PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 91

THE PRECAMBRIAN ROCKS OF TASMANIA, PART I, DOLERITES OF THE NORTH-WEST COAST OF TASMANIA

By

ALAN SPRY

Department of Geology, University of Tasmania

(With 4 Text Figures and 2 Plates)

ABSTRACT

At least 30 small bodies of dolerite have been found intruding sediments of the Pre-Cambrian Rocky Cape Group along the coast between Sulphur Creek and Crayfish Creek. The igneous bodies are chiefly sills although dykes also occur. The dolerites are characterized by strong deuteric alteration which led to the formation of secondary tremolite-actinolite, chlorite, zoisite, albite, calcite, sericite, sphene, leucoxene, serpentine, and prehnite. These rocks show petrological and chemical affinities with dolerites of a similar age in Western and South Australia. They have certain features in common with the lavas of the Cambrian Dundas Group, but the possibility that these bodies acted as feeders to the flows is discounted on structural and chemical grounds.

INTRODUCTION

The dolerites occur as small bodies, ranging in size from a few inches to 400 feet in thickness and, as they are less resistant to weathering than the sediments they intrude, most are only revealed in the coastal rock platform. They outcrop sporadically along the coast from Blythe Heads to Crayfish Creek, but the greatest concentration is between Burnie and Cooee Point so that it is intended to use the term *Cooee Dolerite* to refer to this group of igneous rocks as a whole. It is believed that similar rocks occurring in the vicinity of Frenchman's Cap are part of this group and that as mapping of the Pre-Cambrian continues, more will be found. The Cooee Dolerites thus represent a distinct period of igneous activity, probably late in the Pre-Cambrian. Evidence shown later in this paper indicates that the Middle to Upper Cambrian volcanism was a later and distinct episode. A widespread period of basic to ultrabasic activity earlier in the Pre-Cambrian is represented by amphibolites, &c., and the Interview River dyke swarm described by Spry and Ford (1957) belongs to this episode.

Acknowledgements

The author is grateful to W. St. C. Manson of the Tasmanian Department of Mines who carried out the four chemical analyses which are published by courtesy of the Director of Mines. B. May and A. Rundle assisted in the field work.

Previous Literature

The presence of these basic dykes was first recorded by Twelvetrees (1903, 1905) who found them at Burnie, Boat Harbour and Rocky Cape. Stephens (1909) also briefly mentioned the same bodies in his notes on a traverse along the north-west coast.

COUNTRY ROCKS

The dolerites intrude a group of unfossiliferous sediments which extend from Penguin to Smithton. These sediments consist chiefly of quartzites and slates with siltstones, dolomites and a little conglomerate. They were referred to broadly as the "Rocky Cape quartzites" by Twelvetrees (1903, 1905), but examination now shows that the sediments constitute a group. Thus the Rocky Cape Group is here defined as those sediments, chiefly quartzites, slates, dolomites and siltstones outcropping intermittently from Penguin to Smithton and lying unconformably below the Dundas Group (at Penguin). Its thickness is in excess of 10,000 feet and while the detailed stratigraphy is not yet known, a number of formations have been recognized. A small area of coarse mica-schist along the Inglis River, shown in fig. 1, may lie unconformably below this group but the base of the Rocky Cape Group has not yet been seen. The formations are discussed in order (tentative only) from oldest to youngest.

Burnie Quartzite and Slate

This formation contains those quartzites and slates outcropping along the foreshore at West Burnie. It appears to outcrop from east of Howth to Doctor's Rocks, except where covered by a superficial layer of later material. The formation is probably several thousand feet thick and consists mostly of a monotonous repetition of thin slates and quartzites. The argillites are dark-grey to black siltstones or slates which show a cleavage which is strongly developed in some specimens but lacking in others. Some contain abundant clastic mica and others are graphitic. Many of the coarser siltstones exhibit cross-bedding, scouring and other intraformational structures. The quartzites are generally light-coloured, quartzose, and massive, flaggy or thinly bedded with occasional cross bed-

For "Pre-Cambrian" read "Precambrian" throughout the paper.

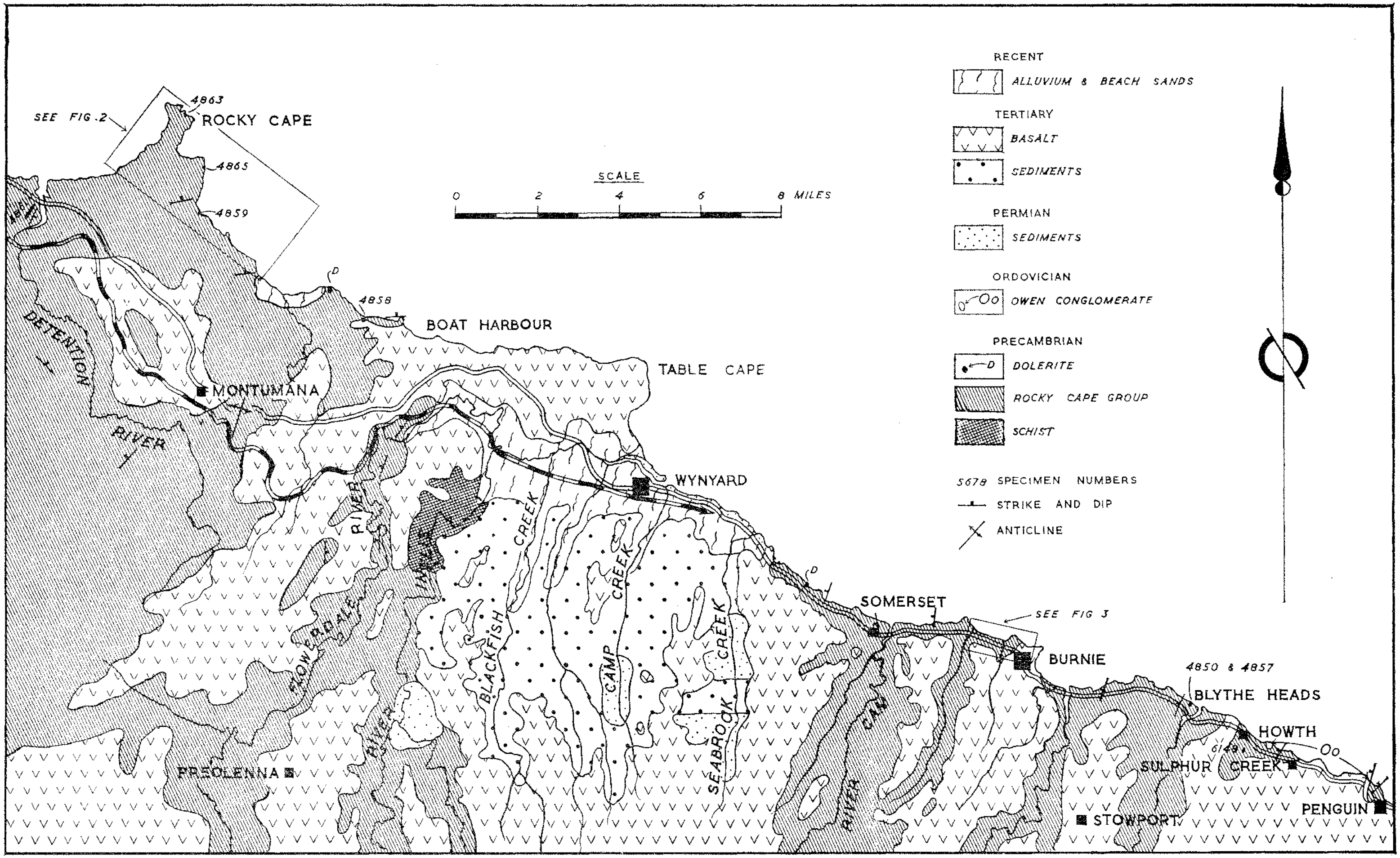


FIG. 1.—Regional geological map showing the distribution of the Precambrian rocks and in particular of the dolerites. Some boundaries after Loveday (1956).

ding. Thin sections of many quartzites show that they contain angular quartz fragments and this fact, together with their association with some beds of sub-greywacke, indicate that they are not normal ortho-quartzites (Pettijohn, 1949). Some arenite layers contain abundant angular slate fragments up to eight inches long and the location of these intraformational breccias is shown in fig. 3.

The lack of recognizable marker horizons, together with the close folding and faulting (see fig. 3) prevents the accurate measurement of the thickness of this formation. The beds generally dip to the west (see fig. 1), but small folds are abundant and these are asymmetrical with the steeper limb either to the east or west, but with a general flat plunge in a direction 230°. Faults are common and cause difficulty in interpreting the structure, and are frequently associated with zones of contortion.

The phyllites at Somerset are more altered and are strongly cleaved with a distinct lineation due to crenulation, but there appears to be a complete transition into the less altered beds at Burnie. These phyllites are overfolded towards the south in the quarry on the Somerset-Waratah road, half a mile south of Somerset and several other places on the wave-cut platform near Somerset.

Black River Dolomite

The Burnie Slate and Quartzite is separated from the sediments in the Rocky Cape area by a cover of Permian sediments and Tertiary lacustrine beds and volcanic rocks, consequently the relationships between the sediments of the two areas is not known. The oldest bed named in this paper from the Rocky Cape area is the thin (50 feet) grey to buff dolomite which outcrops at the bridge where the Bass Highway crosses the Black River. It is brecciated and silicified in parts. A small area of dolomite at the eastern end of Sisters Beach may be the same formation. The Black River Dolomite underlies the Cowrie Siltstone and overlies the unnamed siltstones which occur to the south up the Black River where they are folded into a series of anticlines and synclines about half a mile across, with axes running approximately east-west.

Cowrie Siltstone

The type of locality for this and the following three formations is on the southern part of the western side of Rocky Cape as shown in fig. 3. The name is taken from Cowrie Pt. and it is considered that the formation occurs all the way along the coast from Rocky Cape to Black River although it cannot be proved at present that there is not a fault separating the Cowrie Pt. rocks from those at Rocky Cape where the sequence was established. Thus the Cowrie Siltstone probably lies above the Black River Dolomite and below the Bluff Quartzite. It consists of at least 1500 feet of laminated to flaggy siltstones which are buff, grey and black in colour with a distinct cleavage at an angle to the bedding. They are characterised by possessing intraformational structures such as cross-bedding and slumping, with pyrite nodules in some bands. Thin layers of quartzite occur throughout.

Bluff Quartzite

This is a 1500 foot thick quartzite, light in colour, thinly bedded at the top, but massive towards the base, with coarse cross-bedding and ripple marks (plate I). It overlies the Cowrie Siltstone and lies below the Port Quartzite and Slate. It is lithologically indistinguishable from the Cave Quartzite (defined below) and this causes great difficulty in mapping this area.

Port Slate and Quartzite

This formation is named after the small harbour on the eastern side of Rocky Cape, this being shown as "The Port" on old maps of the area. It lies between the older Bluff Quartzite and the younger Cave Quartzite. It consists of 1500 feet of alternating slates and quartzites. The argillites are grey to black laminated slates and slatey siltstones containing abundant intraformational structures such as sandy lenses, mud pellet conglomerate and slump structures. The quartzites are generally thinly bedded.

Cave Quartzite

The quartzite which forms the extremity of Rocky Cape is called the Cave Quartzite from the Rocky Cape Caves which occur within it. It overlies the Port Slate and Quartzite but the upper limit is not visible. It consists of 1500 feet of light coloured, thickly bedded quartzite with some cross-bedding and ripple marks. The quartzite on the cliffs east of Sisters Beach and at Jacob's Boat Harbour is probably this formation. Exposed in a raised sea cave half a mile east of Sisters Beach is a conglomerate which is named the Sisters Conglomerate, being a member within the Cave Quartzite. The conglomerate occurs as two closely spaced horizons one of which is about 18 feet thick and the other about three feet thick. There are coarse and fine phases but the well-rounded boulders (which are always quartzite identical with that above and below) range up to 18 feet long.

The quartzite at the eastern end of Sisters Beach is of interest as it contains the only trace of organic life in the Rocky Cape Group. Plate II shows a specimen of "worm tracks".

The Cave Quartzite may be equivalent to the Bryant Hill Quartzite named by Carey and Scott (1952) at Smithton where it underlies the Smithton Dolomite. These two formations were referred to as "Carbine Group" by correlation with Elliston's (1954) section at Dundas.

Field mapping has shown that the stratigraphy of the Pre-Cambrian rocks is very complicated and consequently, any correlation of the extensive sediments around Smithton and Rocky Cape with the imperfectly known Carbine Group of Dundas, is unwise at present.

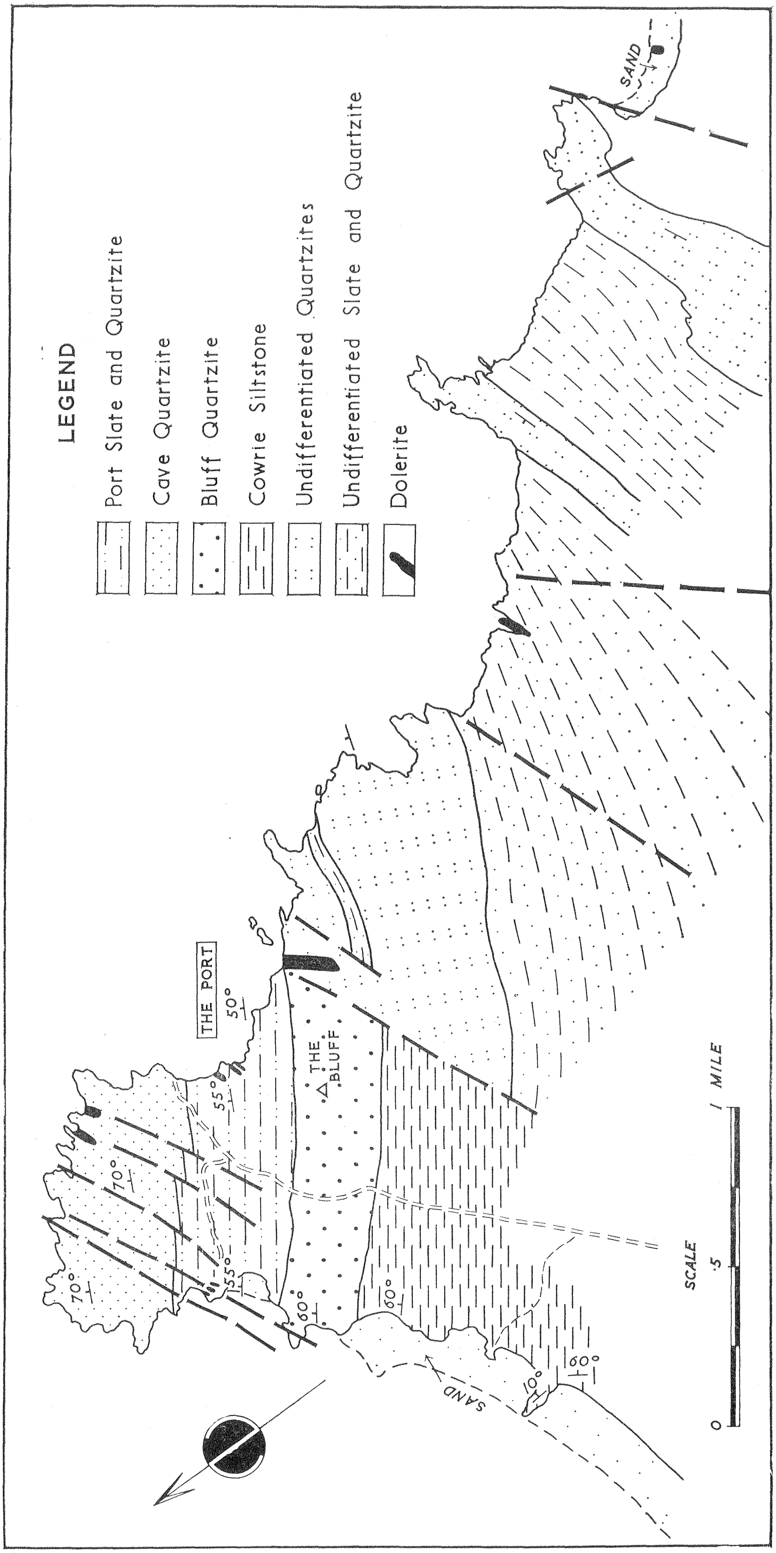


FIG. 2.—Sketch map of Rocky Cape showing the type localities for the named Precambrian formations and also some dolerites.

FIELD RELATIONS OF THE DOLERITES

Sulphur Creek

The most easterly occurrence is near Sulphur Creek where a few boulders of brecciated, fine-grained dolerite are scattered around on the northern slope of the hill about one third of a mile south of the coast, as shown in fig. 1. The field relations are unknown but it appears to have originated in an old adit which apparently explored the pyrite mineralization in the igneous rock.

Blythe Heads

Three sills outcrop on the wave-cut platform north-north-east of the Titan Products factory about half a mile west of the mouth of the Blythe River. Two of the sills are about 100 feet thick while the other is about 12 feet thick. They concordantly intrude quartzites (probably belonging to the Burnie Slate and Quartzite) which dip to the west at 45°. A very crude banding in the thicker sills is due to alternation of coarser and finer grained layers.

Burnie-Cooee Pt.

Dolerite outcrops on the rock platform at West Burnie, as shown in fig. 3. There is probably more inland, but due to the extensive cover of Tertiary basalt the only one found was that in the Brickport Road quarry, about a quarter of a mile south of Cooee Pt. This particular rock is strongly weathered and is being quarried for brickmaking. It occurs as a 300 feet thick sill striking at 15° and dipping west at 50°. Medium and coarse grained phases are separated by a fault surface. The body probably continues beneath soil cover to outcrop poorly in the bay next to the Cooee Railway Station.

The dolerites are well exposed along the platform at West Burnie, but because of the structural complexity and limit of outcrop, it is not possible to state definitely how many individual bodies are present, despite detailed mapping. Fig. 3 shows the distribution of the dolerite together with an interpretive section. It seems most likely that there is one major sill 300 feet thick which outcrops on the shore from Cooee Pt. to Noel St. and possibly again at Park Pt. It is commonly pegmatitic and the country rocks immediately beneath are generally cut by many very thin sills (Plate I, No. 4). There are at least two other sills about 100 feet thick, as well as many smaller ones ranging from 15 feet to 4 inches in thickness. The uniformity of the sediments which have been intruded and the lack of marker horizons prevent the detailed structure from being recognized, especially as there appear to be at least four strike faults with throws of several hundred feet.

One structural characteristic is shown by several bodies here. The upper surface is concordant with the overlying sediments which dip at a moderate angle. The strike of the lower surface is parallel to that of the upper but the dip of both sediment and base of the sill is very steep, often vertical. This may represent an intrusion along a fault, the section across the tightly bent crest of a fold, or a post-intrusion fault along one side of the body.

The intrusions here are generally quite concordant although they show clearly discordant boundaries in some places. Fig. 3 shows a folded sill which transgresses the sediments in a zone between two concordant parts.

Somerset

A small dolerite body on the wave-cut platform about two miles west of Somerset occupies the core of a small anticline in quartzites.

Jacob's Boat Harbour

A sill 100 feet in thickness on the rock platform about one mile west of Boat Harbour intrudes quartzites and slates striking at 50° and dipping 50° to the north-west. The sediments probably are equivalent to the Port Quartzite and Slate. A second dyke occurs two miles west of Boat Harbour and a quarter of a mile east of the end of Sisters Beach. This may intrude the same formation but the structure is not clear.

Rocky Cape

Eleven intrusions at Rocky Cape are shown in fig. 3. On the eastern side of the extremity of the Cape are two dykes which strike at 240° and intrude Cave Quartzite which strikes 280° and dips up to 70° north. On the rock platform extending for a quarter of a mile south of the end of the road to the old jetty are three sills and a dyke intruding Port Quartzite and Slate. The thickest sill is 100 feet thick. The dyke is visible on a small stack where it strikes at 50° across sediments striking at 115°. Several more dykes outcrop on the south-easterly part of the Cape and another on the western end of Sisters Beach. Five small dykes intrude the Port Quartzite and Slate on the rock platform on the west side of the Cape, opposite the jetty.

Detention River

A few hundred yards west of the intersection of the Detention River and the Bass Highway is a low ridge standing about 20 feet above the surrounding flat country. It is composed of dolerite which forms a sill intruding pale coloured flaggy quartzites striking at 220° and dipping east at 20° to 30°. A little pyritization of the quartzites is visible in the small quarry near the road. The sill may be followed for a mile to the south before it is lost beneath a cover of gravels.

Crayfish Creek

A small dyke on the foreshore about half a mile east of Crayfish Creek intrudes the Cowrie Siltstone. The sediments are blue and grey, well bedded to laminated siltstones and impure quartzites striking east-west and dipping north at angles of 45° and higher.

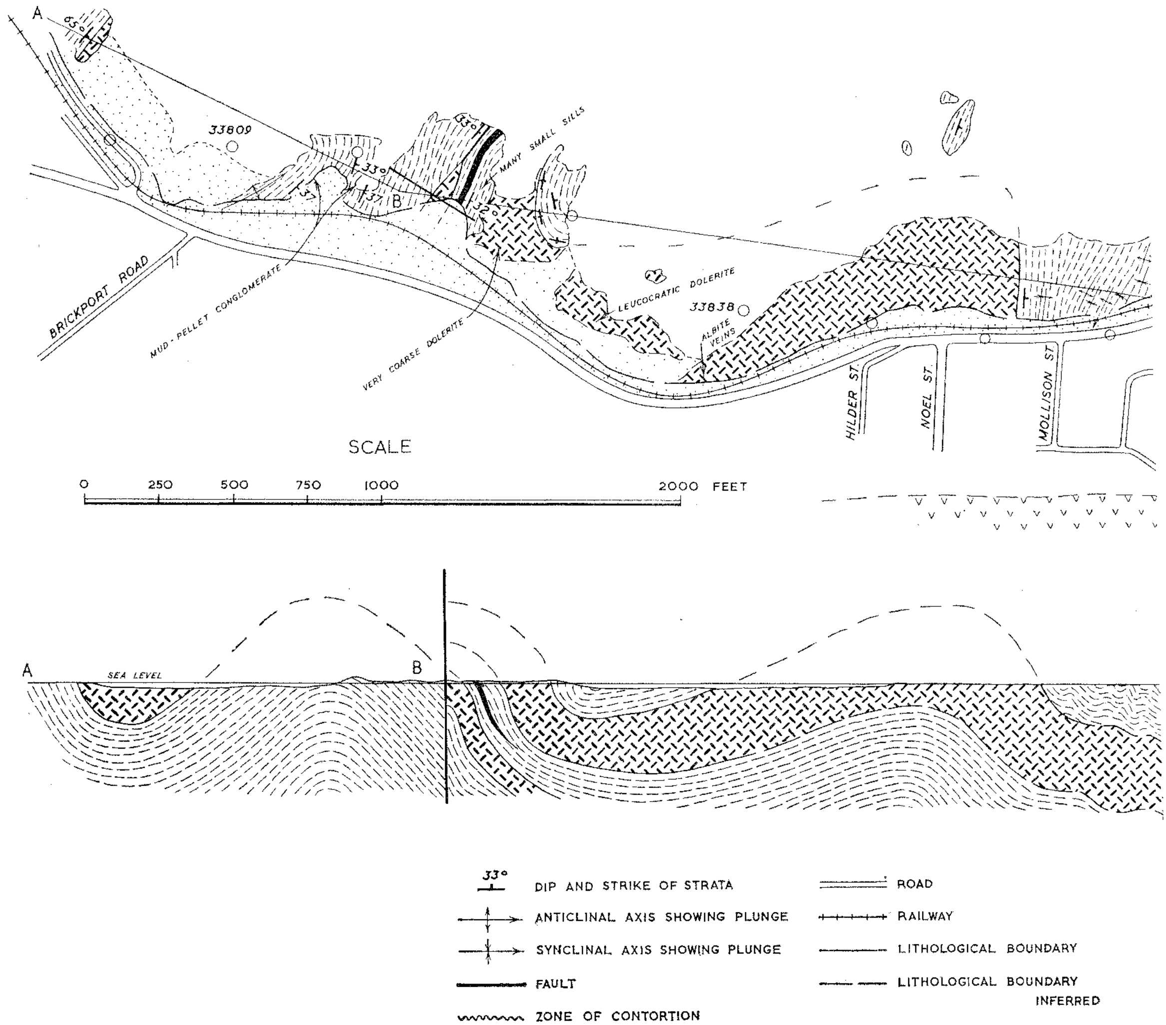


FIG. 3.—Precambrian sediments (Burnie Slate and Quartzite) with dolerite intrusions on the foreshore between Cooee Point and Park Point, West Burnie.

STRUCTURAL RELATIONS

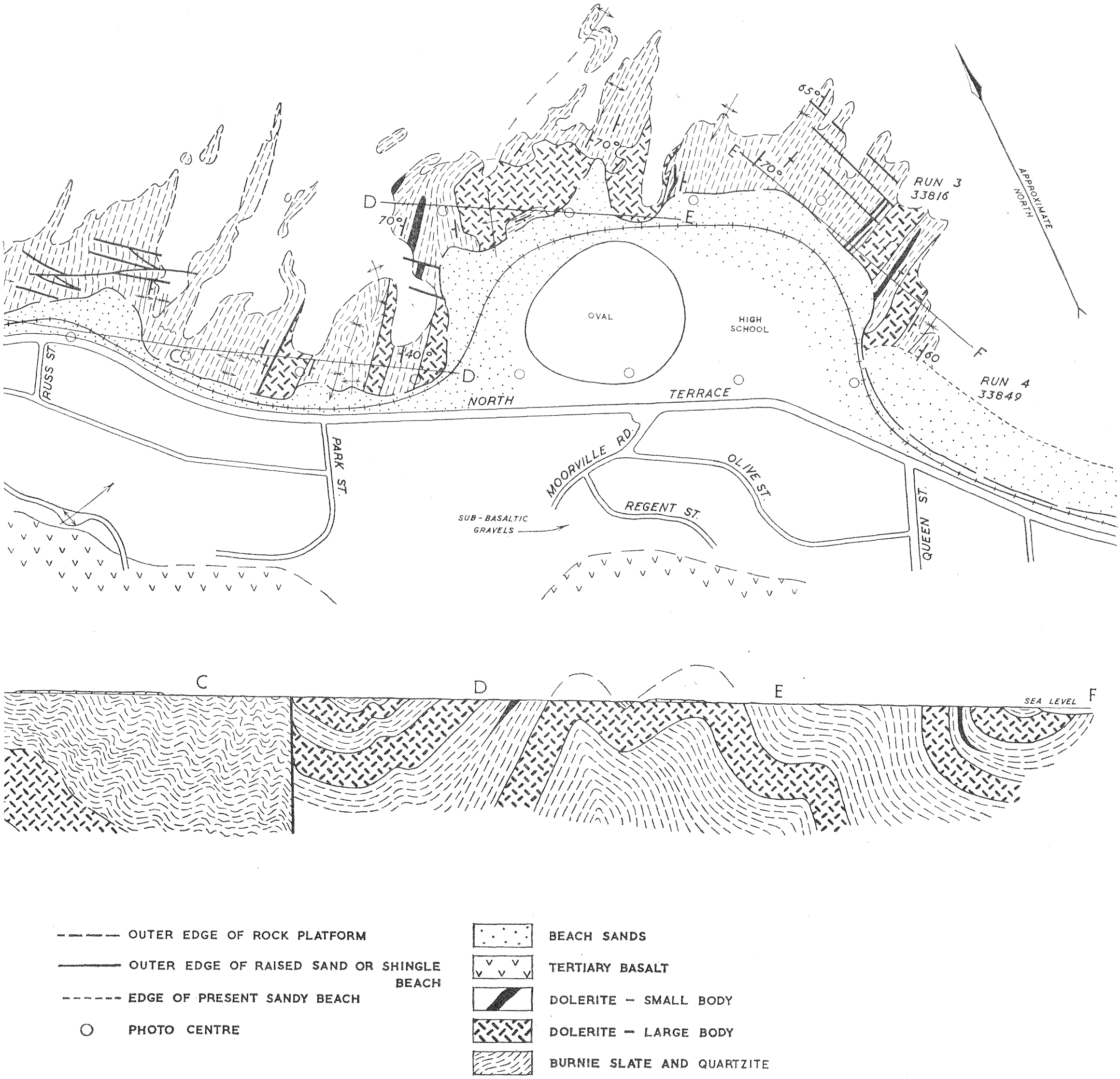
It is possible to divide the dolerites into two groups on structural, geographic and petrological grounds. The intrusions west of Wynyard (i.e., Boat Harbour, Sisters Beach, Rocky Cape, Detention River and Crayfish Creek) are chiefly dykes and show very marked secondary alteration. It is noticeable that practically all of these intrusions strike north-easterly and only a few diverge even as much as 30° from this direction. Not only is this the direction of a prominent set of faults in this area, but the dykes themselves actually lie along faults on the northern end of Rocky Cape.

The intrusions east of Wynyard (i.e., Somerset, Burnie and Blythe Heads) are all sills and show secondary alteration to a lesser degree than those of Rocky Cape, &c. The Detention River Sill shows characteristics common to each group.

The evidence suggests that the easterly group were intruded either prior to, or contemporaneously with, the folding, whereas the westerly group were intruded during the faulting which followed the folding. The two phases are considered to be parts of one period of igneous activity.

MINERALOGY

The dolerites probably originally consisted chiefly of pyroxene and labradorite with minor amounts of brown hornblende, biotite and olivine in some specimens. Accessories are apatite and ilmenite. Secondary minerals are tremolite-actinolite, chlorite, zoisite, sericite, prehnite, albite, leucoxene, sphene, calcite and serpentine.



Primary Minerals

Pyroxene

Most rocks contain relics of pyroxene which show partial alteration to pale fibrous amphibole or chlorite. Some leucocratic dolerite from Burnie and dolerites outcropping from Boat Harbour to Rocky Cape show complete alteration of the pyroxene. The pyroxene is more resistant to alteration than the plagioclase and persists after all plagioclase has been replaced. This relation has been observed repeatedly in similar rocks and has been discussed by Spry (1952, p. 104).

The pyroxene is generally colourless in thin section although very pale-green varieties occur. Purple titanaugite occurs in specimens from Burnie (4868*) and Blythe Heads (4857).

The optic axial angle ranges from 45° to 66°. In a specimen from Detention River (4855) the pyroxenes are zoned with a 2V of 45° in the centre to 49° at the edge and measurements of other crystals in the same slide gave values of 48°, 52° and 58°.

An analysis of the pyroxene from the Blythe Heads dolerite (4857) is given in table 1. It is black in hand specimen, deep purple in crushed grains and in thin section is a pale-purple drab (Munsel Colour Chart). It has 2V = 66°, and $\beta = 1{\cdot}665 \pm {\cdot}003$. The analysis shows several interesting features. Titania is quite high as many titanaugites only contain 1 per cent. The iron content is rather

* Numbers refer to specimens in the collection of the Geology Department, University of Tasmania.

low, as is the lime. The alumina is high (9%) as most augites range from 2-8 per cent. The total of 1·05 per cent alkalis is appreciable although Hess (1949, p. 654) recorded an augite with Na_2O = 1·61 per cent and K_2O = ·06 per cent. The 2·85 per cent of water is unexpected as the sample appeared to be completely fresh but the slight amount of P_2O_5 is due to a small but persistent apatite contamination.

The pyroxene is compared with one from a Cambrian spilite of the Dundas Group, analysed by Scott (1954). The similarities (e.g., high alumina and low iron) are pronounced although there are slight differences in 2V, titania content and colour.

TABLE 1

PYROXENE ANALYSES

	Blythe Heads	Lynch Creek (Scott, 1954)
	Analyst: W. St. C. Manson	Analyst: B. Scott
SiO_2	46·10	48·53
Al_2O_3	9·00	7·10
Fe_2O_3	1·90	0·70
FeO	7·00	5·71
MnO	0·18	not det.
TiO_2	1·60	0·85
P_2O_5	0·15	not det.
CaO	17·70	21·24
MgO	12·60	15·90
Na_2O	0·84	not det.
K_2O	0·21	not det.
H_2O-	0·14	not det.
H_2O+	2·71	not det.
	100·13	100·03

ATOMIC PERCENTAGE

	Blythe Heads	Lynch Creek (Scott, 1954)
Ca	42·0	46·7
Mg	41·9	42·3
Fe	16·1	11·0
Percentage Al in Z	14·3	—
2V	+66°	+51°

Plagioclase

No primary plagioclase was found in any of these rocks and the albite, zoisite, calcite and prehnite are considered to have been derived from original basic plagioclase.

Orthoclase

It is difficult to recognise orthoclase among the strongly altered feldspar, all of which is crowded with tiny inclusions but the analyses in table 2 indicate its presence. The mineral is usually sericitized, e.g., 7265, but occurs in a fresh condition as an intergranular graphic intergrowth with quartz in the Detention River sill (4861).

Hornblende

Several rocks contain large laths of hornblende which are so well formed as to be probably primary. This is abundant in the coarse phase of the dolerite (4856) near Cooee Pt. where crystals up to 1·5 cms. long are visible in the hand specimen. The mineral is pleochroic with X = pale-green, Y = reddish-green and Z = deep green to rusty-brown and has $Z \wedge C$ = 13°. A little olive-green hornblende is developed in other specimens but its somewhat ragged shape suggests that it may be secondary.

Olivine

Some dolerites (4855, 7276) from just west of Burnie contain a few crystals which have the typical shape of euhedral olivine but which now consist of serpentine.

Biotite

Some dolerites, particularly those at Burnie (4855, 4860, 4864) contain a little well-formed biotite which appears to be primary. It is fresh and pale-green in 4858 but is generally strongly pleochroic from pale rusty-yellow to deep brownish-black (4864) with peripheral alteration to chlorite. The crystals are not greater than ·2 mm. in length and the chilled dolerites are rich in very tiny crystallites of biotite.

Quartz

Apart from very minor amounts in the dolerites from Detention River (4861) and Rocky Cape (4853, 4854), the only rocks in which quartz is important are the leucocratic varieties from Burnie. Quartz veins cut the dolerite at Burnie.

Ilmenite

This is an accessory in all of the dolerites. It forms irregular crystals which measure as much as 2 mm. across and which are partially or entirely replaced by either leucoxene or sphene.

Apatite

This is an abundant accessory in all of the dolerites. It appears as colourless hexagonal prisms and needles which reach 3·3 mm. long in 4864 and 7265.

Secondary Minerals

The primary minerals show various degress of alteration and this is made a basis of subdivision of the dolerites in a later section.

Amphibole

This is well developed in some specimens where it has either replaced pyroxene or forms peripheral fringes around it. The amphibole is fibrous and varies from colourless through various shades of pale-green to olive-green. A tremolitic variety is present in the leucocratic dolerite (4851); it is pleochroic from colourless to palest-yellow, has an optic axial angle of approximately 80° (negative) and an extinction angle $Z \wedge C$ of 16°.

Chlorite

Chlorite is the most common alteration product of pyroxene and it has also replaced biotite and feldspar (4859, 4855). It is poorly crystallized as fine fibres or flakes which form clots, shapeless intergranular patches or pseudomorphs after pyroxene. Its properties are difficult to obtain but it is colourless to palest-green and varies from isotropic to weakly birefringent with anomalous interference colours and appears to be optically positive with a very low optic axial angle.

Albite

A plagioclase close to pure albite (Ab_{98}) is present in all of these rocks and is regarded as being due to the breakdown of original labradorite. It shows a considerable variation in its properties. Most albite occurs as large, well-formed laths pseudomorphing original plagioclase and is strongly clouded by innumerable tiny inclusions of zoisite, sericite, kaolinite (?), chlorite or sphene. It commonly displays twinning on the Albite Law.

Albite also occurs as small, shapeless, intergranular crystals which are fresh and untwinned.

The albite in the leucocratic dolerites is generally anhedral and fairly fresh. Some is untwinned (4862), some shows poor twinning on combinations of the Albite and Carlsbad Laws (4851) and some shows fine chequer-board twinning (4860). One specimen (4851) contained feldspar showing slight compositional and alteration zoning.

There are drusy veins an inch or so thick of creamy-white, euhedral albite cutting the dolerite at Burnie in the locality shown in fig. 3.

Prehnite

This is a secondary product formed by the alteration of original plagioclase and occurs abundantly in some specimens from Burnie (4855) and in small amounts in rocks from Detention River (4861), Rocky Cape (4863) and Boat Harbour (4858). In thin section, it is colourless and coarsely crystalline to fibrous or scaly and shows the undulose extinction which is characteristic of this mineral. The birefringence is about ·032 and it is optically positive with a moderate but very variable 2V.

Zoisite-Epidote

Zoisite occurs commonly in these rocks and it represents the lime liberated in the breakdown of labradorite to albite. It is generally small in size (·02 mm. granules) but some well-formed prisms reach ·5 mm. in length. The birefringence is very low and anomalous blue interference colours are prominent. Extinction is straight and it is colourless to pale-green.

In some specimens the colourless zoisite grades into a pale-yellow, ferroan zoisite with a little higher birefringence, or into yellow epidote with much higher birefringence and oblique extinction. An irregular form of twinning is shown by some crystals.

Leucoxene

Fine-grained growths of leucoxene partially or wholly replace ilmenite in all of the dolerites.

Sphene

Small grains (not usually more than ·01 mm. diameter) of pale-brown sphene occur in a few rocks (4860) where it is probably due to the concurrent breakdown of plagioclase and ilmenite.

Calcite

This mineral occurs sporadically both in small grains and large crystals. It is quite abundant in the leucocratic dolerite, e.g., 4862.

Serpentine

There are uncommon crystals of olivine which have been pseudomorphed by pale-green fibrous serpentine with anomalous blue interference colours.

PETROLOGY

All these igneous rocks show strong similarities to each other and there is no doubt that they are closely related genetically. It is convenient to divide the rocks up into groups on petrographic grounds but the differences between groups are not great and it is considered that there is one chief type (referred to as group "a" below) and that the others have been derived from this by chilling, secondary alteration, slight differentiation or fragmentation.

The following rock types have been observed:—

(*a*) moderately altered dolerites,
(*b*) strongly altered dolerites,
(*c*) micro-dolerites,
(*d*) brecciated micro-dolerite,
(*e*) basic pegmatite (pegmatitic dolerite),
(*f*) leucocratic dolerite.

(*a*) The most important group consists of moderately altered dolerites with mildly alkaline affinities. Many of the dolerites at Burnie (4864, 4855) are of this kind, as are those at Blythe Heads (4857) and Detention River (4861). Analyses are given in table 2.

These are greenish-grey dolerites with a rather coarse grain. In thin section they show an intergranular to ophitic texture which has been partially destroyed by the growth of secondary minerals. The pyroxene is a titanaugite (analysis in table 1) which is generally fresh but which has inclusions of zoisite and sphene in some specimens and a partial alteration to fibrous amphibole or chlorite in others.

The plagioclase laths are of albite which is either strongly obscured by inclusions of zoisite, is altered partially or wholly to sericite, or is replaced by prehnite.

Orthoclase is recognisable as cloudy anhedral crystals which are less obscured by inclusions than the albite. It also occurs as micro-graphic intergrowths with quartz in the Detention River sill.

A little, large, well-formed brown hornblende occurs in some specimens together with biotite. Accessory ilmenite with leucoxene, and apatite are present. A little olivine altered to serpentine was found in two specimens.

TABLE 2

ANALYSES OF DOLERITES

(Analyst: W. St. C. Manson)

	4864 Coarse dolerite Burnie	4852 Dolerite Detention River	4861 Leucocratic dolerite Burnie
SiO_2	44·44	58·52	54·64
Al_2O_3	17·97	15·03	15·22
Fe_2O_3	1·74	0·96	1·17
FeO	8·32	2·60	7·81
MnO	0·22	0·11	0·13
CaO	9·42	8·46	7·96
MgO	4·74	4·36	5·39
Na_2O	2·86	3·24	1·69
K_2O	3·04	1·41	2·23
TiO_2	3·00	0·41	0·68
P_2O_5	0·72	0·12	0·10
H_2O-	0·26	0·14	0·02
H_2O+	3·53	5·09 (inc. CO_2)	2·85
	100·26	100·45	99·89

(*b*) The dolerites which occur between Rocky Cape and Boat Harbour are much more altered than the previously described rocks. Examples of this group are 4853, 4854, 4859 and 4863.

The original ophitic to intergranular texture has been almost, if not completely, destroyed by the growth of new minerals. No original plagioclase remains and only in a few cases is pyroxene found. The rocks are composed chiefly of fibrous actinolite, chlorite, albite, zoisite and leucoxene with varying amounts of prehnite, sericite, biotite and quartz. Ilmenite is very abundant in 4863 from Rocky Cape.

Specimen 4858 from west of Boat Harbour contains completely prehnitized feldspar outlined by lines of epidote grains, colourless to olive-green actinolite with cores of chlorite, a little brown hornblende surrounded by growths of actinolite, ilmenite rimned with sphene, and tiny flakes of fresh green biotite.

Specimen 4859 from Rocky Cape contains approximately 35 per cent actinolite, 35 per cent biotite, 15 per cent epidote and zoisite, 5 per cent ilmenite partially replaced by leucoxene and 10 per cent of feldspar, &c. In this rock there are large (2·5 mm.) crystals of plagioclase which have been replaced by chlorite and zoisite.

(*c*) The thin (2 feet and less) sills which are abundant just west of Burnie, particularly near Cooee, have a fine grain due to rapid chilling, and these are best named micro-dolerites. Typical specimens are 7266, 7270 and 7271.

In the hand specimen, they are dense, dark-grey to black, very fine-grained, somewhat spotted rocks. In thin section they are seen to consist of a fine-grained mesh of albite laths with chlorite and abundant iron oxide. Tiny biotite flakes, some chloritized, are arranged in a criss-cross fashion, and finely granular calcite is present. A little epidote occurs in one specimen.

(*d*) The rock (6048) from Sulphur Creek appears to be a brecciated micro-dolerite which has been cemented by calcite. It consists of pale, greenish-grey, fine-grained fragments averaging about 1 cm. across, with a white, calcite cement. There are a few grains of chalcopyrite. In thin section, the fragments are seen to be very fine grained and strongly altered with a flow structure. There are tiny laths of albite set in a dark groundmass. The cement is chiefly of calcite with tiny rhombs of dolomite and some strongly undulose quartz.

(*e*) A coarse-grained pegmatitic rock occurs as irregular patches within the large sill at Burnie, particularly on the beach opposite Hilder Street.

Number 4856 consists of large laths of brown hornblende up to 1·5 cms. long with similarly sized fresh titanaugite crystals set in a finer mesh of altered plagioclase. The feldspar has been prehnitized but fresh albite showing chequerboard twinning is abundant. Leucoxene forms masses up to 2 mm. across and apatite occurs as needles almost 1 cm. long.

Number 7265 contains abundant, large, euhedral hornblende crystals which have grown around fresh titanaugite in optical continuity. Large, fresh biotite crystals are present.

(*f*) The leucocratic dolerites (4851, 4852, 4862) occur as narrow veins of pale-grey to cream, fine-grained rock cutting the dolerite on the beach west of Hilder Street. They shown an allotriomorphic granular texture and consist chiefly of albite, tremolite (after pyroxene which remains as small cores in some rocks), quartz, chlorite, calcite, apatite, ilmenite, leucoxene and sphene. The albite ranges from strongly clouded to fresh crystals and is untwinned, twinned on a combination of the Albite and Carlsbad laws or shows fine chequerboard twinning.

The composition is variable and ranges from 80 per cent albite and 20 per cent of epidote, zoisite, chlorite, biotite, ilmenite, pyrite and sphene in No. 4860 to 35 per cent albite, 20 per cent calcite, 15 per cent quartz and 20 per cent chlorite in No. 4862.

These rocks show affinities with the keratophyres and an analysis is given in table 2. A similar rock was described by Spry (1952) from Hawker, South Australia, where it was shown to have been formed by differentiation from similar dolerites.

As can be seen from the petrographic descriptions, all of these rocks show distinct similarities and can be genetically related as follows. First was the rise of olivine basalt magma from the sima into a deep crustal chamber. Early olivine crystallized and settled and this caused the initial magma which intruded the Rocky Cape Group to be rich in water and somewhat tholeiitic. The residual volatiles caused the secondary alteration of early silicates during the deuteric phase of crystallization as outlined for similar rocks by Spry (1952). Concentration of volatiles in certain areas during the initial phases of crystallization resulted in an increase in grainsize and gave the patches of pegmatitic dolerite. Some slight tectonic movements during crystallization resulted in differentiation by "filter-press" action with a less basic residual magma migrating into fissures in the partially solidified dolerite to crystallize as small bodies of leucocratic dolerite.

Structural evidence shows that the dolerites at Rocky Cape were intruded a little later, and the petrological evidence is in accord as it points to a higher concentration of volatiles in the later intrusives. Fractions drawn from a cooling magma reservoir would be progressively richer in volatiles as time passed.

Related Rocks

Dykes of similar rock have been found intruding the Pre-Cambrian 70 miles to the south at the Raglan and Surveyor Ranges, in the Frenchman's Cap area. These are tentatively correlated with the *Cooee Dolerites* on petrographic grounds.

A number of small dyke-like intrusions outcrop on the Raglan Range along Bradshaw's timber track between Mount Raglan and the huts to the west. The rock is strongly weathered and in some places, merely forms areas of tan-coloured clay. The dolerite intrudes garnet schist. Specimen 6317 is a light-grey dolerite with relics of ferromagnesian minerals visible in the hand specimen. It is fine grained and consists chiefly of interlocking laths of very cloudy albite with chlorite pseudomorphs of the original pyroxene. Opaque minerals are abundant and include pyrite, limonite and magnetite. Apatite is an accessory.

Specimen 6784 was collected by J. B. McKellar south of Frenchman's Cap. It is somewhat porphyritic, with euhedral phenocrysts of sericitized feldspar set in a medium grained, intergranular groundmass which consists of cloudy albite laths and ragged biotite flakes, with a little chlorite and sphene.

The *Cooee Dolerite* show considerable lithological similarities with the lavas of the Cambrian Dundas Group. The spilites and keratophyres of the Dundas Group show pronounced alteration with the development of albite, epidote, chlorite, actinolite, leucoxene and calcite. It has been shown earlier in this paper that the pyroxene from the Cambrian spilite at Lynch Creek is not unlike that from the dolerite at Blythe Heads.

The folded sills at Burnie were intruded simultaneously with, or before the folding of the Rocky Cape Group, whereas the dykes at Rocky Cape were intruded later. As the Rocky Cape Group appears to be conformable with the Dundas at Smithton, it is possible that the folding of the Pre-Cambrian rocks took place in the Cambrian and that these intrusions represent a phase of the Cambrian vulcanicity. It is also possible that the folding took place prior to the Cambrian but that some of the dykes might be the "feeders" of the Cambrian lavas.

In this area the Owen Conglomerate rests directly on the Rocky Cape Group with violent unconformity and it appears that the area from Smithton to Penguin might have been a land mass during the Cambrian. The Dundas Group at Penguin appears to overlie unconformably the Rocky Cape Group.

It thus seems most likely that the Pre-Cambrian sediments were folded before the Cambrian and that the igneous rocks are Pre-Cambrian also. It is shown later that there are considerable chemical differences between the Cooee Dolerite and the Dundas Group.

The similarities between these dolerites and those which intrude Pre-Cambrian rocks in South Australia and Western Australia are very striking. The relationships between the South and Western Australian dolerites were discussed by Spry (1952) and it was suggested that these dolerites showing uralitization, saussuritization, &c., were so distinct in their petrological nature that they could be considered to constitute a petrographic province. The Cooee Dolerite may belong to this province also.

Prider (1945) summarized the characteristics of the Western Australian rocks and it is remarkable that dolerites described by Cole and Gloe (1939) from Malkup resemble some South Australian types down to the last minute detail.

The rocks belonging to this petrographic province may be described as follows. They are medium-grained with a texture ranging from hypidiomorphic granular to intergranular or ophitic. They originally consisted of pyroxene and basic plagioclase with some brown hornblende, accessory ilmenite and apatite and a little olivine in a few cases. A quartz-rich residuum occurs in some rocks. The pyroxene is generally augite, but pigeonite is found in some South and West Australian specimens, and titanaugite in some from Tasmania and West Australia. Secondary alteration is characteristic and has led to the development of actinolite, albite, epidote, zoisite, chlorite, leucoxene, sphene and sericite.

A summary of the chemical data available for the dolerites from Cooee, South Australia and Western Australia is given in table 3.

There are significant similarities between the Cooee Dolerite and those from South and West Australia but the Dundas spilites show marked differences. This is emphasized by the distribution of the analyses in fig. 4. The Na_2O-FeO-MgO diagram used by Sundius (1930) shows that the Dundas spilites differ considerably from the Cooee dolerites which chemically may be grouped with the Western and South Australian rocks.

The compositions are also plotted on a Na_2O-K_2O-MgO diagram to emphasize the importance of the alkalies. Sundius (1930, p. 9) remarked that "undeniably the extreme deficiency in potash is a special character of the spilite series". The high Na_2O and low K_2O is probably the most important characteristic of the spilites and the ratio $\frac{Na_2O}{K_2O}$ is about 6 for Sundius' average spilite and for the Dundas spilites. On the other hand the ratio is about 1 for the Cooee Dolerites, $1\frac{1}{2}$ for the Kimberley rocks, 2 for the West Australian and $2\frac{1}{2}$ for the South Australian basic rocks.

CONCLUSIONS

The petrological and structural evidence suggests very strongly that the Cooee Dolerites and the Dundas spilites represent separate periods of igneous activity. This could be proved if the Dundas was found to overlie unconformably one of the dolerites but the chances of finding this seem remote, due to limitations of outcrop. Radioactive age determinations do not seem likely to help because of the lack of the appropriate minerals.

The dating of this period of igneous activity is difficult but it is probably pre-Dundas, i.e., earlier than Middle Cambrian, and as the Rocky Cape Group is probably Upper Proterozoic, then the dolerites could belong to the Australia-wide group of basic rocks ranging from Late Pre-Cambrian to very Early Proterozoic.

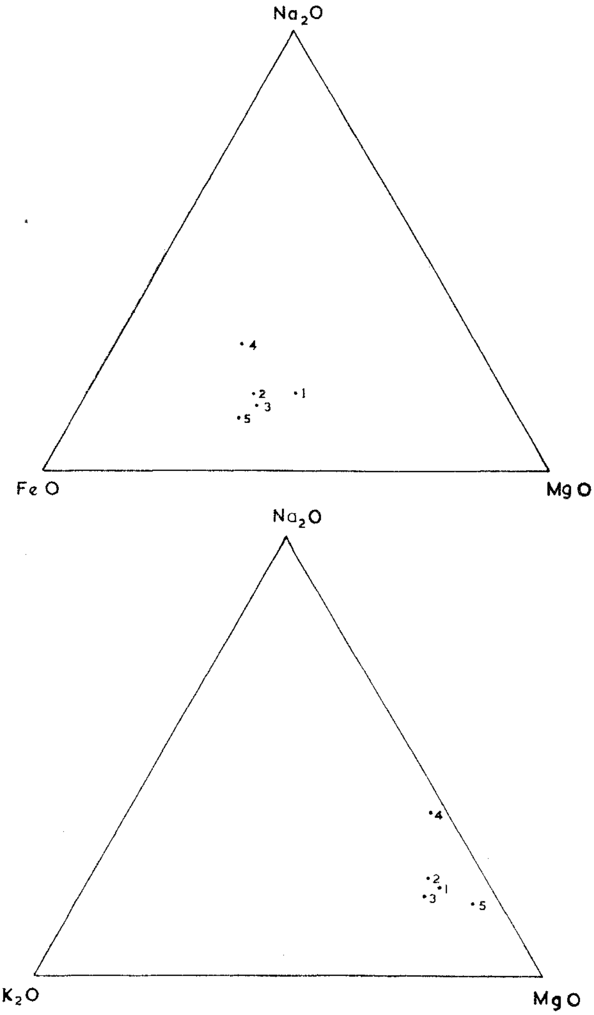


FIG. 4.—Diagrams illustrating the similarities and differences between the compositions of basic rocks from (1) Burnie: (2) South Australia; (3) Western Australia; (4) Kimberley, Western Australia; (5) Dundas Group, Tasmania. See details in table 3.

TABLE 3

ANALYSES OF SOME AUSTRALIAN CAMBRIAN AND PRE-CAMBRIAN BASIC ROCKS

	1	2	3	4	5
SiO_2	52·47	43·42	49·88	49·33	52·27
Al_2O_3	16·07	14·98	13·28	16·39	14·68
Fe_2O_3	1·29	4·21	2·54	2·83	3·88
FeO	6·24	6·21	10·71	8·64	7·70
MnO	0·15	0·16	0·38	0·15	0·25
CaO	8·61	7·47	9·48	7·95	7·61
MgO	4·83	6·09	6·37	4·86	5·09
Na_2O	2·60	2·62	2·21	4·62	2·85
K_2O	2·23	1·05	1·01	0·70	1·97
TiO_2	1·36	1·69	1·73	0·64	1·30
P_2O_5	0·31	0·15	0·24	0·10	—
H_2O—	0·14	2·23	0·14	0·23	0·62
H_2O	3·82	1·56	1·88	2·56	1·03

1. Average of three dolerites from Burnie and Detention River (see Table 2).
2. Average of 10 dolerites and basalts from the Flinders Ranges, South Australia.
3. Average of 10 dolerites from the Pre-Cambrian of Western Australia (Prider, 1945).
4. Average of five spilites from the Dundas Group, Tasmania (Scott, 1954).
5. Average of seven basalts from the Kimberley area, Western Australia (Edwards, 1942).

REFERENCES

CAREY, S. W., 1946.—Ann. Rept. Govt. Geologist for 1945. *Dept. Mines. Tas.*

CAREY, S. W. AND SCOTT, B., 1952.—" Revised Interpretation of the Geology of the Smithton District." *Pap. & Proc. Roy. Soc. Tas.*, 86, 63-70.

EDWARDS, A. B., 1942.—" Some Basalts from the West Kimberley, Western Australia." *Journ. Roy. Soc. West. Aust.*, 27, 79-93.

EDWARDS, A. B. AND CLARKE, E. DE C., 1941.—" Some Cambrian Basalts from the East Kimberley, Western Australia." *Journ. Roy. Soc. West. Aust.*, 26, 77-94.

LOVEDAY, J., 1956.—" Reconnaissance Soil Map—Burnie,, Table Cape." *C.S.I.R.O., Div. Soils.*

ELLISTON, J., 1954.—" Geology of the Dundas District." *Pap. & Proc. Roy. Soc. Tas.*, 88, 161-163.

HESS, H. H., 1949.—" Chemical Composition and Optical Properties of Common Clinopyroxenes." *Am. Min.*, 34, 621-666.

PETTIJOHN, F. J., 1949.—" Sedimentary Rocks." *New York.*

PRIDER, R. T., 1945.—" Igneous Activity, Metamorphism, and Ore-Formation in Western Australia." *Journ. Roy. Soc. West. Aust.*, 33, 43-84.

SCOTT, B., 1954.—" Metamorphism of the Cambrian Volcanic Rocks of Tasmania, &c." *Pap. & Proc. Roy. Soc. Tas.*, 88, 129-149.

SPRY, A., 1952.—" Basic Igneous of the Worumba Area." *Trans. Roy. Soc. South Aust.*, 75, 97-114.

SPRY, A. AND FORD, R. J., 1957.—" Reconnaissance of the Corinna-Pieman Heads Area, Geology ", *this volume.*

STEPHENS, J., 1909.—" Notes on the Geology of the North-West Coast of Tasmania." *Proc. Linn. Soc. New South Wales*, 33, 4, 752-767.

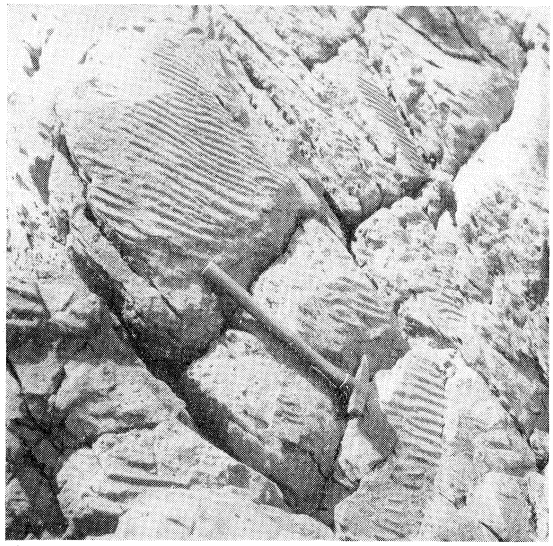
SUNDIUS, N., 1930.—" On the Spilitic Rocks." *Geol. Mag. Lond.*, 57, 1-17.

TWELVETREES, W. H., 1903.—" Report on the Dial Range." *Tas. Dept. Mines Pub.*

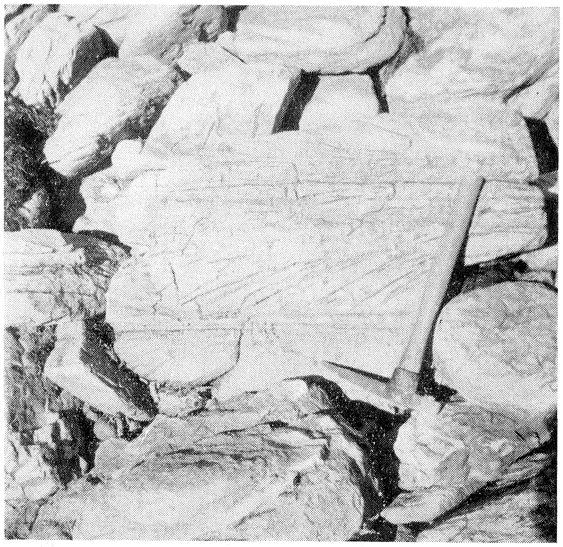
————————, 1905.—" Report on the North-West Coast Mineral Deposits." *Sec. Min. Pap.*

LOCALITY INDEX

	Quadrangles	S. Lat.	E. Long.
Black River	Smithton 21	40° 53′	145° 18′
Blythe Heads	Burnie 28	41° 4′	145° 59′
Boat Harbour	Table Cape 22	40° 58′	145° 38′
Brickport Road Quarry	Burnie 28	41° 4′	145° 53′
Burnie	Burnie 28	41° 3′	145° 55′
Cooee	Burnie 28	41° 4′	145° 53′
Crayfish Creek	Smithton 21	40° 54′	145° 23′
Detention River	Smithton 21 Table Cape 22	40° 58′	145° 30′
Frenchman's Cap	Pillinger 65	42° 17′	145° 50′
Inglis River	Table Cape 22 Burnie 28	41° 0′	145° 38′
Lake Dora	Murchison 51	41° 58′	145° 37′
Lynch Creek	Lyell 58	42° 7′	145° 31′
Penguin	Devonport 29	41° 7′	146° 4′
Raglan Range	Lyell 58	42° 8′	145° 46′
Rocky Cape	Table Cape 22	40° 51′	145° 31′
Sisters Beach	Table Cape 22	40° 55′	145° 33′
Smithton	Smithton 21	40° 50′	145° 8′
Somerset	Burnie 28	41° 3′	145° 51′
Sulphur Creek	Burnie 28 Devonport 29	41° 7′	146°
Surveyor Range	Pillinger 65	42° 24′	145° 52′
Waratah	Valentines Peak 36	41° 27′	145° 32′
Wynyard	Table Cape 22	41° 1′	145° 42′



1

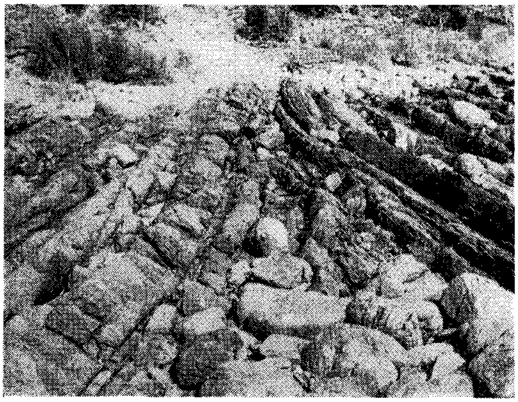


2

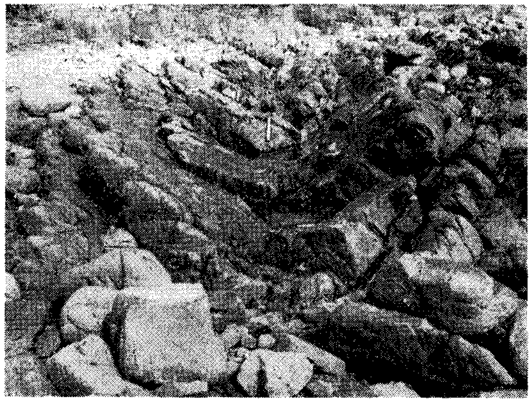
3

4

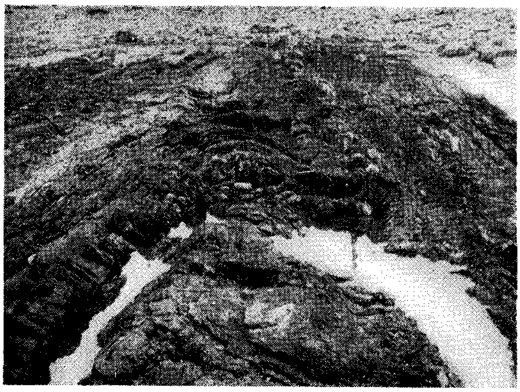
No. 1.—Ripple marks in the Bluff Quartzite on the eastern side of Rocky Cape.
No. 2.—Cross-bedding in the Bluff Quartzite on the eastern side of Rocky Cape.
No. 3.—Overturned folds in the quarry on the Waratah Road, half a mile south of Somerset.
No. 4.—Thin sills intruding quartzite just beneath the thick sill a quarter of a mile east of Cooee Point. The beach in the background is underlain by dolerite.



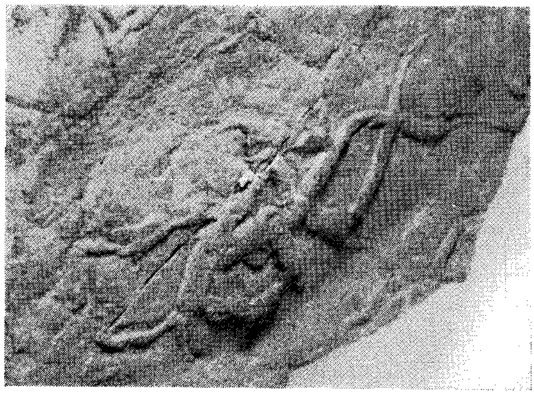
1



2



3



4

Nos. 1, 2, 3.—Minor folds in the Burnie Quartzite and Slate. These folds have been mapped and are shown in fig. 2.
No. 4.—" Worm tracks " on a specimen of quartzite from Sisters Beach. Specimen is six inches across.