

UR 1953/77-105

BY

TERENCE D. HUGHES

2.10.1953

CONTENTS

	<u>Page.</u>
INTRODUCTION	1.
PREVIOUS LITERATURE	1.
LOCATION AND ACCESS	3.
TOPOGRAPHY	4.
RAINFALL	5.
GEOLOGY - PRE-CAMBRIAN	5.
CAMBRIAN	6.
ORDOVICIAN	8.
TERTIARY TO RECENT	9.
IGNEOUS ROCKS	9.
STRUCTURE	12.
ECONOMIC GEOLOGY	13.
MINES AND PROSPECTS	15.
SILVER LEAD DEPOSITS - NEPTUNE AND PENGUIN MINES	15.
HUTTONS	17.
BADGERS	17.
OTHERS	18.
COPPER AND GOLD DEPOSITS - DEVON CONSOLS	18.
KEDDIES ETC.	18.
REVELLS	19.
DIAL	20.
COPPER CREEK	20.
RUSSELLS	21.
IRON OXIDE - PENGUIN CREEK	22.
DIAL IRON	23.
OTHERS	23.
IRON CLIFFS	24.
MANGANESE - BLACKS	24.
OTHERS	25.
BARITE - KAINES	25.
OTHERS	26.
SULPHUR	26.
TIN	26.
SANDS AND GRAVELS	27.
CONCLUSIONS	27.

INTRODUCTION

Dominating the topography of the central north-west coast is a group of peaks and ridges known as the Dial Range. Along this portion of the coast, between Devonport and Burnie, the rich basalt plateau, which in places reaches the sea, ascends to a height of several hundred feet, but the Dial Range because of its composition of hard West Coast Range Conglomerate rises to about two thousand feet.

The country flanking the range has long been known as a potential mineral field and since Charles Gould in 1867 first described portion of the field many geologists have visited the area and many reports dealing mainly with individual prospects or minerals have been written but, strange to say, no comprehensive report of the field has been compiled neither have any geological maps of the area been prepared.

This is an area of contrasts. It is probably the most accessible mineral province in the whole of Tasmania; that is to the fringes. But, in the centre of the area, where roads and tracks do not penetrate, the country is rough and broken and covered with dense secondary scrub. Then too, practically every acre of the surface has been prospected and small holes, trenches and adits abound but scarcely anything has been done to test potential ore bodies at depth. A wide variety of minerals of economic importance have been recorded including those containing copper, gold, zinc, lead, tin, barium, manganese and iron, yet, except for some iron oxide obtained at the beginning of the century from Penguin Creek, production has been negligible.

Because of all this, a survey of an area approximately fifty square miles in extent has been undertaken and a geological map and sections of this country have been prepared.

PREVIOUS LITERATURE

The first recorded geological report is that of Charles Gould in 1867. Gould's investigations were mainly concerned with the north coast line between the Forth River and Penguin Creek and he mentions the occurrence of conglomerates, schists, breccias and clay slates (all of which he calls Silurian) as well as Basalt. He gives a list of minerals discovered in the district including oxides of iron, iron pyrites, manganese, barytes, copper ores, zinc blende and galena and states that this "District appears likely to prove the most valuable one in the Colony".

Between this time and the visit of Thureau in 1881, several prospects had been opened up and development work had taken place at the Penguin, Neptune and Devon Consols Mines. Indeed most of the workings at the first two mines were already flooded. Thureau describes these workings and the various lodes and rock types but makes no correlation between these rock types in relation to age or structure. In 1884, he again visited the area and wrote a short report in which he recommends that some diamond drilling be commenced.

The first comprehensive report on the district is by Montgomery in 1895 but though he describes the stratigraphy generally he does not provide a map. He calls the lowest beds Cambro-Silurian but does mention the possibility that some of the lower beds may be Archean. The Cambro-Silurian beds consist of quartzites, schists, sandstones, slates and limestones and these are overlain by the Dial Range Series (Upper Silurian to Devonian) of conglomerates, slates, tuffs, felsites and breccias. Thus he enlarges the Ordovician beds (his Dial Range Series) with the addition of certain members, tuffs and breccias, of the Cambrian (his Cambro-Silurian) and places the boundary at the Neptune Mine. He appears to include the Cambrian lavas and intrusives with the Tertiary basalt. By this time (1895) the northern portion of the field was being intensively prospected, and Montgomery, as well as describing the Penguin, Neptune and Devon Consols Mines, writes on several prospects particularly those in the pyritic deposits, south east of Mt. Montgomery and the iron oxide deposits to the west of the area. He reaches the conclusion that although not much encouragement has been received to continue development work, it seems clear that there are lodes and indications of minerals and that further prospecting may result in good discoveries.

In 1898, J. Harcourt-Smith reported on developmental work that had been undertaken since Montgomery's visit. This had been carried out at the Penguin Mine near the Iron Cliffs and at Keddies and the Dial Mine. Production of hematite from Penguin Creek had begun.

In 1903 and again in 1905 reports on the area were made by W.H. Twelvetrees. In his earlier report, Twelvetrees is the first to mention the porphyries, which occur so widely to the east of the Dial Range and the red granite to the west of the Range. He states that the porphyries are dykes and prolongations of the main granite mass and that the quartz veins at the Neptune and Penguin Mines proceed from the same source. The Dial Conglomerates, he considers, differ from the West Coast Range Conglomerates, although of the same age (Devonian) and have been laid down after the granite intrusion. He describes the mines and prospects visited by earlier investigators and also some new ones, viz. Russells, Badgers, Lady Braddon, Copper Creek. He concludes that although inspection only showed superficial and occasional occurrences geological factors are favourable for the deposition of ore on a large scale. In his later report, Twelvetrees describes further work done at Penguin Creek, Iron, Dial, Revells and Russells Workings.

In 1909, W.H. Twelvetrees, in Bulletin No. 5, describes areas adjacent to this but touches on the geology of parts of this field and includes a description of the Copper Creek Mine.

Since 1909, no printed reports on this area specifically have been prepared but in "The Iron Ore Deposits of Tasmania", Mineral Resources No. 6, published in 1919, Twelvetrees gives an account of the Penguin Creek Deposits, the Dial Range Deposits, the Iron Cliff Lode and the Manganese Ore at the Dial Range.

The following Departmental typewritten reports have been prepared from time to time :-

Dial Range Iron Cliff Mine,	A.M. Reid,	1923.
Barite in Tasmania,	F. Blake,	1928.
Grooms Slip, near Penguin,	P. B. Nye,	1931.
Land Slips near Penguin,	P. B. Nye,	1931.
Manganese Deposits in Tasmania,	P.B. Nye,	1933.
Dial Range Manganese Deposit,	F. Blake,	1940.
Penguin Pyrite Deposits,	F. Blake,	1940.
Some iron Deposits in the vicinity of Burnie,	Thomas & Henderson,	1943.
Dial Range Manganese Deposit,	" "	1943.
Pyrite Prospect at Dial Creek,	Hughes & Everard,	1952.
Iron Deposits at Penguin Creek,	Hughes,	1952.

LOCATION AND ACCESS

As some limit had to be imposed on the area examined, it was decided to adopt the following boundaries:-

To the north	-	Bass Strait
To the east	-	The Leven River
To the west	-	The basalt plateau, roughly corresponding to the Penguin - Riana Road
To the south	-	The area previously mapped about Gunns Plains.

This, then, an area twelve miles (in a north-south direction) by six miles, covers all of the known mines and prospects in this district, but it should be noted that an extension to this mineral province occurs round the Copper King Mine to the west, separated from the area investigated by some five miles of basalt plateau.

In the north of the area, almost along the coast line, run side by side the Bass Highway, a sealed road, and the main north-western railway line. These pass through Penguin, a town of several thousand people, once a small seaport but now, due to the destruction of the breakwater, dependent for shipping on Ulverstone, six miles to the east, or Burnie eleven miles west. Penguin and Ulverstone are also connected by the macadamised South Road which runs about a mile from the Coast. Branching from the South Road about a mile from Penguin, a road runs South along the route of the old Dial Track. This can be followed by car for three miles, skirting the eastern slopes of Mt. Montgomery. From here the Dial Track is easily followed to Dial Creek but beyond this it is entirely overgrown. From Penguin south, the Iron Cliffs road can be followed for about six miles passing through some isolated patches of rich basalt country.

From Penguin to the south, on the other side of Penguin Creek, a sealed road runs to Riana (8 miles) and beyond this, by macadamised road, a further three miles to South Riana. Between Riana and South Riana, various roads lead south and east to farms, abandoned farms and selections, while beyond South Riana, roads lead to Upper Natone and Loyetee. There is no direct road connection at present between the low lying country at Gunns Plains and the plateau country south of Riana. By passing over farm lands, to the south of the area examined, cars may get through in good weather; a pack track further north is a direct link between these two settlements.

In the eastern portion of the area, there is no through road from north to south. From the South Road, the Lobster Creek Road follows the Leven River for about two miles to Mr. Bowden's farm. From here, an old tram route, now very overgrown may be followed on foot for four and a half miles to Mr. Purdon's farm situated on a big bend of the Leven and connected by a good road to North Motton. There are no other roads on the eastern bank of the Leven until Gunns Plains is reached but north of this settlement the road runs along the west bank of the River and at three miles a bridge crosses to a farm.

The whole of the central part of the area which includes the high peaks of the Dial Range and Mt. Duncan is devoid of car roads but there are certain Forestry roads and tracks and logging roads, some of which are passable by jeeps.

The Leven, between Ulverstone and Gunns Plains, is bridged in three places but it should be noted that the only link over which traffic can pass between the north west coast beyond the Leven and the rest of Tasmania is by the bridge at Ulverstone.

TOPOGRAPHY

The Dial Range is a distinct and dominant physical feature of the north west coast and forms the highest ground anywhere adjacent to the coast itself. This is largely due to the occurrence of thick beds of West Coast Range Conglomerate, which, because of its hard massive character, is the rock comprising the summits of many western Tasmanian mountains.

The Dial Range itself extends from a point about three miles inland from Penguin in a direction a little west of south for six miles. About the centre it is broken by a deep valley formed by two large faults. The average height of the Range is fifteen hundred feet. An offshoot from the northern end of the Range is Mt. Montgomery, a very distinct peak of over 1,500 feet on which is a Trig. Station. The highest and most prominent peak of all is Mt. Duncan which rises to 2,200 feet and forms an offshoot to the east of the northern part of Southern Dial Range.

The different structural arrangements of the rock types in the south of the area give rise to a different type of topography; that is a series of smaller, conglomerate topped ridges, more or less parallel in a general northerly direction. An exception is the rather prominent ridge which rises from the Leven near Purdon's farm, as this ridge is composed of hard siliceous chert.

The streams are all in a fairly youthful state and except for small patches along the Leven River, have no alluvial flats. The Leven is tidal up to the end of Lobster Creek Road, that is for about six miles from its mouth. In the northern and central part of the area, all streams to the east of Dial Range flow into the Leven River and all to the west into Penguin Creek. In the southern part, because of the irregular topography, there is no well defined stream pattern, and, while most of the water finds its way into the Leven, some to the west eventually goes to the Blythe River.

The basalt plateau is a distinct topographical feature of the north-west coast. The western edge of this area follows such a plateau, which, with minor undulations gradually rises from a height of 300 feet near the coast to 1,000 feet near Riana, eight miles inland. Another smaller basalt mass parallels the coast, rising to a maximum height of nearly 400 feet.

RAINFALL

The rainfall over this area increases quite considerably as the coast is left. At Ulverstone, the average annual rainfall over the past fifty years has been 3779 points, whereas at Riana, only eight miles inland but a thousand feet higher, the average is 4989 points. Records have been kept at Penguin only from 1937 to 1945, and during this period the average annual fall was 1.5 inches greater than at Ulverstone. Penguin stands closer to the Dial Range than Ulverstone and this probably accounts for the slight increase. Average monthly figures for Ulverstone and Riana are as follows :-

<u>Month</u>	<u>Ulverstone</u>	<u>Riana</u>
January	155	185
February	166	271
March	197	227
April	285	344
May	350	600
June	483	637
July	482	731
August	433	574
September	393	531
October	367	395
November	246	285
December	222	209
Year	3779	4989

GEOLOGY

Pre-Cambrian. About two miles west of Ulverstone is a small rocky island, connected at low tide to the mainland. This is Goat Island and it has become quite famous to geologists because of its splendid outcrops of conglomerates containing stretched pebbles. These pebbles are mainly quartzite but the matrix is a quartz mica schist and the shearing has affected pebbles as well as matrix. In addition to the conglomerates, the Pre-Cambrian beds here consist of mica-schists and quartz-mica schists containing narrow beds of quartzite and many irregular veins and bunches of quartz. In the conglomerates, the ratio of pebbles to matrix varies considerably. In some places almost the whole rock is composed of pebbles and then there is a gradual decrease until the rock can be called a quartz-mica schist with no pebbles at all. Outcrops of these rocks can also be seen further inland, on either side of the South Road on the Ulverstone side of the Lobster Creek Turnoff.

Although generally agreeing in strike with the rocks that overlie them, these Pre-Cambrian rocks have suffered such deformation prior to the last great regional folding, that crenulations and minor folds

are apt to conceal their true strike and dip. However, generally speaking they appear to strike more to the west than the Cambrian beds. On Goat Island the average strike is about 330° , but on the shore on either side, strikes of 5° to 30° were recorded. The dip is to the west at angles of 45° to 80° . Inland, near Myrtle Creek, strikes were fairly constant to the north-west with dips to the south-west of 25° .

Beyond saying that they belong to the Proterozoic Era, it is not possible to correlate these rocks with others of exact age groups. It has been thought that these schists and conglomerates belong to a series which in the west of the State are overlain unconformably by quartzites of Pre-Cambrian Age and therefore they have been placed low in the Proterozoic. To the west of this area is a younger group (the Carbine) which may be the top of the Pre-Cambrian and are certainly younger than these Goat Island rocks but here these latter are overlain by purple Dundas slates.

Cambrian. Excellent sections of Cambrian rocks are exposed along the coast line from just east of Lonah Point, where they succeed the Pre-Cambrian unconformably to where at Penguin they are themselves succeeded with slight unconformity by Ordovician conglomerates. This section contains the Cambrian portion of the eastern leg of the great Dial Syncline and, even allowing for minor folds and faults, the thickness of the beds amounts to over ten thousand feet. The actual contact of the Pre-Cambrian and Cambrian rocks is obscured by a basalt flow, but, whereas the predominant strike of the Pre-Cambrian rocks is to the west of north, that of the Cambrian and Ordovician is generally east of north. The younger rocks do not show the contortions and minor foldings and crenulations of the schists. The lowest Cambrian rocks, then, are well bedded slates, purple, black and white in colour, which, near the base of the series, have suffered intense silicification, so that in places they may be termed "cherts". Fairly low in this series are narrow beds of volcanic breccia, sometimes only an inch or two in thickness.

Just opposite Lonah and a little west of the three islands off Lonah Point, the Cambrian igneous rocks appear. Although these have been described as all Cambrian lavas, it does seem probable that certain intrusive members also occur. These igneous rocks are very widespread in this section and outcrop along the coast as far as Barkers Point, that is over a horizontal distance of 100 chains. The typical rock type is a dark blue fine grained igneous rock, rather resembling, in hand specimens, the Tertiary basalt. However it is lighter in colour, shows signs of shearing, contains pyrite inclusions and occasional narrow quartz veins and lacks any apparent olivine or zeolites. Included in these lavas or intrusions are numerous blocks and smaller pieces of slates, mainly purple slates, in area up to 100 feet square.

Just east of the old Neptune Mine, the lavas are succeeded by wide beds of volcanic breccia and tuff again containing large blocks of slate. The breccia varies greatly in the size of its fragments, grading from pieces more than an inch square to a fine grained tuff. These beds continue for about 40 chains horizontally when more igneous rocks occur. Near the top of the

series are again breccias and tuffs and, right on top, more slates.

On the western leg of the syncline, the beds near the top of the Cambrian are rather different. There are good outcrops of typical purple slates but surrounding them, and sometimes continuous along the strike with them, are massive white and purple quartzites, often containing hematite. These may represent silicified tuffs which were laid down on an eroded slate surface.

The Cambrian rocks, then, in this area comprise slates, cherts, tuffs, breccias and igneous rocks, mainly lavas but with some intrusive phases.

The slates are by far the most common rocks, occurring both at the top and bottom of the series, but in many cases they have been partially or wholly silicified to cherts. These cherts which are darkish in colour, weather to a pure white and particularly in the south-east form very distinctive hills and prominent outcrops. The effects of this silicification can be clearly seen in cuttings along the Lobster Creek Road. Where the road first meets the river, are chocolate slates, sometimes with not well defined cleavage. A few chains further on the first effects of silicification may be seen where normal slates occur among rather irregular cherty masses. About half a mile further, however, the silicification is complete and cherts of a deep grey to purple, but which weather white, outcrop in small cliff faces along the road. Sometimes, in both slates and cherts, the cleavage is well developed; sometimes it is hardly apparent. Jointing, in more than one direction, is sometimes well developed in the cherts, so that they readily break up into small many-sided fragments.

It is not possible, on this scale at any rate, to map the breccias and tuffs as distinct from the slates and cherts. This is because, in places, the volcanic material has been deposited round small hills and outcrops of slate so that not even along the strike are the beds distinct. These tuff and breccia beds although sporadic are quite common all over the area and contain fragments varying in size from microscopic to over an inch in diameter. The finer grained tuffs are often silicified, but rarely is there any silicification of the breccia. Although the tuff beds are sometimes mineralised (mainly by pyrite) it is in the breccia beds that the most intense mineralisation has occurred, and in places the breccia, both fragments and matrix, is almost wholly replaced by pyrite.

The Cambrian igneous rocks, although extensive along the sea coast are subordinate in extent in all other parts of the area, except along the Leven just north of where the Gunns Plains Road descends to it. On both sides of the River are splendid outcrops and here the rock appears to be a lava. In places may be seen pieces of chert and quartzite embedded in the igneous rock and in one place a narrow quartz vein traverses the rock.

Geologist G. Everard has examined thin sections of these (and other rocks from this field) and he describes a piece from the river bank (29U10) "Fine grained dark greenish-grey rock. Inter-granular texture. The principal minerals are felspar and

augite together with a brownish or greenish coloured glass which has become devitrified to give an obscure microcrystalline texture. The felspar occurs in laths and needles sometimes in ophitic relationship with the augite. The augite is faintly coloured and shows weak pleochroism in green and neutral tints. The rock is an andesitic lava." This piece is typical of the igneous rock outcropping in this locality and this petrographic description together with field observations tends to indicate that these rocks are indeed lavas. However, examination of sections cut from rocks along the shore indicated that there are also intrusive phases, as 29U14 "Fine grained panidiomorphic rock consisting of:- plagioclase felspar in short interlocking laths without preferred orientation lamellar twinning; augite, colourless equidimensional crystals often showing twinning; chlorite as bright green ragged patches showing strong pleochroism and anomalous interference figures; iron ore in opaque irregular masses and skeletal crystals. The rock is a dolerite." However, lavas are also present as 29U15 "Very fine grained contact rock. The rock is in igneous contact with a very fine grained siliceous sediment. Panidiomorphic texture. Principal minerals are:- augite in equidimensional crystals, felspar in minute laths and needles, iron ore in disseminated cubic crystals. These minerals are in a fine grained matrix rendered cloudy by alteration products. There are many small veins and patches of carbonates and feldspathic material."

At the end of the road leading east from Riana is an abandoned farm on which there occurs a curious rock type; not in outcrop, unfortunately but in large boulders scattered over a flat area some 40 by 10 chains in extent. This is a coarse grain greenish rock containing large well developed phenocrysts and in thin section appears as follows - (29U5) "The texture is hypidiomorphic. A sericised felspar in euhedral crystals is the principal mineral. Euhedral augite often altered to hornblende and chlorite equally prominent. Interstitial quartz is common. The principal accessory mineral is ilmenite, largely converted to white opaque leucoxene. The rock is a quartz gabbro." This rock has been mapped with the Cambrian as it is most likely to represent, in spite of its plutonic appearance, an intrusive phase of the Cambrian lavas.

Ordovician

West Coast Range Conglomerate Series. The base of this series can be well observed in two places. In a railway cutting almost in Penguin to the west of the synclinal axis, may be seen these rocks striking at 15° and dipping east at 60° and overlying the Cambrian slates with slight unconformity. The base of the Ordovician contains a narrow breccia bed before passing into the more normal conglomerates. On the west bank of the Leven and just north of Gunns Plains is an excellent section of a fold. Here the Cambrian and Ordovician rocks appear conformable and a series of samples may be gathered showing a gradual transition from slate to conglomerate through first fine and then coarser breccias. Beyond the end of Iron Cliff Road, where Penguin Creek flows through a deep gorge, may be seen patches of slate surrounded by large masses of conglomerate on the same strike. This seems to indicate that these conglomerate beds were laid down on an uneven surface.

At the beginning of this century the Dial Conglomerate, as it was then called, was thought to differ from the conglomerate forming so many of the West coast mountains. However, the two agree so well both lithologically, structurally and stratigraphically that there can be little doubt that they are one and the same series.

This series then, consists principally of conglomerates, often pink or purple in colour, but sometimes white and the associated quartzite beds. The pebbles which vary in size up to 2" in diameter are usually composed of chert and quartzite and are well rounded except near the base of the series where they are quite angular. Hematite is common among these rocks. Sometimes the pebbles, sometimes the matrix and sometimes both are replaced by the red iron oxide.

Caroline Creek Series. This is apparently missing in this district and the West Coast Range Conglomerate is succeeded directly by Gordon River Limestone.

Gordon River Limestone. The outcrops of these rocks begin in the extreme south of this area and have been fully described in my report on the Gunns Plains Area. Any limestone that may have occurred above the conglomerate further north has long since been removed by erosion. Indeed there are no sedimentary rocks, other than the Tertiary, younger than the Ordovician.

Tertiary to Recent

The outpourings of Tertiary basalt along the old sea coast plain blocked the Tertiary Leven at a point about two and a half miles inland. This caused the River to deviate considerably to the east and left Tertiary sands and gravels high and dry along the old course. These may be followed from the Lobster Creek Road to north of the South Road and their course is clearly indicated by numerous gravel pits. On the sea coast, east of Lonah, the gravels have been baked by the basalt to form thin beds, immediately below it, of hard, siliceous, grey conglomerates.

Patches of recent river alluvium occur from place to place along the Leven but, except at Gunns Plains, these patches are never very large in extent.

Igneous Rocks

Devonian. To the south-west of this area and extending many miles beyond it, a large portion of the granite batholith appears at the surface. This is a coarse grained, pink granite, containing large crystals of red orthoclase and white plagioclase, as well as quartz and biotite. This granite is very similar to the well known Coles Bay Red Granite but the orthoclase is a little lighter in colour and there appears to be a higher proportion of plagioclase.

The Porphyries

This is an extremely interesting but rather puzzling suite of rocks. Ever since geologists in Tasmania first commenced the stratigraphical correlation,

the porphyroids, in which these porphyries were included, have been the subject of considerable debate as to their place in the geological succession. The present investigation unfortunately does not quite elucidate the matter. After examination of the rocks in field occurrence and in thin section, from a structural and stratigraphical point of view, two theories are still tenable. In short, are these rock apophyses of the granite batholith injected during the Devonian or are they the product of the silicification of Cambrian lavas? On the surface, this appears an easy question to answer; however, there are difficulties. In the first place these rocks weather rather quickly and except at various places along the Leven and more rarely its tributaries, they appear very little in outcrop and their presence is often detected merely by boulders on the surface. Again it is not possible to say that because they are not inter-bedded with the Cambrian rocks, that they must be Devonian intrusives. The unaltered lavas themselves are not always inter-bedded but have been laid down round hills and patches of slate.

Near Keddies Prospect, the Cambrian breccias in contact with the porphyries do show some silicification so that it could be argued that this was the result of the intrusion of the porphyries. On the other hand, if the porphyries are the result of silicification of Cambrian lavas, then that siliceous front could also have affected the other Cambrian rocks.

The deciding factor of course would be, are the Ordovician sediments intruded as well as the Cambrian? Over the greater part of the area these rocks do only occur in association with Cambrian rocks but to the west of Mt. Duncan, in particularly inaccessible country, is a patch of porphyry apparently intruding the Ordovician. It is just possible, though unlikely, that this is not an intrusion but an up-faulted block of the Cambrian, and, with the absence of any outcrop showing the relationship between conglomerate and porphyry, this possibility cannot be wholly overlooked. However, it is rather unlikely and I should much rather believe that this patch of rocks is intrusive into the Ordovician and therefore, I favour the theory that these particular porphyries are Devonian intrusives. It should be noted, too, that these rocks, particularly in the southern half of the area, are often associated with large faults, in other words, that they have been intruded along fault planes. However, to leave the matter still open I have, on the Geological Map, put these rocks under the general age group of "Lower Palaeozoic".

These porphyries then, are fine grained greyish rocks which in places weather to quite a pink colour. Although they are all related, there is sufficient difference in specimens from various localities to warrant the quotation of Mr. Everard's remarks on their petrographic examination.

29U6 Tunnel on old tram line, south of Dial Creek, on Leven River -

"Fine grained dark grey rock, porphyritic texture with phenocrysts of sericitised felspar showing zoning and chloritised ferromagnesium mineral. The groundmass is fine grained quartz and felspar. The felspar shows both simple and lamellar twinning and lies in the oligoclase

range. The phenocrysts may show a brownish discolouration. The quartz forms minute crystals which are often square in section because of development of alternate rhombohedral faces and suppression of prism faces. It probably crystallised as beta quartz at high temperature. The rock is a porphyrite."

29U7 Russell's Adit.

"Grey, medium grained rock. The texture is hypidiomorphic with euhedral feldspar, almost completely sericitised, sub-hedral colourless amphibole almost completely altered to chlorite speckled with iron ore, and anhedral interstitial quartz. Accessory apatite and zircon. The rock is probably a fine grained granodiorite or microgranite, the feldspars are too much altered for certain identification."

29U8 Vicinity of Lobster Creek.

"Medium grained grey rock with dark and light phenocrysts and some interstitial reddish brown material. Porphyritic texture with large zoned plagioclase crystals in a groundmass of finer grained but largely euhedral quartz and feldspar and scattered irregular greenish masses of chlorite and hornblende. Accessory mineral is opaque black iron ore in disseminated cubes, and inclusions in feldspar and ferromagnesian minerals. The feldspars are almost completely sericitised and some feldspar is brown and opaque, suggesting contact metamorphism. Quartz crystals have square outlines, with suggestion of twinning on the rhombohedron, which indicates beta quartz. The rock is a porphyrite."

29U9 South of Purdon's Farm, Leven River.

"Medium to fine grained pink rock. Hypidiomorphic texture. The minerals are feldspar, quartz, muscovite, ilmenite in order of abundance. The feldspar occurs as large crystals almost completely sericitised, and as smaller twin laths somewhat less altered. Quartz is corroded and often replaced by seriate but separated fragments show simultaneous extinction. Some of the white mica occurs in larger masses and appears to be original muscovite. Ilmenite is in skeletal and rectangular grains, extensively altered to white opaque leucoxene. The rock is a microgranite."

29U11 Logging Road to the south-east of Field.

"Dark grey rock with pink phenocrysts weathering to a pink rock. The texture is porphyritic. The phenocrysts are plagioclase feldspar showing some polysynthetic twinning. Quartz is present in irregular somewhat corroded grains. The groundmass is fine quartzofeldspathic mosaic with feldspar largely sericitised. A green pleochroic micaceous mineral of high birefringence also occurs disseminated in the groundmass. The mineral seems to be the final alteration product of original ferromagnesian. The rock is a porphyrite."

Tertiary.

The typical Tertiary basalt of the north west coast is well represented in this area. To the west is an extensive plateau with a well weathered thick covering of basalt yet still thin enough near the edges to have small conglomerate peaks sticking

through it. Along the coast, too, the basalt rising in places from sea-level is up to 400 feet thick. At other parts, however, there are smaller remnants of basalt in which the rock, or sometimes only soil, is very thin and patches of chert etc. may show through it. In most cases, because of their greater susceptibility to erosion, the basalt is overlying Cambrian rocks. It is this basalt which gives the rich red soil which has made the north west coast so prosperous and wherever it occurs the land is cleared.

This basalt belongs to the titanaugite group and a report on a thin section from Kaines Farm, south-east of Riana is as follows :- "Fine grained black rock. The rock is intersertal in texture and there are phenocrysts of olivine. A plagioclase feldspar in polysynthetically twinned and unoriented laths is the principal mineral. Dark coloured titanaugite in fine granules and a little glassy material fill the interstices. A little olivine occurs in the groundmass but the greater part of this mineral occurs as large crystals, usually somewhat rounded. The rock is an olivine basalt".

Structure

The structural pattern of the district may be divided into two distinct categories. From the sea coast inland to Riana, a distance of eight miles, the strata from the Pre Cambrian through the Cambrian beds to the Ordovician is folded into one large broad syncline. The eastern leg of this is almost contained in the area examined and the axis runs, a little west of south, just to the west of the Dial Range. At the present stage of erosion, the West Coast Range Conglomerate beds form the core of the syncline and because of their resistance to erosion, form a prominent topographical feature. The base of these rocks is not far below sea-level and at Penguin very little thickness, perhaps a thousand feet, remains. There is no sign of an appreciable plunge of the fold either to north or south.

An excellent section across the fold, particularly of the east leg, occurs along the sea shore. No major strike faults or minor folding could be observed, but there must be some concealment of one or other or both of these features, as if not, the Cambrian beds would have a thickness of over eleven thousand feet, which seems a little excessive. At the top of the Cambrian, the beds, mainly slates, because of their lesser competency, are folded and puckered against the more solid Ordovician rocks.

To the south of the area is a distinct change in the structure due to the intrusion of the large granite mass south of Riana. This has not only folded the strata into a series of small sub-parallel folds, but has uplifted this block in relation to the main portion so that the base of the Ordovician is not far from the surface in the synclinal troughs. The effect of this folding is shown by a series of small conglomerate topped hills, parallel in a general northerly direction except where faulting has swung round the ends.

In the extreme south of the area the larger type folding again commences but with different strike. This can be seen more clearly in the adjoining area of Gunns Plains.

Faulting is very prevalent here, but the major faults, the only ones shown on the accompanying map, are mainly confined to the southern half. It would appear that all this major faulting was associated with the Devonian orogeny and is, therefore, contemporaneous or nearly so with the granite intrusion and mineralization.

A well developed fault, with extensive fault breccia, runs in a south-easterly direction from Riana and is the result of the granitic intrusion, so that it divides the two different structural patterns. The upthrust block is to the south. Most of the other faults appear to be subsequent to this and the most distinctive are those that divide the Dial Range into two parts. The faults strike about 110° and have an upthrust block between them. The northern fault may be followed east for almost a mile by the evidence of fault breccia. A magnificent fault scarp is visible for many miles round and forms the southern end of the northern portion of Dial Range. On it may be seen a polished face striking at 120° and dipping south at 75° and carrying many striations. Minor faults, some at right angles are associated with this fault. The southern fault of this pair may be recognised by fault breccia, north of Mt. Duncan and by polished movement planes in conglomerate outcrops near the Riana Road. There is a deal of lateral movement associated with this fault and this has caused the southern block to move to the east relative to the northern and given such prominent topographic expression as Mt. Duncan.

All these faults are far more obvious when they are contained in the Ordovician rocks or between Ordovician and Cambrian rocks. When they enter wholly within Cambrian rocks they appear to become dissipated and some die out altogether. It is interesting to note that except for the northern occurrence, all the intrusions of porphyry are next to major faults.

Economic Geology

In spite of the great diversity of minerals found in this area, nearly all have a common source and a rather similar mode of formation. Therefore, instead of treating each metal or mineral separately, it is proposed to discuss their formation under the headings of source rock, host rock and structure controls.

Source Rocks. With the possible exception of certain of the hematite deposits, all the metallic minerals found in this area have their origin in the Devonian acid magma, portion of which outcrops as the pink granite in the south-western portion of the area. This magma was very extensive as even the outcropping portion may be traced for at least 10 miles. The granite itself does not outcrop to the east of the Dial Range but here are large areas of the rock described as porphyry. As has been mentioned previously there is still some doubt as to the origin and age of this rock, but I am of the opinion that it is a differentiate from this acid magma which was intruded during Devonian times.

However, it seems probable that the porphyry intrusions occurred right at the beginning of the main intrusion before the mineralization. Indeed they themselves have been mineralized and they cannot be regarded as source rocks for these minerals.

In attempting to work out some sort of zonal arrangement for the various minerals, it can be seen that the outcrop portion of the magma cannot be used as a starting point. Although it is reasonably close to such copper prospects as Russell's and Copper Creek, the report of tin in pyrite at Keddies Prospect, situated four miles from the nearest granite outcrop, suggests that the mineralization is connected with some non-outcropping portion of the magma to the east of the Dial Range. In the same way the silver-lead deposits on the coast have their source in a deep-seated portion of the magma and it is reasonable to suppose that at depth these minerals would give way to such high temperature ones as tin.

An early report of an analysis of samples from the Penguin Mine, showing, as well as copper, silver and lead, 2.5% of nickel and 0.8% of cobalt, is interesting. These minerals have basic igneous rocks as their source and the nearest outcrop of this rock is some eight miles to the east; the serpentine at Clayton Rivulet. If this analysis is correct, it would appear that this rock also occurs at no great depth below the surface.

The Cambrian lavas and their associated intrusives are not considered to have supplied any mineralizing solutions, nor are any derived from the Tertiary basalt.

Host Rocks. Here the two principal types of mineral deposits are replacement and lode deposits. The latter are not so common and beyond the fact that they nearly all occur in Cambrian rocks, the type of rock does not seem important. At the Neptune Mine, where at the surface the lode is injected into coarse breccia, it is stated that at depth it traverses slates and quartzites. Apparently the wall rocks do not have any special physical or chemical effect on the precipitation of the minerals from their solutions.

In the replacement deposits, however, the type of rock is very important. Among the Cambrian rocks, the breccias are replaced almost wholly to the exclusion of slates, tuffs and lavas. The prospects round Dial Creek are all pyrite, with lesser amounts of more valuable minerals, replacing breccia. Smaller amounts of pyrite may be found disseminated throughout slates, cherts and lavas and along joint planes in the porphyry.

The two main hematite deposits consist of the replacement of two different types of host rock. At Penguin Creek, although little can be seen in the way of outcrop, it appears as though the iron replaced slates and quartzites, themselves the result of some earlier silica replacement. On the Dial Range, and at numerous other places in the area, iron oxide has replaced either wholly or in part, the West Coast Range Conglomerates.

Structure Control. In order for the solutions to have access from their source to their host rocks, it is necessary for some channel ways to be in existence; that is unless the host rock is in contact with the magma and is wholly replaced. The extensive faulting, during the granite intrusion, seems to have supplied the rocks with a network of small openings through which the solutions could pass. The larger faults with their extensive filling of fault breccia do not seem to have provided much in the way of channels. An exception is the major fault north of Mt. Dunean where manganese deposits are developed in the fault zone. However, the enrichment of these deposits occurred at a much later stage than the original faulting and mineral deposition of the Devonian. Another is the fault up Copper Creek. Not only does the Copper Creek Mine workings show pyrite in cracks in slates and tuffs, but all along the Creek, which follows the fault zone, are signs of mineralization.

The vein deposits at the Penguin and Neptune Mines are associated with minor faulting and signs of movement can be seen on the surface outcrop at the Neptune. A curious occurrence at the Devon Consols Mine is the report of sensible proportions of copper associated with iron pyrites but occurring in the West Coast Range Conglomerate series. The pyrites occurs in small amounts in pug filling a well defined fault.

The conglomerate, although not normally susceptible to mineralization, may act strongly as an impounding structure and concentrations of economic value may be located near the boundaries of this rock. In the southern part of the area, the base of the conglomerate is not far below the surface. The fault pug, too, in the larger faults, may fulfil the same function.

The Mines and Prospects

Although the various shafts, adits etc. put in to develop the various prospects are of very limited extent most of them, in periods of up to 80 years, have become inaccessible. Consequently, much information used here is gathered from old reports. However, it should be noted that 50 to 70 years ago, when the early geologists visited these prospects, many were even then inaccessible. Consequently, much of their information is based on hearsay.

Silver Lead Deposits

Neptune and Penguin Mines. All along the coast line from just east of Penguin to Barkers Point (more than a mile) the Cambrian series of slates, tuffs and breccias have been more or less silicified and later mineralised. Consequently there can be seen stringers and disseminations of quartz and pyrite, sometimes containing more valuable sulphides. These were mentioned by Charles Gould in 1867 and he talks of a lead vein of one foot in thickness. By 1881, when Thureau visited the district, development had taken place in two localities, where the concentration of minerals seemed greatest. Probably the one foot seam of galena became the Neptune Mine and closer to Penguin, at the Penguin Mine, development had not only been commenced but the workings were already flooded and inaccessible.

At the Neptune, too, the earliest shaft, the Peart Shaft and its workings, commenced in 1868, were flooded. By 1884 the main shaft was down fifty feet and at 75 feet in the east crosscut a lode thirty inches wide containing antimonial silver was cut. By 1895 when Montgomery visited the district, all the workings were flooded. The shaft had reached 100 feet and levels had been put out at 50 feet and 100 feet. The shaft was designed to cut the lode at 400 feet and at the 100 feet level crosscuts were put out 175 feet to the north-east and 75 feet to the south without cutting the lode. In 1891, Mr. Ellis extended the bottom level in the hope of reaching the lode but only a vein $1\frac{1}{2}$ inches wide was cut. During the 1914-18 war, the mine was again worked. Mr. W.B. Revell of Penguin worked in the mine at that time and states that it was visited by A.M. Reid, but there is no report by him and no details of work done are available. However, most of the development seems to have been in the Peart Shaft workings, and there was no production.

Little can be seen of any workings or lode today. The course of the lode 1 to 3 feet in width can be traced by surface cuts in the tuffs and breccias, now filled by sand and gravel. The main lode strikes at 320° to 330° and dips to the south-west at 75° and it is joined near an old shaft by a smaller fissure at 305° . In the earlier reports, the lode is stated to consist of dolomite 6 feet wide at the surface (with 3 inches of galena on the foot and hanging walls) but diminishing to 3 feet at depth. Mr. Revell states that the lode increased in width at depth but that the values declined. Today a little pyrite and galena may be scraped off the breccia hanging wall at the surface but there is no sign of any dolomite. Samples taken at various times show that there is about $\frac{1}{2}$ oz. of silver for each unit of lead.

Signs of faulting at the surface suggest that the lode occurs in a minor fault, striking north-west and dipping to the south-west at 75° . Apparently although a main shaft was commenced the lode was never intersected at depth. These workings, being practically at sea-level and in a disturbed zone, are at all times liable to flooding. Apparently in the old days there was a little production and it is said the ore was smelted on the beach.

Three quarters of a mile to the west is the Penguin Mine. Whereas the Neptune consists of one well defined lode, this locality contains a network of small non-persistent veins. Thureau describes four such veins striking at 20° to 30° and dipping steeply to the west; Montgomery talks of a stockwork of veins containing sulphides of iron, lead, zinc and copper and dolomite, trending in a north to north-east direction; while Twelvrees mentions a rectangular system of veins in cardinal directions. Little can be seen today and the workings have long since been filled in. On the beach outcrops of quartzites (probably silicified tuffs) and breccias are sporadically mineralised. A narrow formation of a few inches of decomposed iron-stained material strikes at 20° with a steep dip to the west.

In 1898, J. Harcourt Smith visited the workings, which a company had just unwatered. The shaft was 70 feet deep and development was proceeding both to the north and the south at the 60 foot level. The rock he described as a hard siliceous dolomite, impregnated with

pyrite, and, due to differential movement, broken into several smooth "heads", which had been mineralised. Some hundred feet of driving as well as the sinking of two winzes apparently merely followed these "heads" in all sorts of directions.

This mine was considered, as was the Neptune, as a silver mine, but this one contained a greater variety of minerals. In 1895, Montgomery picked up some pieces of ore round an old shaft and had them assayed as follows :-

Gold	1 dwt.	15 grns.	per ton
Silver	27 oz.	15 dwt.	8 grns. per ton
Lead	10.8%		
Copper	3.4%		
Nickel	2.5%		
Cobalt	0.8%		
Antimony	Trace		

Of course it is dangerous to place credence in any samples picked up from ground but it should be noted that the ratio of silver to lead is much greater than at the Neptune.

The old geologists all had an idea that this irregular network of mineralization would coalesce at depth and form one great big lode. They of course included the tuffs and breccias with the Dial formation and assumed that the slates etc. below would be more susceptible to lode formation. It seems likely that the silicified dolomite described by Smith is a chert or silicified slate and in the area examined this showed just as much mineral dissemination as the tuffs. I see no reason to suggest that the network of veins would make into one payable lode.

Hutton's Prospect. On the west bank of Copper Creek and near its headwaters and not far from the road to Kaines farm is a short adit (30 feet) put into black slates. These slates are rather cherty and heady and contain a little pyrite. At the entrance is a shallow shaft, now filled with water. Mr. Kaine states that many years ago he has seen galena from this show. If so, it must have come from the shaft as there is no sign of lode or any mineralisation other than pyrite in the adit and an assay showed silver and lead nil. This may be the prospect mentioned by Twelvetrees as "Huttons Out crop" although he does mention a quartz vein and some galena in the slates. In any case there is nothing to indicate an economic prospect here.

Badgers Mine. Upstream from "Ferndene" a picnic spot on the Iron Cliff Road are several adits driven in at creek level to the hill on either side. Most of these tunnels are now fallen in and are inaccessible but from the bright red mullock coming from them, it seems that there is some mineralization. In his report in 1903, Twelvetrees mentions two adits. The upper one followed a vein of galena ($\frac{1}{2}$ to 2 inches wide) and some stopes were opened out and three tons of galena obtained. The ore contained $\frac{1}{2}$ oz. of silver per unit of lead. A second adit was driven for 400 feet without encountering the lode. I have been unable to identify these two adits today (there are at least three fallen in) but the area is a favourable one for mineralisation. It is not many chains from the conglomerates and quite close to the celebrated Iron Cliff outcrop.

Other Prospects. Some 60 chains south of the South Road and 60 chains east of the Dial Road is an old adit, now fallen in which has been put into a series of tuffs and breccias similar to those outcropping at the Neptune Mine. Mr. Revell, who showed me this stated that a lode of black material carrying galena had been cut in the adit. He also states that a barium lode 6 feet wide was encountered in the footwall of a small galena lode. Barium may be seen on the surface but there is no sign of any galena. However, the structural set up may be the same as at the Neptune and it is worthy of further investigation.

Copper and Gold Deposits.

The Chief mineralisation in this district is the deposition and concentration of iron pyrites, either by displacement of the breccias or in joints and small fault planes in the slates and tuffs. Associated with this pyrite are small concentrations of other more valuable minerals and many of these pyrite deposits have been developed because of their copper and gold content.

Devon Consols Mine

This prospect which is located on the headwaters of a branch of Myrtle Creek between the Iron Cliffs and Dial Roads, was commenced before Thureau's visit in 1881 and by the time of his second visit in 1884 a shaft had been sunk 50 feet and a drive put in 75 feet. In 1895 Montgomery reports that the adit was extended to 170 feet with a winze, 30 feet deep, at 40 feet and a shaft 49 feet deep at the entrance. Both the shaft and winze were filled with water. Today the adit is only accessible for 60 feet and is not really safe at all. A shaft 18 feet from the adit mouth and another at the approach are both filled.

This is a most unusual type of mineral deposit in that it occurs in the West Coast Range Conglomerates. The reason is that it is near the bottom of the series and the mineralisation has taken place in a well defined fault plane. This fault, which strikes at 311° and dips to the north-east at 80° is filled with 2 to 3 feet of fault pug, plentifully impregnated with iron pyrites, particularly on the footwall side. Although this pyrites is clearly visible, there is no sign of any copper minerals and Montgomery, who took a sample all along the adit, quotes the assay as a trace of copper and gold and 1 oz. of silver per ton. Thureau mentions grey and black oxides of copper and native copper in the shaft, but it is not possible to confirm this. It appears that the fault pug contains plentiful pyrite but little copper and as it is not expected that the fault zone would increase very much in width at depth, this prospect is not considered very favourable.

Keddies and Others

Over a considerable area round both branches of Dial Creek and below their junction are breccia beds, which have been largely replaced by pyrite and lesser amounts of more valuable minerals. In the nineties, considerable prospecting work was carried out by means of shafts, trenches and small adits to investigate these pyritic deposits. The leases were originally taken up for silver, but later (in the nineties) for copper.

Probably the best developed was at Keddies, where an adit was driven 200 feet, from the level of Dial Creek, in a southerly direction and two shallow shafts, now fallen in, were put down 75 feet and 160 feet higher up the hill.

Here a breccia bed in contact with porphyry has been partially silicified and mineralised. The pyritic replacement of this bed, which can best be seen in the adit over a width of forty feet, continues along the strike, here about 330° , for more than twenty chains. This deposit has lately been the subject of investigation in connection with its sulphur content and samples showed that approximately 50% of the breccia had been replaced by iron pyrites or that it contained about 25% sulphur.

In 1895, Smith took chip samples from the pyrite, which showed no silver or copper and 1 dwt. 15 grns. of gold per ton and later Twelvetrees took a sample which showed a trace of gold and no silver. A sample taken during the present investigation across six feet of the outcrop on the road above the adit showed no gold or tin or copper. Geologist G. Everard has lately been investigating the reported occurrence of tin in the pyrite and has taken a series of samples in the adit as well as from outcrops as follows:-

<u>Sample</u>	<u>Gold</u>	<u>Silver</u>	<u>Tin</u>	<u>Copper</u>
Track W. of Adit. Oxidised Zone.	Nil	Nil	Nil	Under 0.1%
do.	Nil	Nil	Trace	" "
do.	Nil	Nil	Nil	" "
15' below track, above Adit	Nil	Nil	Nil	" "
Track above Adit	Nil	18 grns. per ton	Nil	" "
do.	Nil	Nil	Nil	" "
Adit, West Wall 6' - 13' from end	Nil	Nil	0.1%	0.1%
Adit, 13' across back	Nil	Nil	Nil	0.2%

Although valuable metallic substances do exist in the pyrite of this replacement zone, they appear to be of academic interest only, and the only substance that appears likely to be in economic quantities is sulphur.

Revels Prospect

Half a mile up Dial Creek from Keddies and just beyond the first crossing of the creek by the logging road is a short adit driven into the east bank of the creek for 50 feet first on a bearing of 125° and then swinging round to 250° . The adit, which is almost filled with water shows slate and breccia beds striking at 15° . The breccias which are similar, though not the same beds, to those at Keddies have been partly replaced by pyrite, which according to the staining, contains small amounts of copper. This is a similar, though narrower deposit to Keddies.

Dial Mine

Some twenty chains up Stanton Creek (the next creek south of Dial Creek) from the Leven River, are three adits, now fallen in, which together formed the Dial Mine. This was visited by Harcourt Smith in 1895, who describes the first two adits, one on a bearing of 340° for 70 feet and the other at 170° for 120 feet. In the first adit he took a sample over 6 feet of a pyritic formation which contained 3.2% copper and traces of gold and silver. By 1903, when Twelvetrees visited the mine, a winze had been sunk to 13 feet on this formation, stated by him to be 13 feet wide. A sample taken from the bottom of this showed 1.6% copper and a trace of gold and silver. He quotes many assays reported to him that contain on the average 15% copper and 2 oz. silver to the ton but little or no gold. Too much credence should not be placed on these figures as they are all hearsay, but he does mention a parcel of 6 cwt. of crude ore, which was sent to the Smelting Company of Australia and showed a return of 9.1% copper, 4 dwt. of gold per ton and no silver.

A winze was also put down 18 feet in the second adit, a few feet from the entrance on a copper pyrite formation but no percentages are quoted. A good deal of soft clay was passed through in this adit.

By 1905 when Twelvetrees again visited the mine these two adits had been abandoned and a third driven 20 feet down the creek from the second adit on a bearing of 250° for 130 feet mainly in soft clay and with seams of pyrite in the end. Today little can be seen of the old workings, the first and third adits are completely fallen in and the second partially so. Breccia beds similar to those at Keddies have again been replaced by pyrite but according to the old assays there are sensible percentages of copper associated with it. This is probably because the country is faulted here, the white clay and pug mentioned by earlier writers, which caused the complete collapse of the adits, is probably fault pug and a glance at the map will show that the large fault so well indicated by the scarp on Dial Range probably continues, though somewhat abated, through this place. Enrichment has therefore occurred where this fault intersects the breccia beds and further development of these at depth is warranted.

Copper Creek Mine

A pack track leads from Kaines Farm, south-east of Riana to Gunns Plains. Just before this crosses the divide to descend to the Plains a foot track leads off to the left and descends very rapidly to Copper (or Walloa) Creek. Some chains below where this track crosses the Creek are a group of workings once known as the Copper Creek or Applebee's Mine.

In Geological Survey Bulletin No. 5, Twelvetrees gives a long description of these small adits and cuts. Unlike many others they are still accessible but the present examination revealed nothing of promise although the structural set-up is rather favourable.

Just above Creek Level an adit has been driven on a bearing of 160° for 118 feet. At 90 feet a

drive (?) has been put out for 200 feet in a south-westerly direction. At 100 feet is a fault (Twelvetrees calls this a lode) striking at 160° and dipping to the north-east at 60° . The rocks intersected by this adit are a series of slates and tuffs striking at 60° , dipping south at 70° , and showing moderate silicification. There is little pyrite visible; it is very scattered and there is no sign of any lode or replacement zone or indeed of any breccia beds. Forty feet above the adit are two small cuts in which some replacement by pyrite can be seen. A sample from a bunch of pyrite and hematite showed copper 2.5%, zinc 0.6% and no gold, silver or lead.

Another adit, 110 feet up the hill has been driven at 245° for 55 feet. At 30 feet there is a drive at 140° for 20 feet. Although Twelvetrees talks about a drive on a lode, there appears to be little sign of any mineralisation here and the country rock (slates and tuffs) is much contorted. Twenty feet above this adit is a small open cut showing a little mineralisation.

All along the bed of Walloa Creek, which more or less follows a fault, may be seen evidence of mineralisation but the past development has not proved anything of economic value. Perhaps where the fault intersects breccia beds as at the Dial, more hopeful results may be expected.

Russells Prospect

Not far from the mouth of Russells Creek which enters the Leven near Mr. Russell's house, are two adits and several surface cuts which, through the years, have been variously known as Hardstaff's, Roger's and McKenna's and Russell's. This property was visited by Twelvetrees in 1903 and again in 1905, and he described the two adits, both of which are still accessible. The No. 1 Adit, about 20 feet above creek level, has been driven 200 feet in a north-westerly direction. At 110 feet a small lode has been followed south for 20 feet. Russell's Adit lower down the creek has been driven in the same direction for nearly 300 feet without intersecting any formation.

The country rocks are slates, tuffs and breccias intruded by porphyry which has been intersected in No. 1 adit. The porphyry has silicified the rocks near its contact. The sedimentary series is striking at 15° and dipping west at 40° .

The lode is contained in a fissure 18 inches wide striking much the same as the country rocks (25° dipping north-west at 50°) and consisting of a quartz reef carrying minor amounts of pyrite, arsenopyrite, copper pyrites and carbonates. This has been exposed on the surface by a series of shallow cuts extending north from No. 1 adit for several hundred feet. Sixty feet below the outcrop the lode is intersected in the adit but it shows a diminution both in width and value.

In 1949, the Electrolytic Zinc Company investigated this prospect and took a series of samples along the lode. An average of 9 samples, seven from surface, 2 in adit, showed 1.24% Cu, 2.35 oz. Ag, 0.4 dwt. gold.

This deposit differs from the ones further north in that it is a fissure type and not a replacement one. Indeed the breccias do not seem to show any replacement. The extent and value of the deposit do not suggest that it could be developed as a commercial proposition.

Iron Oxide

This is the most ubiquitous mineral of the field and the only one which has been economically won. It occurs in both the Ordovician and Cambrian strata; as a replacement deposit and in reef-like formation; as hematite and as limonite.

Penguin Creek Deposits

As the hematite appears as boulders on the surface, these deposits, situated along Penguin Creek about three miles from the sea, have been known for a long time and in 1895, when Montgomery visited the area it had already been partly trenched. By 1897, two quarries had been opened, a tramway commenced and some ore sold. When Twelvetrees made his report in 1903, the tramway had been built to Penguin wharf, 20,000 tons of hematite had been obtained from quarries on the east side of the creek and others were being opened on the west side. Thirty tons of ore per day, averaging 68% iron and under 2% silica were being shipped by Mr. J.C. Ellis to New South Wales. By 1905, however, the output had dropped to 150 tons a week and by 1909 it had stopped altogether. It has been estimated that altogether 40,000 tons of ore were exported.

The ore which can be seen in the quarry faces consists of angular and rounded lumps of hematite set in a matrix of soft clayey hematite and limonite. The matrix does not contain sufficient iron to use and the amount of it can be judged by the huge dumps left. The hematite boulders, however, are very pure, averaging over 97% Fe_2O_3 with negligible amounts of sulphur and phosphorous.

The origin of the iron is interesting. It is certainly a replacement deposit but there has been some doubt as to the rocks replaced and the time of the replacement. Twelvetrees at first considered the hematite as a replacement of the Dial Conglomerates and then of the sub-basaltic wash. Thomas and Henderson (1943) considered these deposits identical in character to those at the Blythe River, Natone and Highclere and therefore replacement of the Cambro-Ordovician rocks (now Cambrian) along fault zones. There is little in the way of outcrop near the quarries but perhaps the rocks replaced are similar to those outcropping on the bold headland west of Penguin. These rocks, described in an earlier part of the report, are quartzites at the top of the Cambrian and they contain appreciable patches of hematite. Thomas and Henderson also think that the iron was injected at an earlier period than the general Devonian metallogenetic epoch but that the iron-silica solutions continued to flow through lines of weakness over many epochs.

Although there has been no production of hematite since 1909, of recent years Mr. A. Pearson has been selling small quantities of limonite. Since 1946, 2,000 tons have been obtained from shallow pits

to the south of the main quarries. The limonite is present mixed with hematite only to shallow depth and is the result of the weathering of the hematite and also the re-precipitation of iron oxide from solutions.

It appears that although limonite, in limited quantities, can be produced from this deposit, it is doubtful if the hematite lumps can now be commercially exploited.

Dial Iron Deposits

Here and there the West Coast Range Conglomerates have been partially replaced by iron solutions and lumps of hematite may be picked up from the surface or broken from outcrops in many localities. Perhaps the most complete replacement has occurred near the top of the Dial Range in the northern part of the southern section, where leases have been held at various times by different individuals. This place is rather inaccessible being nearly 1,400 feet above sea level and a mile east of the nearest road - the Riana Road.

The main workings consist of two adits. The first, on a bearing of 220°, has now fallen in and the other, a few chains to the north-west has been driven 30 feet on a bearing of 240°. There apparently has been no production of iron from this locality. These workings have been visited and reported on by Twelvrees and others who have had a series of samples assayed. Unfortunately in a deposit of this type, individual samples do not mean very much. It is possible to get a sample of almost pure hematite and within a few feet one containing 50% silica. One thing, however, that the samples do show is that whether there is much silica or not the amounts of sulphur and phosphorus are very low. The nature of the deposit is well illustrated by lumps of material lying on the adit dumps. Here may be seen conglomerate in which sometimes the pebbles have been replaced, sometimes the matrix and sometimes both. It has been suggested that the hematite pebbles are original but this is not certain.

It is doubtful if any use could be made of these deposits, partly because of their silica content and partly because of their location. There may be some limited use in the manufacture of such materials as ferro silicon where the high silica content does not matter but it should be remembered that the Blythe Iron Deposits are of better grade, larger, more accessible and better developed.

Other Deposits

A very accessible deposit of hematite has been opened up within a couple of miles of Penguin and only 5 chains from the Iron Cliffs Road. Here a pit some 30 by 40 by 10 feet has been opened on the top of a hill and it is said that many years ago some 80 tons was shipped to the B.H.P. for use as a flux. Unfortunately this deposit is very limited and the replacement is rather sporadic so that the ore would have to be hand picked.

Another small quarry showing hematite and limonite was commenced to the west of the South Riana Road just south of Riana. This is hardly of economic interest.

Iron Cliffs

Of a totally different character is the huge limonite "lode" known as the Iron Cliffs. Although some iron ore was shipped from here, it could never be regarded as an iron proposition. However, it may turn out that at depth it contains much more valuable minerals. This deposit which consists of limonite, sometimes massive, sometimes botryoidal, fibrous and stalactitic, containing plentiful quartz, outcrops boldly in small cliff faces along the Creek 20 chains from the Ferndene picnic ground.

Various geologists have visited this deposit and formed different theories as to its origin. Twelvetrees considered it to be the oxidation of a huge sulphide deposit. Reid flatly contradicted this and stated that the iron oxide is primary. I do not think there can be much doubt that this is the surface expression of a sulphide lode. Traces of gold and silver have been recorded from assays, reef quartz is plentifully associated with it and the iron oxide is limonite, a secondary oxide and not hematite a primary one. However, oxidation must have proceeded to a great depth as the Lady Braddon Company put in an adit a few feet above creek level and 120 feet below the top of the hill and it was still in the oxide as was a winze sunk to 15 feet below this level.

The adit was driven on a bearing of 110° for 290 feet and is remarkably dry and well preserved. The country rock consists of Cambrian slates and quartzites, dipping at steep angles to the east. From 146 feet to 257 feet are numerous bands of iron oxide, rather siliceous, in puggy slates and at 257 feet a shallow winze has been sunk on the footwall of the main iron lode, which strikes at 25° and dips east at 85° . The end of the adit is still in the iron which, on the surface, has a width of over 100 feet.

Although samples taken on the surface and in the adit show little or no gold, silver or copper the nature of this deposit suggests that deeper development would be warranted.

Manganese

Black's Mine

This deposit is situated a few chains to the east of the headwaters of Dial Creek and on the northern foothills of Mt. Duncan. It may be reached by following a cart road for three miles from the end of the Lobster Creek Road. This cart road follows Dial Creek up from the Leven and crosses it several times. All the bridges need renewing. The workings have been fully described by both Blake (1940) and Thomas and Henderson (1943) in comprehensive reports on the prospect.

This prospect is an iron-manganese aggregate occurring in a brecciated fault zone which strikes about 110° . The workings, which consist of three trench shaped cuts reaching a maximum depth of 14 feet and two shallow shafts, 15 feet and 17 feet deep, stretch across this fault zone for over one hundred feet and expose the manganese deposits. These consist of nodules and lumps of psilomelane-type oxides, as well as the soft wad-type, set in a matrix of clay and limonite. The richest ore occurs near the surface

and as the cuts become deeper they get poorer in manganese until at the bottom of the shafts only slates are present.

To the north of the fault are the Cambrian beds of slates, tuffs and breccias, to the south the West Coast Range Conglomerate series. These manganese deposits are the result of secondary enrichment, at the surface, due to the precipitation of manganese and limonite from the ground waters. The fault zone is an excellent passage way for the circulation of these waters and the main deposits will be found a little down hill, that is north, of the fault itself.

The grade of ore is not high though by hand picking this can be greatly benefited. Blake took seven samples from the upper (or richer) layer - that is down to 7 feet below the few inches of overburden - and the average of these are as follows :-

19.5% Mn, 26.6% Fe, 10.6% SiO₂, 9.1% Al₂O₃, and small amounts of P₂O₅, TiO₂, S, CaO, MgO and BaO.

A hand picked sample of psilomelane-type showed 43.8% Manganese, 10% Iron, 2.8% Silica and 6.6% alumina. During the present investigation a channel sample over several feet showed 28.4% of manganese.

It can thus be seen that although this manganese zone has a wide lateral extent, the portion containing an appreciable manganese content is only a few feet deep and even this ore would have to be cleaned up considerably before it could be sold as a manganese ore.

Other Deposits

Across Russell's Creek from Russell's Prospect three shallow shafts (about 25 feet deep) have been sunk very close together. Material on the dumps show a boxwork of silica with limonite and manganese oxide. The amount of manganese in these samples appears to preclude the material being considered an ore of manganese.

Near the base of the dam for the Penguin Water Supply (old scheme) situated on a branch of Penguin Creek near the Iron Cliffs Road a piece of wad was found. A sample of this showed 20% manganese.

On the beach east of Penguin, Twelvetrees reports the occurrence of psilomelane-type boulders half hidden by the sand. These now appear to be entirely concealed.

Barite.

Kaine's Prospect

Two and a half miles south-east of Riana, and half a mile from the nearest road is a deposit of barite on property owned by Mr. M. Kaine. The country rocks are breccias with minor slate beds, not silicified, striking at 350° and dipping east at 45°. The barite is exposed in a narrow cut one chain in length. It is apparently interbedded with the breccias and varies in width from 2 to 12 inches with some lesser veins. Twenty feet to the east of the south end of the cut is a shallow shaft with water at 6 feet, designed to cut the barite at about 25 feet but apparently not reaching

this depth. To the north are other small cuts with barite on the dumps but now filled with water. The barite is good white clean-looking stuff, occasionally stained slightly a yellowish brown colour by iron oxide. An analysis of a chip sample taken across the lode showed :-

BaSO ₄	98.6%
Fe ₂ O ₃	0.3%
SiO ₂	0.4%

and its brightness value as determined with a "Photovolt" meter was 63.

These deposits, even though they appear to be interbedded with the country rocks, are probably vein deposits and are interesting for two reasons. One for the commercial production of barite should the vein increase in width at depth and secondly for the possibility of the vein carrying metallic minerals as well as barytes.

Other Deposits

Barite is found, usually only as lumps on the surface in two places behind Mr. Revell's house between the South and Dial Roads. This is much greyer in colour than the Riana barite and does not seem of such good quality.

Sulphur

The pyrite deposits in the vicinity of Dial Creek have already been mentioned under "Copper and Gold" and they may be considered as a potential source of sulphur. Another place to keep in mind is the Iron Cliff where the huge limonite deposit may be the oxidised portion of a large pyrite deposit.

Tin

Although granite outcrops over a wide area that impinges on the south-west corner of this district it does not seem to give rise to a very important tin province. The only tin lodes found associated with this granite are some poor grade quartz stringers in aplite differentiated from but contained in the granite. Some small patches of alluvial tin have been worked, all outside this district, the closest being on tributaries of the Blythe River, west of the road between South Riana and Loyetea; but they never seem to have amounted to very much. Some dishes were washed during this investigation near the edge of the granite in tributaries of Adam and Pine Creeks but although a plentiful concentrate of ilmenite was obtained there was no tin.

It has been mentioned that traces of tin have been found in the pyrite in the vicinity of and at Keddies prospect. Although many samples have been taken at various points, nothing like economic quantities of tin were found. There is a possibility that greater percentages of tin may be found in these replacement deposits nearer the source magma, which must underlie the country somewhere at depth, but there is no guarantee of this.

Sands and Gravels

A mention should be made of these non-metallic deposits for two reasons; firstly because they constitute a greater economic asset to the district than metallic deposits ever have and secondly because of the variety of rocks from Pre-Cambrian to Tertiary which provide their source. In a quarry on the banks of the Leven, south of the South Road near the Lobster Creek turnoff may be seen the results of the weathering of Pre-Cambrian quartzites and conglomerates. The hill is very steep and covered with several feet of rubble, very illsorted, ranging from sand to pieces up to 12 inches across, and is quite favourable for the opening of quarries.

The Cambrian cherts because of combined cleavage and jointing are apt to weather to small sharp angular pieces and these are quarried extensively particularly in the hills forming the angle between the South and Dial Roads. The weathering of the West Coast Range Conglomerates form quite a different type of gravel the smooth rounded pebbles simply falling out of the sandy matrix. Sometimes they are recemented by oxides of iron. The principal quarries put in for this gravel are west of the Iron Cliff Road a couple of miles from Penguin.

The most extensive gravel quarries, however, utilise the Tertiary wash left high and dry when the basalt flow along the coast diverted the Leven River to the east. These deposits extend over a width of about twenty chains for nearly two miles in a northerly direction from the Lobster Creek Road, crossing the South Road to the basalt. The principal quarries have been opened up on the hillside above the Lobster Creek Road, but others are worked both north and south of the South Road. Being an alluvial deposit as opposed to the others, which are detrital, the gravels are not of such an even grade. Some beds contain quite coarse material and others are almost clay but the operators, apparently, only open the type of material which suits them.

CONCLUSIONS

Upon studying these notes upon the various mines and prospects it can be seen that irrespective of the metal involved they fall into two main categories, replacement deposits and fissure filling lodes. Of the first type, not much hope can be held out for finding much of economic importance. The main replacing substance is iron either in the form of pyrite in the Cambrian breccias or oxide in the West Coast Range Conglomerates.

The fissure type of deposit may be associated with a major or minor fault and the mineralization becomes concentrated if some impounding structure, such as fault pug or impervious rock, is present. Before considering the individual areas it should be stressed that nothing that has been seen during this investigation or reported with any authenticity in the old reports could by any stretch of imagination be called a payable ore body. However, the fact that this is a mineral province of wide variety, the nearness of a great granite mass, the presence of a vast thickness of the Dundas Group, which are the State's most favourable host rocks, the occurrence of such massive impounding beds as the

conglomerates and more especially the favourable structural features; all these things, then, tend to suggest that valuable mineral deposits not only should but probably do occur in this neighbourhood. Nothing more can be done about surface prospecting. The area has been too well combed by ditch and trench, shallow shaft and short adit and in reminding that nothing of value has been found in the past it must be remembered that only the surface has been scratched and mineral wealth may well be hidden by a hundred or so feet of sediments.

The areas most favourable to future modern prospecting by geophysical methods and drilling are:-

1. Iron Cliff. I have long been fascinated by this huge outcrop of limonite, seemingly the surface expression of an immense sulphide deposit. The fact that on its eastern flank a galena deposit was partly prospected and that a few chains further east is a great wall of conglomerate make the deposit even more promising. The whole area bounded by the creek to the west of the Iron Cliffs and the West Coast Range Conglomerates to the east should be investigated.
2. The Neptune Area. The old workings, even surface trenches, are completely filled in, but from accounts in old reports it would appear that the very definite lode outcropping on the beach was never cut in the deeper (100 feet) workings. Although this lode near the surface only contained a few inches of galena on the walls, it is in a well defined fissure of 1 to 3 feet in width and the amount of galena could quite easily improve considerably at depth. This could easily be tested by boring.
3. The Dial Mine. The local structure of the rocks at this prospect and the host rocks themselves, both favourable for ore deposition, rather confirm the better assays obtained from these adits compared with neighbouring shows. It seems that here the crossing of a major fault zone (though at this point rather curtailed) with certain breccia beds has resulted in the concentration of copper minerals and further investigation is warranted.
4. Other Areas. As the West Coast Range Conglomerate is such an efficient impounding medium, mineral deposits, though perhaps the surface indication of them is concealed, may be sought in the Cambrian near the boundaries and particularly at the conglomerates base. In the southern part of the area; where the rocks are fairly closely folded, the base of the Ordovician is not far from the surface and although few mineral deposits, with the exception of the barite prospect, have been found near the base, it is reasonable to suppose that they may exist there. In the extreme north, that is near the coast line, just to the east of Penguin the base of the conglomerates is fairly close to the surface. On the eastern flank of these beds, the rock has been weathered away but further east mineralisation is common and it is quite probable that this has been concentrated against the conglomerate wall, that is in the vicinity of Watcombe's Beach and within the town boundary.

(Sgd.) Terence D. Hughes
GEOLOGIST

The Department of Mines,
HOBART
2nd October, 1953.