-lying country.

Considering the slight elevation (4,000 feet) of the West Coast Range, and its small range of altitudes (3,000 feet), it is a surprisingly rugged chain. Several factors contribute to this ruggedness, namely, the extremely varied hardnesses of the strata, glacial erosion, and the rejuvenation of rivers. The Range is a monadnock chain rising from the Howards Peneplain, a terrestrial erosion surface which falls from 1,000 feet at the foot of the Range, towards the coast. The surface of the plain is gently undulating and relieved by low quartzite monadnocks at Sisters Hills and Mt. Professor. Inland it forms the tops of the low 1,100 feet hills of the Andrew and King River Basins. A second erosional surface is the Henty Peneplain of Gregory (1903). This stands between 400 and 500 feet lower than the first and is the level of the old flood plain of the King River, and the flat valley floor of the Queen River. The coast of Western Tasmania is, apart from Flandrian drowning, emergent, and some of the uplift near Temma is very recent. There is abundant topographic evidence that the main uplift of the Henty Peneplain is relatively late, certainly post Pliocene. The rivers show all the characteristics of rejuvenation—gorges, rapids, falls, and discordant junctions. The heads of rejuvenation of large streams are situated, at relatively high altitudes, at short distances from the sea. The King and Henty rivers, for example, fall 600 feet and 500 feet respectively in the last twelve miles of their courses. In the case of the King River slow downcutting could be caused by barriers of quartzite which cross its course, but this is thought to be of secondary importance compared with lateness of uplift. Even the Howards Peneplain as a whole is at an early stage of dissection, and in this surface it is only the largest streams and rivers which have cut deep gorges. Between the King and Henty Rivers half the original land surface is undissected. This, in an area of 100-inch rainfall and of relatively unresistant rocks, suggests late uplift. The old surface is tilted seawards but does not reach to sea-level; it is interrupted on a line about one mile east of Strahan by a sudden drop to 200 feet, where it meets a horizontal surface of estuarine deposits. The line of contact of these surfaces is probably an old cliffed shore and an old fault line.

Inland, and along the Range, erosional and structural surfaces are apparent at several levels. The highest of these, at 4,500 feet, is the top of one of the dolerite sills characteristic of Tasmania. In this area the dolerite occurs at Eldon Peak and forms the peak of Mt. Sedgwick. More widespread is the second surface, a resurrected Carboniferous Peneplain (Edwards, 1941). This shows in the horizontal plateaux of Mts. Sedgwick and Dundas, both of which carry Permian tillite and " sugarloaf " dolerite remnants. It is seen more extensively in the concordant summits of the West Coast Range. Below the Carboniferous Peneplain a pronounced erosional surface occurs at 2,750 feet; this is very prominent in the area east of Mt. Dundas, and remnants of it are present on Mt. Darwin, Mt. Farrell, and over much of the country east of the West Coast Range.

GLACIATION

Some of the glacial features of the Range are very fine and even exceptional. In the high country evidence of glaciation abounds, but nowhere is there a mature glaciated landscape. Only on Mts. Murchison and Jukes did cirques meet to form arêtes; elsewhere glacial erosion is even less mature. The Huntley cirque, cut in white quartzites and with a circular plan, is a typical example of biscuit cutting, and the erosion in the rest of the Tyndall Range, while it is the most extensive of the region, is of this type. Old valleys were ice-filled to plateau level, some were over-deepened and lakes, notably Lake Rolleston, were formed in them. Below 2,000 feet, and with the exception of Lake Spicer (900 feet), no over-deepened lakes and few glacial erosional forms occur. During the Pleistocene, the eastern side of the mountains was the lee side, as now, and it is there that cirques and ice-sharpened cliffs occur.

The largest of the glacial phenomena is the mammilation of the country of the Upper King Valley. This area, at 800 feet to 1,500 feet, was swept by an ice sheet which, descending from the Eldon Range, rounded off the hills and left tills and moraine which can be seen along the Lyell Highway. The ice travelled for a further three miles south, gouging out the cliffs of Little Owen (670/180), and leaving a heavy moraine at 670/160. No end-moraine now exists across the centre of the King Valley. This ice sheet must have piled up to a thickness of 700 feet at the King Bridge, for it backed up the ice of the Comstock and Linda Valleys, and some meltwater overflowed to the west. At Gormanston the varves, formed in the small lake extant before the melting ice, reached up to the level of " The Gap ", which was an overflow channel. Gregory's (1904) statement that the King River ice passed west of the Linda Valley is not borne out by the nature of the topography. In the Comstock Valley the limit of the ice is marked by the terminal moraine on the track to the Comstock mine. At the western end of the Comstock Lake the overflow cut a deep channel which is now occupied by the head of the West Queen River.

The most exceptional moraine in Tasmania is that below Lake Margaret. It was formed at the edge of the Mt. Sedgwick plateau, where the ice, descending rapidly, melted and built up a pile of debris on the plain below. The resulting asymmetrical moraine, 1,100 feet high on its western side, is unusual. It must include many stages of retreat of the glacier. The lower Yolande Moraine described by Lewis (1945) is very localised, small and eroded; it could have been formed by a small tongue of ice advancing after the formation of the bulk of the Margaret Moraine. It is not thought good evidence on which to base a thesis of glacial periods. The Henty Moraine reaches to the lowest level of any in this district—that is, to 400 feet. The moraine ends almost along the roadside, where the glacier was halted by a 400 feet high scarp. The glacier was not very thick, and as the Henty Valley is V rather than U shaped, it cannot have been long occupied by ice. According to Lewis (1945), ice reached to sea-level at Malanna, but for evidence of this, in all the area of the Howards Peneplain, I have found no glacial erosional features nor glacial deposits. Gill and Banks (at Firewood Siding, Malanna) described Permian tillites which in a weathered condition look like Pleistocene till, and were probably taken to be of that age by David and Lewis (Lewis 1945).

DRAINAGE

The drainage system is closely related to the solid geology. The broad patterns of rivers are commanded by fold structures in the hard Cambrian rocks and the softer post Cambrian strata. The older rocks form the anticlinal core of the Range. The younger rocks overlying this core are stripped away, and along the flanks of the Range the Ordovician limestone is reduced by solution to below base level. Consequently the lofty Cambrian country is surrounded by wide swampy flats in which wind the King, Queen, Andrew, Sophia and Mackintosh rivers. In the centre of the broad synclines east and west of the Range the Siluro-Devonian sediments are reduced to low hills. Minor streams are closely controlled in trellis fashion, following the north-west and north-east joint patterns of the country. Middle courses of the larger rivers are incised following the Henty uplift, and the lower courses have super-imposed, mature patterns. The striking cross cutting relation of the King River to the West Coast Range is due in part to this superimposing. The river does, however, follow a structural low, and it must once have flowed only 500 feet above its present bed in a syncline of limestone. To the south, a much readier outlet exists for the waters of the King Basin through the low valleys of the Baxter and Andrew rivers. This is demonstrated by the recent capture by the Andrew of the headwaters of the Baxter, and the pending capture of the King. It appears that a much larger Baxter River must once have flowed north in order to have formed the mature valley which occurs near the Andrew Divide. The cross cutting relationship of the Mackintosh River to the Range has an explanation similar to that of the King, but this river is not appreciably incised. The Pieman River, into which the Mackintosh flows, is cut 200 feet below its old plain, and much of its course is unrelated to the structure of the country.

The Henty drainage had a base level about 400 feet above the present sea-level. The erosional cycle prior to that (the Howards) must have been very long. The ruggedness of the Range is most deceptive when estimating lengths of erosional periods, and the extreme chemical degradation of all but the quartzite rocks is the best index of the duration of that earlier cycle.

PREVIOUS LITERATURE

The mining fields of Zeehan, Dundas and Queenstown have attracted much attention, which has been devoted to the study of ores rather than to that of general geology. Many scattered and unco-ordinated observations have, at the same time, been made. A comprehensive account of earlier work at Lyell (meaning Mt. Lyell mines) is given by Gregory

(1905), who summarises the views of workers prior to that date. He gives an excellent history of the field, and description of the topography and climate. In the same area Hills (1913), Edwards (1939), and Conolly (1947), have made notable contributions to the geology. Hills first established the stratigraphic relations of the Cambro-Ordovician sediments and identified the main structures. Conolly has brought the structure at Lyell to a comprehensible stage and Edwards has given an account of mineragenesis. Tasmanian Survey officers have described other mining fields as follows:—Ward—Mt. Farrell (1908), Waller—Zeehan (1904), Hills—Darwin and Rosebery (1913 and 1914), and these accounts are referred to below. Before proceeding any further I must express my admiration for the work of the older geologists who have been a constant source of information through their faithful observations.

Maps of the area are:—the 4-inch to 1 mile sketch map by the Mines Department, and the 4 miles to 1-inch sheet, No. 3, by the Lands and Survey Department. Trigonometrical information is by courtesy of the Hydro-Electric Commission of Tasmania. The maps appended have been constructed wholly from aerial photographs (20 chains to 1 inch) by the writer, and produced by the Geology Department of the University of Tasmania. The maps of the area north of Lake Margaret await the availability of aerial photographs, and it is hoped to publish them in one year's time. Map references scattered in the text refer to the grid on the maps appended.

ACKNOWLEDGMENTS

This work was executed by me while a Research Fellow of the University of Tasmania, and I wish to express my thanks to that institution for financial support and the printing of the maps. My special thanks are due to Professor S. W. Carey for his advice and help. I wish to acknowledge also the friendship and valuable criticism of Dr. C. Loftus Hills and Mr. M. R. Banks, the drafting assistance of Miss June James, the companionship given me in the field by my friends, especially Mr. F. Brown, and the courtesies offered me by several mining companies. The Mt. Lyell Mining Company in particular has been most helpful in giving full access to their maps and property.

Incidental Stratigraphy

In this analysis it is primarily the Owen Conglomerate, the Dundas Group, the Porphyroid rocks and the structure which are of interest. These are treated in detail. Ordovician, Silurian and more recent rocks are used only as keys to structure, and are treated in detail only where they have particular interest.

RECENT

Because of rejuvenation it is only above nick points, in the Upper King and Mackintosh valleys, that recent river gravels have been deposited. There they cover the present flood plains and form low terraces of limited extent.

PLEISTOCENE

The most extensive Pleistocene deposits are the well-preserved river terraces of the middle course of the King River. They are aggradational deposits up to 100 feet thick and vary in texture from boulders to sand. The terraces are dated by a dry overflow channel which issues from the Toft Valley and cuts the highest of them. The absence of moraine across the main part of the valley, and the general form and age of the terraces, suggest that they are of fluvioglacial origin.

Of exceptional interest in Australia are the varves at Gormanston. They cover 10 acres and extend discontinuously over 300 feet of height, but are much less than that in thickness. Being highly variable, ill-graded, and containing numerous lenses of sand, gravel and dropped pebbles, the beds are not ideal examples of varves. It is probable that the Linda Lake was very limited and existed only at this one end of the valley and that the numerous drag structures of the varves are due to grounding and over-riding of advancing ice.

TERTIARY

Included here as latest Tertiary, and named Macquarie Beds, are the estuarine deposits bordering Macquarie Harbour. These are unconsolidated pebble beds, blown sand, lignitic coal seams and seat earths. Near Strahan 200 feet of beds dip gently west and pass below the water. On the western slopes of Mt. Sorell the beds standing at 400 feet also dip west. Around the harbour the formation is cliffed back, while inland there is an incipient dendritic dissection. Many of the valleys cut in the gravels are rounded off, grass covered and dry. At present the porous pebble beds appear able to dispose of all the rain, 40 inches, which falls on them. Presumably the valleys were cut at a time of greater rainfall or lower altitude. Around the Harbour and parallel to the shore run small folds which are slump structures consequent on cliffing. The effect of this slumping extends 50 yards back from the shore, as shown in the small faults of the railway cuttings east of Strahan. The dips at Strahan are, however, too consistent and strong to have this cause or to be initial dips. Rather, the beds appear to have been tilted and raised. Their uplift probably coincides with that of the Henty Peneplain and is possibly Pleistocene. No shelly fossils occur in the strata, but numerous plant remains may ultimately decide their age.

MESOZOIC INTRUSIVES

The small remnants of columnar dolerite capping Mts. Dundas and Sedgwick are clearly part of the basal sill of the plateau of Tasmania, and are post Triassic in age. The Sedgwick mass is described by Edwards (1942) as a quartz dolerite.

PERMIAN

Tillite occurs at Mt. Sedgwick, scattered across the plateau as large blocks bearing characteristic Spiriferids and Fenestellids in abundance. Below the dolerite 50 feet of these beds occur. Similar blocks and patches occur at Mt. Read near, and south of, the Hercules Open Cut. They show the Carboniferous Peneplain there to be an undulating surface with variations of up to 80 feet in height.

SILURO-DEVONIAN

Sediments of these periods constitute the Eldon Group of strata. They are arenaceous and argillaceous sediments overlying the Gordon Limestone. The uppermost limit of the group is undefined, as the strata are everywhere folded and eroded. At Zeehan, the type area, the formations of the group have been defined and described by Gill and Banks (1950), as follows:—

	Orogeny	
Lower Devonian	Bell Shale	1400′
	Florence Quartzite	1600′
Silurian	Keel Quartzite	400′
	Amber Slate	800′
	Crotty Quartzite	1600′
	Disconformity	

Gill (1950) identifies the Bell and Florence Formations as Lower Devonian in age, and provisionally draws the line between Silurian and Devonian at the base of the Florence Quartzite. He adds a proviso that the Keel and Amber Formations may also be Devonian. In the latter case there would be a considerable gap in the Silurian sequence. Despite this possibility there is usually no discordance between formations, and observations over a wide area indicate uniform condition of deposition for each formation. This is very clear, for example, in the case of the Crotty Quartzite, which over a distance of 40 miles is immediately recognisable by its lithology. The Keel Quartzite is also striking, as it forms a sharp ridge in all of the West Coast area. The Florence Quartzite is readily identifiable on the western side of the Range by its hummocky outcrop. In the King Valley it is not so readily identified from topography. In the same area the Bell Shale, which normally forms a negative feature in the Zeehan area, is also unidentifiable by any characteristic landscape form. This is because the pelitic formations of the King Valley are often slates. This is the case, for example, on the Lyell Highway, where the Bell Shales become a positive feature (3695/8195).

These points are of importance, as, in order to cover this area, considerable reliance is placed on aerial photographic interpretation. Not only is the area large but much is inaccessible; the Andrew Basin in particular is an almost impenetrable bush. Despite topographic variation, the Bell Shale is readily identifiable on the ground by the great thickness of shales or slates represented. On the Princess River this thickness exceeds that at Zeehan by more than 1,000 feet. There is a strong suggestion that the Florence Quartzites in this area are more shaly than at Zeehan—on the ground, at least, they are not readily distinguishable from the Bell Shale. Again, in the King Valley there may be some variation in the Crotty Quartzite, which on the Nelson River, 40 chains downstream from the road, is an impure limestone. This may simply reflect varying physiographic conditions, as the Crotty and the Florence Quartzites have been regarded by Gill as leached calcareous sandstones. The formation in the Nelson Valley would then simply be unleached Crotty Quartzite. It is noted in passing that the use of the term " quartzite " in regard to the Eldon formations does not mean silica cemented quartz sandstone but simply a quartz sandstone.

It will be apparent at this stage that the complete geomorphic adjustment to structure of the varied Eldon strata provides an ideal medium for photographic interpretation. Add to this the striking negative topography of the Ordovician limestones and the bold relief of the Owen Conglomerate, and there exists an area which for topographic interpretation of complex structures is unexcelled in any forested country. In the case of the Eldon Group it is generally possible, despite forest, to trace formations on photographs for many miles. Interruption by faulting is frequent, but little difficulty is met in matching beds and elucidating structures. The identification of formations and interpretation of structures are simple integrations of each other. The structural picture obtained by photographic mapping, assisted by lithology and dips, can be brought to a high degree of perfection.

Of the Eldon Group the Crotty Quartzite, whose recognition in the field is important, has some interesting features. The formation name derives from Crotty town (3675/8065) where the sandstone was first noted by Hills, but the recently formulated definition given by Gill and Banks (1950) at Zeehan is accepted. At Crotty Station the formation is well exposed. In descending order three members are recognised:—

(1) The Upper Tubicolar Sandstone. 200 feet. This is a porous white quartz sandstone with grains 0·5-1·0 mm. and bearing "pipe stems".

(2) Variegated Beds. 200 feet. These are very friable, pink, white, and green sandy shales and laminated sandstones; grain size less than 0·5 mm.

(3) Smelters Sandstone. 400 feet. A dazzling white, very friable and pure quartz sandstone. Grain size 0·5 mm. plus.

These sandstones are coarser than any other of the Eldon Group. They differ from the Crotty Quartzites at Zeehan only in that they contain no grit bands. Bedding is less regular than in other Eldon quartzites and cross bedding is common. The sandstone was calcareous, but the long exposure of the rock to peaty and sulphated waters has removed every trace of calcite. This accounts for the friable nature of the rock which on occasion is reduced to heaps of rubble. A common erosional slump breccia character of the rock is due to the same process of solution which removes the underlying Gordon Limestone. This occurs on an enormous scale on the roadside opposite the Lyell Smelters and produces anomalous structures. Such structures at the Queenstown Quarry resemble planes of unconformity or of thrusting.

The Tubicolar horizon, which here is distinguished from that in the Owen Conglomerate by the name Upper, represents a phase more than ordinarily calcareous. The "pipe stems" described by Ward at Zeehan as being parallel to bedding are, at Crotty, normal to the bedding. They have been described as casts of worm tubes or crinoid stems. I have found this bed to be very extensive and a consistent and useful marker horizon. The variegated beds are also useful in this respect as they are relatively rich in iron and stand out as bold bands in the sandstone.

The relation of the Crotty Quartzite to the underlying limestone is, because of the solution effects mentioned, rarely seen. Only one exposure of this boundary, at Bubbs Hill, is known; there appears to be a transition at that locality. At South Queenstown Quarry rolled fragments of limestone are compatible with unconformity at this juncture, and the calcareous character of the sandstone could be attributed to incorporated limestone fragments. This possibility is thought to be slight. An interesting variation in the sandstone is its thinning from Zeehan to the south; from a reported 1,600 feet at Zeehan it falls to 1,000 feet at Queenstown and 800 feet at Crotty. On the King River section, towards Strahan, I cannot easily recognise it. Similarly, at Kelly Basin, the formation, though recognisable, is thin or is changing character.

ORDIVICIAN

The Ordovician is almost fully represented by the Gordon Limestone, which over most of the area extends from the Tremadocian upwards. The Tremadoc strata are in the main the Owen Conglomerate and are treated in detail separately below. The Gordon Limestone has not yet been clearly defined and this name, used on the suggestion of M. R. Banks, is an abbreviation of the customary " Gordon River Limestone ".

The formation has been traced round some 100 miles of outcrop by me, and at least twice that distance by Professor S. W. Carey. Its identity as one bed overlying the Owen Conglomerate is no longer in doubt. It is different from the section on the Gordon River at the Great Bend in respect of thickness, and probably of time range. In the West Coast Range its thickness is 700 feet as compared with 3,000 feet on the Gordon River. This is largely accounted for, in my opinion, by a transgressional relation from south to north, and by the replacement of the underlying Owen Conglomerate to the south by limestone. It may be that the Crotty Quartzite was later formed under conditions of regression, and that it, like the Owen Conglomerate, passes out to the south into limestone. Despite Gill's inclusion of the Crotty Quartzite with the Eldon Group, I anticipate that a large time-break will be found above, rather than below, this formation, and that Hills and Carey's (1949) inclusion of the Crotty in the Junee Group will prove to be a more reasonable arrangement. To the south of this area I expect there will be no Crotty Formation overlying the thicker limestone. The lithology of the limestone cannot be well described from this area as exposures are so poor. Excepting larger exposures on the Nora River, on the Nelson River, at Lynchford and Bubbs Hill, there are probably not twenty exposures of limestone of a total area of one acre in twelve square miles of " outcrop ".

At Zeehan, recent mine draining has lowered groundwater sufficiently to reveal a very rugged karst topography formed below the water table, with solution channels hundreds of feet below. Such a radical base levelling is the general fate of the limestone, which is traced everywhere by boggy flats carrying a black, carbonaceous ? residual clay. The recognition of the Crotty Quartzite and the Lower Tubicolar Sandstone are consequently more than ever important, as these sandstones indicate the presence and the thickness of the limestone. Such thicknesses as are given can therefore rarely be accurate within fifty feet, and, because of the slumping of the overlying strata, often have less accuracy than that. In view of the rarity of exposure it is small wonder that some writers considered the limestone to be a number of lenses. The limestone, where it is exposed, is usually dark-grey and often recrystallised and coarse grained. At Lynchford Quarries it is pure, massive, and without bedding or many fossils. At Queenstown Quarry, and near its base, the limestone is impure and rhythmically banded with black shales. Here and across the river from the quarry it is highly fossiliferous; Hill and Edwards (1941) describe Ordovicion fossils from that locality, and Mr. M. Banks informs me that the latest collections show the limestone to extend from Lower Ordovician to Lower Silurian. On the Nora River great thicknesses of the limestone are very impure and may be more correctly called carbonaceous and calcareous shales. In this area (3648/7900) it is clear that the Lower Tubicolar Sandstones interdigitate with, and pass laterally into, the calcareous shales. The limestone, in the distance of three miles, south of that area, increases in thickness from 800 to 1,300 feet.

The base of the limestone has never been described previously. During the dry summer of 1950 it was possible to examine exposures at the head of Lake Margaret where Nye had previously reported limestone. The islands at the head of the lake, and the bed of the lake, were left high and dry. Limestones there are basal and transitional. They show the following sequence:—

Limestone 4 ft.	Dark, medium grained, with numerous bryozoa.
Limestone 40 ft.	Impure dark-grey limestone weathered to yellow sandstone with tubercles normal to bedding.
Shales 6 ft.	Yellow to black with many recumbent and graphitic tubercles parallel to bedding.
Sandstone 2 ft.	Yellow friable sandstone with small tubercles normal to bedding.
Gap 10 ft.	Apparently eroded shale.
Sandstone 40 ft.	White quartz sandstone.
Quartzite 60 ft.	Dense white quartzite.
Conglomerate 100 ft.	Grits and fine conglomerates.

The importance of the section lies in the information it gives on the nature of the transition and the character of the tubercles. The 40 feet limestone does not appear at first to be limestone. Rather it looks like, and is, the Lower Tubicolar Sandstone which is the uppermost member of the Owen Conglomerate. On smashing up this rock, to a depth of one foot or more, a core of blue-grey limestone, not obviously impure, remains. This limestone is crammed with bryozoa which pass into the tubercles of the weathered rock. A similar relation exists in regard to the 2 foot sandstone and its ⅛-inch diameter branching tubercles. These have not been recorded before but are not uncommon in the Tubicolar Sandstone. The carbonaceous tubercles observed in the shales between the sandstone strongly suggest a vegetable origin. They are up to 10 inches long, ¼ inch wide, are flattened to ⅛ inch thickness, and have a thin carbon coating. In and about this horizon flakes and thin bands of carbonaceous material are common. The presence elsewhere of similar flakes below the limestone is general in the country and they are met as far afield as on Dunkley's tram, four miles north of Zeehan, and in the Caroline Creek beds at Tim Shea.

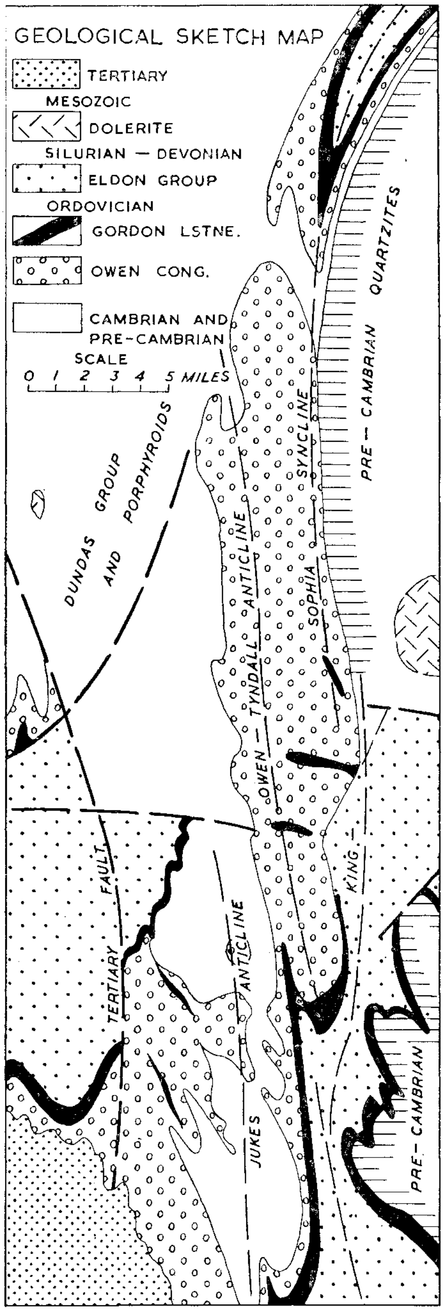

FIG. 3.—Geological sketch map of the area shown in Fig. 2.

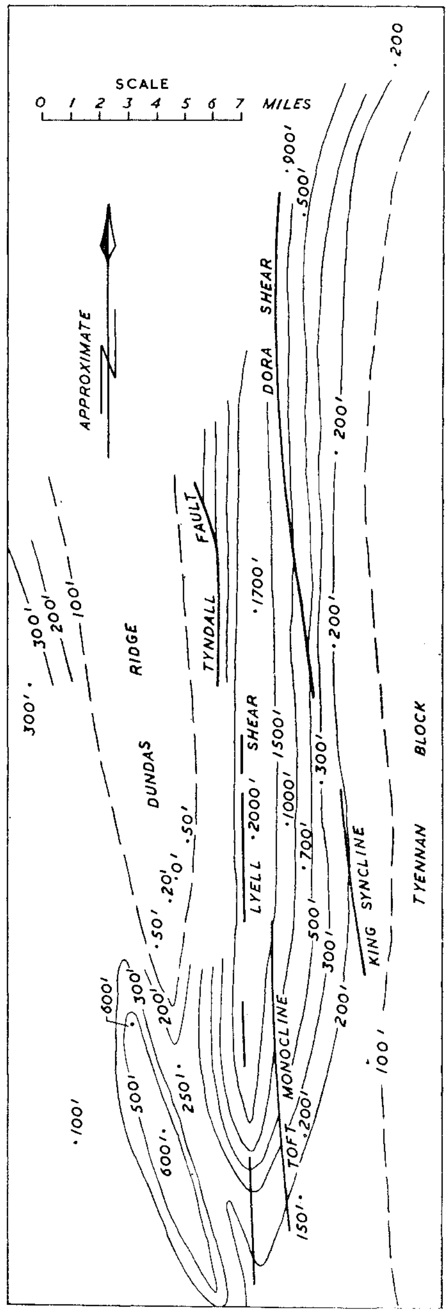

FIG. 4.—Isopach map of the Owen Conglomerate.

THE OWEN CONGLOMERATE

LITHOLOGY

DEFINITION

The West Coast Range or Owen Conglomerate is a quartzose conglomeratic formation occupying the outcrops shown in Figs. 1 and 3. It lies principally in a narrow belt with little longitudinal variation in thickness but with a marked lens shape from east to west. Fig. 4 shows the estimated and deduced thicknesses of the formation in the West Coast Range. Outliers of similar but finer conglomerate occur to the west at Mt. Zeehan, Mt. Professor, Mt. Misery and Sisters Hills, and to the north are exposures at Howth, Dial Range and Leven Gorge. East of the Range thin sandy conglomerates occur at Hawks Creek, on the Sticht Range and Engineer Range, while to the south and south-east are exposures at Tim Shea, Adamsfield, and on the Denison and Elliot Ranges. Representatives occur, therefore, over an area of 150 by 100 miles. While it is probable that the uppermost sandy members once extended over this wide area, the conglomerate proper was laid down in distinct synclinal, fault, or erosional troughs of which the West Coast Range, or Jukes, Trough, bordering an old land, was the largest.

The conglomerate has long been loosely recognised by Survey officers as a formation. The earliest statement giving a name to the formation is that of Officer, Balfour and Hogg (1895), who published an adequate definition of the " Owen Conglomerates " occurring on Mt. Owen. In 1908 Ward further suggested that the conglomerates capping the Range were one formation, but the first precise account of any kind was that made by Hills (1913) on the succession at Mt. Jukes. Hills described the formation, which he called the West Coast Range Conglomerate, in clear accurate detail, and his description I have presented in a tabulated form below. Hills's section, a representative one showing the maximum development of the formation and most of its characters, runs as follows:—

Tubicolar Sandstone: yellow sandstone with pipe stems	400 ft.
Chocolate Sandstones: alternating thin beds of conglomerate, sandstone, and shale	400 ft.
White Conglomerates: quartz pebble beds with 1 to 2 inch rounded pebbles	400 ft.
Red Quartzite: Red or pink quartzite, fine grained, very hard, massive, but often fissured and veined	400 ft.
Red Conglomerates: Red quartzose beds with pebbles up to 6-inch diameter and often with haematitic cement	400 ft.
Breccia Conglomerates (= Jukes Breccia): Coarse breccias with angular to subangular fragments up to 4 feet across. Principally of porphyroid and slate fragments with subordinate quartz or quartzite. Usually deeply stained	300 ft.
Unconformity against underlying Porphyroid rocks.	

Hills emphasises the striking difference between the quartzose West Coast Range Conglomerate and the non-quartzose character of the underlying strata. He points out the almost universal silicification of the formation and its frequent veining by quartz and haematite. As evidence of unconformity, he points out the discordant relation of bedding on Mt. Jukes, the weathered appearance, schistosity, and different lithology of underlying beds, and the presence of igneous rocks of the underlying formations in the basal breccias. The description is a faithful one and is acceptable except for an important qualification concerning the unconformity.

Hills has excellent grounds for supposing unconformity and in a general sense his statement is true. The writer would deduce unconformity near this juncture and in this vicinity, but it cannot be claimed that a clear unconformity is observed. The writer considers the contact to be metamorphic and not sedimentary. The discussion of this point must be delayed while a general picture is given.

The Owen Conglomerate is, as one would imagine from its conglomeratic nature, a variable formation, and from its distribution and thickness, has variable contacts with underlying strata. Further, much variation in its members is to be expected, and a type section cannot strictly describe the formation. Definition of the formation, as distinct from what is recognised as a description of a type section, can only be arrived at by qualifying the kind of variation from the norm which is to be allowed. The following criteria and qualifications are thought useful for defining the formation as a whole:—

1. The formation on grounds of priority and simplicity is to be called the Owen Conglomerate.
2. It is of Tremadocian Age (Hills and Carey (1949, p. 27)).
3. It is essentially quartzose. As this formation and some others are commonly silicified, this statement is qualified by requiring that the Owen Conglomerate contains more than 75 per cent of original quartz or quartzite particles.
4. It is normally conglomeratic but may contain shale and quartz-sandstone beds. Where the formation passes into shales it loses its identity, but where it passes into sandstones the name is retained.
5. It is limited above by the Gordon Limestone Formation. That boundary is often gradational but is normally fairly sharp at the Lower Tubicolar Sandstone.
6. The lateral sedimentary limits of the formation are:—
    (*a*) By transgressional unconformity.
    (*b*) By passage into shales and Gordon Limestone.
    (*c*) By passage into contemporaneous greywacke conglomerates and sandstones.
7. Its lower limit is defined by:—
    (*a*) Unconformity; basal breccias may or may not be present.
    (*b*) In the absence of unconformity, by a change in composition from greywacke type to quartzose sediments. The basal breccias are not always present, but there are very few cases where the change is not abrupt.
8. It may be limited laterally or terminate below by contact with metamorphosed rocks.

All of these conditions have been observed. The thickness of the formation ranges from zero to 2,000 feet and has no definitive value.

GENERAL

The following account is drawn from the area where the Owen Conglomerate is most typically developed, that is, the zone of thick, 1,000 feet-2,000 feet conglomerate, the axial belt of the West Coast Range.

Unfortunately, there can be little stratigraphic detail, because correlation of members inside of the formation is rendered very unreliable by the powerful transverse faulting and subsequent erosion which cuts the country into separate blocks. There are no fossils in the rocks and " walking " of beds is out of the question. There remains " bed for bed " correlation of the several blocks of country. Some results can be obtained by this method, but when it is considered that the east-west variation in thickness of the formation is from two thousand feet to zero in as little as six furlongs, it is rash to suppose that there is a vastly better consistency from north to south inside the formation. There are, however, some general observations which are useful, and some large unbroken blocks of country show the kind of continuity which can be expected. There is, in fact, a surprisingly consistent variation in the Owen Conglomerates, both vertically and longitudinally. Comparative sections have been drawn up, in the accompanying table, which show the broad character of the formation. A fuller account follows:—

PARTICLE SIZE

There is a decrease in pebble size from bottom to top of the formation. The basal breccias are always the coarsest and fragments are generally from six to eighteen inches across; fragments up to two feet are not unusual. The basal breccias are very unevenly sized, and resemble the deposits of a cliffed shore in a hard-rock terrain. The lower members of the Owen Conglomerate are of very even-sized quartz and quartzite pebbles which are rounded, slightly oblate or ellipsoidal, and six to nine inches long. The upper half of the formation shows decreasing grain sizes towards the top, and the gradually diminishing conglomerate bands are of pebbles two inches or less across. The pebbles are rounded, spheroidal, and are wholly of quartz and quartzite.

There is an increase in sandy members towards the top of the formation and, if the middle Red Quartzites are ignored, the gradation from coarse conglomerates to fine sandstones is very smooth. The Chocolate Shale is the finest member and consists of shale units which range up to 20 feet thick, alternating with grit and sandstone, in bands up to two feet thick.

The area at the northern end of the Tyndall Range is exceptional in several respects. There, although the uppermost 1,500 feet of the Owen Conglomerate are progressively finer upwards, the lower 500 feet are progressively finer downwards. Downwards there is also an increasing admixture of greywacke matrix and the formation passes into greywacke sediments. In the heart of the Tyndall anticline, on Newton Creek, occur shales which are interbedded in a 100 foot band low down in the conglomerate. The shales have been schisted to a sericite-chlorite phyllite or schist, whose schistosity is oriented in a drag fashion. The northern end of the Tyndall Range is also different in the fineness of its conglomerates as compared with those of the rest of the Range. Pebbles are rarely more than three inches across and the uppermost sandstones are very thick. There is a gradual change southwards along the Tyndall Range, until at the north end of Lake Margaret a considerable thickness of coarse pink conglomerates occurs. At that point there is still a great thickness of white grits and fine conglomerate, but in the short distance to Mt. Sedgwick the sequence changes until it is very similar to the section of Mt. Jukes. It is possible to draw an east-west line through Lake Margaret to separate two areas in which conglomerates have an appreciable difference of pebble size. In each of these divisions there is a fair degree of consistency of members.

SILICIFICATION

The Owen Conglomerate is almost everywhere cemented into a solid mass by a cherty or chalcedonic matrix. This is most clearly demonstrated in localities like that on the roadside near Gormanston, where road cuttings show freshly blasted surfaces. The matrix there is dense and dark so that dark pebbles lose their identity in the mass, and the whole resembles specimens of the Rand Banket. There is a gradation of silicification which proceeds from intense in the lowest beds to less intense in the highest. This may simply be related to the original variation in permeability of members or it may indicate a deep seated source of silicifying solutions. It happens that the uppermost quartzites are often unsilicified and, in particular, that the bands enclosed in the Chocolate Shales are frequently unsilicified. Occasionally silicification reaches up into the Gordon Limestone, forming a porcellaneous creamy chert (3648/790). When fragments of similar chert are found in the higher conglomeratic beds, as they are at Tim Shea and near the Comstock Mine, it may be suspected that the conglomerate was not originally exclusively quartzose. In the lower beds chert pebbles never appear, but it may be that some few quartzite pebbles are coarse grained replacements of slaty material. Otherwise the exclusiveness of siliceous pebbles in the formation is inexplicable. The same explanation attaches to some of the fine grained quartzites which have microscopic grain sizes. Some look like current-bedded siltstones, but the yellow quartzites at Tim Shea look like finely banded shales. The latter are probably replacements, but it is impossible with some rocks to decide whether recrystallisation or replacement has been most important in their formation. On the whole, the quartzites were originally quartz sandstones, but a secondary origin must always be considered for the very fine quartzites.

WEATHERING

The conglomerate is reduced by a process of spalling, which occurs near or below soil level, and by chemical disintegration on exposed bluffs. Under atmospheric conditions the cherity matrix is sufficiently soluble to facilitate the loosening of pebbles, so that the surface of the rock is deeply etched, and detached pebbles fall to the ground. Because in some areas the exposed rock is ice scratched and still unetched, it is clear that the present corroded exposures are very ancient. As spalling also produces smooth fracture surfaces it is clear that the exposed bluffs with rugged surfaces have not recently been spalled. The spalling process is not the result of frost action or insolation but is somehow connected with the action of soil waters; such a process is not easily explained when the rocks are of chemically inert silica.

HAEMATITE STAINING

This also decreases upwards from the deep blue basal or contact rocks through the rose-pink and white conglomerates. The finer grained sediments are deeply stained irrespective of their position, and some of their colour may be due to an original high iron content. Staining, even in these beds, is always more intense when they happen to be close to metamorphic contacts. Thus, the Red Quartzite of Little Owen becomes purple when it lies in contact with the porphyries, and the Chocolate Shale in the North Lyell open cut is wholly replaced by haematite schist. The blue staining in the contact rocks is effected by haematite which occurs in masses or is diffused into the outer shell of quartz pebbles. The pink pebbles also show a shell, about 2 mm. thick of pink quartz, and in most quartzites the rose colour is completely diffused. Rather different is the colour of the Tubicolar Sandstone which is, except when close to a contact, yellow, due to iron hydroxides. As the hydroxides leach readily the Tubicolar Sandstone is often white.

CONTEMPORANEOUS MOVEMENT

At one locality an angular unconformity of 30° occurs at the base of the Tubicolar Sandstone. It is well exposed at the foot of the old haulage near Linda and has been mapped by Conolly and myself for about 200 yards. It is probable that the structure lies along a contemporaneous fault scarp and that slumping, or drag, and erosion have created a purely local unconformity. At the top of the haulage and along the track to West Lyell open cut occur some fine sandstone dykes. These dykes run through the conglomerate, about 90 ft. below the above mentioned unconformity. They are up to 50 ft. long and pass out of the conglomerate into the adjacent schists. The dykes observable in 100 yards of contact are up to four inches wide and are twelve in number. The infilling is of fine pink sandstone without bedding. These dykes, while straight in the conglomerate, have been intensely contorted and broken in the schists. These structures alone suggest the following:—

1. That there was contemporaneous movement which fissured the conglomerate.
2. That the schist-conglomerate contact is neither intrusive nor faulted.
3. Either—
   (*a*) the contact is an unconformity; or
   (*b*) the contact is metamorphic; i.e., the conglomerate has been replaced leaving the sandstone dykes unaltered.
4. That some plicating movement occurred at a later stage on the lower side of the contact line and that this movement and associated schisting post-date the conglomerate.

Slump structures in the conglomerate are unusual. They are very pronounced only in one area, on the Dora tram south of Lake Julia. There they occur in the transition beds at the base of the conglomerate. While they are individually only small, the movements are numerous and repeated over and over, and slumped beds are separated from other slumped beds by unslumped material. This kind of slumping is characteristic of active orogenic belts.

REACTION TO TECTONIC FORCES

Where the Owen Formation overlies plastic beds as at Mt. Tyndall, it has behaved in a competent fashion. Where the underlying rocks were the hard Cambrian strata the thrusts now pass from these rocks and die out into folds in the 1,500 ft. thickness of conglomerate. While the pebbles are rarely, if ever, drawn out, there must have been much movement of pebbles; this is rarely obvious. Where pebbles lack sphericity their rotation can be observed and can be associated with the drag on particular faults. This is true of the Lyell Shear at South Darwin Peak; as rotation would be impossible in a silicified rock it can be postulated that silicification postdated this fault. Similarly, the absence of drag shears in most folds points to the same conclusion regarding folding. On the other hand, the brecciation of silicified conglomerates at Comstock and North Lyell means that some movement, particularly on north-east faults, postdated or was contemporaneous with silicification. Hills remarked on the strong fissuring of the Red Quartzites as compared with the conglomerate beds; that difference reflects the different abilities of the beds to transmit shearing forces. Even if there were no differential metamorphic effects it is evident that the pebble beds, with so little matrix, would react under compression or shear quite differently from other strata. They could conform like a layer of ball bearings while beds below were schisted and those above were occasionally converted to slate.

THE JUKES TROUGH

The regular grading of the individual members of the conglomerate formation rules out a fluviatile origin for it, and the coarseness and small amount of fine matrix in the lower beds rules out an origin by deposition on a sheltered sea coast. The environment was one of swift currents which rounded pebbles and swept away fine debris. It is imagined that there was a fault coast along the western margin of the Tyennan Block, and that the deposition basin was a narrow strait separating that coast from an island chain some four miles offshore. It is conceived that the trough continuously subsided along its western margin and that thick deposits were formed there. The trough can be roughly divided into an area north of Lake Margaret, where sediments were, on the whole, finer, and one to the south where they were coarser. Further south the strait passed out into open and deep water. The trough is named the Jukes Trough and the offshore chain the Dundas Ridge. The latter appears to be related to the Bischoff Anticlinorium (Carey, 1953, p. 1119 and Fig. 3).

THE BASE OF THE OWEN CONGLOMERATE

The basal breccias denote a major change in the character of sedimentation. On the Tyennan Block unconformity occurs at this level, and although there is conformity in the Jukes Trough there is an abrupt change from greywacke to quartzitic sedimentation.

Typically, the breccias are less than fifty feet thick and are a heterogeneous unbedded mass of unsorted angular and subangular material. Fragments are huge boulders, blocks and slabs of granite, porphyry, schist and slate which might have been locally derived, and of quartzite, haematite schist and massive haematite which appear to be exotic. In the Jukes Trough the Owen Conglomerate is conformably underlain by greywacke conglomerate, and it appears that the breccias were derived from low fault scarps along each side of the trough. The complete change in the fill material of the trough implies movements over a vast area, movements which at once cut off supplies of greywacke and instituted a source of coarse quartzitic detritus, movements which must have almost submerged the Dundas Ridge while elevating the Tyennan Block. It is readily conceived that an even earlier rise of the Dundas Ridge must have produced an unconformity at the base of the greywacke conglomerates. Some confusion has arisen from the fact that Hills and Carey correlated (1949, p. 25) the greywacke conglomerates on the Lyell Highway above the King River Bridge (towards the Linda Valley) with the Jukes Breccia on Mt. Jukes, whereas only the upper part of this conglomerate should be correlated with the Jukes Breccia. The writer proposes that the lower part of this Lyell Highway section, i.e., the greywacke conglomerate, be taken as a separate formation. This will be called the Dora Conglomerate.

The Dora Conglomerate is widely exposed in the glaciated surfaces of the type area around the shores of Lake Dora and for half a mile to the east and west of the lake. The formation is of Upper Cambrian age and lies conformably below the Jukes Breccia but this conformity is expected to pass into unconformity in places. The formation is inferred to be unconformable on Middle Cambrian and on Precambrian strata. The formation is characteristically an ill-sorted greywacke conglomerate with much fine matrix. Pebbles, which vary in size from one to six inches, are rounded and, though tabular or elongate, are not angular. The top of the formation is normally marked by a clean break from, or rapid transition into, the Jukes Breccia. The base of the formation is not definable owing to metamorphic transition. The full thickness of the formation may be very great, and at Lake Dora it is probably between 2,000 ft. and 3,000 ft. thick. As it is probable that the formation was deposited in a trough on one side of the Dundas Ridge it is distinguished in this paper from the Lynch Conglomerate of the Queenstown area, which was deposited in a separate basin on the western side of the Ridge.

The Jukes Breccia is regarded as the basal member of the Owen Conglomerate. It is a breccia which is characterictically coarser than the overlying conglomerates and contains quartz fragments. The Jukes Breccia often contains material common to underlying formations and is usually intensely haematite stained. It is unconformable on Precambrian rocks of the Tyennan Block and probably on the Cambrian strata of the Dundas Ridge, i.e., on the Dundas Group and on the Dora Conglomerate. In the West Coast Range the Jukes Breccia is often seen to be conformable on the Dora Conglomerate.

TABLE OF RELATIONS OF THE

NORTH — THICKNESS ESTIMATED IN FEET

EAST

TYENNAN BLOCK	*Tim Shea* (and probable general relation in Tyenna)		
	Gordon Limestone		
	Shaly fossiliferous Limestone	=	Caroline Creek Beds
	Tubicolar Sandstone and fine conglomerates	200	
	Ultra-fine yellow quartzites	100	
	Conglomerate, grading down into	100	
	Jukes Breccias with dolomite	50–200	
	* * * * * * * *	* *	* * * * *
	Angular unconformity on eroded dolomite and plicated quartzite. (known Precambrian)		

	Hawks Creek		*Sticht Range*	
EAST LIMB OF KING-SOPHIA SYNCLINE	Gordon Limestone		Fine Quartzite	300
	Quartzitic Grit	200	Conglomerate (Owen)	100
	* * * * * *	*	* * * * * *	*
	Granite Dora Cong.	800		
	Hypothesised unconformity			
	Plicated Quartzite		Plicated Quartzites	

	S.W. Mt. Farell		*Lake Dora*	
EAST LIMB OF MAIN ANTICLINE	Tubicolar Sandstone	300	Sandy Conglomerate	400
	Conglomerate (Owen)	200	Jukes Breccia .... } Haematite Zone .... }	50
	Quartz Porpy.—Biotite Granite		Dora Conglomerate	
			Pyritic chlorite schist	
			Dora Conglomerate (Porphyry)	

	Mt. Farrell		*Red Hills*		*Mt. Tyndall*		*Mt. Sedgwick*	
AXIAL BELT	Tub. Sstne.	300	Tub. Sstne.	300	Quartzite	700	Tub. Sstne.	350
	Congl.	700	Congl.	500	Congl.	600	White Cong. ..	500
	Haematite Zone		Jukes Brec. .... } Haematite .... }	60	Phyllite	100	Red. Qtzite. ..	200
	....				Cong.	200	Red Cong.	600
	Syenite to chloritic Greywacke		....		Sub. greyw. trans. into Greywacke silts	600	Jukes Brec. .. } Haem. Zone .. }	60
	???		Felsp. porphy.	150	??		....	
	Farrell Slate		Pyritic Zone ..	150			Dora Cong.	800+
			Felsp. Por.					

	Mt. Misery		*Queenstown Smelters*	
WEST MARGIN DUNDAS RIDGE	Tub. Sstne. with Cong. bands	100	Fine Quartzose Grit with greyw. matrix	80
	Red Greywacke silts with Qtz. Grit bands	200	Varvoid clays	100
	Chloritic Greywacke with Cherty Conglomerates	1200	....	
			Chloritised and kaolinised Greywacke	

		Sisters Hills	
ZEEHAN BASIN		White Quartzites	150
		White Conglomerate	150
		Yellow Shales	500
		Lynch Conglomerate	2000
	Chloritised	....	
		gradational contact	
WEST		Quartz porphyry	

OWEN CONGLOMERATE TO UNDERLYING ROCKS

UNCONFORMITY * * * METAMORPHIC BOUNDARY............................SOUTH

Adamsfield (probable south margin of Tyenna)

Gordon Limestone	200
Quartzites	200
Conglomerates	600
Jukes Breccia of serpentine	60

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Angular unconformity on Cambrian pyroxenites

Raglan Range		*Engineer Range*	
Red Quartzites	80	Red Quartzite	200

* * * * * * * * * * * * * * * *

Plicated Quartzite; probably Precambrian

Lyell Peak		*Crotty*		*Darwin Town*		*Ten Mile Hill*	
Tub. Sstne.	500	Tub. Sstne.	400	Tub. Sstne. .... }	200	Fine grained Conglomerate (Owen)	200
White Cong.	400	White Cong.	600	Cong. & Grit .... }		???..........................	
Red Qtzite.	200	....		Finely bedded chloritic cong. (greywacke)	600	Chlorite sericite schist	
Red. Cong.	300	gradational change to Sericite chlorite schist		....			
Jukes Breccia .... }	60			Chlorite schist			
Haem. Zone .. .... }							
....							
Dora Cong. .... (Qtz. porphyry)	800						

West Lyell		*Mt. Jukes*		*Snake Spur*		*South Darwin*	
Tub. Sstne.	300	Tub. Sstne.	300	Tub. Sstne.	200	Red Quartzite	400
Choc. Shale	200	Choc. Shale	100	Haem. Zone	15	Conglomerate and Grit.	200
White Cong.	500	White. Cong.	400	....		Jukes Brec. .... }	40
Red Qtzte.	200	Red Qtzte.	400	Felsp. Porph.		Haem. Zone .... }	
Red Cong.	400	Red Cong.	400	Pyritic Zone		....	
Haem. Zone		Jukes Brec. .... }	60	Felsp. Porph.		Granite and Hornfels.	
....		Haem. Zone .. .... }		Porphyries = Owen Cong.			
Lyell Schist = Porphyry		....					
		Dora Cong.	300				

Lynch Creek		*Currie River*		*Clark River*	
Red Quartzite	10	Red Quartzite	150	Red Quartzite	200
Quartzose greyw.	15	Conglomerate	100	Chloritic greywacke shales	
Varved clays	200	Jukes Brec. .... }	50	....	
Lynch Cong.		Haem. Zone .... }		—gradational change to Schist.	
Battery Volcs.		....			
Miners Slate		Sericite—chlor. schist.			
....					
gradational change to Quartz porphyry					

Mt. Sorell

White Quartzites	500
Conglomerates	100
Sorell Conglomerate (haematite zone)	= 500
Quartz porphyry and ? granite	

BASAL AND MARGINAL FACIES OF THE OWEN CONGLOMERATES

THE AXIAL BELT OF THE RANGE (from North to South)

MT. FARRELL

The coarse (3 inch) Owen Conglomerate overlies, with an abrupt change, similarly sized chloritised greywacke. There are no signs of unconformity or of conformity, as the sheared chloritic rocks do not provide good evidence. In this vicinity the base of the conglomerate is not very rich in haematite and the greywackes are feldspathised in bands mapped by Ward as intrusive syenites.

LITTLE FARRELL AND MURCHISON RIVER

On Little Farrell and in the Murchison Gorge the basal rocks are normal Owen Conglomerate but are rich in haematite, which occurs in the massive form as pebbles and interstitially as specular crystals. The underlying rock varies from quartz porphyry on Little Farrell to syenite and granite in the Murchison Gorge. These "igneous" rocks are metamorphosed conglomerates, and the relict bedding seen in the porphyries is conformable to that in the Owen Conglomerate. Veins of haematite, pyrite and quartz run out of the granite into the Owen Conglomerate.

MT. MURCHISON

Three hundred yards north-east of the northernmost of the Red Hills copper prospects lies the best exposure yet found of the Jukes Breccia. It is 50 ft. thick and contains slightly rounded 3 ft. cubic blocks of quartzite, 2 ft. slabs of slate and rounded quartz porphyry boulders. The rocks are haematitic and contain 2 ft. slabs of haematitic schist whose source is unknown. The underlying strata are perfectly conformable "greywackes". They are conglomerates with pebbles up to 3 inches, but with much fine material as matrix and as bands. Both pebbles and matrix contain feldspar porphyroblasts and are petrologically feldspar porphyry. Feldspar porphyry is not represented in the breccia, nor are any of the breccia rocks present in the porphyries. At least 100 yards of exposed contact is seen. Important points about the contact and porphyry rocks are as follows:—

1. The change in rock type is often complete in one inch and usually in 3 ft.
2. The rock types are texturally different. The underlying rock is not well graded and is texturally distinct from the Owen Conglomerate or the Jukes Breccia.
3. The contact is a conformable one but it suggests some unconformity nearby.
4. The contact marks the margin of a metamorphic zone.
5. The haematite schist is most in evidence near the richest copper ore body, while haematitic slate and slate are progressively less in evidence. The haematite fragments have a metasomatic origin.
6. The Red Hills copper body is a tabular anticlinal structure structurally conformable below the Owen Conglomerate. It is a bed of almost pure massive chlorite with some pyrite and chalcopyrite. It is a metamorphosed stratum, probably a pelite.
7. The stratum for 300 ft. below the ore body is a barely recognisable conglomeratic sediment which has been altered to a feldspar porphyry or syenite.

THE GOOSENECK

One mile south-west of the last exposure a coarse basal conglomerate is found containing large (12 inch) boulders of quartz porphyry. The base is not seen, but in the vicinity lies a vast quartz porphyry body which follows under the Owen Conglomerate. The evidence for unconformity is good, but the massive porphyry is unusual in that it is sometimes bedded and carries palimpsest pebbles.

NORTH END OF MT. TYNDALL

Where the power line and Dora tram intersect, the Owen Conglomerate seems to pass downwards into sub-greywacke sediments. Lenses of every size, from one inch upwards, of small quartz pebbles are found in the fine grained greywackes. The beds are commonly slumped and the lenses of quartz pebbles contorted. Immediately at hand, but overthrust on to these rocks, are beds of conglomeratic quartz porphyry.

About one mile east of the latter exposure, where Newton Creek penetrates the Tyndall Range, the base of the Owen Conglomerate is exposed over a wide area. There is the same transition into subgreywacke as in the previous example.

LAKE DORA

On the high ridge 40 chains west of the middle of the lake is an exposure of the Jukes Breccia which is coarse, 50 ft. thick and very similar to that at Red Hills. The transition here is as conformable but not so abrupt, and quartz pebbles up to 9 inches long begin to occur in the underlying strata 50 ft. below the contact. The rocks in this zone bear haematite as pebbles, as disseminated crystals, and in quartz haematitic veins. The strata 200 ft. below, carry, as at Murchison, a massive chlorite bed about 150 ft. thick; this bears pyritic ore in a dissemination of microscopic grains. Underlying the ore bed is a thick sequence of " greywacke " beds with many conglomerate bands. Exposures are in the surface of large roches moutonnées along the shores of Lake Dora, and are very good but discontinuous. The rocks are made up of quartz porphyry pebbles set in much fine bedded matrix. They are immediately acceptable as normal sediments with unusually fresh looking pebbles. It is hoped to show the rocks were once greywacke conglomerates which have been porphyritised. This locality is chosen as the nameplace for the Dora Conglomerate.

MT. JUKES 3624/8075

The type section of Hills (1913) is very like those at Lake Dora and Red Hills. It has 60 ft. of coarse subangular breccia underlying the Owen Conglomerate and conformably overlying an observed 300 ft. of greywacke conglomerate. It is clear from Hills's thicknesses, and Hills and Carey's (1949) account that they have included these greywacke conglomerates in their " Jukes Breccia ".

UPPER LAKE JUKES 3622/8060

This section, continuous with the type section, is more accessibly exposed. The track to the lake crosses bedded greywacke conglomerates on the tarn shelf where they have been scoured by ice issuing from the cirque. These greywackes are non-schistose rocks which show a halted process of feldspathisation. Pebbles and matrix alike contain porphyroblasts of feldspar and quartz. As the contact is approached, small quartz pebble bands are evident, and one would expect a transition into Owen Conglomerate. Instead, there is a zone of pyritisation and then the usual abrupt change into haematitic breccias. Despite faulting, the formations appear conformable.

SOUTH DARWIN PEAK 363/793

The map appended shows this peak as the down-faulted nose of a south plunging anticline.

The succession contains 40 ft. of Jukes Breccia, 200 ft. of conglomerate and 400 ft. of red quartzite with pebble bands. From the Peak towards the south-west the formation degenerates until, on the Clark River, it is only a 200 ft. thickness of quartzite. To the east and south-east it passes into thick calcareous shales, and the Tubicolar Sandstone alone is recognisable. The crucial exposure of this area is, however, that of the Jukes Breccia which, lying adjacent to the Darwin Granite, contains much haematite and granite pebbles. Hills has claimed that this exposure demonstrates an unconformity and a phase of Cambrian intrusion and mineralisation. For the sake of argument I will propose that the Darwin Granite is a granitised sediment and that the granite pebbles were formed in the contact zone in Devonian time. They were originally pebbles, of greywacke perhaps, which were altered to granite while other pebbles were replaced by haematite. The opposing views are conveniently called the granitisers' and magmatists' views.

The Jukes Breccia is fairly typical of the formation and consists of large 18-inch rounded boulders of granite, slabs of haematitic slate, many rounded pebbles of haematite, small fragments of a quartz chlorite rock (not schist) and small rounded pebbles of magnetite. An estimate of the proportions of ingredients is:—

Granite—2 to 18 inch pebbles	40%
Haematite—1 to 9 inch pebbles	30%
Haematite schist and slate fragments up to 12 inches long	5%
Quartz chlorite pebbles	15%
Magnetite pebbles	3%
Indefinable matrix with quartz, chlorite, and specular haematite	7%

About 100 ft. × 30 ft. of exposed breccias are seen in a low bluff. They stand in a vertical attitude and the granite appears to pass under this mass and to terminate it in a vague, undefinable fashion. The contact could be a weathered surface, but hardly a straight-forward unconformity. Again there might be a gradation of breccia into granite. It is the presence of magnetite above a fairly sharp surface which really defines the two bodies. The boulders of granite are perfectly fresh, unsheared and unschisted; they are clean cut and not at all diffuse; they weather out and fall to the ground. It is odd that, while quartz pebbles often have a blue-black rim of haematite, or further away have a pink suffusing of iron colouring, the granite is quite unstained. The structure is described later.

The Western Flank of the Main Anticline

MT. SORELL 3595/7950

This mountain, which is structurally an overturned anticline and syncline, presents three thicknesses of the lower beds to view in its eastern and vertical face. The western side of the mountain is a dip slope of Owen Conglomerate which consists of pink and white quartzites with strong conglomerates toward the base. The conglomerate bands are of relatively small pebbles, being rarely more than three inches and usually less than two inches across. The total thickness of the formation is 600 ft. to 700 ft., which diminishes southwards to only 200 ft. on the Clark River. The base is intensely haematite stained.

The lower portion of the eastern face of Mt. Sorell consists of 500 ft. of haematite-granite conglomerate. Though Hills called this the Jukes Breccia it is not a breccia, and is of much finer grain than any of the lower members of the Owen Conglomerate. Pebbles are, on the whole, well rounded and ellipsoidal and less than three inches long. They are in about equal proportions of haematite, a coarse quartz chlorite rock, and indisputable Darwin Granite. As it stands, these pebbles of granite, situated at least a mile away from the Darwin Granite mass, provide strong support to the magmatist view. The beds are probably in a position like those at Lake Dora and equivalent to the Dora Conglomerate. For the present they will be called the Sorell Conglomerate. It is unfortunate that the base of this stratum is covered by broad scree, for it is quite possible that if the Darwin Granite is sill-like it may extend under Mt. Sorell and so explain the Sorell Conglomerate as contact metamorphic rock. The presence of a coarse feldspar porphyry, not unlike some of the Darwin Granite, is demonstrable in the core of the Sorell anticline at Flannagans Flat. It is highly probable that this, or a variant of it, extends under Mt. Sorell.

CURRIE RIVER 3577/8036

Between Mt. Strahan and Mt. Darwin a lucky exposure reveals the full thickness of the Owen Conglomerate. Here, there is less than 300 ft. of vertically disposed strata which are cut through by a gorge of the superimposed Currie River. The Jukes Breccia is present and lies in contact with quartz chlorite schist of conglomeratic origin. About 100 ft. of coarse Owen Conglomerate overlies this and 150 ft. of quartzites complete the sequence. Forty chains downstream the Gordon Limestone overlies the quartzites. The Jukes Breccia, about one mile along the strike from the Sorell Conglomerate, contains no Darwin Granite.

MT. STRAHAN 3555/8050

The mountain has the structure of an asymmetric anticline overthrusting the sharp syncline of the Currie River. It is composed almost wholly of quartz sandstone and grit, but some underlying thin conglomerates are seen at Flannagans Flat Goldfield in the core of the fold. The contact is not well seen but is haematitised and pyritised, and the underlying rock is coarse feldspar porphyry. The total thickness of the Owen Conglomerate is 800 ft., and it appears that the formation becomes less conglomeratic from Mt. Sorell northwards.

KING RIVER GORGE 855/807

This difficult section occurs in a vertically walled gorge cut by the King River in steeply dipping quartzites. These are highly silicified, fine grained, red quartz sandstones with cross-bedding; they carry a few six-inch bands of quarter-inch quartz pebbles. It is difficult to tell the thickness as beds are repeated and the base is not seen; but 600 ft. of quartzites are known.

KING RIVER PACKBRIDGE 3577/8098

Below and to the west of the bridge about 20 ft. of conglomeratic greywacke occurs lying under limestone pug. The conglomerate contains small quartz pebbles to the extent of 30 per cent. This is not Owen Conglomerate as defined but is a facies of it.

LYNCH CREEK 3577/8149

At the King River-Lynch Creek confluence occur 10 ft. of fine grained, silicified, red quartz sandstones which immediately underlie the Gordon Limestone and are underlain by 15 ft. of greywacke conglomerate with small quartz pebbles. The greywackes peter out northwards, so that the quartzites and grits conformably overlie 200 ft. of varved yellow clays. This sequence is identifiable in several places further north.

SMELTERS RAILWAY 3604/8200

The railway cutting runs through much-faulted quartzose grits which have a sprinkling of greywacke pebbles and a sericitic matrix. There are 80 ft. of these grits underlying the Gordon Limestone. Despite intense chloritisation and kaolinisation these beds are clearly conformable on underlying greywacke conglomerates. The grits possibly lie outside the definition of the Owen Conglomerate, but are close to it. They are traceable northwards for a further forty chains.

SISTERS HILLS 3525/8250

The Owen Conglomerate consists of 150 ft. of fine grained sandstones and an underlying 150 ft. of conglomerate in which occasional quartz porphyry pebbles occur. There is no Jukes Breccia and the formation passes out by interdigitation with greywackes to the north-west. To the east the formation overlies thick yellow shales.

MT. MISERY. Road metal quarry, Zeehan Road.

The formation, 100 ft. thick, is dominantly of sandstones and coarse grits which conformably overlie red argillaceous greywacke sediments. The juncture is transitional and no breccias occur.

THE EASTERN FLANK OF THE ANTICLINE

Contacts along this limb are almost always intensely sheared and Owen Conglomerate lies against chloritic schist. The vertical conglomerate along the King Valley stands like a wall, and the formation diminishes in thickness southwards from 1,000 ft. at Crotty Smelters to 800 ft. on the Andrew River and less than 200 ft. at Darwin town.

DARWIN TOWN 3652/8000

The conglomerate for ten miles south of the town is of coarse grits between 100 ft. and 200 ft. thick. At Darwin it overlies very thick, fine greywacke grits and shales which are exposed on the mine foot-track. The contact appears conformable and the lower beds continue south for two miles, after which they pass into chloritic schists. South of the ten mile post the grits become finer and pass into Tubicolar Sandstone. Then a shaly limestone facies, like the Caroline Creek beds, becomes very prominent at the six mile post. The conglomerate is not recognised to the south of this point except as Tubicolar Sandstone or sandy limestone.

EAST OF THE SOPHIA-KING SYNCLINE

HAWKS CREEK

The conglomerate below the limestone is a fine grit 200 ft. thick. It rests on, or is "intruded" by, porphyritic granite. Both formations can be traced for several miles, and the granite, which is 300 ft. thick and a sill-like body, appears to pass under the Sophia syncline and to be continuous with the metamorphic granite and syenite in the Murchison Gorge. It is believed that the Hawks Creek granite is altered Dora Conglomerate, and it presumably rests unconformably on the adjacent Precambrian quartzites.

STICHT RANGE

The face of the range overlooking Anthony Creek consists of typical Owen Conglomerate with pebbles only two inches across. It is about 200 ft. thick and overlies intensely plicated quartzites. The latter are assumed to be Precambrian, for the reason that they most closely resemble known Precambrian strata of the centre of Tasmania.

ENGINEER RANGE

Here fine pink quartzites dip west below the Andrew syncline; they are less than 200 ft. thick and overlie plicated quartzites of Precambrian age.

THE OWEN CONGLOMERATE IN AREAS OUTSIDE OF THE WEST COAST RANGE

HOWTH

15 ft. of fine conglomerate and 10 ft. of Tubicolar Sandstone overlie slates. The contact has long been accepted as an unconformity.

TIM SHEA

The Owen Conglomerate overlies with a 60° unconformity the Precambrian dolomite of Tasmania. The contact was once a ravined and caved surface whose hollows, up to 100 ft. deep are filled with a breccia of dolomite which grades upwards by inclusion of quartz pebbles into conglomerate, and may be assessed at 200 ft. thick. The overlying quartz conglomerate is only about 100 ft. thick. It, in turn, is overlain by exceedingly finely bedded yellow to red quartzites. There are 200 ft. of these beds, then follow normal grits and fine conglomerates with porcellaneous chert fragments. These grits underlie the Caroline Creek beds at Tim Shea, and Mr. Banks informs me that the Caroline Creek beds, which are yellow shales, are passage beds of leached impure limestone. This exposure was shown to me by Professor S. W. Carey and the two succeeding descriptions have been recounted to me by him.

ADAMSFIELD

The conglomerate is 800 ft. thick, quite typical, and it unconformably overlies osmiridium-bearing serpentines. Elsewhere in Tasmania such bronzitites intrude Middle Cambrian formations. As the conglomerate is Tremadocian, Carey has thus shown the intrusion of the bronzitites to have occurred in later Cambrian time. The basal beds consist of serpentine detritus and the unconformity is marked by a placer of osmiridium.

ELLIOTT RANGE

The Owen Conglomerate which is less than 100 ft. thick rests with sharp angular unconformity on Precambrian quartzites. It is followed conformably by a great thickness of fossiliferous calcareous pyritic sandstones and shales (Caroline Creek Beds) which are followed conformably by Gordon Limestone.

LORINNA AREA

The conglomerate members of the Owen Conglomerate are not in evidence. Instead there is an enormous thickness, perhaps 1,500 ft., of the Tubicolar Sandstone. This is conformable below the Gordon Limestone.

LEVEN GORGE

The Conglomerate is 500 ft. thick. It overlies greywacke conglomerate and shales with abrupt change, but conformably and in well exposed section. There is no marked metamorphism at this point and the underlying strata are very similar to those at Mt. Misery.

MT. PROFESSOR

The whole formation is of quartzitic sandstones with grit and fine conglomerate bands.

MT. ZEEHAN

The conglomerate is 800 ft. thick and is similar to that of the West Coast Range. It unconformably overlies greywackes and lavas and thins out rapidly to the north of Zeehan where the Gordon Limestone rests directly on plicated quartzites of known Precambrian age.

THE DUNDAS GROUP AND PORPHYROID ROCKS

Underlying the Owen Conglomerate in the Range is a great thickness of greywacke sediments in various degrees of metamorphism. Recognisable formations have received local names such as Dundas Slates, Farrell Slates, and Read-Rosebery Volcanics. Recently Elliston, of the University of Tasmania, has analysed a 10,000 ft. sequence at Mt. Dundas, and proposed the name of "Dundas Group" for the collection of greywacke and volcanic formations there (this journal, p. 165). The term "porphyroid " refers in Tasmanian literature to a suite of metamorphosed porphyritic rocks, which are almost all Dundas Group strata. The users of the term applied it equally to sediments and " intrusives ", whatever the nature and time of their origin. The general criterion applied was that the rocks were porphyroblastic or porphyritic. As the Cambrian greywackes are very susceptible to metamorphism it is natural that Dundas Group and Porphyroids should be almost synonymous, and that in general Porphyroids has had a stratigraphic significance. It will be shown that quite locally the Owen Conglomerate may also be changed to porphyry so that Porphyroids has no time or stratigraphic sense, and really refers to a metamorphic suite. Accounts of Dundas and Porphyroid rocks must always overlap, but they are treated separately in the following instance.

THE DUNDAS GROUP

Apart from the Dundas area, there is only one extensive and unbroken section of slightly altered older strata. That is the sequence on, and to either side of, Lynch Creek. About 10,000 ft. of strata are represented and three major divisions are clear:—

1. An upper formation which is dominantly conglomeratic. 3,000 ft.
2. A formation of lavas and lava breccias. 4,000 ft.
3. A formation of fine grained dense greywackes and slates. 3,000 ft.

It is proposed to call these the Lynch Conglomerate, Battery Volcanics, and Miners Slate Formations.

LYNCH CONGLOMERATE

This formation is best seen in timber tracks north of Lynch Creek (3584/8154). From the red quartzites at Lynch Creek bridge the sequence runs downwards:—

Quartz bearing greywacke grits	15 ft.
Varved yellow clays	200 ft.
Coarse subangular conglomerates	200 ft.
Alternations of finely laminated siltstone and fine conglomerate	1,000 ft.
Coarse conglomerates	250 ft.
Alternations of siltstone and fine conglomerates	1,200 ft.

The coarser conglomerates consist largely of lava boulders derived from the underlying formation, and smaller pebbles of lava are very common throughout the formation. The finest conglomerates consist, however, mainly of slate and greywacke pebbles, and the pebbles are only one inch across and well-rounded. The siltstones show a markedly rhythmic banding. The formation dips west at 40°, and participates in all the folds of the overlying strata. There is no hint of unconformity between Gordon Limestone and Lynch Conglomerate. For structural reasons it is believed that there is discordance somewhere between the Lynch Conglomerate and the Miners Slate. The lavas are so obscure because of weathering, and by their irregular habit, that it is impossible to observe unconformity above or below them. The presence of lava breccias and pebbles of lava in the Lynch Conglomerate suggests that earlier lavas had been elevated and eroded, but this evidence could almost as readily signify that there was contemporaneous subaerial igneous activity in the neighbourhood. Erosion would not necessarily mean that orogenic movement had occurred but the presence of a very thick volcanic sequence does make it probable that some earth movement was taking place during Battery Volcanic times. Apart from these facts, there is no evidence to date an unconformity. Insofar as thick greywackes are characteristic of active orogenic belts, there is a distinct possibility that the Lynch Conglomerate contains repeated minor unconformities too small to show up in the crude structures which can be mapped. In total these unconformities might account for some of the discrepancies of dip between the Lynch Conglomerate and Miners Slate, but there is no way of assessing the degree of contemporaneous movements.

The one remaining piece of evidence on the relations of the Lynch Conglomrate lies in the attitudes of the formation as compared with those of the Gordon Limestone. The accuracy of mapping these two formations in detail is very low, but their strikes can be mapped for fully two miles in folded country, and any great discrepancy of dips and any great unconformity would show up under these circumstances. This is a small area to work with, but it is the largest intact piece of country available, and it does indicate conformity in the immediate area discussed here. In view of this conformity it is reasonable to include the Lynch Conglomerate in the Junee Group rather than in the Dundas Group of rocks, but the position of the lavas is left unsolved. It is suggested that these rocks be retained in the Dundas Group.

With this contention, the Lynch Conglomerate is a formation of greywacke sediments, predominantly conglomeratic, conformable below the Owen Conglomerate or the Gordon Limestone, and by inference unconformable on the Dundas Group or earlier sediments. It is analogous to the Dora Conglomerate.

THE BATTERY VOLCANICS

Proceeding upstream from the King Battery (3584/8146), the rocks met are augitic tuffs and spilitic lavas, deeply weathered and strikingly red in outcrop. The usual exposure is of vesicular lumps of lava in very weathered ochre. The vesicles are filled with dark-green chlorite which, because it does not weather further, gives a spotted appearance to the ochres.

The breccias are of heterogeneous, unsorted, angular fragments up to nine inches across. They are interbedded with subordinate greywacke conglomerates and shales. The formation was traced by asbestos seekers, who followed up veins of tremolite in the lavas. The tremolite is a normal alteration product of the augite in this vicinity. The diggings provide the few " fresh " samples of lava, which is an albite augite rock. The large extent of the lavas is indicated by the enormous amount of them in the associated and overlying conglomerates rather than by exposures of lava. There is a considerable variation in rock types from almost pure soda trachyte without augite to pyroxene rich spilites. The formation is difficult to define because of lack of knowledge but would seem to be of subaerial lavas and breccias of the keratophyre-spilite suite as defined by Wells (1922). It conformably overlies the Miners Slate and is overlain by the Lynch Conglomerate. By correlation with the Dundas area its age is considered to be Upper Middle Cambrian.

THE MINERS SLATE 3593/8145

This formation, exposed on Lynch Creek, is a hard, tough rock. Typically it is of dense greywacke siltstones hornfelsed or minutely recrystallised. It is not strictly a slate as it is not cleavable but only strongly sheared, and bedding is distinct. The formation, which is 3,000 ft. thick, has a well defined top but no recognisable base. Near the top it is dark-grey and fine grained, but lower down it is light-grey; particles become visible and the rock may be tuffaceous. There is often clear laminated bedding, and individual bands show tiny cross-bedding. Larger sedimentary features are absent except for the fantastic slump structures seen at 3631/8148, away from this section. That is a concertina-like folding which is restricted to the inside of bands one foot thick. The sediments are typical of a young, greywacke, phase of a geosyncline and the rhythms and slumping typical of redeposition in macigno facies. (Kuenen and Migliorini, 1950.) The formation is divided into three parts by interspersed breccias and lavas. It is represented in the topography by a ridge which is often split by erosion of the softer materials. This ridge, which often carries small mineral showings, is locally called the Miners Ridge, and it is from this that the formation name is taken. The slate forms a highly positive feature which, though broken at Queenstown, can be traced the rest of the way to Dundas. The base of the formation passes downwards into porphyries which may represent an underlying set of volcanics, but are really undefinable as other than porphyry. The formation can only be dated by analogy with the slates at Dundas which Opik (1951) dates as Upper Middle Cambrian.

Parts of the Lynch Creek sequence are readily identified elsewhere. The thick yellow shales near the Henty Bridge, 3533/2780, and the laminated shales at the Smelters are closely similar, and it is probable that they, the Lynch Creek varves and the red and green shales at Mt. Misery, are continuous. The greywacke conglomerates which occupy the area west of the Zeehan Road, between the Henty River and Pearl Creek, are all Lynch Conglomerate. Those beds become finer northwards, but, unlike the strata they pass into at 3505/8300, they contain no chert pebble bands. The Miners Slate is recognised on Reservoir Creek, in the middle of quartz porphyries on Conglomerate Creek, at the lower Power Station on the Yolande River, and alongside the Langdon River. Battery Volcanics and Lynch Conglomerate are met in a complex arrangement along the Comstock tram, with a good example of soda trachyte occurring in a bluff on the west bank of the river near Bridge 21, 3613/8242.

THE PORPHYROIDS

Twelvetrees and Petterd (1898, p. 43), referred some of the altered rocks from Mt. Read to Rosenbusch, who compared them with altered keratophyres of Thuringia and Wales and gave them the name porphyroid. This name has been freely used by the Geological Survey and was defined by Twelvetrees (1902), who stated that "a porphyroid is a dynamically altered quartz porphyry" and added that "the term can be applied to all the rocks of the porphyry complex". Tyrell (1930) gives the same impression of porphyroid, as a mylonitised and banded rock in which feldspar and quartz phenocrysts have escaped smashing. A. Holmes

(1920), attributing the term to Lossen, describes porphyroids in terms which best apply to Tasmania, that it, as " porphyroblastic metamorphic rocks intermediate structurally between halleflinta and granite gneiss ".

If the Tasmanian Porphyroids are typical of porphyroids elsewhere, and they seem to be so, then the mylonitisation of Tyrrell and dynamic metamorphism of Twelvetrees are misinterpretations of relict bedding or relict cleavage. Such impressions are readily understood on examining sections of porphyroblastic fine grained greywacke, or of sheared material which has recrystallised. It may be that Tasmania is exceptional in that rocks are wholly reconstituted without dynamic stress participating.

GRADATIONAL METAMORPHISM IN GREYWACKE FORMATIONS

SOUTH QUEENSTOWN

The Porphyroids are best studied in the area between Lynch and Roaring Meg creeks. Along the latter creek there is an exposure over a mile wide of quartz porphyry, and on Lynch Creek is the section just described. The Miners Slate continues from Lynch Creek through the quartz porphyry and provides an excellent marker bed. The lavas and conglomerates show a progressive alteration from south to north and pass into the porphyry. The first noticeable difference is the growth of small albite crystals which are red, and then a growth of larger pale crystals of oligoclase. The second stage is accompanied by much veining by epidote and speckling with pyrite. Next there is a growth of clear glassy quartz which forms a distinct rock type—quartz feldspar porphyry; the feldspars are up to a quarter inch across and quite sharp. The succeeding stage is relatively sudden, and feldspars are altered largely to sericite and their role taken by large quartz crystals, often milky with inclusions. An unusual phenomenon is apparent to the unaided eye in the beds which are well exposed in low bluffs at 3588/8165. The replacement of pebbles is selective, so that individual pebbles in a green augitic and tuffaceous breccia are the first to develop pink feldspars and the first to be quartzified. The margins of the pebbles are not sharp but diffuse. They appear to have reacted with surrounding rock and grown into it rather than to have reacted with outside solutions. No doubt both agencies were involved and were complementary. At first sight the fragments appear to be partly assimilated pebbles caught up in a lava, but the palimpsest pebbles constitute the entire rock, and the bed itself can be traced along its strike into normal breccias or conglomerate. The ultimate result of this process is best seen at a point, 3614/8251, 100 ft. above the Zig-Zag on the Comstock tram. At that point weathered surfaces show the rock as greywacke conglomerate, but on smashing, it is seen to be a uniform feldspar porphyry throughout. The same locality provides excellent examples, in blasted boulders on the railway side, of the intermediate stages of alteration to quartz porphyry. The pebbles, of which some portions now remain, were a pale chert at one stage, and in a process of outward growth have lost their identity. It is seen that crudely concentric growths of crystals when they extended to three inches across, merged into a homogeneous solid mass of quartz porphyry. There are many variations on this theme. Sometimes the centres of pebbles become void and are lined with epidote and red feldspar and sometimes calcite and galena fill the cavity (3569/8238).

The kind of diffused alteration described is not so general as a kind of metamorphism which results in a pebbly mass with very clear relict structures. Palimpsests are more distinct, for some reason, in the feldspar porphyries than in quartz porphyries. This may be connected with the process of formation; the quartz and feldspar are sometimes formed with only a slight lag between feldspar and quartz growths, but sometimes a rock is converted entirely to feldspar porphyry and only then to quartz porphyry; these latter rocks preserve palimpsests best.

Of course, the change from dark-green greywacke or lava to red or pink feldspar rocks is accompanied by loss of ferromagnesian minerals and by a change of augite through chlorite stages. Intermediate amphibole, tremolite, stages are very rare, and the common ferromagnesian mineral of the porphyroids is chlorite. The reaction of slaty or fine grained greywacke in this environment is odd. There seems no tangible reason, apart from texture, why these rocks should appear unaltered long after others have become unrecognisable. It happens that whole beds of such hornfelses run into porphyries, and even through granite, with very little alteration. Where such hornfelses have been brecciated prior to granitising the quartz porphyry replaces along the fissures and the porphyry appears to have a vast proportion of fragments in it. Such inclusions are common enough in quartz porphyries elsewhere and are sometimes interpreted as intrusion breccias, but these are clearly residuals. Unfortunately, the smashing of the country rarely allows the tracing of gradational processes along strikes, and work proceeds by observing at one point and applying at another until a complete picture is built up. The final argument rests in the consistency of the structural and metamorphic pictures established, and to a large extent in the consistency between this and other examples in literature.

Tasmanian literature contains many references to keratophyres and intrusive keratophyres and felsites. Although Ward (1908) located a lava at Tullah, and Waller (1904) mapped spilites at Zeehan, no other lavas are detailed anywhere. Similarly, there are numerous broad mentions of intrusive felsites, but only one mention (Gregory, 1905), of an " intrusive " contact. Microscopically, the felsitic rocks are very similar to intrusive felsites such as those of the Tertiary complexes of Scotland, and that is the only evidence for their intrusive character. Describing the Battery Volcanics and Lynch Conglomerate, Twelvetrees (1901, p. 29), finds that " microscopical examinations shows " it " to be an augite syenite porphyry "; " *Segregations of quartz much resembling pebbles have been taken for foreign inclusions* "; and " *the appearance of the pseudo pebbles is deceptive* "*. This appeal to the microscope blinded the vision of many, but not all, investigators. Some, including Ward (1908), who remarks on the " insensible gradation from felsite into feldspar porphyry and quartz porphyry ", and Hills (1927, p. 2) regarded the Lyell Schists as metamorphosed igneous breccias. Waller has remarked to me personally on the puzzling appearance of " intruded " blocks of porphyry in slate where intrusion was out of the question and replacement alone was possible.

* All italics in this work are the author's

Acceptance of microscopical evidence was the rule of that time. In England, in the Lake District in 1875, Clifton Ward had described the Tasmanian type of phenomena excellently, pointing out the *differential replacement of coarse ash pebbles which " at a distance from the granite puts on more of the appearance of granite than does fine ash close to the granite "*. With the aid of the microscope, Green found this a strange old-fashioned view. Hatch is less ungenerous. Ironically enough, Ward also described Harker's classic Carrock Fell Gabbro as metamorphosed lavas.

In Tasmania, as in the Lake District, the magmatist has a problem; when conglomerates have a porphyritic matrix it is necessary to call the rock a brecciated lava or intrusion breccia, and when bedded rocks become feldspathised they are keratophyres, banded porphyries and felsites. So far there are no nodular or banded rhyolites, but I think that some of the conglomerates at Red Hills would pass for nodular keratophyre.

In the Range there are few exposures of unaltered keratophyric lavas, and it is thought that they were never extensive. The augitic lavas are much more frequently identifiable and of much greater extent. The best localities for keratophyre exposures are between the one and two mile posts of the Tullah tram, i.e., from Farrell Junction; on the Tullah track one mile from Rosebery; and on the Comstock tram. The areas of spilitic lavas include extensive tracts west of Zeehan, above the slates of Dundas, and on Lynch Creek as well as on the Tullah tram and track.

Intrusive phenomena of the felsites such as dykes, are not demonstrable, but some of the marginal phenomena of the quartz porphyries, on Roaring Meg and Cusick creeks, appear to be intrusive at first sight, i.e., lit-par-lit.

It is even probable that in the large structureless bodies of Mt. Read there were intrusive bodies of keratophyre comagmatic with the lavas, but they can only be hypothesised. On the other hand, there are no demonstrable lavas of quartz keratophyre anywhere, and it is probable that any similar intrusive rocks have had their quartz introduced after consolidation.

Apart from the Lake District and Tasmania, the porphyroid metamorphism of greywacke conglomerates and spilites is widely recognised. In Ontario, Holmes (1944, p. 1116) recognises a process by which " *conglomerates are metamorphosed to porphyry while fine grained greywackes are not* ". Goodspeed (1937) and Evans (1944) speak also of *selective replacement of pebbles by porphyry.* There are many such cases where the phenomenon has been recognised, but many more where rocks have been described and the process of replacement has not been recognised. Consider the Tregidden Conglomerates, which are associated with spilites in Cornwall; Flett (1946, p. 154) remarks on the odd feature of feldspar phenocrysts in the matrix of conglomerates. The crystals make it appear that the finer particles of sand were actually deposited as whole crystals. That phenomenon is common in Tasmania, particularly in the Red Hills feldspar porphyries. At Porcupine, Evans (1944) has used phenocrysts in matrix as the feature which distinguishes a porphyritised conglomerate.

He also remarks on finding mineral grains running from one pebble into its neighbour. In the West Coast Range this criterion, in hand specimen, is only applicable to the feldspar porphyry at the Zig-Zag. I have little doubt that the phenomenon of porphyritising is a common event in the history of geosynclines. Having seen the nodular rhyolites which form the base of the Borrowdale Volcanics in the Lake District, I should call them porphyritised conglomerates. If other nodular rhyolites of the Caledonian geosyncline are similar, then the process of porphyritising must be very common indeed.

MURCHISON RIVER

The example described at South Queenstown is only excelled by the exposures at Mt. Farrell. The rocks involved include the whole Dundas sequence. The lavas and breccias along the Tullah tram appear little altered, but are followed at the Mackintosh Bridge by syenite porphyries. About 150 yards upstream from the bridge are remarkable grey feldspar porphyries with very distinct bedding and lamination. The grain size is one-eighth of an inch, and apart from a little chlorite only feldspar is present. At the Murchison Gorge occur the Farrell Slates, very similar to the Miners Slates but with quartz pebble bands. They are followed above by chloritic breccias which, it was mentioned earlier, include syenites. Further upstream the syenites become progressively coarser and grow coarse biotite and feldspar porphyroblasts. The rock is clotted with all kinds of fragments and has no definable boundary against the schistose breccias. The margins are chloritised and pyritised. Pyrite, haematite, quartz and chalcopyrite appear in veins running into the Owen Conglomerate. About two miles upstream from the entrance to the gorge the syenite gives way to a porphyritic granite, whose relation to the conglomerate is like that of the syenite. The granite is still clotted, but with fewer fragments than before. The large pink feldspars are of orthoclase. The granite sill, mentioned earlier, on the far side of the Sophia Syncline, has been traced in a similar position below the Owen Conglomerate to within a mile of the Murchison granite. The two rocks are of the same biotite granite, and the probability is that the " sills " are continuous and all of metamorphosed greywacke sediments. From the Murchison River the granite passes west over the north end of Mt. Murchison into quartz porphyry, then feldspar porphyry. Everywhere this stratum preserves a structural position overlying the Farrell Slates; it is certainly a tabular body, certainly a metamorphosed sedimentary formation, and it occupies the position of the Dora Conglomerate.

PORPHYRIES WITH CONCORDANT CONTACTS

RED HILLS

The porphyry contacts at Red Hills and Lake Dora have been described. At Red Hills the porphyries show the following descending sequence:—

Jukes Breccia with haematite replacements	50 ft.
Feldspar porphyry = greywacke conglomerate	150 ft.
Massive chlorite, pyrite beds	150 ft.
Feldspar porphyry, massive with conglomeratic bands—	200 yards across
Quartz porphyry with occasional pebbles —	50 yards across
Fault zone of schistose porphyry and chlorite sericite schist.	
Massive quartz porphyries.	

In this area there can be no question that the rocks are metamorphic, nor that they are typical quartz porphyry or feldspar porphyry. The rocks have a rusty colour on weathering, and in fresh specimens the quartz porphyry has a reddish-brown or purple colour. The fresh feldspar porphyry is pink, has orthophyric texture, and an even grain size of 2 mm. There are all grades from feldspar porphyry (felsites of earlier writers) through a rock with tiny clear quartzes, to the quartz porphyry which is studded with phenocrysts up to 1 cm.

At Lake Dora there is even less possibility of confusion on the original constitution of the rocks. There, they are so patently conglomeratic and bedded that they would not normally be regarded as metamorphosed. Some bands near the Lake are highly altered, however, and the general sequence is the same as that at Red Hills. In both areas the original conglomerates were well bedded but not well graded. Their pebbles run up to 3 inches across, are well rounded, and are set in much fine matrix which is now porphyroblastic.

MT. SEDGWICK

The rocks of the Mt. Sedgwick Dome are conglomeratic quartz porphyries with thin hornfels bands. They are identified with the Dora Conglomerate and consist of coarse pebble beds whose diffuse margins fail to separate them from massive porphyry. The pebbles are exclusively of porphyry, and at first sight it appears that they are derived from, and deposited on, the massive rock. This view is not tenable, because the massive rock and pebble beds are interbedded, nor can it be allowed that the " igneous " rock is intruded; apart from the vague contacts and coarseness of the porphyry, the structure would demand three phases of intrusion and of erosion; each erosion should produce a conglomerate and each conglomerate should be almost exclusively of porphyry pebbles. The bedding of the porphyries is conformable with that of the Owen Conglomerate, but the juncture of the formations is oblique to bedding, for it lies below the Jukes Breccia at 364/828 and below the Red Quartzite at 3645/8255. All contacts are haematitised.

MT. LYELL, 3660/8220, AND LITTLE OWEN, 3665/8180

The Dora Conglomerate in these areas is similar to that in the last, except that on Mt. Lyell it is slightly schistose and its pebbles are drawn out a little in the vicinity of the North Lyell Fault. The Dora Conglomerate pebbles, on the whole, are coarse—up to six inches across; they are tabular, elongate and ellipsoidal, and are fairly well rounded. There is no doubt that they underlie the Owen Conglomerate, and they do so conformably. The rocks show quite sufficient of the bedding, much of it on aerial photographs, to compare the structures above and below the contact line. Both formations form low domes which are concentric. The contact line below Lyell Peak lies below the Jukes Breccia, which is haematitic, but following it to the east the contact passes from bottom to top of the Owen Formation, until at 3687/8228 only the uppermost sandstones of the formation overlie quartz porphyry. The same happens above the railway on Little Owen where it is more accessible. There the conglomerates are down to 300 ft. thick and almost the full thickness can be seen in the cliffs. The contact stratum there is the blue haematite stained " Red " Quartzite. Unhappily in view of the known sedimentary variation of the Owen Conglomerate, these changes of horizon are almost useless for demonstrating discordance of contacts.

PORPHYRIES WITH PROVEN DISCORDANT CONTACTS

Regional metamorphism in the traditional sense does not allow for this kind of situation to be described; that is, that quartzites might alter abruptly and, within an inch, be replaced wholly by feldspar porphyry. Classic metamorphism allows only a restricted diffusion of material, but in porphyroid metasomatism there is complete freedom of migration within clear cut zones. The absence of dynamic stress phenomena is the second great difference between porphyroid and " regional " metamorphism. Although there are excellent descriptions of gradual alteration of quartzites in the work of Reid (1945), Quirke and Collins (1930) in Canada, and Ellis (1947) in South Africa, only Perrin and Roubault (1942) in France describes an abrupt metamorphic boundary quite similar to that at the Lyell Mines.

MT. LYELL-COMSTOCK MINE

The eastern side of the open cut shows vertical quartzites which, passing downward, have an indefinable margin against sericite schist. The massive structures of the schist and quartzite are continuous, and the margin between the two is a diffuse irregular zone. Continuing downward, the schists are completely replaced by a mass of pyrite, which has a knife edge contact with schist. There are two stages of replacement—one of quartz by sericite and one of sericite by pyrite. Because the latter is commonplace, and because we think of sulphides as " mobile ", it is readily conceivable that pyrite replaces sericite. Because we usually think of sericite as resulting from the alteration of chemically similar feldspar, without a vast change in composition, it is difficult to believe that quartz can " change " to sericite. In fact, the quartz is not " changed " but is removed, and sericite takes its place. The contact is such that sericite penetrates the shaly layers between quartzite bands in the manner of lit-par-lit " injections ", and that red quartzite fades to pale-yellow and then disappears into coarse, almost pure, sericite. The latter change takes place in a distance of less than two inches. The only direct evidence that the schists are altered quartzites lies in the residual bedding which occurs, and which can be traced across the contact. Neither microscope nor chemical analysis can demonstrate that this change occurs, half as well as can the naked eye; complete reliance must be placed on recognising the residual structures and on the interpretation of the shapes of contacts.

MT. LYELL MINES

The Lyell structure has been described by Conolly (1947) as resulting from the intersection of a monocline with smaller folds. Along the resulting upturned margin of the Owen Conglomerate a metamorphic contact occurs. On the one side are quartzites, and on the other schists. Chlorite and sericite are the predominant minerals of the schists, in which schistosity is not regionally oriented but is parallel to local faults and shears. The schists appear to be Owen Conglomerate which has been bodily replaced by feldspar, sericite, chlorite and pyrite. The schists, Mt. Lyell Schist of Hills and Gregory, are green to rusty looking rocks which do not fit into any recognised category. They vary considerably from the pale-yellow sericite, or paragonite, schists of the Old Blow to massive unschisted chlorite rocks. In the low grade ore which is, like the other bodies at Dora and Darwin, a stratum, the rock contains much sericite as well as pyrite and chlorite. Although pyrite is only just discernible in the ore it is easily seen in stream sections below the North Lyell Ridge. The rocks frequently show a banding which has consistent strikes, and frequently the schist is nodular or lumpy as if it were, in fact, altered conglomerate. This banding agrees with the disposition of the Owen Conglomerate of the North Lyell Ridge and with that across the contact. When strata on both sides of the contact are mapped on the supposition that they are continuous, a consistent picture of structures is obtained. Of minor structures, the white rectangular flecks in the schist are interesting. Though now wholly of sericite these indicate that the schistose conglomerate once passed through a feldspathising stage.

The shape of the contact is only less complex than those of lit-par-lit intrusion surfaces. It led Gregory (1905), Edwards (1943) and Nye (see Edwards) to believe the schists were altered intrusive porphyries. The contact wanders erratically from the Tubicolar Sandstone down to 1,200 ft. underground, and Conolly, from mine surveys, finds that the Owen Conglomerate and the schist interpenetrate as though the schist had replaced individual beds.

Both Conolly and I, independently, have traced palimpsest features of the schists, and can demonstrate the continuity of beds and folds across the contact line. Only rarely is it possible to trace beds through the contact zone because of the local intense metamorphism.

On the outside of the contact surface is a zone of conglomerates which are made up very largely of hard blue haematite pebbles. The possible origin of these pebbles is debatable, and their true interpretation of utmost importance. Hills contended that they indicated unconformity and were derived from pre-existing Cambrian deposits. Dr. Opik has suggested to me that they might be of lateritic origin—I contend they are of metasomatic origin. The " facts " are as follows:—

1. The pebbles are clean cut.
2. The pebbles are mixed with quartz pebbles over some 50 ft. from contacts, but are most numerous and almost exclusive near the contacts.
3. Pebbles occur to a depth of six inches alongside sericite veins which cut the bedding of normal quartz conglomerate.
4. The contact and haematite pebble zones run vertically through the 1,200 ft. of the conglomerates.
5. Despite 4, no haematite pebbles occur elsewhere as bands in the conglomerates.

Looking at the regional picture we find:—

6. The haematite pebbles are most numerous when close to mineralised faults and copper ore bodies of Devonian age. This applies all over western Tasmania—Mt. Balfour, Mt. Darwin, and Dial Range.
7. In the cases where porphyry-Owen Conglomerate contacts are concordant the haematite occurs only at the contact and neither below nor above.

8. The slab-like haematite schist of the Jukes Breccia was not transported in that condition because it is friable, nor was it "schisted" *in situ*, because the neighbouring haematite pebbles are massive. The specular haematite has grown *in situ* and adopted the lineation of random slabs of slate.

9. Where the Owen Conglomerate is in contact with little altered greywacke, as on Newton Creek, not only are there no haematite pebbles, but the whole formation is almost unstained and white.

It is hardly necessary to add that the proposed sources of haematite are hypothetical.

Allowing that the pebbles are metasomatic in origin it follows that all of the "underlying" rocks are probably metasomatised. That means that, among others, the innocent looking porphyry conglomerates at Lake Dora are reasonably interpreted as metamorphosed. More important still is the inference that, as the pebbles of haematite are replacements of individual pebbles, rather than of the rock as a whole, the original conglomerate must have had varied constituents. Considering only that section at Lyell, it is clear that as the Owen Conglomerate was all quartz or quartzite, the differential replacement is attributable to the texture of the pebbles. By a process of elimination it appears that the quartz schist is the first type to be replaced, perhaps because of the straining and raggedness of its crystals. Vein quartz goes next and quartz sandstone last. Replacement of the Owen Conglomerate by sericite follows the same order, which is probably an order of decreasing energy content of crystals.

On the outside of the contact line there are many hundreds of small quartz veins which peter out upwards, but which end abruptly downwards against the schist. It appears that the formation of these veins and the silicification of the Owen Conglomerate represent a front of silicification overlapped by one of haematitising. It is thought that the overlapping silica-haematite fronts are relatively low temperature phenomena which, in less intensely mineralised areas, are represented by a single zone of jasperising. The different crystallinity in these contacts is probably a function of volatiles present. This outer zone of silicification is not to be confused with Reynolds's (1946) front of silicification, which is a higher temperature phenomenon. To avoid confusion it is best to speak of a zone of jasperising.

At Lyell there is a second and much later phase of low temperature silicification associated with late north-east veins. It cuts porphyroids and quartzites alike and is not a zonal phenomenon. The silica of these veins is cherty and never coarse; it results in the silicification of the schists which Gregory (1905) and Hills (1927) remark on at North Lyell and Conolly notes at Comstock. Two phases of silicification of the Owen Conglomerate make it difficult to assess either of them accurately.

The conglomerate-schist contact surface is a relatively thin zone, being rarely more than twelve inches, and often only one inch, across. It is imagined as having been an isothermal surface of a critical kind, perhaps at the critical temperature of water. At favourable points round the North Lyell Ridge (3627/8220), the gradation of quartz conglomerate to quartz sericite schist is observable. The change is complete in six inches; the pebbles first become loose as the matrix is replaced by sericite, the red stain of haematite changes to green or yellow and the lustre of quartz is replaced by a dull porcellaneous appearance. The succeeding stage, when the pebbles are wholly replaced by sericite and chlorite, is sudden. The change is preferential, the sandstone bands being the last to alter. Near the Blow they are left as ragged blocks deep in the schist (3629/8204). Sometimes the Red Quartzites and associated pebble beds are left as a broad ridge or band interdigitating with schists. This is the nature of the North Lyell Ridge.

Unfortunately, the haematite zone usually masks other processes, but it appears that both sericite and haematite have replaced quartz pebbles. It also happens that feldspar porphyry has replaced quartz pebbles, but this is rarely clear because the feldspar porphyries are themselves replaced by sericite chlorite schist. Most of the schists originated in this way, which is why Nye, in Edwards (1943), described them as altered intrusive porphyries. Such sericitising of feldspars must be regarded as a retrograde process. While a well defined zone of sericitising is common there are places, on granite contacts, where it is missing and in many cases sericitising is clearly a late phenomenon and is not zonal. The chloritising is associated with sericitising to a considerable extent but is often independent. I believe that chloritising is fundamentally zonal and that it coincides with a zone of pyritising. This zone is very clear indeed and, very oddly, it is usually inside the zone of feldspathising. At Lake Dora, Red Hills, Lake Jukes, Darwin, and West Lyell the sequence runs:—Quartzite, haematite, feldspar porphyry, chlorite, feldspar porphyry, quartz porphyry (or schistose varieties of these). I imagine that the arrangement is accidental, dependent on the nature of the original rocks, and that the chlorite zone can be regarded as following that of haematite. It is conceived that the zone of chlorite and pyrite does not move forward smoothly but proceeds in distinct steps from one suitable host to the next. On the small scale that principle is implied by the selective replacement of pebbles by haematite.

SNAKE SPUR 3637/7997

The red quartzite cliffs overlooking the long-derelict Darwin town are of slightly dipping Tubicolar Sandstone 200 ft. thick. That is a dense, current bedded, fine grained silicified rock which overlies schisted feldspar porphyry. 300 ft. below lies the structurally conformable low grade ore, a tabular body of sericite, chlorite, pyrite schist. The quartzite is blue with haematite; it contains rectangular sericite chlorite pseudomorphs of feldspar and grades into the feldspar porphyry of Darwin Peak. The evidence clearly indicates the following replacements: quartz to haematite, quartz and haematite to feldspar, quartz and feldspar to sericite and chlorite.

LATE PROCESSES

QUEENSTOWN 3597/8184

It may be anticipated that any zoning of metamorphic processes which once existed must have been followed by processes consequent on cooling. One might expect to find retreating isogeotherms and, in a crude fashion, retreat of fronts; the unzoned and random processes of retreat are analogous and similar to, and in some cases identical with, the late phases usually attributed to magmatism.

At Queenstown it is possible to study the effect of late processes which post-date the formation of the quartz porphyry there. The porphyry body south of the town has been completely leached by steam and reduced to a mass of china clay studded with quartz crystals. The adjacent Crotty Quartzite at the Sandhill has been deprived of any binding material it might have had and is now a heap of soft white sand. This leaching is most intense along the north-eastern fractures, and it is supposed that it is the silica lost in this process which is deposited higher up in the north-eastern vein system. It is probable that the gold and galena content of these veins has a similar derivation. Where north-east veins cut the low grade copper ores enrichments occur (see Conolly (1947)), and these are probably the result of leaching and redeposition. This is almost certainly true of the siliceous ores of Comstock and North Lyell, which are both late in origin. Where the augitic tuffs behind the Smelters (3604/8197) have been injected, the resultant rock is a dark-green clay consisting of kaolin and chlorite. This is the "fresh" rock of much of the country and it reveals its origin through the "ghosts" of breccia and lava fragments it contains. Where peat cover remains this green muck is preserved as "fresh" rock, but on exposure oxidation turns it into a limonitic clay whose livid rusty hue characterises the landscape.

It is emphasised that these processes of hydration, leaching and redeposition; of kaolinising, sericitising, silicifying, pyritising and chloritising, though similar to those existing on the outer fronts of metamorphism, are not zonal; they are late and retrograde.

SUMMARY OF ZONING

After allowing for late phase anomalies, the following system of zones is thought to exist in an ideal sequence:—

(*a*) Silicification. } Jasperising
(*b*) Haematitising. }
(*c*) Contact of schist-non schisted rocks. Barite common.
(*d*) Sericitising; desilicifying.
(*e*) Chloritising and pyritising; reduction of haematite to magnetite.
(*f*) Feldspathising.
(*g*) Feldspathising and epidotising.
(*h*) Introduction of potash as biotite and orthoclase.
(*i*) Introduction of quartz.

This scheme will be developed in Part II.

Some endorsement of the sequence is obtained from Dunham who, contributing to Reynolds (1946), suggests that the zone of haematite at the copper mines at Butte is a front of desilicification; from Lapadu Hargues (1948A and B), who proposes a front of mineralising and reduction; and from Leedal (1952) who describes the metasomatic replacement of quartz by haematite and albite. A zoning of chlorite schist and jasper is very apparent in Miles's (1943) account of West Australian jaspers; the repeated association of gold and pyrite at such contacts is a world wide phenomenon.

The schist-jasper or pyrite-haematite contact is a most important metamorphic and economic index.

THE DARWIN GRANITE

This topic has been delayed while some principles were made clear at other less controversial places. The Darwin Granite is a metamorphic complex which occupies the plateau of Mt. Darwin in a rectangular outcrop. The granites occupy the core of an asymmetric anticline, and their strike, which is very obvious, is parallel to the anticlinal axis. At each end of the granite the anticlinal roof has been dropped and the body terminated. The granite margins to east and west are defined by their contacts with hornfelsed fine-grained greywacke beds and adinoles respectively. The granite is then either sill-like or like several sills with "concordant" walls. Hills has mapped a roof pendant which runs through the granite and which consists of sericite schist. Two more roof pendants have been mapped by myself, but these, while being a more distinct black hornfels, are not as long as the former. The granite consists of three broad bands of Darwin Granite, one of graphic granite and another of quartz porphyry. At the northern end of the body, just about on the fault line, the granite merges into quartz porphyry.

The granite itself is a coarse porphyritic rock identical in places with that on the Murchison River. It contains pink phenocrysts of feldspar with a green and white matrix of feldspar, chlorite, and quartz. The rock is quite hard and fresh and has not been subject to marked alteration, so that the chlorite is considered to be original. Biotite does occur as thick books, but sparingly and localised. The granite is a massive rock weathering into large blocky forms with few joints and no shear planes. It would make good building stone on this account, but the importance of lack of jointing lies in the fact that this granite (if we accept the evidence of unconformity), has been folded acutely. It must, also, have been sheared with some force at the exposure of the "unconformity"; sufficiently to create a sharp tear fault and rotation of pebbles in the overlying Owen Conglomerate. The granite is sheared neither in its mass nor in its pebbles. The granite is, by its form alone, metamorphic, and if further confirmation were needed it contains palimpsest pebbles which weathering has brought out very clearly at 3636/7946 (Plate I). These are not vague shapes; they are sufficiently clear to show the granite conglomerate to be made of large rounded ellipsoidal pebbles from six to nine inches long. They show no appearance of being drawn out and are arranged parallel to the strike of the other members of the complex.

The graphic granite occurs at 3636/7963 and is some forty yards wide. It is a white rock with fine-grained graphic intergrowth of quartz and feldspar. The quartz porphyry on the north and west of the plateau is the typical red rock of the region. The adinoles are the only example in the region of feldspar porphyroblasts growing to macroscopic size bedding, and are black with pink flecks and streaks. The complex can hardly be other than Dundas Group greywackes or Lynch Conglomerate, in fine grained greywacke. They have a somewhat wavy but not plicated or both. A traverse across the granite on the creek at 3636/7963 shows the following cross section from east to west:—

Black fine grained greywacke hornfels	100 ft.
Darwin Granite	800 ft.
Black fine grained laminated greywacke hornfels	200 ft.
Darwin Granite	600 ft.
White Graphic Granite	120 ft.
Sericite schist	100 ft.
Darwin Granite grading into—	
Quartz Porphyry	600 ft.
Adinoles with magnetite veins	500 ft.

This shows no repetition which would demonstrate an anticline, and the thicknesses, which are based on the rocks being vertical, indicate a total of the order of 3,000 ft. It is unfortunate that only one area of contact with the breccias or conglomerates is seen. This is the vertical limb of the fold at South Darwin Peak (see below under Lyell Shear). Naturally, the fault which dropped the conglomerates and eliminated contacts could not eliminate the vertical limb so readily, and this remains on the north side of the fault. The breccia is vertically disposed and appears to face topside to the west. As the breccia lies on Hills's roof pendant, the structure requires that it, as well as the pendant, should pass into the granite. In a broad sense, then, the granite is discordant to the attitude of the breccia, but the evidence is not convincing.

There is only a very vague and worthless suggestion of gradation between the Jukes Breccia and granite. Some distance away (3617/7923) a small downfaulted block of Owen Conglomerate lies in contact with granite. The arrangement suggests that the granite, like the conglomerate, is tabular. At this contact the rocks are pyritised and sericitised, a feature absent from the first exposure, the Jukes Breccia is missing and the contact is parallel to bedding in the Owen Conglomerate. The presence of haematite and magnetite at the contact do not, especially in view of the reduction change at contacts, carry any weight for unconformity at this locality or on Mt. Sorell. The presence of granite pebbles carries a great weight, and in order to explain them in a granitising hypothesis it would be necessary to postulate that they were fragments of a rock similar to that from which the local granite was formed, and that they have been selectively replaced by feldspar and quartz. One must further propose that other pebbles have been replaced by haematite, and that some of these, low down in the contact zone, have been converted to magnetite. It is indisputable that the granite complex is a metamorphic one and the Darwin Granite a metamorphosed conglomerate. Inside the complex itself it is certain that beds of hornfels have not been replaced while other beds have been changed to Darwin Granite, graphic granite, or schist. Each has been differentially affected, and so clearly that contacts are very sharp. If one allows that this is true, and it is commonplace, then it is unreasonable not to allow that varied pebbles within fifty feet of the contact might be similarly affected.

The arguments now are that the contact represents a straightforward unconformity, or a metamorphosed unconformity between Jukes Braccia and Dundas Group rocks, or a metamorphosed juncture between conformable Jukes Breccia and Dora Conglomerate. The evidence of conformity elsewhere and the presence of "pebbles" in the granite suggests that the third case is the most probable of the three.

If one accepts the thesis of a Cambrian granite one must also accept that the Darwin Granite was formed *in situ* by metamorphism of conglomerates, and that it was granitised again in Devonian times. This would appear to require a lot of coincidence.

On the other hand, and viewing the wider problem of Jukes Breccia contacts, the granitiser must explain the presence of quartz porphyry pebbles in places like Red Hills, where the underlying rocks are feldspar porphyries. It happens that in such localities as Red Hills the Jukes Breccia, overlying pebbly feldspar porphyry, never contains feldspar porphyry pebbles. It will be contended, in Part II, that both the quartz porphyry and feldspar porphyry pebbles were originally greywacke, and that they have been differentially affected in the two zones of feldspathising and silicification.

Looking further afield there is very strong evidence on record to show that the granitising thesis is a possible one. The following examples are useful illustrations:—

(1) O. A. Jones (1947) reports on observations made by Professor Bryan and himself on a granite contact in Queensland, "in favour of the granite being intrusive":—

(*a*) The *granite is intruded as dykes into a conglomerate.*
(*b*) The strata end abruptly against granite.
(*c*) Shales appear baked.

and "in favour of it not being intruded":—

(*a*) *Granite pebbles appear in the conglomerate.*
(*b*) The granite contact is coarse.
(*c*) The granite clearly consists of boulders.

These observations had been previously made by several other geologists. The example clearly parallels the Darwin case and is well authenticated.

(2) The next example has to be compiled from reports on the Mesabi Range. Allison (1925, p. 500) finds that "*unmistakable fragments of it* [*the Embarrass granite*] *occur in the conglomerate* at the base of the Animikie series". The contact is described as having been weathered and later metamorphosed, and the overlying haematite pebbles are, of course, lateritic. In the opposite camp Richarz (1930, p. 611) finds, as did Leith, that the same granite is intrusive, and that "*pebbles of the overlying iron formation are partially encompassed by granite* and surrounded by a contact rim" (he imagined the haematite to be a prior deposit). He states (p. 609) that "an examination of stratigraphic conditions [meaning discordant relation] re-establishes beyond doubt the intrusive character of the granite", and that (p. 607) "feldspars grow from the granite into the sediment". Winchell, independently of all and supporting intrusion, is quoted by Richarz as saying "*the magnetic quartzite* [of the overlying formation] gradually becomes less highly charged with magnetite, acquires feldspathic and quartzose material, and finally *is changed into the syenite of the Giants Range*", i.e., the Embarrass Granite; and as observing "that the Animikie appears to be feldspathic in spots, as if there were boulders of syenite in it". In neighbouring

areas of the Giants Range everybody is happy about the unconformity with its haematite and granite boulders, but very puzzled about the source of the haematite of the pebbles. This is a highly authenticated example and the writers were discussing the same localities. The granite pebbles were fairly clear to some people, though apparently nothing like as clear as at Mt. Darwin. The parallel of the example, even down to the presence of pyrite and magnetite zones, is very clear, and if we consider the jaspers and haematite pebbles as silica and haematite zones there is a very marked parallelism. Winchell's example of gradation is very like that hypothesised for Mt. Darwin and his boulders of syenite are equivalent to boulders of granite at South Darwin.

(3) Goodspeed and Coombs (1937) give an excellent example of preferential replacement of boulders. They propose that in a cataclastic breccia certain *blocks of hornfels have been preferentially replaced by granodiorite,* while *other blocks, which were of the same material, have been left unaffected,* and explain the difference in reactivity of the two sets of fragments as due solely to a more sheared condition in the replaced blocks. Photographs show boulders of granodiorite with margins quite as sharp as those at Darwin Peak.

(4) Collins *et al.* (1926, pp. 11-32) describe a conglomerate sequence which runs from granite porphyry, through a conglomerate of granite porphyry boulders, and through pyritic, sideritic, haematitic and jasperoidal rocks into greenstones. *The unconformity cannot be delineated because the granite and granite boulders merge.* Moreover, the matrix of the conglomerate consists of sharp unweathered feldspars and quartz. Because of this it is deduced that conditions of formation of the conglomerate were most unusual. While it is deduced that there is an unconformity, the authors conclude that there is also a second granite which can be demonstrated to intrude the overlying strata. The two granites are so alike as to defy their separation in the field, and their *distinction rests solely on the distinction of unconformable and intrusive relations.* It is worth remarking that this is in a region where granitising of the gradational type of South Queenstown has been beautifully described (Quirke & Collins (1930)).

(5) Perrin and Roubault (1942) describe a type of metamorphism very similar to that proposed for the porphyroids of Tasmania. They propose that such metamorphism can terminate abruptly against non-metamorphosed rocks and they provide a wealth of detail to support this contention. They demonstrate that what has previously been widely accepted as an unconformity between Mesozoic strata and crystalline rocks is a metamorphic contact. They also give a number of references to similar phenomena.

(6) Kihlstedt (1948, pp. 425-553), describes the occurrence in the Phillipines of magnetite and pyritic ores at the juncture of non-metamorphosed and regionally metamorphosed rocks. The lower rocks belong to the Miocene " Universal " formation, a sequence of basalts, andesites and sediments which have suffered intrusion by diorites and consequent " porphyroblastic " non dynamic metamorphism. Unconformably overlying this formation is the agglomeratic " Larap " formation. The ore zone is interpreted as lying along the unconformity which is also a line

of intense thrusting. The thrusts are associated with the early introduction of iron and a later phase of intrusion by syenite porphyry. This porphyry is reputed to intrude below the magnetite and by metasomatic fluids to convert the Larap agglomerates, above the unconformity, into a rock resembling aplite. This new rock has textures varying from massive, through agglomeratic, to conglomeratic [nodular syenite? J.B.]. The removal of dark minerals in these rocks occurs on fronts which may be from a "fraction of an inch to two inches wide".

The involved explanation requires that the magnetite ore has been thrust and brecciated and the "fragments rolled and rounded off to pebbles"; there has been thrusting, and two periods of intrusion, of extrusion, and of metamorphism. All of this is supposed to have happened since Miocene time.

To the writer it seems that the ores have been the result of granitising similar to that at Mt. Darwin. From these and several other examples there appears to be a common association of lines of thrusting with vulcanism, unconformity, tectonic and sedimentary breccias, metasomatic granitising and mineralisation.

Strong confirmation for the general thesis proposed for the porphyroids comes from Per Geijer (1910) in his account of the igneous rocks at Kiruna. His section, pp. 701-2 and text runs, for the upper portion.

1. Quartzitic sandstone and conglomerate.
2. Phyllite and greywacke with quartz porphyry and iron ore pebbles.
3. Barite and quartz haematite veins, silicified tuffs and sericite rocks with interstratified syenite porphyry. This zone is pyritic.
4. A narrow band of magnetite.
5. Quartz porphyry with agglomerate bands [replacement breccia? J.B.].

(N.B.—Barite veins are common at Lyell and Darwin.)

For comparison the writer has inverted the eastern half of the section thus:—

1. Sodic greenstones with tuff bands.
2. Kurravaara Conglomerate—tuffaceous.
3. Nodular syenite porphyries.
4. Recrystallised syenite.
5. Magnetite.
6. Quartz porphyry (No. 5 of the upper portion).

These sequences are very similar to the two types of metamorphism seen at Queenstown, i.e., the abrupt type against quartzites and the gradual type against spilites. The nodular character of the Kiruna syenites is celebrated.

These examples cannot be left without citing the alternative view put forward by Pettijohn (1949, pp. 259-60). Rocks which some observers have described as granitised he regards as recomposed granitic detritus. It is probable that his view is sometimes the correct one but it certainly does not apply to the porphyroid rocks of western Tasmania. The writer contends that his criteria of recomposition, all of which apply to the porphyroids in one place or other, are inexact or negative generalisations. They are almost useless for distinguishing between granitised and "recomposed" rocks.

Conclusion

The problem of the Darwin Granite is part of the problem of the porphyroids, that is, even if one chooses to adopt a thesis of two periods of granitising. The magmatists' difficulties in explaining the known phenomena are overwhelming in number in each of the fields of structure, lithology and sedimentation. To take a few examples of those difficulties; he must explain:—

1. Greywacke-porphyry transitions.
2. The restricted distributions of porphyry, granite and haematite pebbles.
3. The source of haematite pebbles.
4. The " roof pendants " of the Darwin Granite.
5. The variation of the composition of the granite.
6. The " pebble " character of the granite.
7. The unsheared nature of granite and granite pebbles.
8. The absence of dykes.
9. The phenocrystic matrices of conglomerates.
10. The coarseness of granite and porphyry contacts.

The thesis outlined above is structurally, lithologically and historically consistent, and though the propositions are novel they are fundamentally simple. Field evidence here and elsewhere supports the general contention of a metamorphic boundary.

While it is thought that the evidence for an intrusive phase in the Cambrian has been negatived, it is still probable that an unconformity exists between the Darwin Granite (Dora Conglomerate) and the adinoles (Dundas Group Slates) at Mt. Darwin.

Finally, there are the problems of nomenclature of porphyroids and of the Dundas strata. It is proposed that the Dora, Lynch and Sorell Conglomerates be identified as one and be called the Dora Conglomerate, and that this formation be included in the Junee Group. The term porphyroid should be restricted to suites of rocks characterised by intense metasomatic metamorphism in the absence of stress. Porphyroid should rank with the terms dynamothermal, thermal, and cataclastic as applied to metamorphism. It is proposed that the usage of " Porphyroid " as a bag name for unidentified and often unaltered rocks (i.e., Twelvetrees's usage), be dropped. In a particular region the term may be given a time significance by prefixing the time of metamorphism as " Devonian Porphyroids " in the case of Western Tasmania.

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LOCALITY INDEX

	Internat. Grid. Reference K/55 Quadrangle	S. Lat.	E. Long.
Adamsfield	Huntly 73	42° 47′	146° 20′
Andrew Divide	Lyell 58	42° 11′	145° 37′
Andrew River	Lyell 58	42° 13′	145° 38′
Anthony Creek	Murchison 51	41° 42′	145° 36′
Baxter River	Lyell 58	42° 12′	145° 42′
Blow	Lyell 58	42° 04′	145° 35′
Bubbs Hill	Lyell 58	42° 07′	145° 46′
Clark River	Macquarie Harb. 64	42° 18′	145° 30′
Comstock Mine	Lyell 58	42° 02′	145° 35′
Comstock Tramway	Lyell 58	42° 03′	145° 34′
Comstock Valley	Lyell 58	42° 03′	145° 38′
Conglomerate Creek	Lyell 58	42° 06′	145° 35′
Crotty	Lyell 58	42° 10′	145° 38′
Crotty Smelters	Lyell 58	42° 10′	145° 37′
Currie River	Lyell 58	42° 10′	145° 31′
Cusick Creek	Lyell 58	42° 03′	145° 31′
Darwin Peak, South	Pillinger 65	42° 18′	145° 36′
Darwin (Town)	Lyell 58	42° 14′	145° 38′
Denison Range	Huntly 73	42° 34′	146° 17′
Dial Range	Devonport 29	41° 11′	146° 01′
Dora Tramway	Murchison 51	41° 58′	145° 38′
Dundas	Zeehan 50	41° 53′	145° 24′
Dunkley's Tramway	Zeehan 50	41° 54′	145° 20′
Eldon Peak	Murchison 51	41° 58′	145° 44′
Eldon Range	Murchison 51	41° 59′	145° 44′
Elliot Range	Pillinger 65	42° 30′	145° 42′
Engineer Range	Pillinger 65	42° 18′	145° 44′
Farrell Junction	Mackintosh 44	41° 43′	145° 34′
Firewood Siding	Zeehan 50	41° 59′	145° 16′
"Gap, The"	Lyell 58	42° 04′	145° 35′
Gordon River	Pillinger 65	42° 45′	145° 45′
Gormanston	Lyell 58	42° 04′	145° 35′
Hawks Creek	Mackintosh 44	41° 42′	145° 40′
Henty Bridge	Zeehan 50	41° 59′	145° 27′
Henty Moraine	Zeehan 50	41° 59′	145° 28′
Henty River	Strahan 57	42° 02′	145° 18′
Hercules Mine	Zeehan 50	41° 50′	145° 30′
Howards Plain	Lyell 58	42° 04′	145° 31′
Howth	Devonport 29	41° 05′	146° 01′
Huntley Cirque	Murchison 51	41° 56′	146° 37′
Kelly Basin	Pillinger 65	42° 21′	145° 34′
King Battery	Lyell 58	42° 07′	145° 32′
King River	Lyell 58	42° 05′	145° 39′
King River Gorge	Lyell 58	42° 11′	145° 30′
King River Packridge	Lyell 58	42° 08′	145° 33′
King River Valley, Upper	Lyell 58	42° 03′	145° 40′
Lake Dora	Murchison 51	41° 58′	145° 39′
Lake Julia	Murchison 51	41° 54′	145° 34′

	Internat. Grid. Reference K/55 Quadrangle	S. Lat.	E. Long.
Lake Margaret	Murchison 51	41° 59′	145° 34′
Lake Rolleston	Murchison 51	41° 55′	145° 37′
Lake Spicer	Murchison 51	41° 59′	145° 40′
Langdon River	Murchison 51	41° 59′	145° 31′
Leven Gorge	Devonport 29	41° 15′	146° 10′
Linda	Lyell 58	42° 04′	145° 37′
Linda Valley	Lyell 58	42° 04′	145° 37′
Little Farrell	Murchison 51	41° 47′	145° 37′
Little Owen	Lyell 58	42° 05′	145° 37′
Lyell Mine, North	Lyell 58	42° 03′	145° 36′
Lyell Mine, West	Lyell 58	42° 04′	145° 35′
Lyell Peak	Lyell 58	42° 03′	145° 37′
Lyell Ridge, North	Lyell 58	42° 03′	145° 36′
Lyell Smelters	Lyell 58	42° 04′	145° 34′
Lynch Creek	Lyell 58	42° 07′	145° 33′
Lynchford	Lyell 58	42° 07′	145° 31′
Lynchford Quarries	Lyell 58	42° 07′	145° 31′
Mackintosh Bridge	Mackintosh 44	41° 44′	145° 36′
Mackintosh River	Mackintosh 44	41° 43′	145° 37′
Mackintosh Valley	Mackintosh 44	41° 43′	145° 37′
Malanna	Strahan 57	42° 01′	145° 13′
Margaret Moraine	Murchison 51	41° 59′	145° 32′
Miners Ridge	Lyell 58	42° 07′	145° 32′
Mt. Balfour	Balfour 34	41° 17′	144° 54′
Mt. Darwin	Lyell 58	42° 16′	145° 36′
Mt. Dundas	Zeehan 50	41° 55′	145° 28′
Mt. Farrell	Mackintosh 44	41° 44′	145° 22′
Mt. Jukes	Lyell 58	42° 11′	145° 36′
Mt. Lyell	Lyell 58	42° 03′	145° 37′
Mt. Misery	Zeehan 58	41° 55′	145° 22′
Mt. Murchison	Murchison 51	41° 50′	145° 36′
Mt. Owen	Lyell 58	42° 06′	145° 37′
Mt. Professor	Zeehan 50	41° 59′	145° 22′
Mt. Read	Murchison 51	41° 53′	145° 33′
Mt. Sedgwick	Lyell 58	42° 00′	145° 35′
Mt. Sorell	Pillinger 65	42° 15′	145° 32′
Mt. Strahan	Strahan 57	42° 13′	145° 28′
Mt. Tyndall	Murchison 51	41° 56′	145° 35′
Mt. Zeehan	Zeehan 50	41° 56′	145° 18′
Murchison Gorge	Murchison 51	41° 51′	145° 42′
Murchison River	Murchison 51	41° 51′	145° 42′
Nelson River	Lyell 58	42° 07′	145° 43′
Newton Creek	Murchison 51	41° 55′	145° 34′
Nora River	Pillinger 65	42° 19′	145° 37′
Pearl Creek	Strahan 57	42° 03′	145° 29′
Pieman River	Corinna 43	41° 50′	145° 20′
Princess River	Lyell 58	42° 04′	145° 41′
Queen River	Lyell 58	42° 07′	145° 33′
Queen River, West	Lyell 58	42° 02′	145° 33′
Queenstown	Lyell 58	42° 05′	145° 33′
Queenstown Quarry	Lyell 58	42° 05′	145° 33′
Queenstown Quarry, South	Lyell 58	42° 06′	145° 33′
Red Hills	Murchison 51	41° 52′	145° 35′
Reservoir Creek	Lyell 58	42° 06′	145° 34′
Roaring Meg Creek	Lyell 58	42° 07′	145° 34′
Rosebery	Murchison 51	41° 48′	145° 32′
Sisters Hills	Strahan 57	42° 01′	145° 28′
Snake Spur	Lyell 58	42° 13′	145° 35′
Sophia River	Mackintosh 44	41° 45′	145° 38′
Sticht Range	Murchison 51	41° 52′	145° 38′
Strahan	Strahan 57	42° 10′	145° 20′

	Internat. Grid. Reference K/55 Quadrangle	S. Lat.	E. Long.
Temma	Bluff Pt. 26	41° 14′	144° 42′
Tim Shea	Huntly 73	42° 43′	146° 29′
Toft Valley	Lyell 58	42° 09′	145° 37′
Tullah	Mackintosh 44	41° 44′	145° 36′
Tyndall Range	Murchison 51	41° 57′	145° 36′
Walfords Peak	Murchison 51	41° 56′	145° 38′
West Coast Range	Murchison 51 Lyell 58 Pillinger 65	41° 44′ 42° 18′	145° 33′ 145° 38′
Yolande Moraine	Lyell 58	42° 02′	145° 31′
Yolande River	Strahan 57	42° 04′	145° 29′
Zeehan	Zeehan 50	41° 53′	145° 20′
Zig-Zag	Lyell 58	42° 02′	145° 04′

		Lat.	Long.
Giants Range	Minnesota, U.S.A.	48° 10′ N.	93° 20′ W.
Kiruna	Sweden	67° 55′ N.	20° 20′ E.
Lake District	England	54° 35′ N.	3° 10′ W.
Mesabi Range	Minnesota, U.S.A.	49° 37′ N.	92° 04′ W.
Phillipine Is.	—	14° 40′ N.	121° 30′ E.
Porcupine	Ontario, Canada	48° 30′ N.	81° 08′ W.

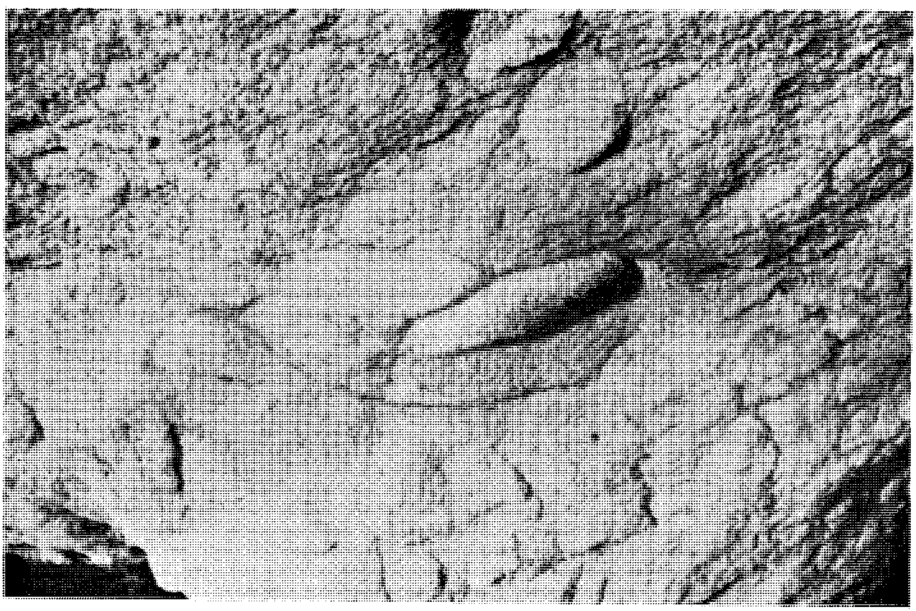


PLATE I

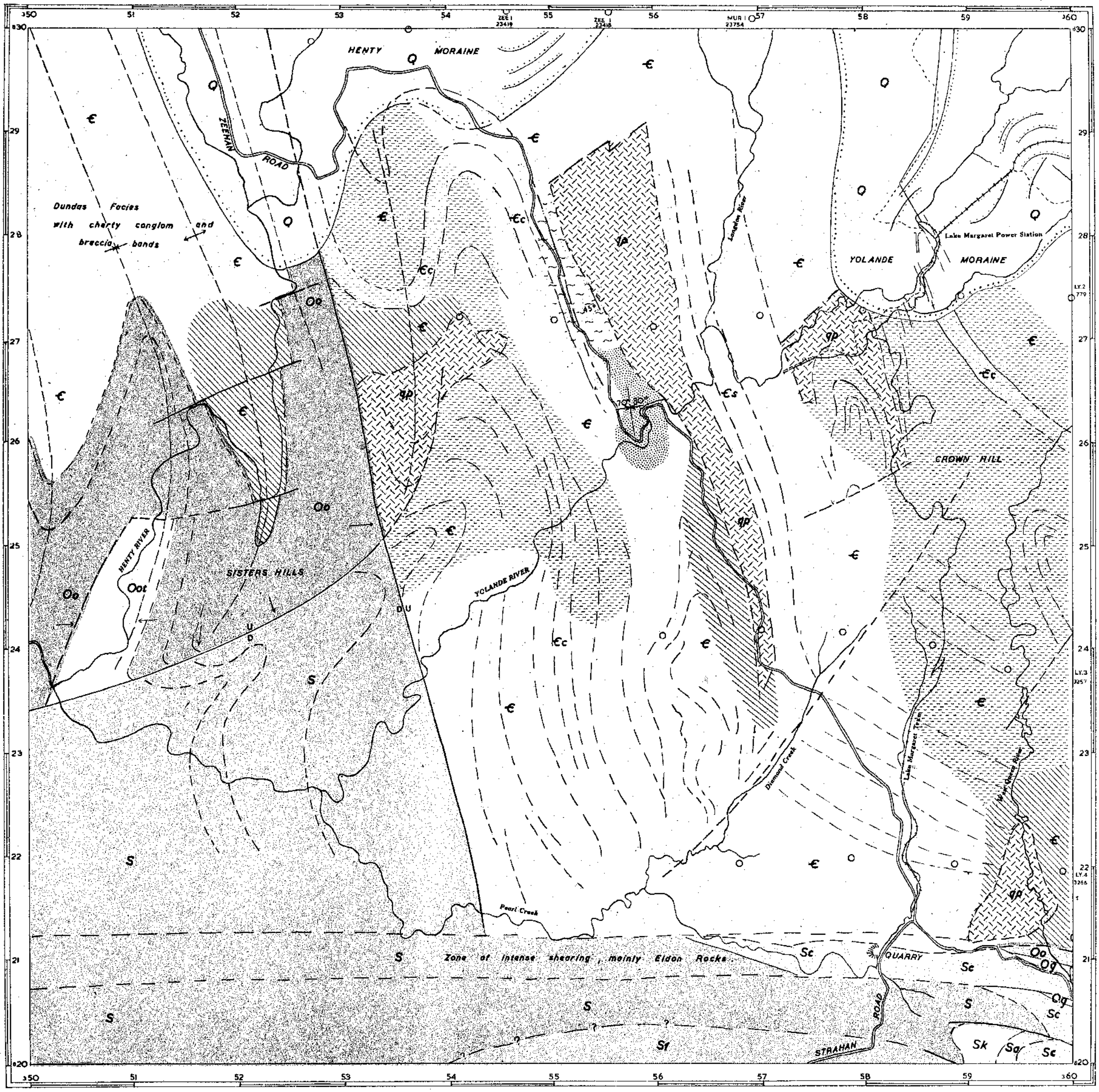
Palimpsest pebbles in granite at grid reference 3636.7946, Mt. Darwin, Tasmania.

GEOLOGY OF TASMANIA

ONE INCH SERIES – UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT

YOLANDE RIVER

MAP SQUARE 3582



LEGEND

Quaternary System
- Q — ALLUVIUM AND MORAINES

Eldon Group
- Sf — FLORENCE QUARTZITE
- Sk — KEEL QUARTZITE
- Sa — AMBER SLATE
- Sc — CROTTY QUARTZITE
- S — UNDIFFERENTIATED

Junee Group
- Og — GORDON LIMESTONE
- Oo — OWEN CONGLOMERATE
- Oot — TUBICOLAR SANDSTONE MEMBE

Dundas Group
- €c — CONGLOMERATE AND BRECCIA
- €s — SLATES
- € — UNDIFFERENTIATED

METAMORPHIC ROCKS
- qp — QUARTZ PORPHYRY MASSIVE
- AREA OF QUARTZ PORPHYRITISED ROCK
- AREA OF FELSPATHISED ROCK
- AREA OF CHLORITISED ROCK
- qss — QUARTZ SERICITE SCHIST

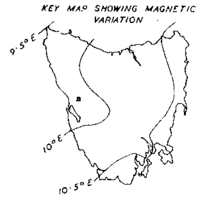
- FAULT
- FAULT – POSITION APPROXIMATE
- BOUNDARY
- BOUNDARY – POSITION APPROXIMATE
- BOUNDARY INFERRED
- TREND OF OUTCROP
- SYNCLINAL AXIS
- ANTICLINAL AXIS
- STRIKE AND DIP
- MORAINE
- TRAM
- ROAD
- TRACK
- ADIT

MAPPED AND COMPILED BY
J BRADLEY *JANUARY 1951*

— SCALE —
0 – 1 – 2 – 3 – 4 – 5,000 – 10,000 FEET; 0 – 2 MILES

Compilation from Aerial Photographs.
Trigonometric Station Control by courtesy Hydro-Electric Commission.
Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC VARIATION



SUMMARY OF THE GEOLOGY OF THE YOLANDE RIVER
SHEET 350/820.

PHYSIOGRAPHY.

The area has an undulating and mature erosional surface, the Henty Peneplain, rising from 900 feet in the west, to 1,200 feet in the east. The Sisters Hills are conical monadnocks rising 400 feet above the plain while the gorges of the rejuvenated Henty and Yolande Rivers are incised 400 feet. The southern margin of the area is defined by a low, 200 feet range of hills formed of the friable but chemically resistent Crotty Sandstone. The minor drainage, including the heads of Pearl Creek and East Queen River, is mature and of an older cycle. The tributary junctions of the Henty and Yolande are discordant. The Henty, above Sisters Hills, is graded while the Yolande is actively degrading. The topography suggests the relatively recent uplift of this country, perhaps in late Pliocene or early Pleistocene times.

GLACIATION.

The Margaret Moraine, formed by the Lake Margaret glacier, is of unusual character. The steep declivity of Mt. Sedgwick on its western side caused the superposition of almost all retreat stages along this line so that one vast moraine 900 feet high up the west side is built up to the edge of the plateau. Very minor retreat phenomena are visible above this moraine. The scanty Yolande Moraine represents an earlier advance of the ice but is very difficult to date. The Henty Moraine marks a relatively brief advance of the Henty glacier and is shown, 544/290, by perched erratics and thick tills, 520/290. The Henty Valley is V rather than U shaped and shows few signs of ice wear. Grading of the river has been hastened by slight glacial erosion and deposition. Over the rest of this area the absence of glacial till, erratics, and glacial erosion phenomena, along with the presence of deep old soils, indicates that there was no glaciation beyond the moraines.

STRATIGRAPHY.

Eldon Group: Crotty Quartzites occur at the quarry 581/211.

Junee Group: Gordon Limestone occurs only as residual pug. Owen Conglomerate: Tubicolar Sandstone forms most of the Sisters Hills and is about 200 feet thick. The underlying conglomerate beds are quartzose, up to 2" grade and contain pebbles of quartz porphyry.

Dundas Group: Breccias, conglomerates, and chert pebble bands occur in the area (510/290) and pass conformally upwards into Owen Conglomerate. Isoclinally folded strata occur over the rest of the area in indecipherable sequences of slaty beds, tuffaceous breccias, and conglomerates. Folds are traceable, however, and a maximum thickness of about 10,000 feet of strata is deduced.

METAMORPHISM.

Quartz porphyries are concordant and stratiform, and vary laterally into feldspar porphyries and albitised tuffs. At the roadstone quarry, 568/241, occur such tuffs with vughs containing albite, epidote, and galena. In the area 590/250 to 598/262 feldspar porphyries, uniform on broken surfaces and in section, show perfect palimpsests of fragments on weathering. Despite contortion and shearing among these rocks there is little trace of schistosity and slaty cleavage is rare. Adjacent beds react very differently to metamorphism and make it difficult to sort out zones. Chloritised, albitised and silicified strata all appear within distances of ¼ mile and interdigitate in a manner dependent on the initial composition and texture of the rock.

STRUCTURE.

A very broad (½ mile) zone of intense crushing and faulting downthrows Eldon rocks along the southern margin of the area. This fault zone is situated on a tear fault with an easterly displacement on the southern side. The rest of the area is folded on W.N.W. axes with folds tightening to the east. Complementary structures, mainly faults, run in arcs broadly N.E.-S.W. Of these, the fault 500/234-534/250 is a faulted overfold overriding to the S.E. and dying out to the north. All of these are Devonian structures. The fault 523/300-545/210 runs for many miles north and south and dislocates most other structures. It is of a different age, probably Tertiary.

ECONOMIC.

Only road metal is taken in the area but galena showings occur at several points along the crush zone 581/211, at the base of the conglomerates 523/255, and scattered with pyrites in the porphyries. Barytes veins trending W.S.W. occur at 580/220.

POINTS OF INTEREST.

Yolande Hill. 569/246: View of West Coast Range structures, Margaret Moraine, and Henty Peneplain.
Henty Hill. 544/290: Perched erratics and till of Henty Moraine.
Lake Margaret Track and Haulage: View of Henty Peneplain and of glacial features.
Strahan Road. 597/208: Talus breccias are the result of slumping of Crotty Sandstone.
Zeehan Road. 580/220: Barytes veins.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

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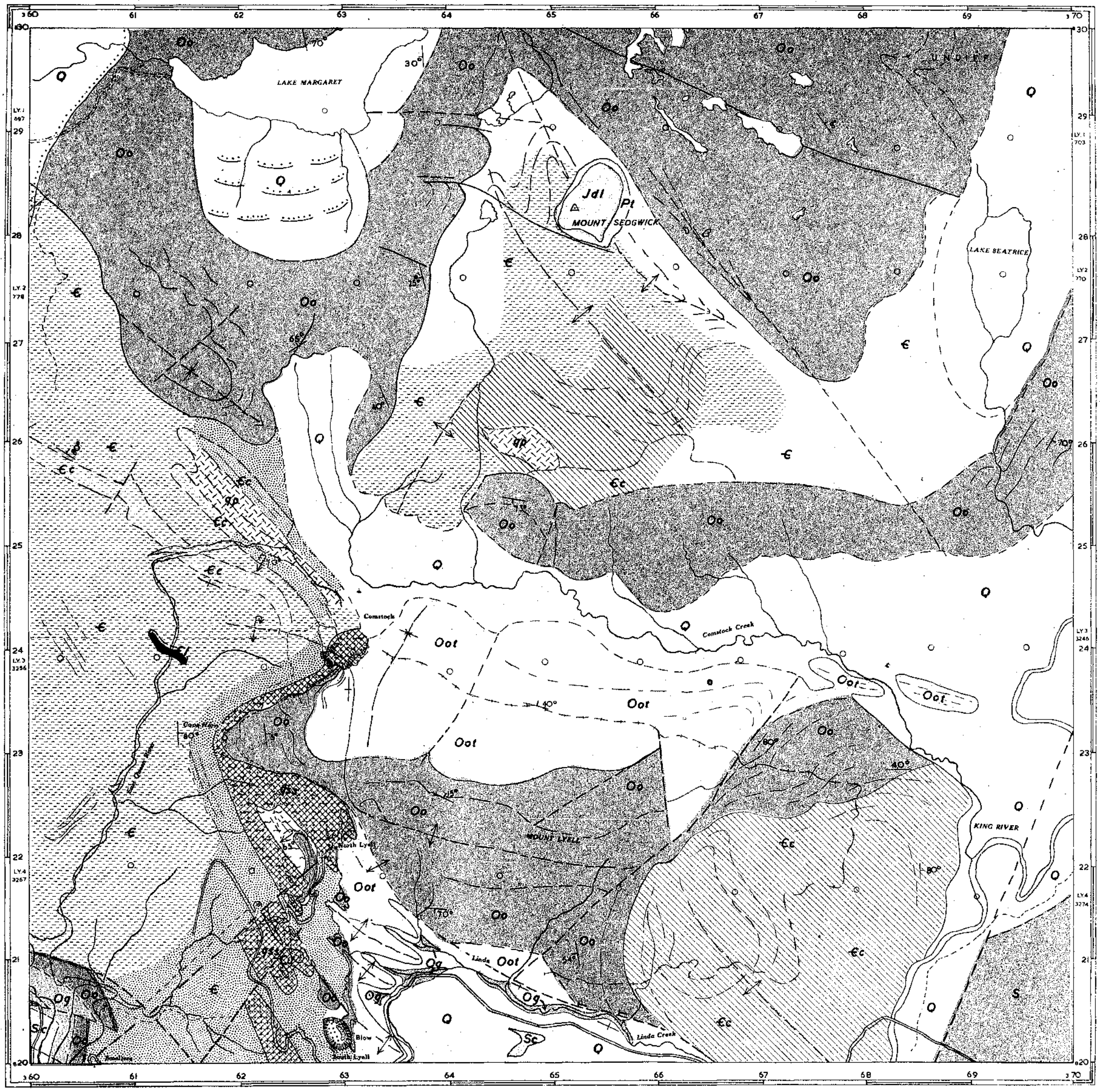
MOUNT SEDGWICK

MAP SQUARE 3682



LEGEND

Quaternary System

| Q | ALLUVIUM AND MORAINES |

Permian System

| Pt | TILLITE |

Eldon Group

| Sc | CROTTY QUARTZITE |
| S | UNDIFFERENTIATED |

Junee Group

Og	GORDON LIMESTONE
Oo	OWEN CONGLOMERATE
Oot	TUBICOLAR SANDSTONE MEMBER

Dundas Group

| €c | CONGLOMERATE AND BRECCIA |
| € | UNDIFFERENTIATED |

IGNEOUS ROCKS

Jurassic System

| Jdl | DOLERITE |

Dundas Group

LAVAS

METAMORPHIC ROCKS

| qp | QUARTZ PORPHYRY MASSIVE |

AREA OF QUARTZ PORPHYRITISED ROCK

AREA OF FELSPATHISED ROCK

AREA OF CHLORITISED ROCK

AREA OF PYRITISED ROCK

| qss | QUARTZ SERICITE SCHIST |
| cu | ORE OF 1·5 % CU |

FAULT

FAULT — POSITION APPROXIMATE

BOUNDARY

BOUNDARY — POSITION APPROXIMATE

TREND OF OUTCROP

STRIKE AND DIP

ANTICLINAL AXIS

SYNCLINAL AXIS

ROAD

TRACK

RAILWAY

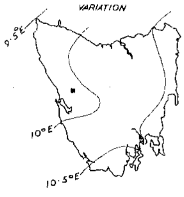
MORAINE

OPEN CUT

VERTICAL DIP

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Hydro-Electric Commission. Origin of co-ordinates 400,000 yds West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC VARIATION



— SCALE —

0 1 2 MILES

0 1 2 3 4 5,000 10,000

MAPPED AND COMPILED BY

J BRADLEY JANUARY 1951

SUMMARY OF THE GEOLOGY OF THE MOUNT SEDGWICK

SHEET 360/820.

PHYSIOGRAPHY.

Mt. Sedgwick is a erosional plateau, altitude 3,000 feet, and is bounded by Lake Beatrice 900 feet, Comstock Creek 800 feet, and the Henty Peneplain 1,000-1,200 feet. The plateau, scored by torrents and ice action, is a resurrected (Carboniferous) peneplain. Forming the Peak is a sugar-loaf residual of dolerite overlying thin Permian tillite which in turn rests on the peneplain.

Comstock Valley, Mt. Lyell 2,700 feet, and Linda Valley 800 feet are structural surfaces being more or less the top of the Owen Conglomerate stripped of softer limestone. The fall on the west from the monadnock-like West Coast Range to the softer rocks of the Henty Peneplain is precipitous and is often controlled by erosion on Devonian fault lines

GLACIATION.

Lakes Margaret and Beatrice are over deepened and their exits are margined by moraines. At its maximum some of the Lake Margaret ice spilled over into the head of Comstock Creek forming a low-level cirque. A minor cirque forms the recess south-east of Lyell Peak. Comstock and Linda Valleys were the sites of proglacial lakes dammed by an ice sheet from the east. This ice occupied the northern end of the King Valley rounding off slate knolls and leaving tills. The Comstock Lake outflow cut a channel, the upper course of the East Queen River 620/250, and the Linda Lake outflow a channel at the Gap 633/198. Varved clays at Gormanston reach as high as the latter (now debris-filled) channel. Ice did not at any stage pass west of Lyell.

STRATIGRAPHY.

Eldon Group: King Slate Bell Shale 689/201 sparsely fossiliferous grey slates. Crotty Sandstone, 647/202, is a typical friable white quartz sandstone.

Junee Group: Gordon Limestone occurs in Linda Creek, 653/205, and as black pug, 641/208. Owen Conglomerate: Tubicolar Sandstone forming the erosional surface of plunging folds 635/212 is 200 feet thick. Unconformity: An angular break is seen at foot of Haulage, 633/204. Conglomerates 2,000 feet: Conglomerates, quartzites and Shales.

-------------------------Unconformity and/or metamorphic contact-------------------------

Dundas Group: Porphyroid conglomerates, slates, tuffs and lavas including fluxion banded trachyte (614/238) occur in various degrees of metamorphism.

METAMORPHISM.

Altered rocks include the Mt. Lyell schists and porphyries, i.e., chlorite, sericite, and quartz sericite, schists and feldspar and quartz porphyries. The porphyries are bedded conglomerates and breccias in which pebbles and matrix have had feldspar and quartz porphyroblasts introduced. The schists are localised in areas of strong shearing and are either schisted porphyry or schisted shaly bands of Owen Conglomerate. Metasomatic replacement is zoned in a descending order of haematitisation, pyritisation, sericitisation and choritisation, and albitisation, but recession of fronts has imposed outer zones on inner. Hence it is common to find sericitised and schisted feldspar porphyry which was originally a conglomerate.

STRUCTURE.

The above processes are controlled by lines of fracture and structures of Devonian age. Mt. Lyell and Linda Valley are anticline and syncline respectively, the Linda Syncline having minor folds. The line Old Blow-North Lyell-Comstock is a vertical and faulted monocline uplifted to the west. The broken intersections of folds are favourable for passage of solutions and ore deposition.

ECONOMIC.

Disseminations of pyrite and chalcopyrite occur adjacent to the metamorphic contact and tend to be restricted to favourable beds in the schists. The present West Lyell mine open-cuts 2 x 10^6 tons of 0.5% Cu ore which is a chlorite sericite pyrite schist with variable chalcopyrite and quartz Richer bodies occurred at North Lyell, Comstock, and Blow open-cuts in Chocolate Shales of the Owen Conglomerate. These were followed underground.

POINTS OF SPECIAL INTEREST.

North Lyell and Old Blow: contact phenomena.
Comstock Track: Owen Conglomerate, ore bodies at Comstock, and porphyries at 621/250 and 615/250.
West Lyell: Mining operations.
Lake Margaret: Glacial phenomena and view of Henty Peneplain.
Gormanston: Varves.
Linda: Characteristic weathering of limestone, plunging folds of Lyell.
King Bridge: Porphyroid conglomerates.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area. **Pap Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

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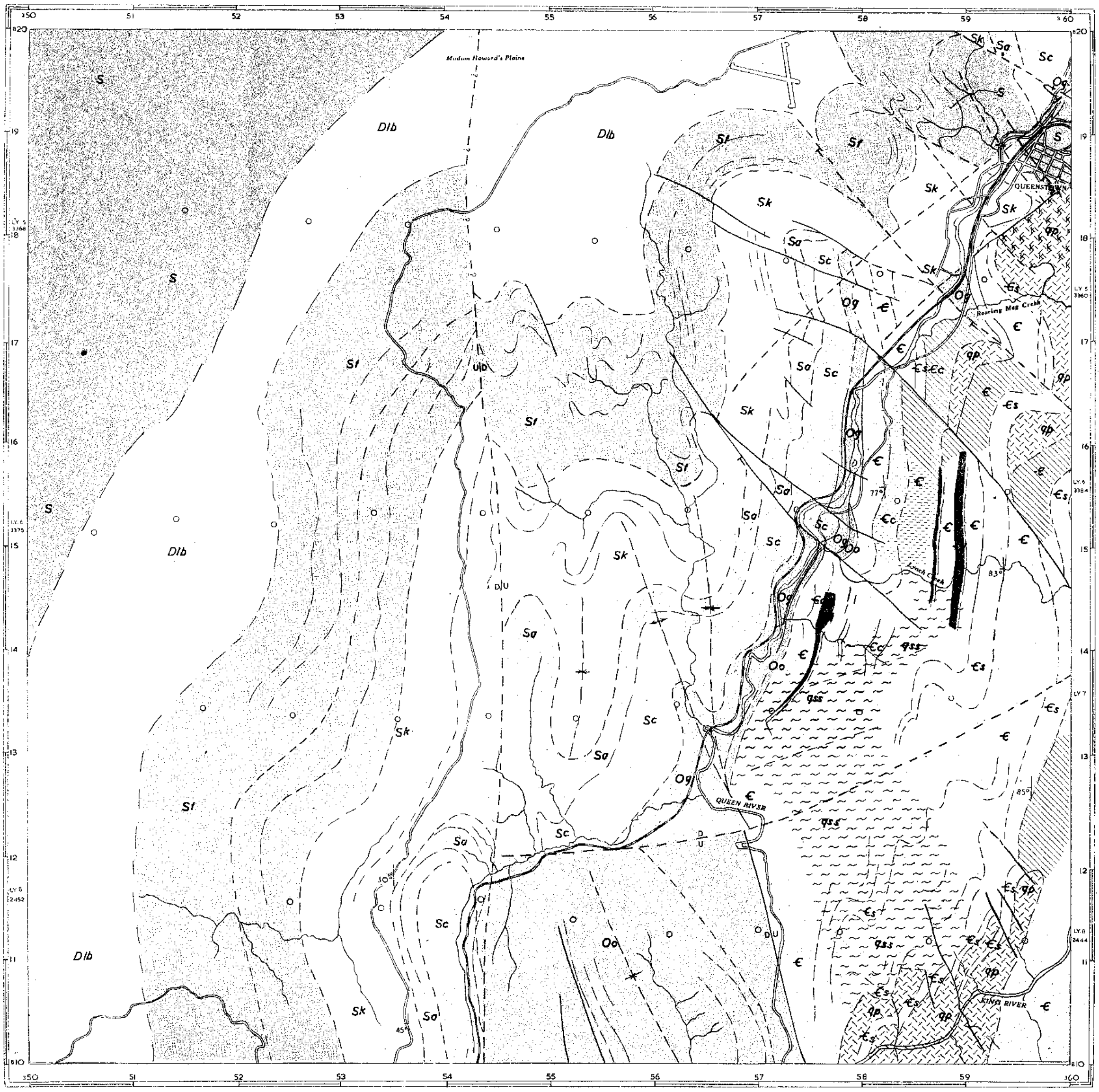
QUEEN RIVER

MAP SQUARE 3581



LEGEND

Eldon Group

- Dlb BELL SHALE
- Sf FLORENCE QUARTZITE
- Sk KEEL QUARTZITE
- Sa AMBER SLATE
- Sc CROTTY QUARTZITE
- S UNDIFFERENTIATED

Junee Group

- Og GORDON LIMESTONE
- Oo OWEN CONGLOMERATE

Dundas Group

- €c CONGLOMERATE AND BRECCIA
- €s SLATES
- € UNDIFFERENTIATED

IGNEOUS ROCKS

Dundas Group

- LAVAS

METAMORPHIC ROCKS

- qp QUARTZ PORPHYRY MASSIVE
- AREA OF QUARTZ PORPHYRITISED ROCK
- AREA OF KAOLINISED ROCK
- qss QUARTZ SERICITE SCHIST
- AREA OF FELSPATHISED ROCK

MAPPED AND COMPILED BY

J BRADLEY JANUARY 1951

- FAULT
- FAULT – POSITION APPROXIMATE
- FAULT INFERRED
- BOUNDARY
- BOUNDARY – POSITION APPROXIMATE
- TREND OF OUTCROP
- SYNCLINAL AXIS
- ANTICLINAL AXIS
- STRIKE AND DIP
- ROAD
- THRUST FAULT, ⊢ ON UPTHROWN SIDE
- AERODROME

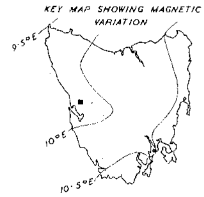
— SCALE —

0 — 2 MILES

0 1 2 3 4 5,000 10,000 FEET

Compilation from Aerial Photographs
Trigonometric Station Control by
courtesy Hydro – Electric Commission
Origin of co-ordinates 400,000
yds West and 1,800,000 yds
South of True Origin of Zone 7

KEY MAP SHOWING MAGNETIC VARIATION



SUMMARY OF THE GEOLOGY OF THE QUEEN RIVER

SHEET 350/810.

PHYSIOGRAPHY.

The area is a gently undulating erosional surface rising from 900 feet to 1,200 feet from west to east. This surface was elevated some 600 feet in late or post-Pliocene time and is still in the initial stages of dissection. Lower courses of streams occupy narrow valleys and the lower Queen and King Rivers flow in gorges 400-600 feet deep. On either side of the Queen River adjustment to structure has produced hogback ridges in the hard Cambrian slates and Silurian quartzites. In the Queen Valley erosion of the Gordon Limestone has produced at 600-700 feet a graded reach of the river with small high terrace remnants.

STRATIGRAPHY.

Estimated thickness of formations are Bell Shale 2,000 feet, Florence Quartzite 1,200 feet, Keel Quartzite 1,500 feet, Crotty Quartzite 1,000 feet, Gordon Limestone 700 feet, Owen Conglomerate missing or represented by 20 feet of quartzite at Lynch Creek Bridge. The Dundas Group is divisible into the Lynch Conglomerate 2,000 feet, the Battery Volcanics 3,000 feet, and the Miners Slate 5,000 feet.

The juncture, between the quartzites and greywacke conglomerates at Lynch Creek Bridge, or elsewhere, between the limestone and the Dundas Group, represents a break in deposition and is possibly erosional. There is no angular discordance between the formations.

IGNEOUS ROCKS.

Vesicular spilites of Cambrian age occur in Lynch Creek 587/147 and Specimen Creek 575/142. Tuffaceous breccias associated with these lavas are thick and extensive.

METAMORPHIC ROCKS: 'Porphyroids.'
Quartz porphyries on Roaring Meg Creek and the King River are normal types. They contain numerous slate inclusions and beds of slate. At Queenstown the porphyry is intensely kaolinised, 595/182. From Lynch Creek to Roaring Meg Creek the coarser greywackes grade into feldspar porphyry, quartz feldspar porphyry and quartz porphyry. Palimpsest bedding and fragments are common in the porphyries. The rocks carry veins and vughs of epidote and pink albite. They are massive and lightly sheared. The "slates" are indurated and sheared, but not cleavable, greywacke siltstones and mudstones. They are hornfelsed towards the quartz porphyries.

PETROLOGY.

The Cambrian lavas are spilitic. Feldspars, albite-oligoclase, are secondary in many cases, and augite alters to chlorite and tremolite. Asbestiform tremolite veins the rock and chlorite and calcite fill vesicles. The greywackes are free of quartz and contain augite. Initial stages of alteration show growth of interstitial quartz and albite porphyroblasts. With the growth of macroscopic feldspars (oligoclase) chloritisation and epidotisation occur. Some development of tremolite after augite is common. Growth of quartz phenacrysts is accompanied by sericitisation of feldspar and removal of FeMg minerals.

STRUCTURAL GEOLOGY.

Strata generally dip west at 70°, minor structures, thrusts and overturned folds are aligned N.W.-S.E. Folding is most pronounced in the Eldon quartzites but dies out in the Bell Shale and passes downwards into thrusts and minor shears. A complementary set of folds and faults trending N.E.-S.W are not so prominent.

ECONOMIC GEOLOGY.

Gold occurs in creeks draining the porphyries but is unimportant. Galena in limestone occurs at Queenstown 597/183. Limestone at Lynchford is the only worked deposit.

POINTS OF SPECIAL INTEREST.

Queenstown Limestone Quarry 598/194. This, and outcrops due east across the Queen, are fossiliferous Gordon Limestone. Fossils extracted include **Alveolites** sp., **Protorea** of. **richmondensis Acidolites, Tetradium tasmaniense, Acantholites, Favistella, Favosites,** Aulorporid corals, bryozoa and gastropods.

South Queenstown 583/158. Porphyritised breccias occur alongside timber tracks leading east from the road. These tracks also expose sections of the uppermost Dundas rocks.

Lynch Creek. The section is structurally unbroken for 2 miles. Lavas occur in the track on the northern side of the stream for half mile after passing the King Battery.

Roaring Meg Creek. 595/174. Quartz Porphyry contact with slates.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

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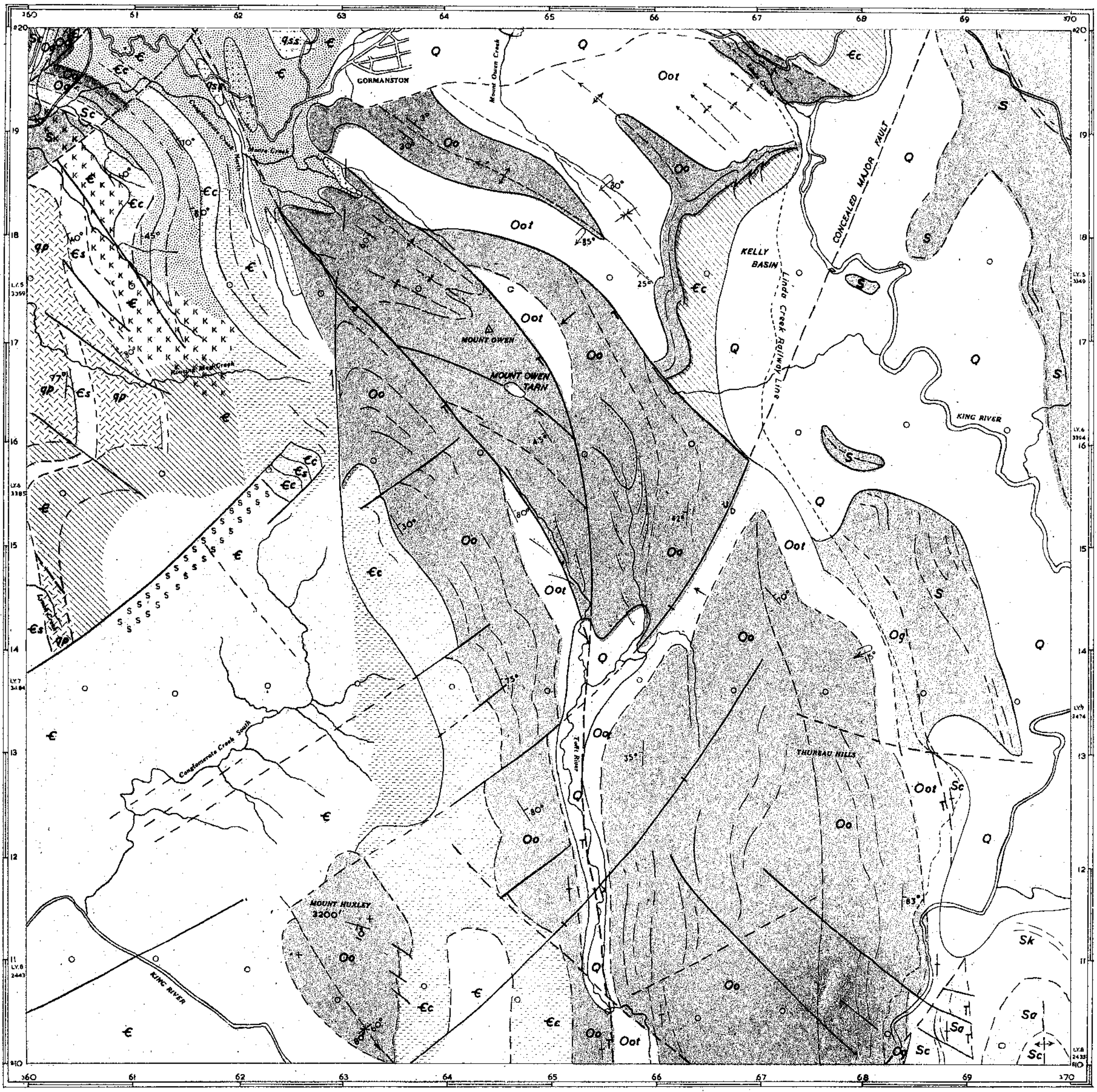
MOUNT OWEN

MAP SQUARE 3681



LEGEND

Quaternary System

Q	ALLUVIUM AND MORAINES

Eldon Group

Sk	KEEL QUARTZITE
Sa	AMBER SLATE
Sc	CROTTY QUARTZITE
S	UNDIFFERENTIATED

Junee Group

Og	GORDON LIMESTONE
Oo	OWEN CONGLOMERATE
Oot	TUBICOLAR SANDSTONE MEMBER

Dundas Group

€c	CONGLOMERATE AND BRECCIA
€s	SLATES
€	UNDIFFERENTIATED

METAMORPHIC ROCKS

qp	QUARTZ PORPHYRY MASSIVE
	AREA OF QUARTZ PORPHYRITISED ROCK
	AREA OF FELSPATHISED ROCK
	AREA OF CHLORITISED ROCK
	AREA OF PYRITISED ROCK
K K	AREA OF KAOLINISED ROCK
qss	QUARTZ SERICITE SCHIST
S S	AREA OF SERICITISED ROCK

MAPPED AND COMPILED BY

J BRADLEY *JANUARY 1951*

- FAULT
- FAULT — POSITION APPROXIMATE
- BOUNDARY
- BOUNDARY — POSITION APPROXIMATE
- TREND OF OUTCROP
- SYNCLINAL AXIS
- ANTICLINAL AXIS
- STRIKE AND DIP
- MORAINE
- ROAD
- TRACK
- RAILWAY
- HORIZONTAL CONTROL STATION
- THRUST FAULT ⊢ ON UPTHROWN SIDE

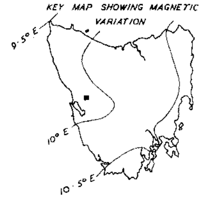
— SCALE —

0 — 1 — 2 MILES

0 1 2 3 4 5,000 10,000 FEET

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Hydro–Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC VARIATION



SUMMARY OF THE GEOLOGY OF MOUNT OWEN

SHEET 360/810.

PHYSIOGRAPHY.

Mounts Owen and Huxley form a physiographic unit bounded by the Linda Creek and King and Queen River valleys. These valleys lie at 500 to 700 feet and the summits of the range at 3,200 feet+. The mountains are monadnocks. The topography is structurally controlled, the range being an asymmetric anticline and the King Valley a syncline. The Linda Valley and the King Gorge are transverse synclines and the King River, though now incised in quartzite, was originally established in limestones 600 feet above the present river. The core of the range is of hard quartzites and the synclines are of limestone and sandstone. The thrusts of Mt. Owen and the deep syncline of the Tofft River allow the erosion of the country into blocks and pinnacles while N.W. and N.E. shearing determines the minor drainage. South of N160 the King Valley is beautifully terraced and the river, rejuvenated to a point 694/154, cuts through the valley fill of the terraces into bedrock.

GLACIATION.

North of the line N160 the King Valley was glaciated by a broad ice sheet which probably contributed material to the terraces. Dry glacial overflow channels at 683/130 are related to the highest terrace. On Mt. Owen a tarn occupies a small cirque whose glacier must have dammed the then Tofft River. The natural outlet for this stream is the wide low valley to the north-east but drainage is still south through the gorge cut by the Tofft lake overflow.

STRATIGRAPHY.

Eldon Group: The King Slate, 695/194, containing distorted casts of crinoids and brachiopods, is of great thickness 3,000 feet+. With scattered outcrop and complex and unknown structure it may represent much more than the Bell Shale of Devonian age. Crotty Sandstone is identifiable at 688/100.

Junee Group: Gordon Limestone is mapped by residual pugs but rarely seen. The most interesting exposure is faulted in schists at 605/193. Owen Conglomerate is variable. At 605/194 ten feet of quartzite underlies limestone. At 644/160 the conglomeratic phase is 1,500 feet thick. At 665/180 the Tubicolar Sandstone overlies 250 feet of chocolate shales and is 200 feet thick. The basal breccias are well developed east of Huxley.

Dundas Group: In this area no sequences are determinable. Slump structures rhythmically repeated, are preserved in silicified fine grained greywacke at the knoll 620/155. Altered columnar lavas (so-called keratophyres) occur in Conglomerate Creek 616/128. Pebble beds at 665/180 are almost wholly of quartz porphyry and are conformable below Owen Conglomerate. Elsewhere Dundas strata are highly metamorphosed and unrecognisable.

METAMORPHISM.

This is similar to that of Lyell and Queen River areas but schistosity is more pronounced and exposures are poorer. The rocks at 607/194 are chloritised, kaolinised, sericitised and silicified, and are very like the Killas and associated rocks of Cornwall.

STRUCTURE.

The main structure is the asymmetric fold of the range but this is complicated by several smaller oblique folds and thrust masses in complementary sets. The more prominent set of thrusts trends in north-westerly striking arcs which join together to form the vertical limb of the main fold along the Tofft River. The remarkable line of upturning at Lyell persists southwards into this area. This structure is a faulted monocline with northerly movement and upthrow on the west side. It was formed during an Upper Cambrian orogeny as an east facing scarp and was a line of intrusion and movement then and in Devonian times. The Breccia Conglomerates occur east of this line probably originating as a fault scarp breccia.

ECONOMIC.

Outlying ore bodies of the Lyell mines clearly replace bedded rocks. More diffuse pyritic bodies occur along most of the conglomerate-schist contact and richer showings occur below Mt. Huxley 630/097.

POINTS OF INTEREST.

Lyell Highway, 696/194: fossiliferous Eldon slates.
Linda Valley, 661/196: Chocolate shales.
Gormanston, 632/196: Varves.
Lyell Highway, 620/193: Pyritic bodies, view of Owen thrusts.
Conglomerate Creek: Stream section of chloritised rocks.
Mt. Owen, 644/170: by track from Gap—view of Owen tarn and country.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

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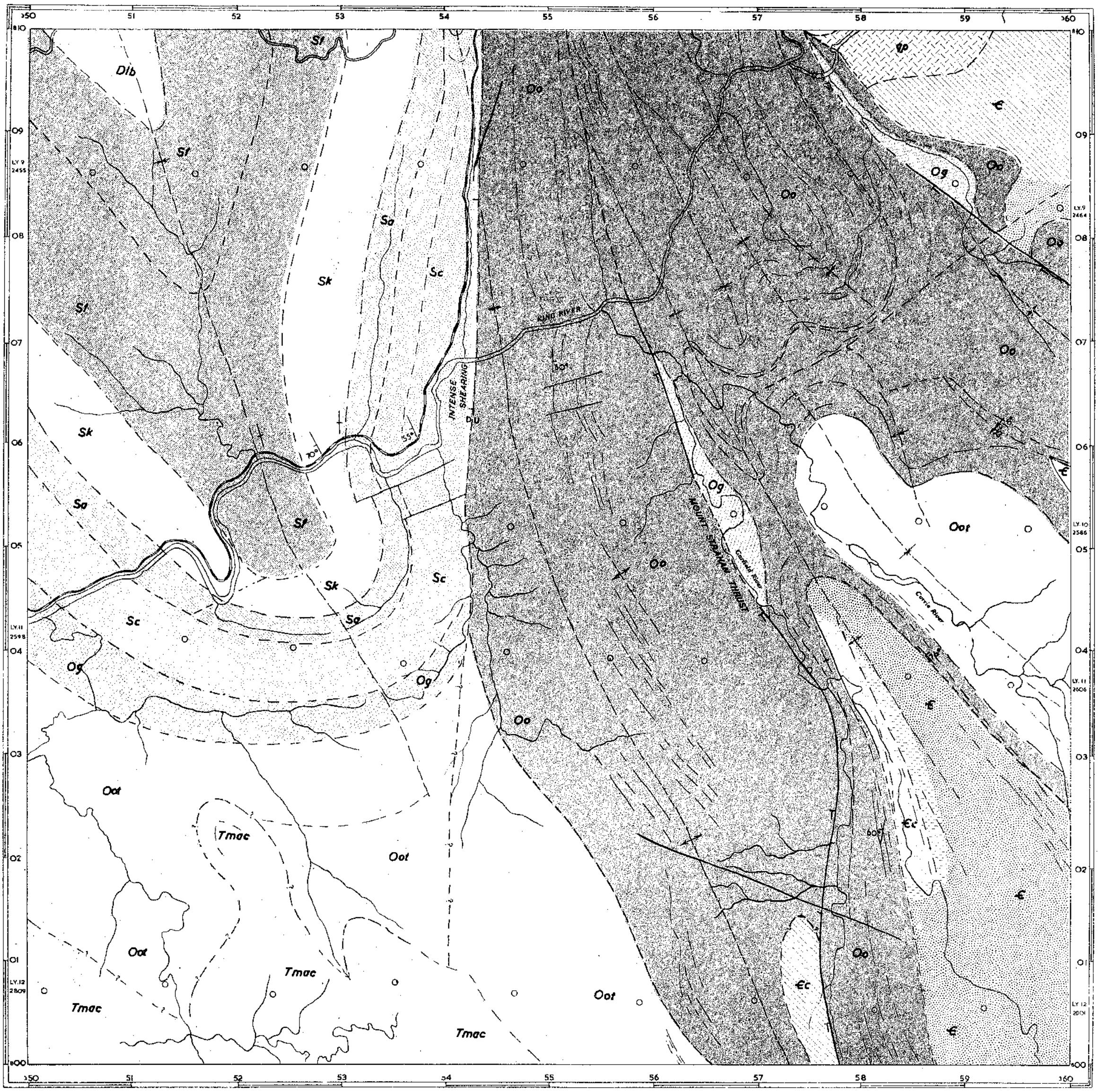
MOUNT STRAHAN

MAP SQUARE 3580



LEGEND

Tertiary System

Tmac	MACQUARIE BEDS

Eldon Group

Dlb	BELL SHALE
Sf	FLORENCE QUARTZITE
Sk	KEEL QUARTZITE
Sa	AMBER SLATE
Sc	CROTTY QUARTZITE
S	UNDIFFERENTIATED

Junee Group

Og	GORDON LIMESTONE
Oo	OWEN CONGLOMERATE
Oot	TUBICOLAR SANDSTONE MEMBER

Dundas Group

€c	CONGLOMERATE AND BRECCIA
€	UNDIFFERENTIATED

METAMORPHIC ROCKS

	AREA OF QUARTZ PORPHYRITISED ROCK
	AREA OF FELSPATHISED ROCK
	AREA OF CHLORITISED ROCK
qp	QUARTZ PORPHYRY MASSIVE

FAULT

FAULT — POSITION APPROXIMATE

BOUNDARY

BOUNDARY — POSITION APPROXIMATE

BOUNDARY INFERRED

ANTICLINAL AXIS

SYNCLINAL AXIS

TREND OF OUTCROP

STRIKE AND DIP

ROAD

THRUST FAULT, ⊢ ON UPTHROWN SIDE

MAPPED AND COMPILED BY

J BRADLEY JANUARY 1951

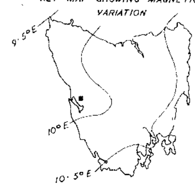
— SCALE —

0 1 2 MILES

0 1 2 3 4 5,000 10,000 FEET

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Hydro-Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC VARIATION



SUMMARY OF THE GEOLOGY OF MOUNT STRAHAN

SHEET 350/810

PHYSIOGRAPHY.

The area is a highly dissected portion of the uplifted Henty Peneplain. Remnants of this erosional surface occur at 1,000 feet along the northern boundary. Mount Strahan is a monadnock ridge which has persisted from the Henty cycle into the present phase of erosion The King River is superimposed and incised in a gorge some 60 feet deep and its tributaries plunge from narrow gullies. The minor drainage is structurally controlled, sometimes superimposed, and follows softer limestone, shales, and the soft chloritic rocks of the Garfield Anticline. At point 543/069 the character of the King River changes abruptly from graded to actively degrading. This change coincides with the N.-S. (Tertiary?) fault line and the change from softer Eldon rocks to Owen Conglomerate. The conglomerate country has bare scarps and shoulders, in contrast to the forested and prominently ridged Eldon quartzites and shales, and to the flat low areas of limestone. In the southwest a low platform of late Tertiary beds falls west-southwest from 600 feet to near sea level and has a characteristic dendritic drainage.

STRATIGRAPHY.

The Macquarie Beds of the southwest are estuarine conglomerates, sands, clays and lignitic peats. They are about 400 feet thick, are tilted west-southwest and pass below sea level at Macquarie Harbour. They are probably Late Pliocene or Pleistocene in age. Their uplift coincides in part at least, with that of the Henty Peneplain, and involves westerly and southerly tilts in this area.

Eldon Group: Devonian strata (Bell Shale) along with a full normal sequence of Silurian quartzites and shales are exposed along the King River and Strahan Rd. Crotty Sandstone along the railway is not quite typical—it is possible that it is largely faulted out along with the limestone and that some of the strata marked Crotty belong to the Amber formation.

Junee Group: Gordon Limestone is poorly exposed at very few points, e.g., 500/044, 578/092 and 572/045. Owen Conglomerate is mainly represented by quartzites but is very variable, from thin 20 feet grits at 577/099 to 700 feet thick quartzites at 578/038. At the latter locality a thin conglomerate overlies ideally exposed and typical Breccia Conglomerate.

METAMORPHOSED ROCKS.

These are probably Dundas Group strata. They are poorly exposed and have no demonstrable structural continuity. Hornfelses and chlorite sericite schists are the usual rock types.

STRUCTURE.

Folds aligned N.W.-S.E. are strike faulted and thrust. They are intersected by N.E.-S.W. trending complementary folds and faults, e.g., 535/054 to 595/080. A gentle anticline produces the interesting opposed plunging folds, 567/064. The N.-S. fault, 540E, dislocates the Devonian structures and downthrows to the west at least 1,000 feet. It is earlier than the Henty Peneplain which it does not affect, and is probably of Tertiary age.

ECONOMIC.

Flannagans Flat was once a rich small alluvial goldfield. This gold was probably derived from the pyritised contact of porphyry. against conglomerate.

POINTS OF INTEREST.

There is scenic interest on the train journey through the King Gorge. The Eldon rocks are conveniently and well exposed on the Strahan Road at many points.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

ONE INCH SERIES—UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT.

MOUNT JUKES

MAP SQUARE 3680

LEGEND

Eildon Group

- Sf FLORENCE QUARTZITE
- Sk KEEL QUARTZITE
- Sa AMBER SLATE
- Sc CROTTY QUARTZITE

Junee Group

- Og GORDON LIMESTONE
- Oo OWEN CONGLOMERATE
- Oot TUBICOLAR SANDSTONE MEMBER

Dundas Group

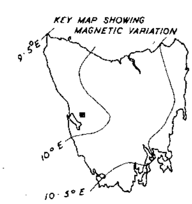
- €c CONGLOMERATE AND BRECCIA
- € UNDIFFERENTIATED

METAMORPHIC ROCKS

- AREA OF QUARTZ PORPHYRITISED ROCK
- AREA OF FELSPATHISED ROCK
- AREA OF CHLORITISED ROCK
- AREA OF PYRITISED ROCK
- AREA OF HAEMATISED ROCK
- qss QUARTZ SERICITE SCHIST
- cu ORE OF 1·5% CU

- FAULT
- FAULT – POSITION APPROXIMATE
- BOUNDARY
- BOUNDARY – POSITION APPROXIMATE
- TRENDS OF OUTCROPS
- SYNCLINAL AXIS
- ANTICLINAL AXIS
- 5° STRIKE AND DIP
- TRACK
- VERTICAL DIP
- THRUST FAULT, ⊢ ON UPTHROWN SIDE

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Hydro-Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.



SCALE

0 — 2 MILES

0 1 2 3 4 5,000 10,000 FEET

MAPPED AND COMPILED BY J BRADLEY JANUARY 1951

SUMMARY OF THE GEOLOGY OF MOUNT JUKES

SHEET 360/800.

PHYSIOGRAPHY.

Mt. Jukes is a rugged scarped mass of hard old rocks and has several summits concordant, at about 3,200 feet, with other peaks of the West Coast Range and the resurrected, but here deeply dissected, Permian peneplain. In the King Basin, erosion surfaces at 1,100 and 700 feet occur. The first of these, quite even and falling away to the south, is maturely dissected, and shows as strike ridges in Silurian quartzites. The second, substantially the old King Valley flood plain level, is now undergoing a further stage of dissection along the main streams. The detail and mass of the topography is, however, adapted to structure. Mt. Jukes is an asymmetric anticline with gentle westerly dip slopes. The eastern limb is carved by a series of cirques and their effluent streams into sharp spurs and valleys directed southeast. These valleys are carved in the cores of the subsidiary northwesterly anticlines while the ridges are essentially synclinal remnants of hard covering conglomerates. The eastern margin of the block is a steep wall of vertical conglomerates. The Andrew River, cutting back in limestone, has captured the head of the Baxter River, which, now a minor stream, flows by vast and recent terraces. The King River is superimposed, but originally made its way across the range by the low syncline and faults north of Mt. Jukes. Almost continuous glacial cirques under the lee of Jukes were the site of very local glaciers which, though failing to reach below 1,500 feet, cut a magnificent escarpment.

STRATIGRAPHY.

Eldon Group: Crotty Sandstone, very like that at Zeehan, occurs throughout the area. Other Silurian formations are more uniform in this area than at Zeehan and being thrust and folded are difficult to distinguish and represent.

Junee Group: Gordon Limestone exposures occur in small patches in the rejuvenated King and Andrew Rivers. Owen Conglomerate: the type section of Loftus Hills is at 625/074, the total thickness being 2,000 feet. The section on the Andrew is about 600 feet thick, and mainly of sandstones, while at Camp Creek the thickness is less than 250 feet, and at Darwin Spur only 150 feet. Breccia Conglomerates are seen in the Main Jukes cliff 624/074.

METAMORPHOSED ROCKS.

Rocks everywhere below the conglomerates are of metamorphosed greywacke types (porphyroids) and are probably of the Dundas Group. The quartz feldspar porphyries below Upper Lake Jukes 625/060, are clearly bedded and contain bands of small quartz pebbles. The occurrence of quartz pebbles in the porphyroid rocks is unique for this district.

STRUCTURE.

An anticlinal structure and fault scarp, 620E, facing east was in existence before the Breccia Conglomerates were formed. Fault scarp talus and succeeding Owen Conglomerate, coming from the east, filled the fault angle depression and finally overlapped it. Renewed compression in Devonian times from the west and south west caused further folding some of which (the 620E shear and monocline) followed the earlier lines.

ECONOMIC.

The latest fault lines are those on which alteration and mineralisation are most pronounced. They are the N.E.-S.W. and the 620E faults. Numerous haematite bodies occur on the 620E line and veins of copper sulphides occur at Lake Jukes. A low grade deposit occurring under Snake Spur in a sericite schist is clearly replacing a bed of shale.

POINTS OF INTEREST.

Lake Jukes Track: Glaciation and metamorphism.

Mt. Jukes: 625/074: Type section for Owen Conglomerate.

Crotty Station: 675/063: Section of Crotty Sandstone.

East Jukes Peak: View of Huxley Syncline and King River Gorge.

REFERENCE.

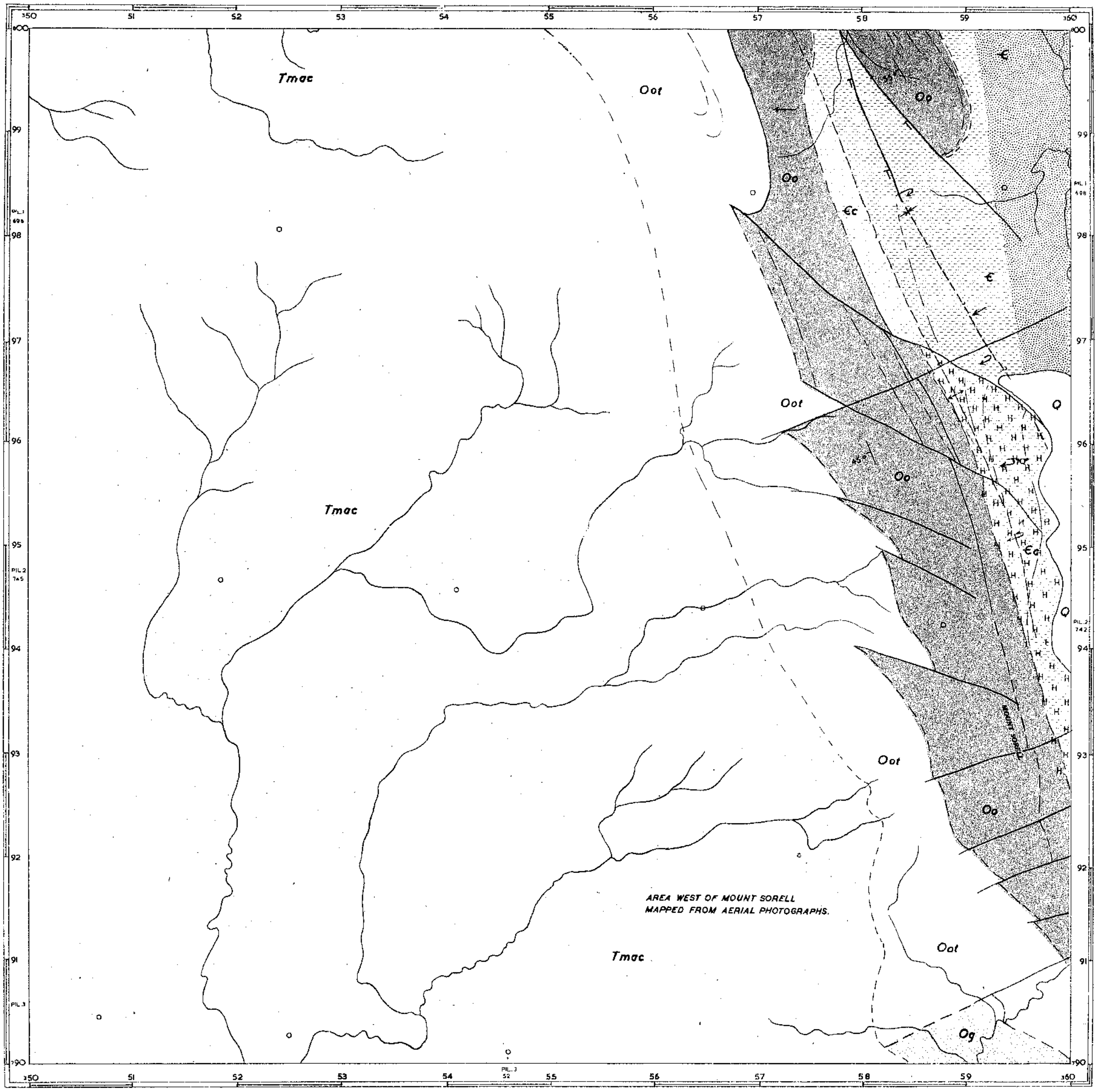
Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

MOUNT SORELL

GEOLOGY OF TASMANIA

ONE INCH SERIES-UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT

MAP SQUARE 3579



LEGEND

Quaternary System

Q — ALLUVIUM AND MORAINES

Tertiary System

Tmac — MACQUARIE BEDS

Junee Group

Og — GORDON LIMESTONE

Oo — OWEN CONGLOMERATE

Oot — TUBICOLAR SANDSTONE MEMBER

Dundas Group

€c — CONGLOMERATE AND BRECCIA

€ — UNDIFFERENTIATED

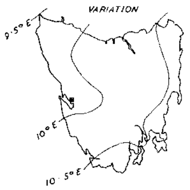
METAMORPHIC ROCKS

AREA OF FELSPATHISED ROCK

AREA OF CHLORITISED ROCK

AREA OF HAEMATISED ROCK

KEY MAP SHOWING MAGNETIC VARIATION



FAULT

FAULT — POSITION APPROXIMATE

BOUNDARY

BOUNDARY — POSITION APPROXIMATE

TREND OF OUTCROP

SYNCLINAL AXIS

ANTICLINAL AXIS

5° STRIKE AND DIP

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Hydro-Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

— SCALE —

0 — 1 — 2 MILES

0 — 1 — 2 — 3 — 4 — 5,000 — 10,000 FEET

MAPPED AND COMPILED BY

J BRADLEY JANUARY 1951

SUMMARY OF THE GEOLOGY OF MOUNT SORELL

SHEET 350/790.

PHYSIOGRAPHY.

The topography is of two extreme types In the east is the residual ridge of Mt. Sorell while the centre and west of the area consists of a platform of emergence. This platform is an elevated and declined surface of estuarine deposits. It falls in a west-southwest direction from 400 feet at the base of Mt. Sorell to 80 feet where it is cliffed back on Macquarie Harbour. Dissection is still very youthful with the result that almost half of the initial surface remains. Surface drainage was at first extended but insequent streams have developed a dendritic pattern. The unconsolidated conglomeratic strata allow perfect underground drainage of the higher undissected areas which are consequently stable and may be of considerable age. Dry valleys at the heads of streams show that a more extensive drainage system once existed. These valleys may have been carved under conditions of greater rainfall. Mt. Sorell is a monadnock ridge of quartzite with westerly dip slopes rising to a ridge over 3,500 feet high. The eastern face of the mountain is a spectacular 1,500 feet precipice. The scarp, due to differential erosion, must have been sharpened by broad cirque-like glaciers on the eastern, lee, side of the mountain.

STRATIGRAPHY.

Tertiary: The Macquarie Beds, on the northern and eastern shores of Macquarie Harbour, consist of some 400 feet of unconsolidated estuarine sediments which in this area dip gently west-southwest. The major portion of the formation is made up of conglomerates and sands. The conglomerates contain pebbles of Owen Conglomerate, occasional porphyroid rocks, and dolerite. They are probably derived from the northeast and could have been deposited by the King. Extensive laminated clays containing detrital wood fragments but no shell fossils occur at several levels. Lignitic peats occurring in lenses up to 30 inches thick and resting on seat earths are common. The age of the formation is only generally deduced as Late Pliocene.

Junee Group: Owen Conglomerate. Tubicolar Sandstone forms the western slopes of Mt Sorell. It is dense pink and white quartzite about 500 feet thick thinning to less than 200 feet in the south. The conglomeratic members of the formation are unusually fine in grade—not more than 2"—3" grade—and sandy beds are common. These rocks are only 300 feet thick and pass out to nothing in the Clark River. The rocks described by Hills as Breccia Conglomerates are not texturally typical of this member. They also are fine, 2"—3" grade, and consist of granite, haematite, magnetite and quartzite pebbles. The Breccias are 450 feet thick and though the contact is not seen they overlie quartz feldspar porphyries at Flannagans Flat. 577/999.

STRUCTURE.

The Macquarie Beds are inclined at about 1°-2°. Round the harbour small folds run parallel to the shore and small faults and shears occur inland for about 100 yards in the clays. These structures are due to slumping of cliffs into the harbour. Looking south from Mt. Strahan an overfold is seen on the north end of Mt. Sorell. This is part of a complete anticline and syncline which die out to the south.

ECONOMIC.

Flannagans Flat was once a rich small goldfield situated on porphyry and limestone pugs.

REFERENCE.

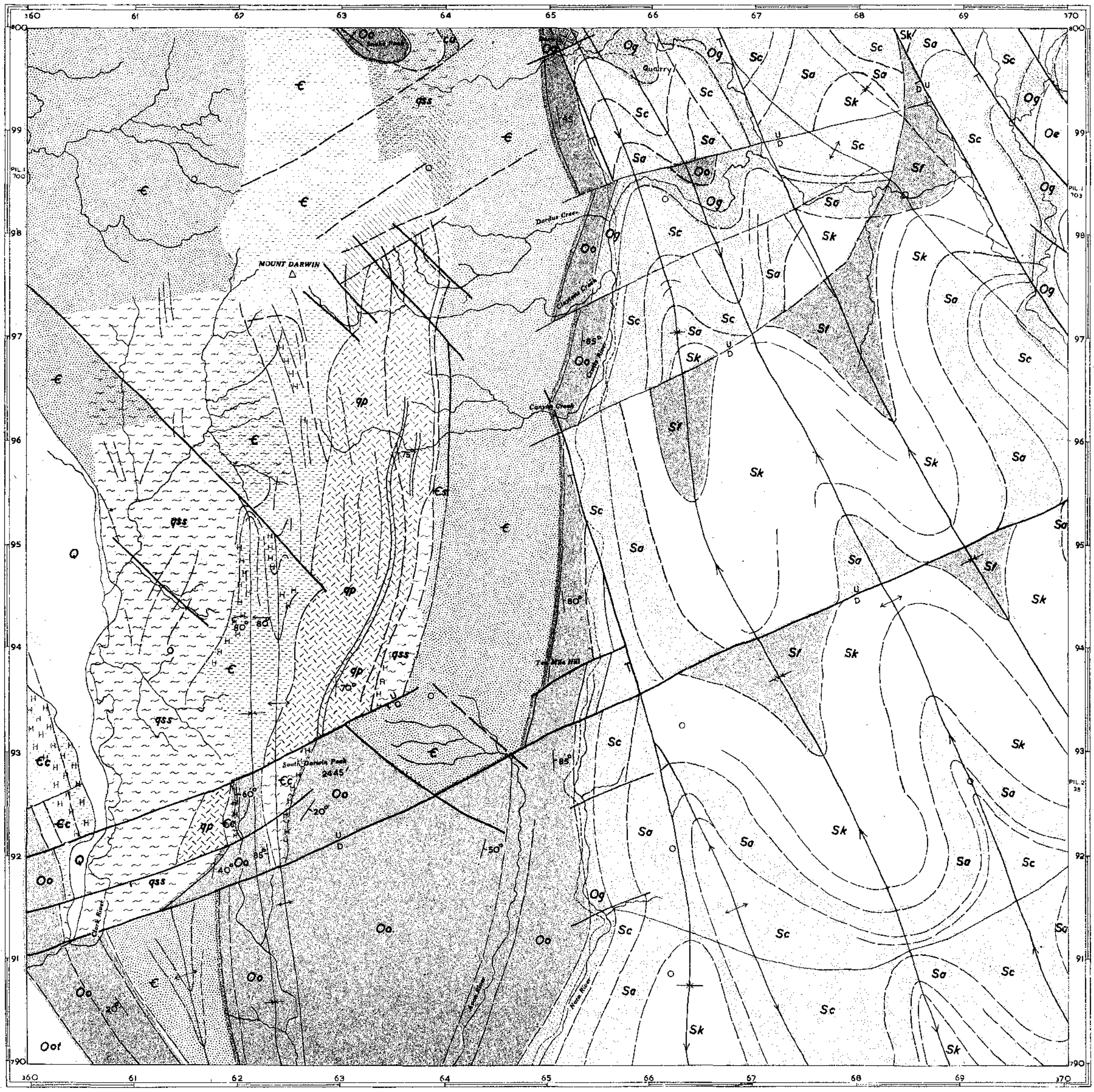
Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**

GEOLOGY OF TASMANIA

ONE INCH SERIES – UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT

MOUNT DARWIN

MAP SQUARE 3679



LEGEND

Quaternary System

- Q — ALLUVIUM AND MORAINES

Eldon Group

- Sk — KEEL QUARTZITE
- Sf — FLORENCE QUARTZITE
- Sa — AMBER SLATE
- Sc — CROTTY QUARTZITE

Junee Group

- Og — GORDON LIMESTONE
- Oo — OWEN CONGLOMERATE
- Oe — ENGINEER QUARTZITE
- Oot — TUBICOLAR SANDSTONE MEMBER

Dundas Group

- €c — CONGLOMERATE AND BRECCIA
- €s — SLATES
- € — UNDIFFERENTIATED

Metamorphic Rocks

- qp — GRANITE, MASSIVE (QUARTZ PORPHYRY)
- AREA OF QUARTZ PORPHYRITISED ROCK
- AREA OF FELSPATHISED ROCK
- AREA OF CHLORITISED ROCK
- AREA OF HAEMATISED ROCK
- qss — QUARTZ SERICITE SCHIST
- ORE OF 5% COPPER

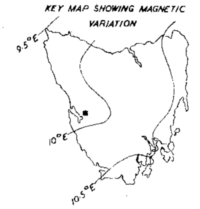
MAPPED AND COMPILED BY

J BRADLEY *JANUARY 1951*

- FAULT
- FAULT – POSITION APPROXIMATE
- BOUNDARY
- BOUNDARY – POSITION APPROXIMATE
- TREND OF OUTCROP
- ANTICLINAL AXIS
- SYNCLINAL AXIS
- STRIKE AND DIP
- ROAD
- TRACK
- HORIZONTAL CONTROL STATION
- THRUST FAULT, ⊢ ON UPTHROWN SIDE

Compilation from Aerial Photographs. Trigonometric Station control by courtesy Hydro-Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC VARIATION



– SCALE –

0 — 1 — 2 MILES

0 1 2 3 4 5000 10,000 FEET

SUMMARY OF THE GEOLOGY OF THE MOUNT DARWIN

SHEET 360/790.

PHYSIOGRAPHY.

Mt. Darwin is a residual block anticlinal in structure. To the east is an erosional surface at about 900 feet maturely dissected, and structurally developed to a marked degree. This is a complex syncline in Eldon rocks and beyond it to the east rises the Precombrian core of Tasmania. The drainage of this syncline is effected by rivers running on the east and west sides in the Gordon Limestone. Most of these streams are rejuvenated and in the Clark, Aron and Nora Rivers, gorges are cut in limestone and shale. To the east of Darwin lies the broad Clark Valley carved in the soft core rocks of a lofty anticline. West again is a lower anticline, Mt. Sorell, with its ice sharpened eastern face 2,000 feet high. The U-shape Clark Valley is, however, not primarily glacial but is adapted to structure. The Clark River, flowing over soft rocks, has its head of erosion only six miles from the sea at a height of 750 feet.

STRATIGRAPHY.

Eldon Group. These rocks are similar to those of the Jukes area but are less faulted and are readily traced. Crotty Sandstone well exposed at 635/960 is the typical friable rock of other localities.

Junee Group. Gordon Limestone: this is a critical area for this formation. North of Ten Mile Hill the limestone is less than 800 feet thick and lies on quartzite. South of this and between the Nora and Aron rivers the Tubicolar Sandstone passes laterally into calcareous shales and impure limestone which are highly fossiliferous and are similar to the Caroline Creek Beds. On the map these are indicated as Tubicolar Sandstone. Passing south these shales become progressively calcareous until, at the confluence of the Nora and Aron, there is 1,200 feet of impure limestone and perhaps 800 feet of limestone overlying them. This rapid facies change coincides with the dying out of the West Coast Range structures and the disappearance of Owen Conglomerate.

METAMORPHIC AND IGNEOUS ROCKS.

These are probably Dundas strata but are strictly unidentifiable. On the east flank of Darwin fine kaolinised and chloritic shales, not at all schisted, show perfect bedding and conglomeratic forms. A sudden but apparently conformable passage through hornfels reaches the porphyritic Darwin granite. At its most typical this is a highly distinctive quartz. chlorite, feldspar, rock with 1 inch phenocrysts of oligoclase, but graphic granite, quartz porphyry and non-porphyritic types are common. These types can be traced as bands along with patently sedimentary beds of sericite schist and hornfels inside the granite for two miles. At 636/951 the massive granite shows palimpsest pebbles 6" to 9" long, rounded and apparently water worn. The faulting and displacement of the granite indicate a stratiform shape and it seems that the body is "concordant" with the sediments it "intrudes" and contact metamorphoses. The chlorite is the only ferromagensian mineral of these rocks and is considered "original," i.e., not after biotite or hornblende. At South Darwin Peak the Owen Conglomerate shows a coarse basal conglomerate, with 18" boulders of Darwin Granite, and slate and haematite pebbles. Two miles away the basal conglomerates of Mt. Sorell have smaller pebbles of the same types. Although the contact is not clear, the evidence is overwhelmingly in favour of unconformity at this juncture.

STRUCTURE.

The major structure is a compound anticline formed of three folds, the Darwin, Clark River, and Sorell Anticlines. These are separated by sharp synclines or thrusts. The nature of the Sorell fold is shown at its culmination on Flannagans Flat as an overfold. The Darwin fold is exposed at South Darwin as a sharp anticline. The minor N.W. structures, folds and faults, are very strongly developed in this area.

ECONOMIC.

Alluvial gold at Mount Darwin forms the only metalliferous deposit to be worked in the area. This was a small field and had a short life. Limestone at 658/997 and quartz sand at 654/960 were worked for the Crotty smelters. Numerous small copper prospects occur.

POINTS OF INTEREST.

Darwin Plateau: views east, of Central Plateau of Tasmania, and west, of Mt. Sorell; Granite and metamorphic rock types.

South Darwin Peak: Unconformity.

Seven mile post: Exposures of Caroline Creek Beds.

REFERENCE.

Bradley, J., 1954: The Geology of the Queenstown Area: **Pap. Proc. Roy. Soc. Tas. Vol. 88.**