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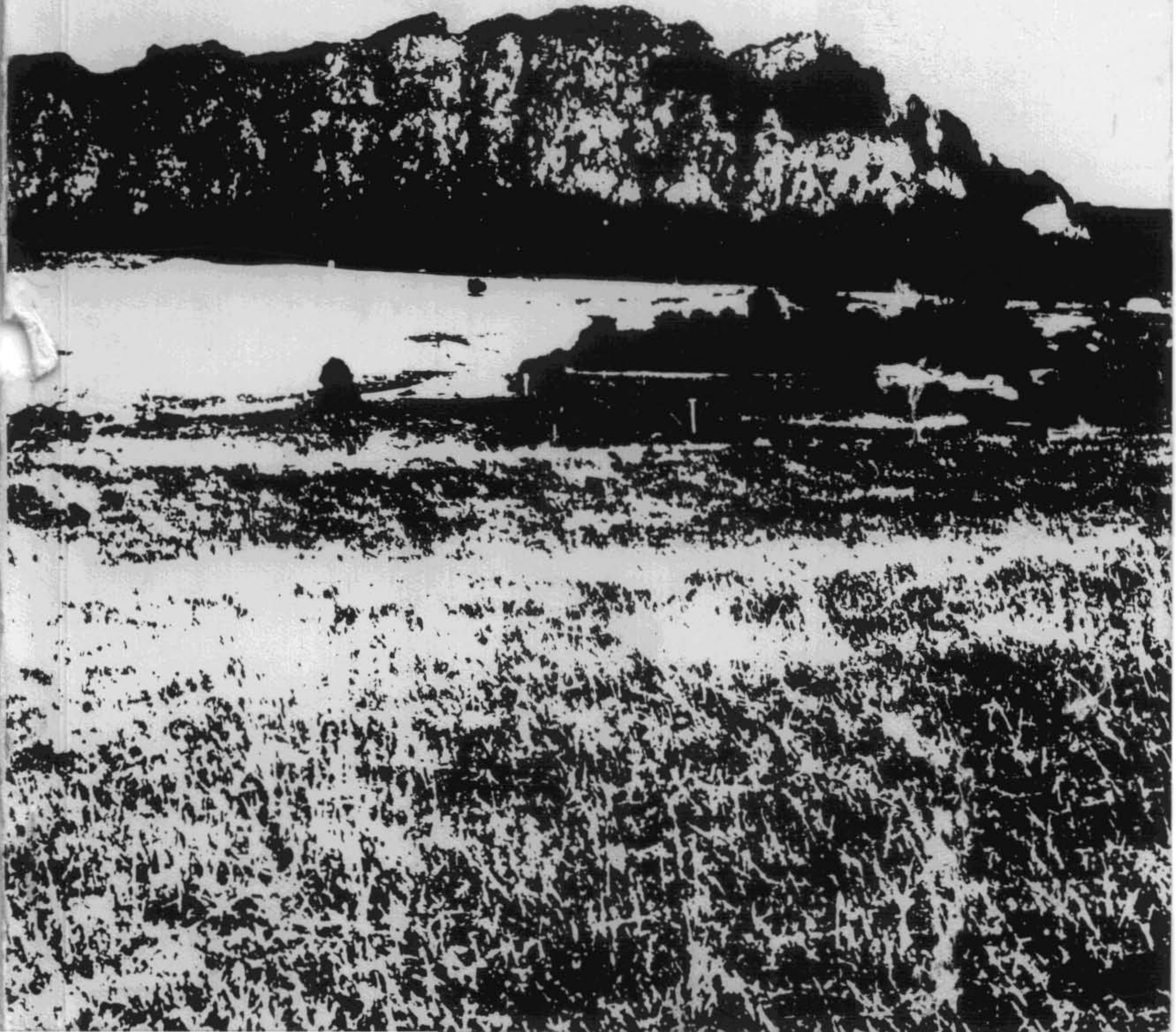
GEOLOGICAL SURVEY EXPLANATORY REPORT

DEPARTMENT OF MINES TASMANIA

SHEET 37

SHEFFIELD



TASMANIA DEPARTMENT OF MINES

1979

GEOLOGICAL SURVEY EXPLANATORY REPORT

GEOLOGICAL ATLAS 1 MILE SERIES

ZONE 7 SHEET 37 (8115S)

SHEFFIELD

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PREFACE

These explanatory notes describe the geology and mineral resources of the Sheffield geological atlas 1 mile sheet published in 1959. The Sheffield Quadrangle covers an area approximately bounded by the River Leven in the west, the Mersey River in the east and Gog Range - Mt Roland - Mt Claude in the south, extending north almost to Latrobe.

Agriculture and forestry provide the main employment within the quadrangle, with the Goliath Portland Cement Company Ltd being the only major industry. The deeply incised nature of the Wilmot and Forth Rivers has been utilised for the production of hydro-electric power, with four power stations operating in the quadrangle.

The mineral resources of the quadrangle have attracted much attention, with active exploration dating back to 1850. These resources include the Moina - Round Mount mineral field, the Dulverton - Nook coalfield, the Latrobe oil shale and the limestone deposits at Railton, which are currently being mined for the manufacture of cement. This report includes a detailed discussion of the geology and history of these deposits.

J.G. SYMONS, Director of Mines

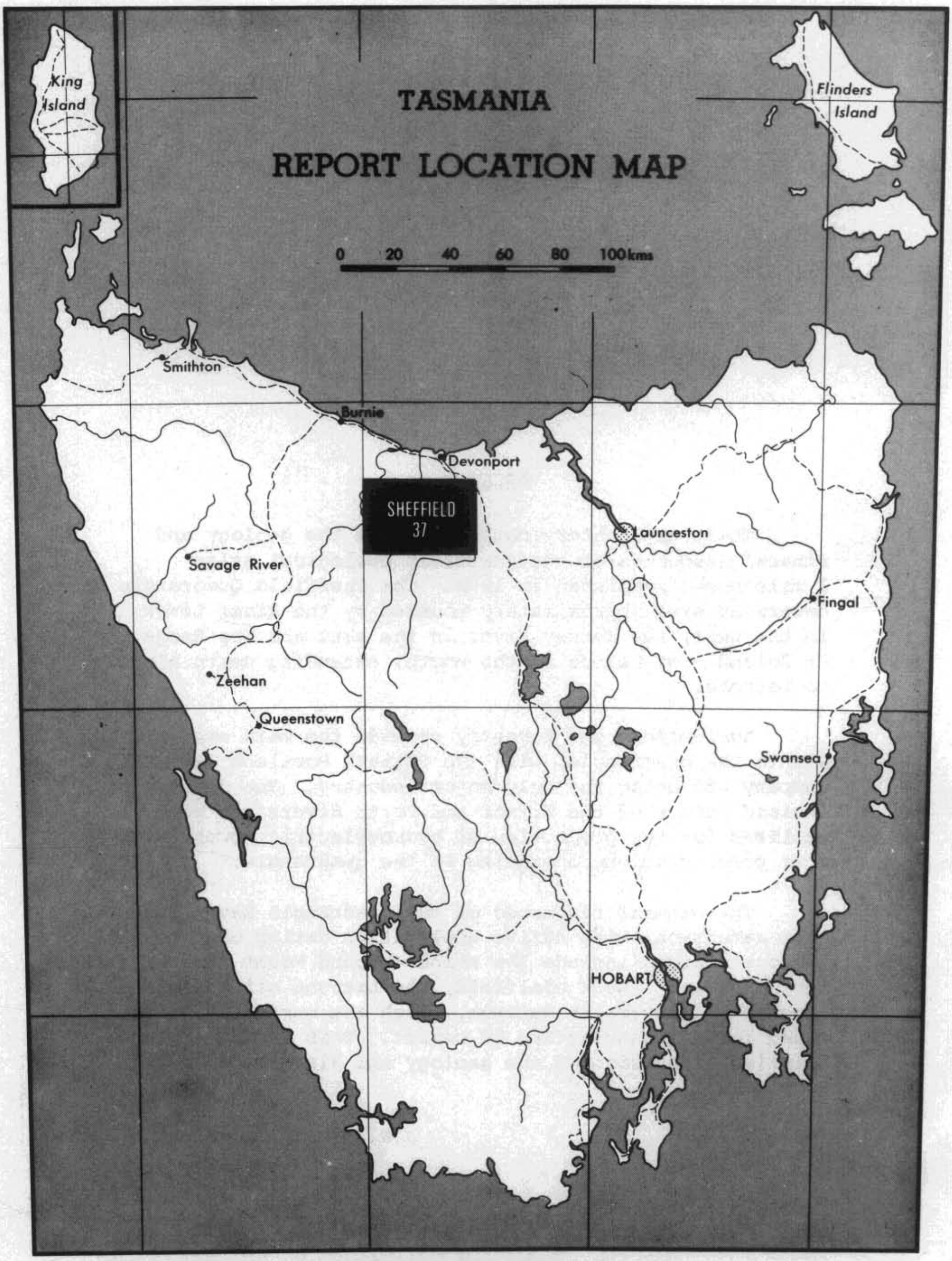

Figure 1. *Location of Sheffield Quadrangle*

5 cm

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INTRODUCTION

The Sheffield Quadrangle lies between latitudes 40°30'S and 41°15'S and longitudes 146°E and 146°30'E (fig. 1) It comprises about 1150 km^2 of the central north of the State and includes extensive tracts of farmland and forest and several old mining fields.

In the past, a number of mining fields were developed which yielded considerable quantities of tin, wolfram, gold, bismuth, silver-lead and other metals. The metalliferous deposits which were worked proved to be of relatively high grade but were small in extent and erratically distributed. The exploration and development costs were therefore relatively high and for this reason the mining fields did not attract companies interested in large scale production and mining activities declined until there are now no metalliferous mines operating in the quadrangle. However the wide range and distribution of minerals present indicates that the quadrangle is worthy of further attention.

Non-metallic minerals have played an important role in the economy of the quadrangle with coal, oil shale, limestone, clay and barite having been quarried. At present, large amounts of limestone and clay for use in the manufacture of portland cement are quarried at Railton, whilst smaller quantities of shale for brick making are produced at Haines Siding north of Railton.

PREVIOUS LITERATURE AND ACKNOWLEDGMENTS

A number of workers have prepared geological reports and maps on small areas within the Sheffield Quadrangle. These reports have generally dealt with individual mines or mining fields in the district, but some of the literature dealing with the Permian oil shale has been on a more regional scale. Since many of the exposures and mines which were available to the early workers are now either obscured or inaccessible, the writer has drawn extensively upon the available literature. Full acknowledgment is accorded to these early workers.

The mapping of the Sheffield 1-mile geological sheet was carried out in conjunction with mapping in the Middlesex Quadrangle and is the combined effort of many workers over several years. The earliest work on this project was that of J. Elliston and L.G. Nixon, who covered a part of the southern edge of the sheet including the Moina and Mt Claude districts. Subsequently, Elliston's work was modified slightly and the Cambrian sequences were studied in more detail.

K.L. Burns mapped the Gunns Plains, Sprent and Paloona map squares as part of an Honours thesis for the University of Tasmania (Burns, 1957) and this work has been incorporated in the map sheet. R.C. Robinson mapped the Nietta square and carried out numerous traverses in other parts of the quadrangle. The basalt boundaries and Permian rocks in the vicinity of Railton and Latrobe were mapped by S.J. Mayne.

The base map for the geological map was adapted from 40 chain topographic sheets of the quadrangle prepared by the Mapping Branch of the Lands Department. Petrographic descriptions incorporated in the text of this publication were prepared by G.B. Everard. Rock analyses and assays were carried out by the staff of the Department of Mines Laboratory, Launceston.

ACCESS AND FACILITIES

At the time of mapping, the Sheffield Quadrangle was covered by the road system indicated on the geological map. The high country along the Fossey Mountains* was inaccessible to vehicles and the routes indicated along the foothills of this range were mainly timber tracks which were often impassable during wet weather. Recent construction activity of the Hydro-Electric Commission in this area has resulted in the construction of several all-weather roads.

The Western Railway Line traverses the north-eastern part of the quadrangle around Railton, but the branch lines from Railton to Roland and Ulverstone to Nietta, indicated on the map, closed in 1957 and 1955 respectively.

Accessibility in the basalt areas is good, as most of this land is open grazing country. Much of the area underlain by Cambrian rocks is steep and thickly forested and access is restricted. The Permian country south of Latrobe is relatively open and although not cleared for farming is freely accessible.

RAINFALL AND VEGETATION

Average annual rainfall for various localities in the Sheffield Quadrangle is given below.

Station	*Average annual rainfall (mm)*	*Station*	*Average annual rainfall (mm)*
Sheffield	1209	Riana	1347
Wilmot	1287	Kindred	1094
South Nietta	1619	Castra	1336
Moina	1814	Railton	1058

These figures indicate an increasing rainfall gradient toward the higher country along the south and south-western portions of the quadrangle. Elsewhere the rainfall is fairly uniform at approximately 1140 mm.

The vegetation is governed by aspect, drainage, rainfall and the nature of the underlying rock types. All of these factors are complementary to some extent, but the dominating factor appears to be aspect. Several associations are present within the quadrangle.

Thick eucalypt rain forest is restricted to areas of high rainfall and shaded aspect. It is best developed along the gorges of the Forth and Wilmot Rivers and in the foothills of the Fossey Mountains. In the early days of settlement, the basalt country was occupied by dense stands of eucalypt forest which barred access inland from the coast. Almost all of this forest has now been cleared.

Stunted eucalypt forest with light undergrowth is largely restricted to the north-east corner of the sheet. It is closely confined to the Permian sediments but denser stands of eucalypt have developed on Permian soil in shaded areas or in areas of high rainfall. A myrtle-sassafras association occupies shaded gullies and areas of high rainfall, chiefly along the Forth and Wilmot Rivers and the slopes of the Fossey Mountains.

Where cleared land has been neglected for any length of time, a thick growth of bracken fern and blackberry vines becomes rapidly established and impedes foot access considerably. Plantations of pines have been established

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*The Fossey Mountains is defined as that range of mountains running east-west between Mt Magog and Black Bluff. The range is structurally and lithologically similar to the West Coast Range.

on a variety of soils at Stoodley, Beulah and in the Castra-Nietta and Railton-Sassafras districts. Tea-tree thickets on swampy ground are developed on most soils but are more conspicuous in the clear basalt country. Button grass plains are locally developed on The Badgers, north-east of Sheffield and on top of the Fossey Mountains, but they form only a small proportion of the vegetation in this district.

Generally, the increase in annual rainfall to the south and west across the quadrangle is reflected in the increasing density of vegetation, but local variations of soil type and aspect may influence this greatly. The highest country along the Fossey Mountains is most exposed and subject to winter snow. It is only sparsely vegetated with small areas of alpine vegetation.

The influence of rock type on vegetation is most clearly shown by the relation of cleared land to the basaltic soils. Over most of the Sheffield Quadrangle the edge of the basalt soil can be accurately mapped by studying the boundaries of cultivated land. The actual basalt boundaries, however, often lie some distance upslope from the soil boundaries due to soil creep.

The preference of farmers for basalt soil has led to the clearing of much land occupied by Cambrian basic lavas, which produce a soil very similar to that of the Tertiary basalt but which is not as fertile. Much of this type of land in the vicinity of Beulah was cleared in early times, but proved to be unsatisfactory and was allowed to degenerate into light bush with a thick cover of bracken fern and blackberries. The Tertiary sediments at Nook were once covered by basalt and the soils are heavily contaminated with iron leached from the basalt, which results in soil types similar to the parent basalt.

Poor drainage produces swampy conditions with resulting inferior vegetation. Local perched water tables in the basalt are responsible for the swamps and tea-tree thickets in basalt areas, whilst the Gordon Limestone has been eroded deeply and is covered by a blanket of impermeable residual clay in the vicinity of Railton. Perched water tables on the clay horizon have resulted in widespread swampy areas in the Railton Valley, with little of this country being used for agriculture.

SURVEY AND RELIABILITY

Geological mapping was carried out using aerial photos on a scale of 40 chains to 1 inch. Mapping standards vary between the various formations. The Tertiary basalt boundaries have been very largely traversed on foot and the resulting accuracy is high. The Magog Group rocks crop out boldly, show structure well, and may be accurately mapped without difficulty, but the Cambrian formations usually only crop out well in major streams. The complex structure and stratigraphy of the Cambrian rocks, together with the poor outcrop, has led to some uncertainty of correlation between the various rock units. Although most of the areas covered by Cambrian rocks have been carefully traversed on foot, the most useful information was obtained from detailed traverses of the major rivers. As these rivers are several kilometres apart and the interfluves between the rivers are covered by Tertiary basalt, much extrapolation has been necessary. The resulting stratigraphic sequence and structure pattern is therefore somewhat interpretive.

The Permian boundaries are based on limited surface exposures, together with information available from bore records and exploratory workings for coal and oil shale. Since many of the early bores were logged by drillers,

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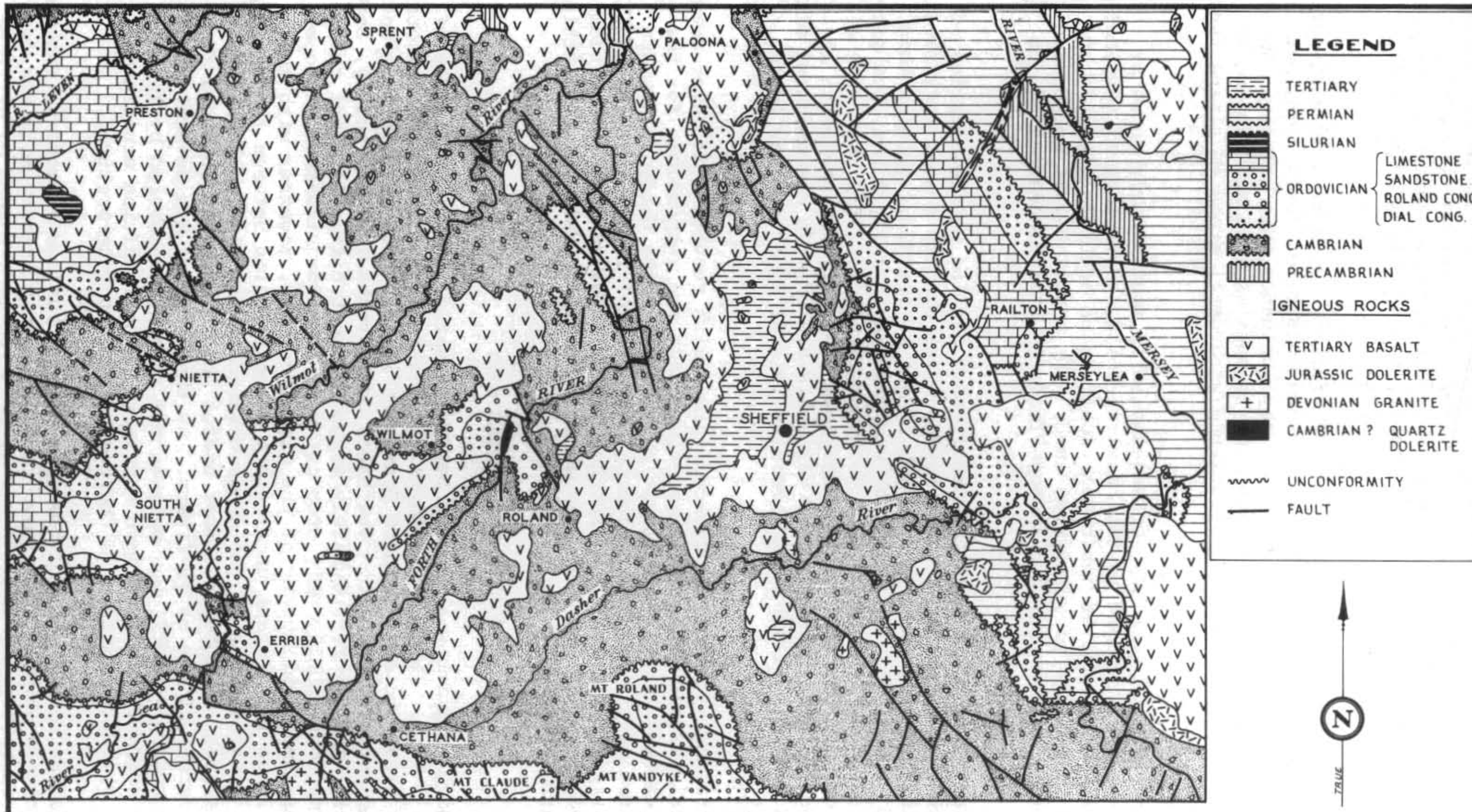


SOLID GEOLOGY — SHEFFIELD QUADRANGLE

Figure 2.

the positions given for these bores is suspect; the accuracy of this portion of the map therefore is likely to be variable.

PHYSIOGRAPHY

The generalised bedrock geology of the Sheffield Quadrangle is shown in Figure 2. The central portion of the quadrangle consists of dissected Cambrian rocks overlain by Tertiary basalt. The eastern, western and southern margins of the quadrangle are bounded by resistant ridges of Ordovician quartzite and conglomerate. In the east and north-east the Cambrian and Ordovician rocks are overlain by flat lying Permian sediments which have tended to smooth out topographic irregularities in the basement rocks.

There is some evidence that small ice caps may have been present on the higher portions of the Fossey Mountains during the Pleistocene but the glaciation has not left any strong imprint on the area.

Ordovician limestone at Railton, Gunns Plains and west of South Nietta has been eroded to local base levels and forms depressed areas. Limestone caves at Gunns Plains are sufficiently well developed to constitute a tourist attraction.

DRAINAGE SYSTEM

The main factors influencing the drainage system are the distribution of the Ordovician rocks and resistant formations in the Cambrian sequence. The broad drainage pattern is probably inherited from post Tertiary basalt time. Three major rivers, the Forth, Mersey and Wilmot drain most of the area. All of these rivers have breached the Ordovician ridge along the southern edge of the sheet and are locally deflected by quartzite and chert formations north of the Fossey Mountains.

These rivers all have their sources in the glaciated highlands of the central plateau, south of the quadrangle, and a high proportion of the bed load of the rivers is re-worked fluvio-glacial material being transported from extensive periglacial deposits higher upstream. All the rivers show evidence of an earlier period of aggradation, probably dating from the Pleistocene, and their tributaries in many cases are still aggrading upstream from rock bars of resistant Ordovician rocks.

River Forth drainage system

The present courses of the Forth and Wilmot Rivers are largely unrelated to the structure of the basement rocks and are therefore considered to be inherited from the drainage system established immediately after the basalt extrusions. The gorge cut by the Forth through the Fossey Mountains is probably a much older, pre-basalt erosional feature.

The main tributary of the River Forth is the Wilmot, which is formed by the confluence of the Iris and the Lea Rivers at Lake Gairdner. The River Forth rises some 48 km south of the quadrangle and lies at a much lower altitude than the Wilmot over most of its course. The Iris and Lea Rivers have their headwaters in the Fossey Mountains a few kilometres south of the quadrangle boundary at an elevation of about 820 m. A comparison of levels along these rivers indicates a difference in gradient between the Forth and the Wilmot of about 5:1 which is reflected to some extent in the valley profiles. Both rivers occupy deep gorges, although the Wilmot gorge is certainly more spectacular. The rough similarity of valley form, despite the different gradients, is probably due to the fact that the Forth has re-exhumed its previous valley, with slight modifications, in post-basalt times whilst the Wilmot has excavated its valley through a variety of rock types and appears to be unrelated to any previous drainage system. The evidence that the River Forth north of Lorinna occupied a valley entrenched in the Palaeozoic rocks before the basalt extrusions has been presented elsewhere (Jennings, 1963).

Terraced river gravel, characteristically showing imbricate structure, occurs locally along the Forth and Wilmot Rivers upstream from their confluence. The deposits are generally small and related to rock bars along the rivers. Boulders up to 300 mm diameter are typically ellipsoidal and composed of the more resistant rocks along the course of the rivers, such as Cambrian chert and lava, Ordovician quartzite and conglomerate, Tertiary basalt and, in the Forth only, granite and Precambrian rocks.

More extensive alluvial tracts occur upstream from Paloona along the Forth and Wilmot Rivers. Burns (1957) presented evidence to show that the river gravel at Paloona accumulated up to 12 m above the present river level and erosional terraces have subsequently been cut into this material. The broad history of river development appears to be:

(1) Strong erosion from post-basalt time up to the Pleistocene.

(2) Extensive aggradation during and immediately following the Pleistocene.

(3) Degradation, interrupted by minor eustatic changes, from post-glacial time up to the present.

Since the general north-east course of both the Forth and Wilmot Rivers is at right angles to the structural trends in the basement rocks, it is inferred that this trend has been inherited from drainage channels established on top of the Tertiary basalt. The rivers have subsequently become incised sufficiently into the Palaeozoic rocks for differential erosion to have locally modified the river courses. The most notable local deflection of this kind is shown by the River Forth south-west of Barrington, where it makes two right angle turns around the mass of Cambrian chert.

Mersey River drainage system

The main tributary of the Mersey River within the quadrangle is the Dasher River, which drains a large area of Cambrian rocks lying north of Mt Roland. The Dasher River occupies a broad alluvial plain throughout; it meanders in a sinuous fashion over most of its course until about 8 km before its confluence with the Mersey where it falls rapidly through a steep gorge cut into Ordovician conglomerate and quartzite. The main tributary of the Dasher River is the Minnow, which drains an area of Cambrian rocks surrounding Beulah and has the same physiographic pattern as the Dasher. The Dasher and Minnow Rivers were probably originally tributaries of the pre-basalt Don River, but were subsequently captured by tributaries of the Mersey.

The Mersey River is somewhat similar to its tributary streams in that it occupies a meandering course through alluvial plains upstream from rock bars composed of Ordovician and Precambrian rocks. In the Merseylea district, the flood plain of the Mersey River is up to 3 km in width and is underlain by coarse alluvial deposits composed of rounded and sub-rounded boulders which frequently show an imbricate texture. Much of the material appears to be derived from outwash or fluvio-glacial material of Pleistocene age which has become re-cycled in the present erosional cycle.

STRATIGRAPHY

Precambrian

Rocks assigned to the Precambrian system crop out along the Mersey River in the vicinity of The Great Bend, in the valley of the River Forth north of Paloona and in the valley of the Clayton Rivulet. The regional thinning of the Lower Palaeozoic sequence toward the north-east of the Sheffield Quadrangle and the outcrops of Precambrian rocks along the Mersey River indicates that the area is on the north-eastern boundary of a Lower Palaeozoic depositional basin.

Twelvetrees (1911) noted the presence of sericitic quartz mica and mica schist for approximately 7 km along the Mersey River and also at Cherry Hill. Reid (1924) described highly foliated, puckered and strongly contorted schists of various types in the same area. He considered that these formed an anticline extending from Latrobe to Native Plain.

During the course of mapping, a belt of quartzite and schist in the areas described by these early workers was mapped, but exposure was poor and the similarity of lithological types makes it difficult to substantiate Reid's structural view. In the quarry north of Hoggs Bridge, the quartz sericite schist strikes generally about 300° and dips south-west at about 60°. Minor folds, parallel to the dominant foliation, plunge 30° towards 140°.

Burns (1957) described the following sequence in the Forth Valley north of Paloona:

Unit 1. Quartzite with pebbles of black schist (post Precambrian).

Unconformity

2. Graphite schist.
3. 120 m of contorted chlorite schist with quartz veins.
4. 3 m of quartzite.
5. Chlorite and quartz mica schist grading downwards to albite mica 'gneiss' with albite(?) bands about 3 mm thick and thin laminae of muscovite, also some coarse biotite schist.
6. Mica schist with interbedded pink quartzite. The quartzite members increase in thickness until the unit becomes a quartzite with thin bands of mica schist.

The total thickness of this sequence was estimated by Burns to be about 450 m. Burns (1965) tentatively correlated these rocks and those along the Mersey River with the Ulverstone Metamorphics.

Along Moreton Road in the valley of Clayton Rivulet, Burns (1957) described the probable Precambrian rocks as consisting of sheared quartzites with the schistosity dipping north at about 50°, and the upper part of the outcrop being structureless quartz. Some outcrops were conglomeratic. Burns (1963a) correlated adjacent outcrops of Precambrian rocks in the Devonport map sheet with the Rocky Cape Group.

Cambrian

The Cambrian System comprises a complex pile of greywacke sediment, volcanic material and chert about 4000 m thick which was deposited in an actively developing basin trending in a north-westerly direction through the Sheffield area. The sedimentary pattern clearly indicates tectonic and

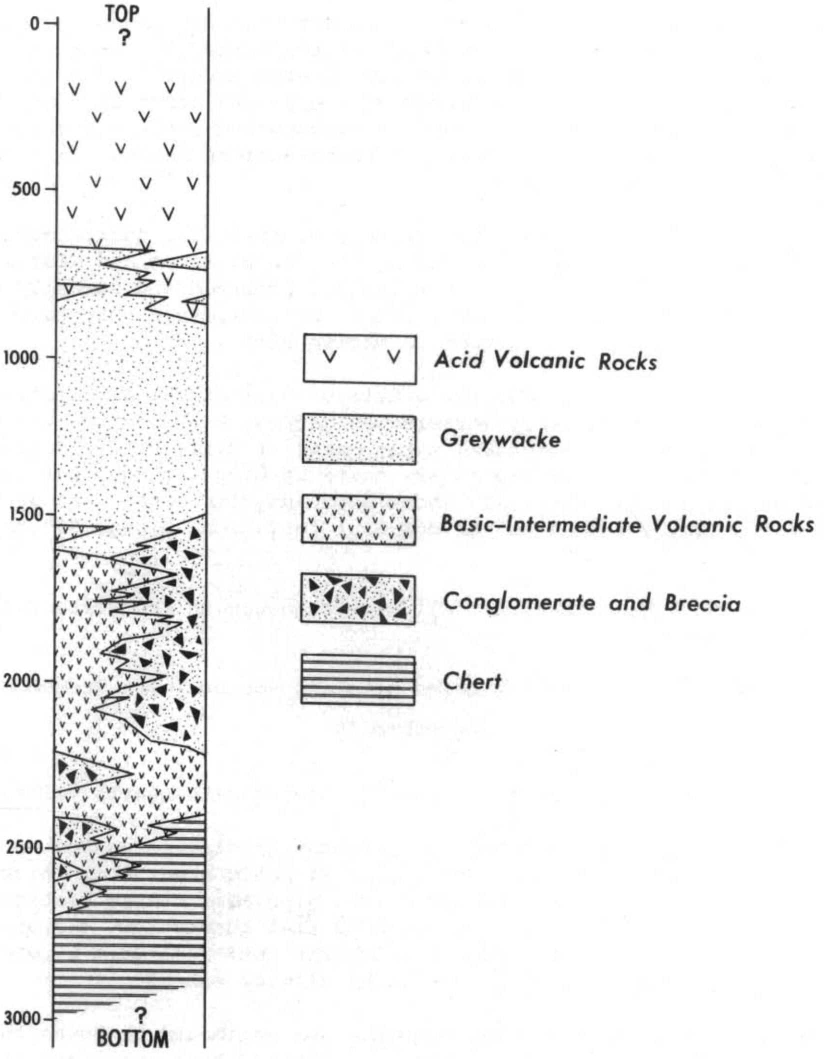
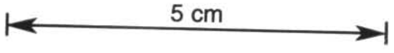


Figure 3. *Diagrammatic section showing relationships of main facies in the Cambrian System.*



volcanic activity within and around the basin during deposition. Fragments of chert and volcanic rocks from the lower units are ubiquitous in the higher formations.

The stratigraphic position of the Bull Creek and Lorinna Formations is somewhat uncertain, as the boundaries appear to be gradational in some areas and are faulted or obscured in others. They may be restricted to the south-western part of the basin but are not strongly developed in the quadrangle. The remainder of the Cambrian sequence may be subdivided into four main facies; first chert followed by basic to intermediate volcanic rocks which interfinger with and are overlain by breccias and conglomerate and later thick greywacke sediment overlain by acid volcanic rocks. The general sequence and the relationship between the facies is shown in Figure 3.

An alternative hypothesis is that the chert and basic to intermediate volcanic rocks were restricted to the axial region of the trough whilst, perhaps penecontemporaneously, greywacke and acid volcanic rocks were deposited further out. The most likely interpretation is that some of the main facies, whilst essentially local, laterally interfinger with and overlap the other facies.

The basin in which the rocks of the Cambrian System were deposited extends south-east from the Dial Range at least to Golden Valley (Quamby Quadrangle). This elongated trough, centered around Sheffield, is about 80 km long by 32 km wide and 3 km deep. In the vicinity of Golden Valley, the basin becomes restricted and the Cambrian System is overlapped by Permian rocks and little information is available. East of the Dial Range, the basin runs into a trough extending south-west from the coast near Penguin towards Mt Farrell.

Early in the orogenic cycle, uplifts occurred along the axis of the trough so that chert from the Barrington Ridge* contaminated most of the later sediment. Concomitant with the formation of this ridge, spilite, basic lavas, pyroclastic breccias and conglomerate were deposited along its flank. Elsewhere, localised uplift of the marginal areas provided local sources of Precambrian material to form tongues of quartz conglomerate. Piles of greywacke and pyroclastic material were deposited during the relatively quiet phases, much of it by turbidity currents.

BARRINGTON CHERT

The type locality for this formation is between 49/226069 and 49/232078 near Devils Gate on the River Forth. At this locality, the formation is about 1000 m thick, but the bottom is not exposed. The formation also occurs at the Sheffield reservoir, on the River Forth around the old town reserve of Alma and on Barren Knob, 5 km north-east of Gunns Plains. Burns (1965) correlated this formation with chert in the Dial Range district. No complete section through the formation has been found and it is unlikely that a more complete section than the type area will be located.

At Devils Gate, the chert is fairly pure (table 1, analysis 1, 2), often finely laminated and somewhat brecciated, particularly in the vicinity of major faults. The chert varies in colour from black to red and grey, but the colour boundaries are frequently irregular and unrelated to bedding, suggesting that they may be due to diffusion. South of The Big Bend on the River Forth, the chert grades conformably upwards through argillaceous chert to greywacke siltstone containing beds of chert pebble conglomerate.

*Barrington Ridge is a tectonic ridge extending across the Sheffield Quadrangle from Barren Knob (49/090180) to Lower Beulah (48/360930).

Paterson (1959) recorded joints of at least two ages. The older joints are filled with quartz and carry small quantities of pyrite and chalcopyrite which are reported to be distorted in the vicinity of the major faults. The younger joints are reported to be mainly open, with thinly brecciated surfaces.

At Alma, a few kilometres north of Barrington, Burns (1957) described the chert as flaggy bedded and containing thin beds of porcellanite, keratophyre tuff, greywacke and shale. Burns (1957) described the chert at Barren Knob as a thick sequence of thinly bedded grey chert at least 150 m thick. He also noted the presence of contemporaneous slumping in some areas but reported that this was frequently obscured by tectonic folding. The basal beds consist of several hundred metres of cherty breccia, consisting of rounded pebbles of banded black chert averaging 100 mm in diameter.

Finely laminated grey, black and white chert is exposed on the small hill on which the Sheffield reservoir is situated. This chert shows small-scale soft sediment deformation and considerable later tectonic deformation. At Barren Knob, Burns (1957) considered that the chert overlay three different Cambrian formations with structural discordance and therefore placed it high in the Cambrian sequence. However the formations which he considered older than the chert contain fragments of it or of a similar chert. In the type locality, the Cambrian rocks adjacent to the formation also contain fragments of chert which are considered to have been derived from the Barrington Chert. For this reason, it is considered that the Barrington Chert is the lowest Cambrian formation exposed in the Sheffield Quadrangle.

The origin of the chert has been discussed by earlier workers, some holding it to have been formed by replacement and others that it is an original sediment. I. Crespin (pers. comm.) observed radiolaria in a boulder of chert from the River Forth downstream from Barrington, presumably derived from the type area. The presence of chert breccia interbedded with the chert indicates that if replacement has occurred, it must have been highly selective or have taken place soon after deposition. Burns (1965) also noted the presence of chert interbedded with other sediments and concluded that the bulk of field evidence indicated a sedimentary origin. This is in accord with the evidence collected during the survey of the Sheffield Quadrangle.

BEULAH FORMATION

A complex pile of basic to intermediate lavas together with pyroclastic material and breccia crops out in the vicinity of Beulah and Lower Beulah. These rocks comprise the Beulah Formation.

The frequency of outcrop in the type area is insufficient to determine the relationship between the various rock types. No useful type section can be assigned for the formation, but the unit can be separated from the underlying chert and overlying greywacke for mapping purposes. Similar rocks have also been mapped along the northern slopes of the valley of the Dasher River, north-west of Claude Road.

The formation underlies the Gog Range Greywacke and is considered to be equivalent to the Motton Spilite, which overlies the Barrington Chert near Barren Knob. The uncertain field relationships do not preclude the possibility that this assemblage is restricted to a narrow zone and that it may be coeval with the basal beds of the Gog Range Greywacke in certain areas.

Fine-grained vesicular augite andesite occurs at 48/355955 (table 1,

Table 1. CHEMICAL ANALYSES OF CAMBRIAN ROCKS

Analysis	1	2	3
SiO_2	93.66	95.50	48.86
Al_2O_3	1.7	1.25	17.75
Fe_2O_3	2.27	0.50	3.63
FeO	0.38	0.26	6.01
MnO	-	-	0.19
TiO_2	0.06	0.08	0.68
P_2O_5	0.02	0.03	0.13
CaO	0.52	1.28	8.58
MgO	0.45	0.29	5.75
Na_2O	0.07	0.14	2.88
K_2O	0.24	0.11	2.75
H_2O^+	0.20	-	2.45
H_2O^-	1.0	0.75	0.23
Total	100.57	100.19	99.89

1. Barrington Chert, Devils Gate Dam, River Forth
2. Barrington Chert, Devils Gate Dam, River Forth
3. Fine-grained vesicular augite andesite, Beulah

analysis 3). In thin section, this rock contains greenish glass and zoned stumpy andesine phenocrysts containing numerous inclusions. Augite is present as twinned irregular crystals which are cracked and partly altered to chlorite. Irregular patches of chlorite and carbonate are also present, the chlorite sometimes forming a margin to the carbonate.

A breccia made up of fragments of andesite also occurs at the same locality. The andesite contains altered feldspar, augite, magnetite and glass. The augite has been altered to chlorite and the glass varies in colour from black to almost colourless.

A fine-grained dark bluish-grey porphyritic lava crops out at 48/367960. In thin section, this rock consists of phenocrysts of feldspar from 0.5 to 1.5 mm in diameter together with augite phenocrysts about 0.5 mm across. The groundmass consists of small rectangular feldspar crystals. The feldspars are sericitised but were originally plagioclase, as shown by zoning of the inclusions and alteration. Some of the phenocrysts have been pseudomorphed by chlorite and others by chalcedony, chlorite and magnetite.

At 48/339940, a rock containing slightly sericitised phenocrysts of plagioclase about 0.75 mm long set in a groundmass of tiny laths of plagioclase occurs. Small flakes of chlorite and granules of quartz occur between the laths. The rock is probably a trachy-basalt or a feldspathic basalt (B. Nashar, pers. comm.).

Outcrops of a chocolate-coloured vesicular lava containing veins of epidote and white rectangular phenocrysts occur at 48/375955. In thin section, this rock consists of laths of sericitised plagioclase ranging from microliths up to phenocrysts 5 mm long in a groundmass of opaque hematite. The rock is cut by broad veins of epidote with associated quartz and hematite.

A breccia at 48/354966 contains fragments of all the rocks described above together with quartz and quartz feldspar porphyry fragments.

MOTTON SPILITE

This formation is defined from rocks cropping out in the West Gawler River between 49/090164 and 49/096167 (Burns, 1957). The formation conformably overlies the Barrington Chert and attains a maximum exposed thickness of about 500 m at North Motton (Burns, 1965). The formation is lenticular and is missing entirely in some areas.

The formation consists mostly of spilite with some interbedded tuff and breccia, the latter containing abundant chert fragments. At the southern end of Barren Knob, Burns (1957) noted argillite, chert and indurated siltstone interbedded with the spilite.

In the West Gawler River at 49/092165, the spilite is a massive dark green fine-grained rock carrying ramifying veins of light green material and thin seams of pyrite. It is interbedded with tuff and chert breccia (Burns, 1957).

A thin section of a specimen from the West Gawler River shows augite as irregular anhedra averaging 0.1 mm diameter and surrounded by rims of penninite. About 35% of the rock is sericitised plagioclase in laths averaging one millimetre in length and showing albite twinning. Sphene occurs as abundant subhedral crystals averaging 0.1 mm in diameter, or as tiny rounded grains less than 0.05 mm diameter. Calcite and magnetite are fairly common while chlorite is concentrated in narrow bands. Flow structure is present and veins of calcite and magnetite containing broken strung out fragments of pyroxene also occur.

A specimen from Leven Gorge consists of large rounded subhedral phenocrysts of albite up to 0.6 mm diameter, but averaging 0.2 mm, in a groundmass containing laths of albite showing marked flow structure in the vicinity of the phenocrysts. The phenocrysts contain frequent small patches of sericite and some augite. There is every transition from feldspar crystals with a few augite fragments to large clumps of augite with a rim of feldspar. The feldspar is usually well rounded and extensively resorbed at the margins. Sphene, a common accessory, occurs as scattered anhedra. Magnetite, green pleochroic penninite and rare needles of tremolite are also present. The amygdules are filled with large anhedra of quartz, epidote and radiating masses of penninite.

Burns (1957) concluded that although no pillow structures were observed in the area, the occurrence of interbedded tuff and breccia indicated a submarine effusive origin for the spilitic rocks.

SPRENT FORMATION

Overlying the Motton Spilite in the West Gawler River is a lenticular accumulation of breccia with some minor shale intercalations. The type locality for the correlates of these rocks is the bed of a tributary of the West Gawler River between 49/085148 and 49/078148 (Burns, 1957).

The breccias are variable in composition, although chert is ubiquitous, and they usually reflect the composition of the underlying rock type. In the vicinity of Barren Knob, they consist chiefly of chert fragments in a matrix of finely divided chert, whilst they contain fragments of the underlying spilite, together with chert, along the River Leven. Chert pebble conglomerate interbedded with greywacke forms the basal beds of the Gog Range Greywacke at Barrington and these are possibly coeval with the Sprent Formation. Similarly, breccia in the Beulah Formation probably represents the same period of deposition.

All these deposits indicate uplift along the Barrington Ridge. Following and concomitant with this uplift, submarine volcanic activity occurred at the north-west end of the ridge resulting in spilite lava and spilite-bearing breccia, whilst subaerial activity occurred at the south-east end around Beulah, resulting in basalt-andesite volanic rocks and breccia.

Burns (1957) described the basal unit of this formation in the West Gawler River as a coarse breccia containing pebbles of chert up to 150 mm in diameter in a matrix of feldspathic sandstone. He described the remainder of the formation as: 'immediately overlying the coarse basal breccia is a thin band of shale perhaps 100 feet [30 m] thick, and then a very thick breccia, consisting of fragments of mainly black chert in a finer grained matrix of chert fragments. At 9142N/4080E [49/080142] breccia is in bands 2 to 3 feet [0.6 to 1 m] thick, with fragments averaging ½ inch [12 mm] but up to 6 inches [150 mm] diameter interbedded with micaceous arkose. This arkose contains boulders of itself up to 2 feet [0.6 m] diameter.

In the West Gawler River at 9168N [49/097168] the formation overlies the Motton Spilite and contains in addition to the chert angular pebbles of spilite and boulders up to 2 feet [0.6 m] diameter in a matrix of brecciated chert. Typically associated with the breccia in this locality is a hard, blue, coherent siltstone, showing lenticular structure noted as common in less highly indurated rocks, and also showing contemporaneous slumping.

This breccia is well exposed in the Leven Gorge, where it contains occasional lenses of spilite breccia. A very common constituent, almost characteristic, is limestone. A very similar breccia outcrops in the Gawler River at the fork of the Gawlers interbedded with tough, blue, laminated shale with strong fracture and axial plane cleavage. Here the breccia contains keratophyre pebbles, and boulders of limestone up to 6 inches [150 mm] diameter which are mineralised at the Duncan McLarens mine. The underlying rocks are cherts and volcanics.

Limestone is absent in the south but begins to appear in the formation as it approaches the north-east and becomes progressively more abundant and larger. This suggests the limestone pebbles are derived from the north-east and could conceivably be Cambrian limestone from the shelf region.'

BOTT CONGLOMERATE

Several hundred metres of mainly quartz conglomerate occurs in the vicinity of Lower Barrington. These rocks, which appear to underlie the Gog Range Greywacke, resemble Ordovician conglomerate and have been the subject of some discussion by earlier workers. Based on the evidence given by Burns (1957), the formation is regarded here as of Cambrian age, conformably underlying and interfingering with the Gog Range Greywacke. It represents an influx of siliceous material into the basin from Precambrian source areas to the north and north-east during or following the uplift of the Barrington Ridge. Burns (1957) described the Bott Conglomerate as 'the thick conglomerate occurring in the bed of Aitken Creek between Nook and the Don River. This conglomerate is about 700 feet [215 m] thick, and outcrops in the Bott Gorge and near Buster Road. North of Buster Road claystone breccias considered equivalent to this conglomerate make a 60° unconformity with the Ordovician rocks. The rock is a greywacke conglomerate consisting of rounded boulders and pebbles of Precambrian rocks ranging from ¼ inch [6 mm] up to 6 inches [150 mm] diameter, averaging about one inch [25 mm] and constituting 50% of the rock in a matrix that is sometimes schistose, due to the high proportion of flakes of green schist, and sometimes quartzose. The siliceous phases strongly resemble the Owen Conglomerate, and have been considered as such by all previous workers in the area. The conglomerate is interbedded with the underlying Cambrian formations .... The pebbles include quartzite, banded quartzite, dolomite, and other less common rocks such as biotite schist and possibly mineralised matter, but the bulk of the pebbles are mica and chlorite schist.

The rounded quartzite pebbles occurring in a poorly sorted rock like this suggest that they are recycled and the source is probably a Precambrian conglomerate such as outcrops on the Clerke Plains Road at Kindred. Microscopically, the pebbles show strong shearing with the development of quartz augens. The matrix contains shreds of chlorite and rounded, anhedral quartz with calcite in veins.'

GOG RANGE GREYWACKE

Upstream from The Big Bend on the River Forth, the Barrington Chert passes conformably upwards into a sequence of argillaceous chert, siltstone and greywacke, including numerous beds of chert pebble conglomerate. Towards the top of the greywacke suite, volcanic material appears interbedded with the greywacke, which eventually passes upwards into a thick sequence of acid volcanic rocks.

This largely greywacke sequence, which is at least 600 m thick, lies between the Barrington Chert and the Minnow Keratophyre and has been named the Gog Range Greywacke. The boundaries of the formation are difficult to define precisely. At Barrington, it overlies the chert directly but in the vicinity of Leven Gorge it overlies the Motton Spilite and Sprent Formation, whilst at Lower Beulah it overlies the Beulah Formation. It is considered as an influx of turbidite sediments into the basin concomitant with the uplift of the Barrington Ridge and associated vulcanism. The conglomerate members in the formation are frequently graded and contain fragments of the underlying rocks.

In most areas, the formation contains volcanic members, particularly towards the top. These rocks are usually acid types related to the keratophyre suite. At the Star of the West mine near Lower Beulah, the greywacke is interbedded or interfingered with the overlying Minnow Keratophyre, which in turn contains numerous sedimentary intercalations. The Gog Range Greywacke represents a period of deposition during which only minor volcanic activity occurred between the extrusion of mainly basic to intermediate volcanic rocks below and the acid vulcanism of the Minnow Keratophyre above. Since both the overlying and underlying volcanic assemblages contain sedimentary units, it will be apparent that the boundaries of the formation are ill defined and may vary in age from place to place. For the purpose of mapping, the formation boundaries have been chosen at those places where the volcanic content regionally becomes dominant.

Burns (1957) noted dendroids and minute brachiopods in correlates of this formation on the south bank of the Don River near Barrington, causing Banks (*in* Burns, 1957 p.53) to suggest a probable Upper Cambrian age for the formation. A boulder of greywacke from the Mersey River near Weegeena, which could only have come from this formation, yielded *Pseudagnostus* and other trilobites which suggest an Upper Cambrian age (Öpik, pers. comm). Banks (1956) and Burns (1962) recorded *Clavagnostus, Lejopyge laevigata* (Dalman) and *Kormagnostus* in correlates of the Gog Range Greywacke at Leven Gorge. Thus although the palaeontological evidence is sparse, it suggests an Upper Cambrian age.

At the Star of the West mine workings, the typical rock is fine-grained, light brown and slightly weathered, with white spots 1-2 mm across due to weathered feldspar crystals. In thin section, it consists of a fine sericite matrix stained brown by iron oxides containing angular fragments of quartz, feldspar and quartzite.

Some dense rocks resembling chert occur in the same area. These consist of euhedral and somewhat rounded or irregular crystals of feldspar and fragments of quartz in a fine-grained quartzo-feldspathic groundmass.

A specimen from this formation in the vicinity of West Kentish consists of sub-rounded fragments of shale and angular fragments of quartz and quartzite in a sericitic matrix. The fragments vary in size from about one millimetre down to the limits of visibility. Occasional grains of glauconite are present but feldspar is rare.

Elsewhere, the formation contains thick members of yellow argillite interbedded with greywacke siltstone and conglomerate. The pebbles in the conglomerate are usually chert toward the centre of the basin but quartz, quartzite and lavas are the more common phenoclasts away from the axial region.

Burns (1957) described a sequence of soft yellow shale with some tuff and greywacke in Aitken Creek and this is correlated with this formation. At this locality, the formation contains thick quartz conglomerate beds or lenses and it is associated with the Bott Conglomerate. It is possible that the conglomerate is simply a facies of the Gog Range Greywacke in that area.

Greywacke and greywacke conglomerate in graded beds are interlayered towards the top of the sequence north of 49/000070 on the River Forth. The succession is confused but it appears to pass from acid volcanic rocks downwards through a sequence of fine-grained conglomerate and pyroclastics with increasing grain size in the conglomerate. The conglomerate contains rounded and sub-rounded fragments of white and purple quartzite, lava, porphyry and slate set in a greywacke matrix. The matrix contains clastic euhedral β-quartz crystals characteristic of the Minnow Keratophyre, indicating that there may be an overlap in time between the two formations. Further north, the conglomerate contains beds of greywacke with lenses of conglomerate which often show a disrupted framework. The conglomerates range from 70% pebbles and 30% matrix to 20% pebbles and 80% matrix. The phenoclasts are up to 300 mm across and consist of lavas, tuff, slate and greywacke as well as pink and white quartzite. This sequence forms a transition zone between 15 and 30 m thick consisting of 0.6 m thick beds of greywacke and conglomerate with turbidite characteristics which overlie a quartz conglomerate about 18 m thick. This conglomerate has a closed framework and consists of pebbles of quartzite with a minor proportion of slate, greywacke and porphyry which makes up 90% of the rock. The whole sequence is about 90 m thick. Purple greywacke conglomerate with a few siltstone and greywacke sandstone beds occurs on the River Forth west of Staverton. The conglomerate contains pebbles of keratophyre, slate and fine-grained greywacke. Further upstream, the formation consists of greywacke with some slate and, occasionally, pebbly sandstone and conglomerate before passing upwards into sheared porphyry. The southern boundary consists of sheared porphyry containing a few bands of slate and greywacke about 300 mm thick.

In the Leven Gorge area, east of Gunns Plains, Burns (1957) mapped the following sequence:

			Thickness (m)
Radfords Creek Group	(1)	Mudstone and sandstone	60 top
	(2)	Applebee Volcanics	60
	(3)	Mudstone with chert conglomerate	120 bottom

This is considered to be equivalent to the Gog Range Greywacke in the Sheffield area. The Applebee Volcanics is keratophyric and in that area can be traced for some distance from the north-west corner of the Sheffield Quadrangle into the Dial Range district. Burns' sequence is terminated above by the Beecraft Megabreccia which is probably restricted to that area.

The Applebee Volcanics is petrologically similar to the Minnow Keratophyre and may be equivalent. If so, it suggests that greywacke sedimentation was largely terminated in the south-east of the area with the advent of the Minnow vulcanism, but was only temporarily halted in the north-west by the Applebee vulcanism. With the resumption of quiet conditions, renewed greywacke sedimentation occurred. The vulcanism possibly took place earlier in the Gunns Plains area and later spread toward the south-east portion of the basin.

MINNOW KERATOPHYRE

Along the Gog Range, the Gog Range Greywacke is transitionally succeeded by a thick sequence of acid volcanic rocks. As described elsewhere (Jennings, 1963), the upper limit of these rocks is difficult to define. They are overlain unconformably by Ordovician conglomerate in many areas and in the few areas where an upper boundary may be expected, the rocks are strongly sheared and hydrothermally altered.

The formation consists of a large thickness of soda-rhyolite, keratophyre, tuff and subordinate greywacke. It overlies the Gog Range Greywacke near Lower Beulah but may be coeval with similar rocks in the vicinity of Leven Gorge. At Beulah, the most common rock is a hexagonally jointed quartz-feldspar porphyry, sometimes containing hornblende. Analyses and petrographic descriptions of this rock have been given elsewhere (Jennings, 1963, p. 52). In the River Forth between 48/150970 and 48/135950 and near Bell Mount, the rocks are strongly sheared and the original texture is destroyed, although phenocrysts of β-quartz can usually be recognised in a sheared groundmass. In addition to this dynamic alteration, much of the porphyry has suffered considerable hydrothermal alteration.

Rocks correlated with this formation occur in the River Forth between the confluence of Claude Creek and 48/135950. These consist principally of sheared feldspar porphyry containing the euhedral β-quartz crystal characteristic of the formation, together with pink feldspar up to 5 mm across. Occasional blotches resembling boulders and phases similar to the Bull Creek Formation are present.

The uppermost part of the formation is exposed in the River Forth downstream from the Cethana Dam. This section begins with a faulted boundary between Ordovician rocks to the south against brecciated and re-cemented Cambrian chert to the north. Further downstream the chert is less brecciated and about 100 m below the dam it passes into chert interbedded with tuff and sheared porphyry. Grey and pink quartz feldspar porphyry is exposed near the mouth of Claude Creek. The phenocrysts in the porphyry are of pink feldspar, ranging in size from about 1-5 mm across, and β-quartz.

Here the porphyry is somewhat blotchy, due to either xenoliths or basic segregations, and the rocks resemble the Geales Bridge Member of the

Bull Creek Formation of Burns (1961). Since no continuous section can be traced from the Minnow Keratophyre to the Bull Creek Formation due to interrupted sequences, it must be conceded that they could be equivalent. If this is so, the Lorinna Greywacke appears to pass conformably and transitionally downwards into the Bull Creek Formation which then becomes either a facies variant or a somewhat more pyroclastic and hydrothermally altered unit at the top of the Minnow Keratophyre.

LORINNA GREYWACKE

As discussed elsewhere (Jennings, 1963, p.39), the stratigraphic position of this formation within the Cambrian sequence has not been rigidly established. The formation consists of a mixed assemblage of greywacke, chert and porphyry which may lie above the other Cambrian formations or may be a facies restricted to the southern margin of the Palaeozoic trough.

Downstream from the Cethana Dam, brecciated chert cropping out in the River Forth between the Moina Sandstone and correlates of the Minnow Keratophyre is assigned to this formation. A somewhat similar sequence is poorly exposed on the northern slopes of Black Range and this has also been assigned to the Lorinna Formation. At this locality, the rocks consist of fine-grained sheared and altered volcanic rocks and porphyry interbedded with pale grey chert which is exposed in washouts along the track to the old Devonport gold mine.

BULL CREEK FORMATION

Small areas of rocks assigned to this formation occur along the southern margin of the quadrangle and are continuous with the outcrops described previously in the Middlesex Quadrangle. No significant differences have been noted in the rocks in this area and the reader is referred to the earlier account of this formation (Jennings, 1963, p.41).

Ordovician

Ordovician rocks unconformably succeed the Cambrian System along the north facing slopes of Mt Claude. The best exposure is in a road cutting along the old Lorinna road near Cethana (Jennings, 1958, fig. 3), where there is a structural discordance across the boundary and the basal Ordovician conglomerate contains fragments of the underlying Cambrian rocks. A similar relationship occurs on the Gog Range, in Leven Gorge and near Kindred and is inferred over the remainder of the area.

The Ordovician System has been subdivided into the following units:

		Thickness (m)
	Gordon Limestone	0-600
Magog Group	Moina Sandstone	245
	Roland Conglomerate	0-275
	Dial Conglomerate	

The stratigraphic nomenclature concerning these units has been discussed elsewhere (Jennings, 1958, 1963). The Moina Sandstone includes the Caroline Creek Sandstone of Stephens (*in* Etheridge, 1883) which contains a fauna of Tremadocian age. The upper part of the Gordon Limestone in the Gunns Plains district is probably Upper Ordovician age (Banks, 1962). In the vicinity of Gunns Plains, the limestone is succeeded by a quartz sandstone formation correlated with the Crotty Quartzite, which is elsewhere regarded as being of Lower Silurian age. Thus, although the information regarding the age of the top of the sequence is not precise, the succession appears to span the whole of the Ordovician in this quadrangle.

ROLAND CONGLOMERATE

This formation is a lenticular body of quartz conglomerate which varies in thickness from a few metres up to a maximum of about 300 m. The formation thins out rapidly in the south-west corner of the quadrangle and is overlapped by the Moina Sandstone further south. The conglomerate is 240-300 m thick along the Fossey Mountains, about 275 m on The Badgers and about 200 m in Leven Gorge (Burns, 1957).

Detailed lithological descriptions of the Roland Conglomerate in this area have been given elsewhere (Jennings, 1958, 1963). Briefly, the formation consists of thick beds of white, pink and purple quartz conglomerate interbedded with occasional thinner beds of white and pink quartzite. Except for the basal beds, the pebbles are almost exclusively siliceous, consisting of reef quartz, quartzite and quartz schist set in a dense, frequently recrystallised fine-grained siliceous matrix. The conglomerate is well sorted, sometimes showing a rough imbricate texture and rarely cross-bedded. The pebbles are almost always subrounded to rounded. Apart from local variations in the basal beds and the variation in colour due to varying amounts of finely divided hematite, the lithology of the formation is fairly consistent. However local variations in grain size occur between adjoining beds.

The basal beds overlying the unconformity sometimes reflect the composition of the underlying Cambrian rocks. At Cethana, where the formation overlies argillite, the matrix is argillaceous and fragments of argillite are included in the lowest bed. On the Gog Range, the conglomerate succeeds purple keratophyre and the lowest beds are made up of keratophyre boulders in a keratophyric matrix; the actual unconformity is difficult to identify. In other areas the unconformity is not exposed and the lowest exposed beds consist of normal quartz conglomerate.

Hills (1915) and Campana *et al.* (1958) suggested a terrestrial origin for correlates of this formation because of the lack of fossils, the presence of 'red beds', texture and distribution. The notably elongate distribution and changes in thickness and facies are rather more subdued in the Sheffield area, although Burns (1965) described similar features for the correlate of the Roland Conglomerate a few kilometres north-west of Sheffield along the Dial Range. The lack of fossils and the lenticular distribution of this formation suggests a terrestrial environment for deposition in the Sheffield area.

MOINA SANDSTONE

The Roland Conglomerate is overlain by a sequence of quartz sandstone and shale with minor grit and some conglomerate beds. This unit has been termed the Moina Sandstone following Twelvetrees (1913) and includes the Caroline Creek Beds of Stephens (*in* Etheridge, 1883). It probably also includes the Florentine Valley Mudstone of Etheridge (1904). The stratigraphic nomenclature concerning this unit has been discussed elsewhere (Jennings, 1957, 1958, 1963).

The Moina Sandstone crops out widely throughout the Sheffield district and forms the tops of several mountains. The formation is about 300 m thick, but no undisturbed sequences have been measured and the thickness given has been obtained by unwinding folded sequences which are also commonly faulted. Regional mapping indicates that no large scale variations in thickness occur in the Sheffield area.

At Caroline Creek, a fairly abundant marine fauna of Tremadocian age has been described by Stephens (*in* Etheridge, 1883) and by Kobayashi (1940). Brachiopods of uncertain age have been noted near Round Mount and in the vicinity of Bell Mount. The Moina Sandstone indicates a change in the depositional environment from the unfossiliferous and probably terrestrial deposition of the Roland Conglomerate. Jennings (1958, 1963) recorded the presence of at least two thin horizons of pyritic spherulites in the formation. Characteristic of the formation is the presence, in certain beds, of abundant tubicolar casts, worm burrows orientated at right angles to the bedding and from which the original name for the formation, the 'Tubicolar Sandstones', was derived.

The structure of the Moina Sandstone has been described in detail by Jennings (1958).

DIAL CONGLOMERATE

The Roland Conglomerate and Moina Sandstone are difficult to separate in the vicinity of Barrington and along the northern edge of the Sheffield Quadrangle. In these areas, the Ordovician rocks below the Gordon Limestone consist of interbedded quartz conglomerate and sandstone which are lithologically similar to both the formations described earlier. For this reason, the writer has grouped the rocks in these areas together under the formation name of Dial Conglomerate, following the usage of Twelvetrees (1903). The Dial Conglomerate, later redefined as the Dial Group by Burns (1965), is therefore stratigraphically similar to the Magog Group of Johnston (1888) as used by the writer in the Middlesex Explanatory Report (Jennings, 1963). Burns (1965) considers the source area for the material comprising the two groups as quite distinct.

Paterson (1959) described exposures of correlates of the Dial Conglomerate in the River Forth north of Devils Gate as 'interbedded sandstone and quartzite with 6-inch [150 mm] bands of conglomerate near the base of the section. The conglomerates are formed of subrounded quartz pebbles ranging in size from ¼-¾-inch [7-20 mm]. The sandstones are current bedded in part and the bedding varies from flaggy to massive (up to 6 feet) [1.8 m].'

GORDON LIMESTONE

This formation conformably overlies the Moina Sandstone at Gunns Plains, Railton, Moina, Paloona, along the upper River Leven and in the underground workings of the Round Hill mine. At Gunns Plains, the limestone is overlain by a sandstone sequence which is considered to be equivalent to the Crotty Sandstone.

Banks (*in* Hughes, 1957) noted that fossils 100 m stratigraphically above the base of the limestone at Railton were considered to be of Chazyan or Mohawkian age. At Gunns Plains, Banks (*in* Hughes, 1957) described a fauna from beds cropping out on the hillside above the caves and which he considered suggested an Upper Ordovician age.

The maximum thickness of the limestone in this region is about 1000 m at Gunns Plains. The sequence at Railton is incomplete and the writer considers that the outcrop data indicate a thickness of 700 m. Hughes (1957) suggested that the incomplete sequence near Loongana contains 450-600 m of limestone. The smaller outcrops at Moina and Round Hill are much dissected and only a small thickness remains.

Lithological descriptions of the limestone occurrences in the Sheffield Quadrangle are given by Hughes (1957). Generally , the formation consists of thick, massive beds of fairly pure blue-grey fine-grained limestone. Occasionally, the limestone is highly sheared and somewhat schistose. Wide veins, knots and stringers of crystalline calcite are fairly common in large exposures. The limestone appears to range in composition from 60 - 95% $CaCO_3$, with common impurities of Al_2O_3, SiO_2, MgO and iron oxides. The quality of the limestone at Railton is suitable for the manufacture of portland cement, with the plant of the Goliath Portland Cement Company being in operation since 1923.

Deep weathering in limestone areas is common and outcrop is rare, particularly near Railton. Caverns have been opened up as a tourist attraction at Gunns Plains and solution cavities are exposed in the quarry at the Goliath Portland Cement Company, Railton.

Metasomatic and contact metamorphic alteration of the transition zone beds at the base of the Gordon Limestone has resulted in the formation of variable skarn assemblages in the Stormont, Ti-Tree Creek, Moina and Tin Spur Creek areas.

Webb (1974), using X-ray diffraction methods, described the garnet skarn (in the Moina and Ti-Tree Creek areas) as consisting mainly of garnet (andradite-grossular) and pyroxene (diopside-hedenbergite), whilst the garnet skarn at the Stormont bismuth mine is composed of garnet (andradite) and actinolite.

Webb (1974) and Askins (1978) have presented detailed descriptions of the magnetite-fluorite skarns occurring mainly at Moina; these skarns are extremely fine grained and have a complex composition including the following accessory minerals: feldspar, ferrohastingsite, epidote, biotite, vesuvianite, sericite, chlorite, pyrite, pyrrhotite and arsenopyrite. The mineralogy of the skarn, particularly fluorite mineralisation, is discussed in more detail on Page 82.

Silurian

1.5 km south-east of the caves at Gunns Plains, the Gordon Limestone is overlain, apparently conformably, by a white sandstone. The upper portion of the sandstone is obscured by basalt talus. No fossils have been found in the sandstone but fossils in the Gordon Limestone nearby indicate an Upper Ordovician age. This suggests that the sandstone is possibly Silurian and equivalent to the Crotty Sandstone.

Permian

The occurrence of coal and oil shale in the vicinity of Railton and Latrobe and the Don River - Nook area stimulated interest in the Permian rocks of this area from the earliest days of settlement. In 1855, A.R.C. Selwyn, the Government Geologist of Victoria, made a study of the coal deposits in the Bott Gorge - Denny Gorge (Devonport Quadrangle) areas along the Don River (Selwyn, 1855). Gould (1861), Thureau (1883), Johnston (1888, 1900), Twelvetrees (1909*a*, 1911), Hills *et al.* (1922), Reid (1924), Nye (1933), Blake (1931, 1937*a*) and others studied or commented on various aspects of the coal and oil shale deposits in the Sheffield and Devonport Quadrangles. The history of coal mining in the Devonport Quadrange is detailed by Burns (1965). Although coal mining ceased in the Sheffield Quadrangle in 1944 and Devonport Quadrangle in 1960, active exploration of the oil shale deposits is still being undertaken.

In spite of all this geological field work, together with a considerable volume of information obtained from drilling, the stratigraphy of the Permian rocks in this area has not yet been rigidly established. This is due to the lack of natural outcrop, the paucity of fossils throughout most of the sequence, the uncertainty regarding the positions of some of the early bore holes, and the inaccuracy of the bore logs. The map has been compiled from somewhat fragmentary field data combined with a study of the early geological reports and drill results.

For mapping purposes, the Permian sequence in the Sheffield Quadrangle has been subdivided in the following manner:

Unit	*Approximate thickness (m)*
'Ferntree Group'	120+
'Woodbridge Group'	60
Mersey Coal Measures	30
Basal Beds	75-180+

Other authors working in this area have adopted different subdivisions. The probable relationship between the stratigraphic units used by the various workers both locally and in adjoining areas is shown in Figure 4.

BASAL BEDS

This unit includes all the marine rocks below the Mersey Coal Measures. The lack of adequate outcrop in the Sheffield Quadrangle precludes a subdivision of this sequence. In adjoining quadrangles, rocks below the Mersey Coal Measures often comprise several distinct and mappable lithological units and have been variously subdivided (fig. 4). The lack of uniform nomenclature is a consequence of rapid lateral facies changes. The similarity of stratigraphic position below the Mersey Coal Measures (Liffey Sandstone), together with palaeontological considerations, provide the basis for correlation rather than strict lithological comparisons.

The best exposure of the lowermost basal beds is at The Great Bend on the Mersey River. Here the base of the sequence consists of a boulder conglomerate (tillite) containing fragments of Ordovician limestone and Cambrian volcanic rocks, as well as quartzite and other exotic rock fragments set in an abundant silty-sand matrix. The conglomerate is exposed for only a few metres above river level and the base of the unit is not seen.

The conglomerate and tillite at this locality are overlain by about 20 m of dark grey to bluish-grey mudstone containing few pebbles and very rare fossils. This unit appears to be lithologically similar to the Quamby Mudstone in its type area (Wells, 1957; Clarke, 1968).

MERSEY COAL MEASURES

Coal was first discovered in the Sheffield Quadrangle in the Bott Gorge in 1850 and the first recorded production in the area was in 1853. Production from the whole of the Mersey Coalfields, including Dulverton and Nook, was approximately 480 000 tonnes. The last operating mine in the area was the Illamatha No. 2, which ceased production in 1960.

The coal seam which has been worked averages about 0.6 m in thickness. The horizon within which it is contained is overlain by a sandstone member and the floor is usually of sandstone with occasional mudstone lenses. Burns (1965, fig. 19-21) shows correlated bore results and other details of the coal basin.

QUAMBY Barton *et al.* 1969	BEACONSFIELD Gee and Legge 1974	DEVONPORT Burns 1963*a*	DU CANE Jennings *et al.* 1961	MIDDLESEX Jennings and Burns 1958	SHEFFIELD Jennings *et al.* 1959
Bogan Gap Group	Clog Tom Sandstone Middle Arm Group	Kelcey Tier Beds	Ferntree Group	Ferntree Group	Ferntree Group
Poatina Group	West Arm Group		Woodbridge Group	Woodbridge Glacials	Woodbridge Group
Liffey Group	Liffey Sandstone	Mersey Coal Measures	Mersey Group	Liffey Sandstone	Mersey Coal Measures
Golden Valley Group Quamby Mudstone Stockers Tillite	Masseys Creek Group	Spreyton Beds Basal conglomerate	Wallace River Group Basal conglomerate	Kansas Creek Beds	Basal Beds

Figure 4. *Lithological units used in 1:63 360 map sheets, northern Tasmania.*

The total thickness of the coal measures can only be estimated from the old drilling records. Burns (1965) estimates that for the Devonport district, the total thickness lies between 19.2 and 29 m. In 1934, the Department of Mines put down a series of bores at the 'New Bed' coalfield at Dulverton, which indicated a possible thickness for the Mersey Coal Measures of about 36 m. From an interpretation of all the early drilling records, varying thicknesses may be obtained due to the lack of detailed lithological logging.

Burns (1965) suggested a tripartite subdivision of the coal measures into a 'top' sandstone overlying a 'coal horizon' which in turn overlies a 'bottom sandstone'. From the drilling records, this division appears to hold reasonably well in the Dulverton district. However, in many of the holes, part of the top of the coal measures is missing and in only two holes were the beds underlying the coal measures completely penetrated.

Burns suggested that the 'top' sandstone varied in thickness from 6.4-7.9 m, the 'coal horizon' varied from 1.6-5.5 m and the 'bottom' sandstone was of unknown thickness. The drilling at Dulverton indicates that the thickness of the corresponding units there are 'top' sandstone 16 m (maximum thickness), 'coal horizon' 1.85-4.5 m and the 'bottom' sandstone 12.8-19.8 m.

The top and bottom sandstones appear to be persistent units within the area studied. The coal horizon consists of interbedded mudstone and shale units with the coal occurring overlying the bottom sandstone.

Outcrops of this group within the Sheffield Quadrangle are very poor and the areas indicated on the map are based upon scanty field evidence. Early bore hole records from this area indicate that the Mersey Coal Measures are overlain by a variable sequence of fossiliferous marine siltstone and sandstone. This general succession is in agreement with the succession described to the south of this area along the face of the Western Tiers in the Middlesex Quadrangle (Jennings, 1963). Consequently, the marine unit overlying the coal measures has here been correlated with the 'Woodbridge Group' in conformity with the usage adopted for the Middlesex Quadrangle.

The marine sequences within the Permian system in this area have been the subject of some controversy over the years. Early workers such as Twelvetrees (1911) and Reid (1924) regarded the Permian system as being made up of four main units; an upper marine mudstone overlying coal measures, lower marine mudstone and a basal conglomerate, sandstone and limestone unit.

This interpretation of the Permian sequence was retained by Voisey (1938), who accepted the previous stratigraphy but amended the nomenclature to:

(1) Upper Latrobe stage, consisting of marine mudstone and sandstone.
(2) Mersey Coal Measures or Tasmanite stage.
(3) Lower Latrobe stage, consisting of marine conglomerate, pebbly sandstone and mudstone.
(4) Basal glacial stage, consisting of conglomerate and sandstone without fossils.

Since all these workers based their stratigraphy upon the assumption that the Permian system contained only two marine sequences (the Upper and Lower Marine or Latrobe stages), they were forced to accept the conclusion that the Tasmanite and coal beds were equivalent. This assumption was retained despite the evidence from the Adelaide Oil Exploration Company Bore No. 4 drilled at Native Plains, which demonstrated that these two units occurred within the one bore separated by more than 150 m of marine sediments (Reid, 1924, p. 84).

Twelvetrees (1911, p. 23) sets out the faunal lists for the 'Upper' and 'Lower Marine' beds of this district upon which the identification of these units was based. Most of the localities assigned by Twelvetrees to the 'Upper Marine' are now known to occur in the Lower Marine (Basal Beds). The sole exception may be the locality reputedly 'above the coal at Caroline Creek'. The only exposure in this area at present (Haines brick pit) shows mudstone with rare *Eurydesma* and Tasmanite Oil Shale (Banks, 1965); if this is the same locality as that quoted by Twelvetrees, then it too belongs in the Lower Marine. In either case the record by Twelvetrees of *Dielasma* sp. (= *Fletcherithyris* sp. or *Gilledia* sp.) and *Fenestella* sp. is inconclusive.

There is no firm evidence that Twelvetrees had access to, or recognised any specific fossils from the beds which have been assigned in this publication to the 'Woodbridge Group'. The author considers that of the bore holes included in Reid's (1924) work, the following intervals are indicative of the presence of the 'Woodbridge Group'.

Page		*From (ft)*	*To (ft)*
110	Adelaide Oil Exploration Company Bore No. 6. Mudstone with marine fossils.	54	138
108	Section at Don coal shaft. Blue marl with abundant remains of marine fossils.	36	57
85	Adelaide Oil Exploration Company Bore No. 10. Half mile [800 m] east of Merseylea Bridge. Fossiliferous mudstone.	21	222
74	Mersey Valley Oil Company Bore No. 4. Sandstone, mudstone and pebbly mudstone with marine fossils.	71	209

All the above intervals directly overlie the Mersey Coal Measures. In this work, the Mersey Coal Measures are correlated with the freshwater sequence (Liffey Sandstone) of the Western Tiers. Consequently, the marine sequence which overlies the coal measures in the Sheffield Quadrangle is regarded as the correlate of the marine sequence ('Woodbridge Group') which directly overlies the non-marine sequence in the Middlesex Quadrangle.

'FERNTREE GROUP'

Along the western flanks of The Long Hill, 0.5 km east of Merseylea, and around the upper slopes of Bonneys Tier, fairly extensive sequences of unfossiliferous pebbly siltstone, siltstone and sandstone occur. The outcrop in these areas is poor and the precise stratigraphic position is difficult to establish. However early bore holes in both of these areas indicate that these rocks can be expected to overlie the marine 'Woodbridge' unit and that they are lithologically similar to rocks of the 'Ferntree Group' which occur along the face of the Western Tiers to the south of this area. They have therefore been correlated with the 'Ferntree Group' of the Middlesex Quadrangle.

PALAEONTOLOGY

M.J. Clarke

Recent deep trenching and pipeline installations by Associated Pulp and Paper Mills Ltd has greatly clarified the Permian sequence at The Great Bend of the Mersey River. The section comprises a basal tillite which passes laterally into conglomerate (seen to about 4.5 m, base not exposed); dark grey, poorly-bedded, spheroidally-weathering pyritic mudstone with few pebbles and without fossils (23 m); Tasmanite Oil Shale in four bands (1.5 m); pale grey siltstone (47 m); and ochreous and khaki-coloured, very pebbly siltstone with lesser sandstone and shale (seen to 33.5 m). The top of this sequence is at least 45 m below the base of the Mersey Coal Measures, assuming a thickness of 150 m for the Basal Beds at The Great Bend (Burns, 1965). Fossils occur at several levels. The Tasmanite Oil Shale yields strophalosiid fragments, *Streptorhynchus* sp., *Etheripecten* spp. including *E. tenuicollis* (Dana), *Eurydesma hobartensis* (Johnston), *Megadesmus pristinus* Runnegar, *Merismopteria* sp., and *Peruvispira* sp. Immediately above the Tasmanite horizon *Trigonotreta stokesi* Koenig, *Schuchertella* sp., *Neoschizodus australis* Runnegar and *Keeneia twelvetreesi* (Dun) occur in addition to the previously listed forms. The ochreous siltstone and sandstone 47 m above the Tasmanite Oil Shale is richly fossiliferous. The fauna includes *Trigonotreta stokesi* Koenig, a syringothyroid cf. *Cyrtella nagmargensis australis* Thomas, *Martiniopsis konincki* Etheridge, *Strophalosia* sp. nov., *Deltopecten illawarensis* (Morris), *D. waterfordi* Dickins, *Eurydesma hobartensis* (Johnston), *Etheripecten* spp., *Megadesmus pristinus* Runnegar, *Neoschidozus australis* Runnegar, *Pyramus laevis* (J. Sowerby), *Stutchburia* sp., *Keeneia ocula* (J. Sowerby), *K. twelvetreesi* (Dun) and *Peruvispira* sp.

These faunas unequivocally demonstrate a broad correlation with the Allandale Fauna in New South Wales (Runnegar, 1969) and other 'Lower Marine' sequences elsewhere in Tasmania. A more detailed correlation is less evident. Lithologically, those mudstones between the tillite and the Tasmanite Oil Shale are similar to the Quamby Mudstone, whereas the fossiliferous beds above most closely resemble the lower parts of the Golden Valley Group in the Quamby Bluff area. Strict temporal equivalence, however, is not implied. Moreover, these beds are considered to be significantly older than the base of the Golden Valley Group at Poatina and Golden Valley (Clarke and Farmer, 1973). Evidently the spread of conditions suitable for the establishment and proliferation of shelly faunas in siltstone and mudstone of 'Golden Valley Group' facies varied in time from place to place.

The recent fossil collections from below the Mersey Coal Measures at The Great Bend largely confirm the accuracy of the determinations listed by Twelvetrees (1911, p. 23). Unfortunately most of this early material has been lost. It seems probable, however, that *Chonetes* sp. is a misidentification of a small *Schuchertella* sp., since chonetids are so far unknown in the Tasmanian Permian. Similarly the record of '*Spirifera tasmaniensis*' Morris probably refers to *Trigonotreta stokesi* Koenig , since *Sulciplica tasmaniensis* (Morris) as currently understood (Armstrong, 1968), is unknown below Fauna II (Dickins et al, 1964). The record of *Productus brachythaerus* G.B. Sowerby 1844, a name which is now invalid (I.C.Z.N. Opinion 486, 1957) from the 'Upper Marine' at Kimberley, must also be treated with caution. *Terrakea brachythaera* (Morris) is a species which typifies Fauna IV elsewhere in Tasmania and eastern Australia and the genus is unknown below Fauna II. Recent collections from the Kimberley locality indicate a typical pre-Mersey Coal Measures (Allandale) Fauna with *Trigonotreta stokesi* Koenig , *Strophalosia* sp. nov., *Deltopecten illawarensis* (Morris), *D. waterfordi* Dickins, *Eurydesma* spp., *Keeneia ocula* (J. Sowerby), *K. twelvetreesi* (Dun) and *Peruvispira* sp. It is possible that the original record of *Productus brachythaerus* G.B. Sowerby refers to *Stophalosia* sp. nov., since the sole extant specimen of Sowerby's species is a strophalosiid. However, since the original Kimberley specimen is now lost the problem cannot be fully resolved.

Tertiary

Terrestrial sediments of Tertiary age within the Sheffield Quadrangle occur interbedded with Tertiary basalt flows and along the floors of the old pre-Tertiary river systems. The main areas of deposition were in the Sheffield-Nook district, at Lower Barrington, south of Paradise and north-west of Warringa.

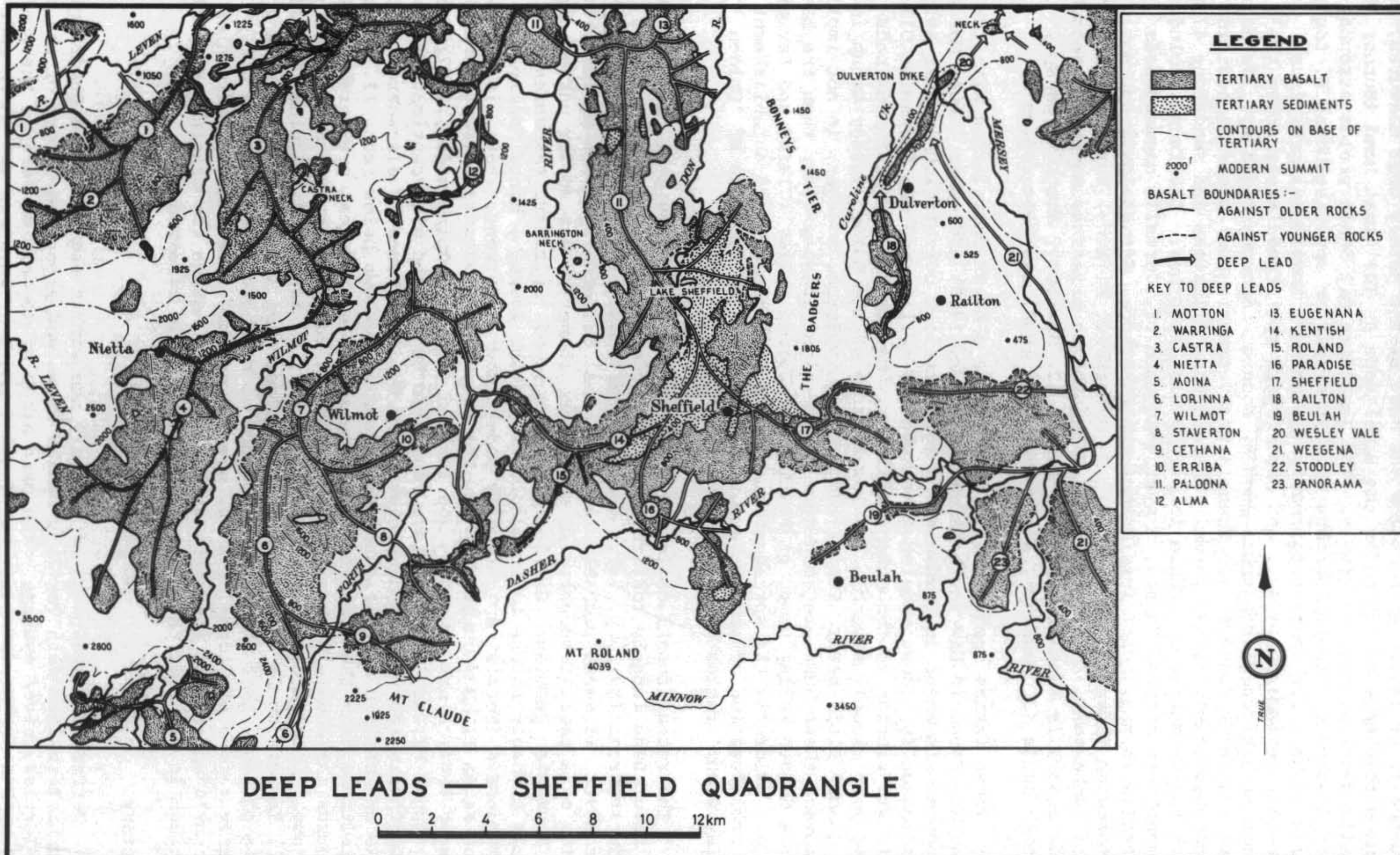

LEGEND
TERTIARY BASALT
TERTIARY SEDIMENTS
CONTOURS ON BASE OF TERTIARY
MODERN SUMMIT
BASALT BOUNDARIES :-
AGAINST OLDER ROCKS
AGAINST YOUNGER ROCKS
DEEP LEAD
KEY TO DEEP LEADS
1. MOTTON
2. WARRINGA
3. CASTRA
4. NIETTA
5. MOINA
6. LORINNA
7. WILMOT
8. STAVERTON
9. CETHANA
10. ERRIBA
11. PALOONA
12. ALMA
13. EUGENANA
14. KENTISH
15. ROLAND
16. PARADISE
17. SHEFFIELD
18. RAILTON
19. BEULAH
20. WESLEY VALE
21. WEEGENA
22. STOODLEY
23. PANORAMA
Nietta
Wilmot
Sheffield
LAKE SHEFFIELD
Dulverton
Railton
Beulah
CASTRA NECK
BARRINGTON NECK
DULVERTON DYKE
BONNEYS TIER
THE BADGERS
MT ROLAND
4039
MT CLAUDE
DEEP LEADS — SHEFFIELD QUADRANGLE
0 2 4 6 8 10 12km
TRUE

Figure 5.

A reconstruction of the pre-Tertiary drainage pattern, obtained from a consideration of the relationship of topographic contours and the distribution of the basalt, has been made by K.L. Burns and R.D. Gee (fig. 5). These authors named both the main drainage channels and the tributary streams. Burns (1957) described the pre-basalt topography as a dissected plateau, the original plateau having a local relief of 215 m at Nook, 150 m at Upper Castra and about 120 m at Gunns Plains. The original plateau level was at 275 m at Nook, near 335 m at Sprent and Preston and probably about 365 m at Riana.

Burns considered that the amount of dissection of the plateau was almost exactly comparable with the present stage of dissection of the Tertiary lava plain. Narrow V-shaped gorges were incised into the plateau, the Paloona Gorge at Lower Barrington being 275 m deep and about 1.6 km across, similar to the present valley of the River Forth. The Paloona and Motton Rivers expanded considerably in limestone, forming valleys nearly as wide and deep as the modern River Leven. A valley at Melrose which was filled with lake sediments has not yet been completely exhumed.

The Paloona River may have risen beyond Staverton and may have flowed through the pre-basalt valley at Lorinna and Moina. The river formed a wide valley at Sheffield but narrowed considerably through the gorge at Lower Barrington. Near Paloona, the river widened on limestone, then turned west to cross the present Forth near the Paloona bridge, entering the sea between Don and Ulverstone. The valley floor had an altitude of 30 m at Paloona and lake sediments are exposed at Nook at 182 m, so the floor of Lake Sheffield lay somewhere in between (Burns, 1957).

Burns considered that the Alma River had its source at Lower Wilmot and ran along the same general course as the present Wilmot, joining the Paloona River at Kindred. The source of the Castra River was south of Upper Castra and the river flowed parallel to the present Camp Creek, joining the Paloona River at Sprent. The Motton River source was somewhere near Loyetea and flowed into Gunns Plains from Riana, forming a wide valley. North of Gunns Plains, the river turned east and breached the Palaeozoic ridge in a narrow gorge between Barren Hill and the Dial Range. This gorge has been exhumed by the present River Leven. The river continued to the east of North Motton, joining the Paloona River near its mouth, which was probably near Gawler. The drainage pattern was therefore markedly different to the modern pattern, being arborescent with the trunk outlet probably at Ulverstone, whereas the modern streams run parallel with separate outlets at the coast. To the east, at the dolerite capped highlands of Bonneys and Kelcey Tiers, the plateau surface was tilted east, which may have represented Tertiary tilting or have been inherited from the Carboniferous. The drainage responded to the tilt, with the largest river (Paloona River) being to the east, against the edge of the highlands. The basalt completely filled this area and may even have overlapped across the top of Bonneys Tier. The massive flows at Nook are remnants of the scarp bordering basalt (Burns, 1957).

Burns (1957) described the Tertiary sediments in the bed of the old Paloona River, where it crosses the Forth, as ferruginous bedded sandstones which have yielded a little gold. On the western bank of the Forth the sediments comprise deeply weathered conglomerate containing pebbles of Cambrian claystone in a matrix of soft red shale overlain by fine white feldspathic sandstone.

Fine white sandstone, similar to that described by Burns, and clay occupy the floor of the pre-Tertiary drainage basin beneath Sheffield. This material was used for the production of bricks in the early days of settlement. At Nook, Burns described a Tertiary sequence at least 15 m thick consisting of laminated feldspathic siltstone containing abundant wood fragments and pieces of bark.

Quaternary

RECENT ALLUVIUM

Extensive alluvial deposits occur along the major river systems. The best developed deposits are those along the Mersey River, particularly in the vicinity of Merseylea where extensive flood plain and terrace deposits occur. These deposits mainly consist of boulders and cobbles frequently exhibiting well developed imbrication and set in a clayey or sandy matrix. The deposits at Merseylea were used as a source of aggregate for concrete by the Hydro-Electric Commission. It is notable that the other major river in the quadrangle, the Forth, contains only local accumulations of alluvial deposits upstream of rock bars along the river. The alluvial gravels and boulders along the Forth contain a very high proportion of Cambrian porphyritic rocks derived from the section of the river below Lorinna. In contrast, the Mersey gravels contain a large proportion of Jurassic dolerite, much of which is probably derived from the re-working of periglacial deposits in the Middlesex and Du Cane quadrangles.

BASALT TALUS AND LANDSLIDE DEBRIS

Extensive deposits of basalt talus and landslide debris occur around the margins of the dissected basalt plateau areas. Active erosion, combined with intensive agricultural practice and the presence within the lava flows of soft plastic clay, promotes the formation of landslides around the margins of the basalt areas. However unlike the talus deposits derived from dolerite, quartzite and conglomerate, the basalt talus usually contains sufficient soil to make it useable for agricultural purposes.

The higher hills capped by dolerite, such as Bonneys Tier and Long Hill, yield extensive talus slopes composed of angular dolerite fragments set in a sparse matrix of soil derived from the weathering of dolerite. Along the north facing slopes of Mt Claude and Mt Roland, widespread and extensive deposits of Palaeozoic quartzite talus and conglomerate boulders intermingled with fragments of Cambrian porphyries and greywacke occur. Some of these deposits reach well out onto the frontal plains and contain boulders more than 6 m in diameter.

IGNEOUS ROCKS

Cambrian

SERPENTINITE

Reid (1919) reported an outcrop of diabase on E.L. Knowles' property, about 1.5 km north-east of Cethana in the Dasher River valley. He described the rock as '.....a fairly fresh looking rock, but under the microscope the mineral components are found greatly altered. Thus the plagioclase has become kaolinised and the hornblende partly altered to serpentine and epidote. The plagioclase shows broad lamellar twin structure, and is frequently idiomorphic. The hornblende is commonly found in allotriomorphic remnants, though idiomorphic crystals are not infrequent'.

QUARTZ DOLERITE

An elongated strip of quartz dolerite occurred on the western bank of the River Forth between 49/189027 and 49/193039. This location was subsequently flooded by the Hydro-Electric Commission as part of their Mersey-Forth power development.

The rock at this location was a medium-grained greyish green rock with visible laths of feldspar and dark prismatic crystals of ferromagnesian minerals.

In thin section, a typical sub-ophitic or dolerite texture is seen with feldspar crystals penetrating amphibolised, chloritised and epidotised ferromagnesian minerals. Biotite is present in ragged plates. Strongly pleochroic iron ore minerals, sometimes in skeletal crystals, are common and may enclose feldspar prisms. Quartz is interstitial and is present in appreciable amounts and apatite is common.

A more felsic and finer grained specimen consisted of an interlacing mass of feldspar crystals with hornblende, epidote and chlorite. Amphibolised, chloritised and epidotised ferromagnesian crystals were not present in sufficient size and quantity to give an ophitic texture. Magnetite, ilmenite, biotite and interstitial quartz were common in the rock.

Devonian

HOUSETOP GRANITE

The fault-bounded eastern extension of the Housetop Granite batholith occurs in the extreme north-west corner of the quadrangle. The rock is generally a coarse to medium-grained pink biotite granite. K-Ar and Rb-Sr age determination on biotite from the granite gave ages of 360-363 Ma and 375 ±10 Ma respectively (McDougall and Leggo, 1965). The rock has been more fully described by Burns (1965), Gee (1977) and Hughes (1953, 1959).

DOLCOATH GRANITE

This granite crops out as a small stock approximately 1.5 km in diameter on the River Forth south of Cethana. The rock is typically a medium to coarse-grained cream to pink biotite granite with common narrow aplite veins and dykes (Jennings, 1958, 1963). Biotite from a single specimen gave a K-Ar age of 345 Ma (McDougall and Leggo, 1965). During intrusion of the granite the basal sections of the Gordon Limestone were metamorphosed and metasomatized to both magnetite-fluorite skarn and garnetiferous skarn, which are exposed in the Stormont, Ti-Tree Creek, Moina and Tin Spur Creek areas (Askins, 1978; Collins, 1975*c*; Jennings, 1958; Webb, 1974). The intrusion of the granite was responsible for the extensive mineralisation of the Round Mount (Jennings, 1958, 1963) and Moina (Collins, 1975*c*) districts.

BEULAH MICROGRANITE

Fine-grained granite and microgranodiorite of varying lithologies intrude Cambrian sedimentary rocks west of Beulah. Five samples from this area have been described by G.B. Everard.

Mersey 2.13.2 [48/319953]

A grey even-grained, medium- to fine-grained rock. In thin section, the rock has an hypidiomorphic granular texture. Essential minerals are feldspar, quartz and hornblende.

Feldspar occurs as two kinds; firstly as cloudy but fairly fresh orthoclase crystals which assert their crystalline forms against quartz, but otherwise tend to be rather irregular. Twinning is simple or absent with parallel extinction. Secondly, there are many somewhat larger rectangular crystals completely altered to sericitic microcrystalline aggregates. This was probably a more basic feldspar but is now unidentifiable.

Hornblende occurs in larger irregular patches and is partly altered to biotite with pleochroic haloes. The sericitised feldspar has an ill-defined ophitic relationship with the hornblende.

Interstitial quartz is fairly plentiful. Accessory magnetite is disseminated through the rock, associated with hornblende and altered feldspar. Rare zircon and apatite also occur. The rock is a microgranodiorite.

Mersey 2.13.10 [48/344961?]

A light coloured medium-grained rock. Crystals of pink feldspar make up most of the rock, with dark yellowish green material between them.

In thin section, the rock has a hypidiomorphic granular texture. Pink orthoclase is the principal mineral with inclusions of oligoclase feldspar and hornblende. Interstitial quartz is prominent. Yellow-green hornblende appears as an alteration of colourless augite, very little of which remains. The hornblende is closely associated with quartz and epidote. A little iron ore, rutile and zircon appear as accessories.

The rock is a granite.

Mersey 2.13.11 [48/342946]

A medium- to fine-grained rock, very similar to 2.13.10, but a little finer grained.

In thin section, the rock differs from 2.13.10 by the presence of biotite and chlorite and a greater proportion of quartz.

Mersey 2.14.1 [48/338943]

A medium- even-grained rock consisting chiefly of pink feldspar crystals and a dark green mineral.

In thin section, the texture is hypidiomorphic with rectangular crystals of interstitial quartz.

The feldspar crystals are oblong in shape, show strong cleavage and are cloudy pink in colour. Extinction is parallel to the cleavage and the axial angle is large. The mineral is orthoclase.

The ferromagnesian mineral is green-brown pleochroic, with characteristic hornblende cleavage. The crystals are largely chloritised.

Quartz is prominent as irregular crystals, filling the interstices between other minerals. A small amount of oligoclase is present as oblong crystals showing multiple twinning. Ilmeno-magnetite is a fairly common accessory disseminated through the section.

The rock is a fine-grained granite.

Mersey 2.14.8 [48/315995]

A light grey medium to fine-grained rock, made up of white and dark green crystals.

In thin section, the rock consists of quartz, feldspar, biotite and hornblende in that order of abundance. The hornblende crystals are the largest in size, then biotite, feldspar and quartz. Feldspar and quartz make a granular groundmass of anhedral crystals averaging 0.1 mm across. The larger feldspars average 0.5 mm; they are euhedral and, unlike those of the groundmass, kaolinised. Orthoclase may be the principal feldspar, but alteration prevents identification. There is a suggestion of graphic intergrowth between quartz and feldspar in the groundmass. Biotite is associated with hornblende and is suggestive of alteration.

The rock is a fine-grained granite.

Jurassic dolerite

D.E. Leaman

Dolerite crops out only in the eastern part of the quadrangle where it is associated mainly with Permian rocks. Some exposures occur wholly in Ordovician or Cambrian rocks in the Beulah-Kimberley region and at these localities the dolerite is in the form of small dykes or plugs. In many cases, such bodies are small, highly weathered and not always unambiguously recognisable as Jurassic dolerite (*e.g.* Minnow River [48/398990], Mersey River [48/413948], Kimberley [49/442020]). Outcrop is rare and basalt or possible basaltic talus occurs nearby. Several of these small intrusions may represent finger roots for the main sheet found in the region. Other low level exposures near Railton [49/360150] and Don River [49/285155] may be pipes for this sheet. Frequent observation of root structures is to be anticipated in such a marginal region where the Permian rocks thin rapidly and variably westward and the basin structure and basement are randomly exposed. Three small bodies north of The Great Bend on the River Mersey have been shown on the map as fault-connected. There is no direct evidence for such a connection although the dislocation at 49/403185 is real and small dolerite plugs commonly occur on pre-intrusion faults elsewhere. If a pre-intrusion control exists, then the body at 49/360115, north of Railton, could also be associated. This body is larger and fans outward to the south. It has not been possible to determine whether many small plug-like bodies have been subsequently faulted as the map implies (*e.g.* 49/413063, 49/390100) or whether the disruption was concomitant or pre-intrusion, since exposure of these smaller bodies is poor and field evidence on texture and contacts unconvincing.

Gravity surveys extending eastward from the Railton-Kimberley area (Leaman, 1973*a*; Longman and Leaman, 1971) suggest major sources east of the Bass Highway (Frankford Quadrangle) and it appears that the dolerite at Sassafras, Bonneys Tier and Merseylea represents fragments of the resulting main sheet, although sources near Railton may be local contributors. There is no evidence of multiple intrusion.

Tertiary basalt

Basaltic rocks occur over approximately 30% of the quadrangle. These rocks cap fresh-water clay, sand and conglomerate deposits of Tertiary age in the Sheffield-Lower Barrington area. Elsewhere within the quadrangle, basaltic flows overlie rocks of virtually all older sequences. As in other places in Tasmania (Sutherland, 1969), the flows are mainly valley fill from numerous small centres rather than extensive flood plain or central volcano types. In some places valleys were overtopped and small lava fields were formed.

One specimen, described by G.B. Everard, was a fine- to medium-grained grey, saccharoidal rock. In thin section, an intergranular texture was prominent with granular titaniferous augite between laths of feldspar. A good deal of olivine in larger rounded crystals with strongly marked cracks occurred. Skeletal crystals of ilmenite were scattered through the section. The rock was an olivine basalt.

Combined with the three analyses listed in Table 2, it appears that, in part, the basaltic flows of this quadrangle comprise mainly alkaline olivine basalt.

Table 2. CHEMICAL ANALYSES OF TERTIARY BASALT

Analysis	1	2	3
SiO_2	46.06	46.30	45.00
Al_2O_3	15.98	13.78	15.05
Fe_2O_3	5.88	3.18	2.43
FeO	7.58	8.57	8.86
MnO	0.09	0.13	0.10
TiO_2	2.27	2.24	1.58
P_2O_5	0.41	0.13	0.08
CaO	6.85	10.50	9.42
MgO	4.92	10.27	10.76
Na_2O	2.28	1.94	1.89
K_2O	0.83	1.26	0.68
H_2O^+	2.59	1.25	3.25
H_2O^-	4.60	1.15	1.15
Total	100.34	100.70	100.25

1. Swimming pool, Sheffield; 370.
2. Volcanic centre, Barrington; 809.
3. Volcanic centre, Upper Castra; 810.

Analyses by Department of Mines Laboratories, Launceston

STRUCTURAL GEOLOGY

The Sheffield Quadrangle lies in the central and north-eastern section of a large north-west trending elongated dome in Lower Palaeozoic rocks rimmed by Precambrian meta-sediments. The outline of this structure is shown by Precambrian rocks north-east of Railton, by discontinuous outcrops, partly obscured by Permian and younger rocks, of Precambrian rocks along the northern portion of the Sheffield Quadrangle and in the Devonport Quadrangle, by the Precambrian rocks to the south in the Upper Forth and Mersey Rivers and in the west by the belt of Precambrian rocks running south from Emu Bay to Natone.

To the south-west, the structure appears to be open and swings away through Lake Lea toward Mt Farrell; it may also have openings to the west toward St Valentines Peak as well as to the north, but these marginal areas are partly obscured by younger rocks. It is noted that no Permian sediments occur within the central portion of the structure, although there are small overlaps on the north-east and eastern margins, many of which are fault bounded. This suggests that this area has been tectonically unstable since the late Precambrian, being depressed more than the surrounding areas during the Palaeozoic but more emergent than the surrounding areas during the Permian. The post-Permian fault systems in the north-east indicate continued emergence of that portion of the structure, probably continuing to the Tertiary.

The overall features of this structure have been described by Jennings (1963) and are shown in Figures 6 and 7. Essentially, Cambrian and Ordovician rocks are deformed into a series of broad east-west trending folds upon which are superimposed a set of major north-west trending folds. The major folds tend to follow the outline of the overall structure around the margins of the dome, forming the main bordering folds of the Dial Range, the Railton Syncline and the Mole Creek Synclinorium.

The development of the basin in which the Lower Palaeozoic rocks were deposited commenced in late Precambrian or early Cambrian time. Although palaeontological data within this area is sparse, it seems reasonable to correlate most of the Cambrian sequence with the Middle Cambrian Dundas Group of western Tasmania. Thus, the basin had commenced to subside by at least the Middle Cambrian and the accumulation of Palaeozoic sediments, perhaps up to a total thickness of 3000 m, had commenced. During the Cambrian, greywacke and volcanic rocks interspersed with lava were deposited, forming a complex sedimentary pile. The cannibalistic nature of many of the Cambrian formations indicates that concomitant uplift and folding accompanied the deposition.

Structural unconformity between the base of the Roland Conglomerate and the underlying Cambrian rocks occurs at Cethana, Tin Spur and other places. The basal Ordovician conglomerate contains pebbles of sheared Cambrian rocks on Mt Claude, in the vicinity of Tin Spur and along the Gog Range. The well marked axial plane schistosity of the Cambrian rocks does not penetrate into the overlying Ordovician System. These features indicate that the Cambrian rocks had suffered extensive deformation before the onset of Ordovician sedimentation. This period of folding appears to correlate with the Jukesian movements in western Tasmania.

Within the Sheffield Quadrangle, the Cambrian rocks consist of a complicated sequence of lenses and wedges of greywacke and volcanic material which have little lateral extent. These features render deductions based on structural geology within the Cambrian System somewhat unreliable. The main structural features of the area are therefore best deduced from the outcrop distribution of the Ordovician and younger rocks.

The structural trends of the Sheffield area and the rock distribution and faulting are shown in Figures 6 and 7. The main first order structural elements consist of a series of roughly east-west trending folds upon which are superimposed north-west trending structures. The main east-west structure is a major anticline trending east through Erriba, Staverton and Claude Road to the vicinity of Stoodley. To the west, the structure is outlined by the outcrop of Moina Sandstone and Roland Conglomerate on the northern and southern flanks of the dome, but it becomes less easily seen in the Cambrian rocks to the east. The influence of the major structure may be readily recognised where it impinges upon the western boundary of the Railton Syncline, causing the hooked outcrop distribution of the Roland Conglomerate in the Stoodley-Beulah area. To the north of the east-west anticline lies a major east-west trending syncline which runs from the Loongana district through South Nietta to West Kentish. Immediately east of Sheffield, the influence of the superimposed syncline on the western margin of the Railton Syncline may be seen by the deflection of the Roland Conglomerate

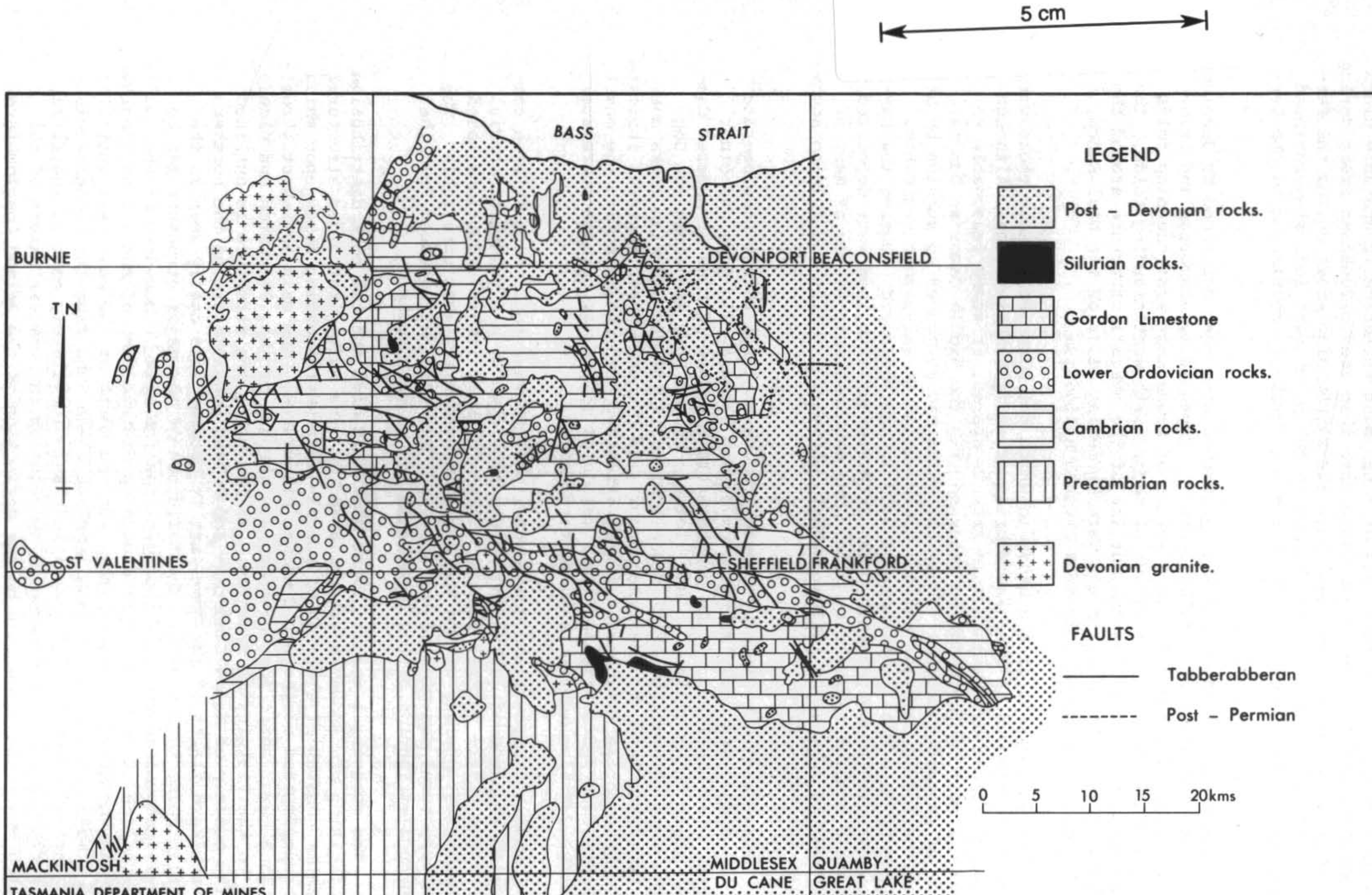


Figure 6. *Rock distribution and faulting, Sheffield area.*

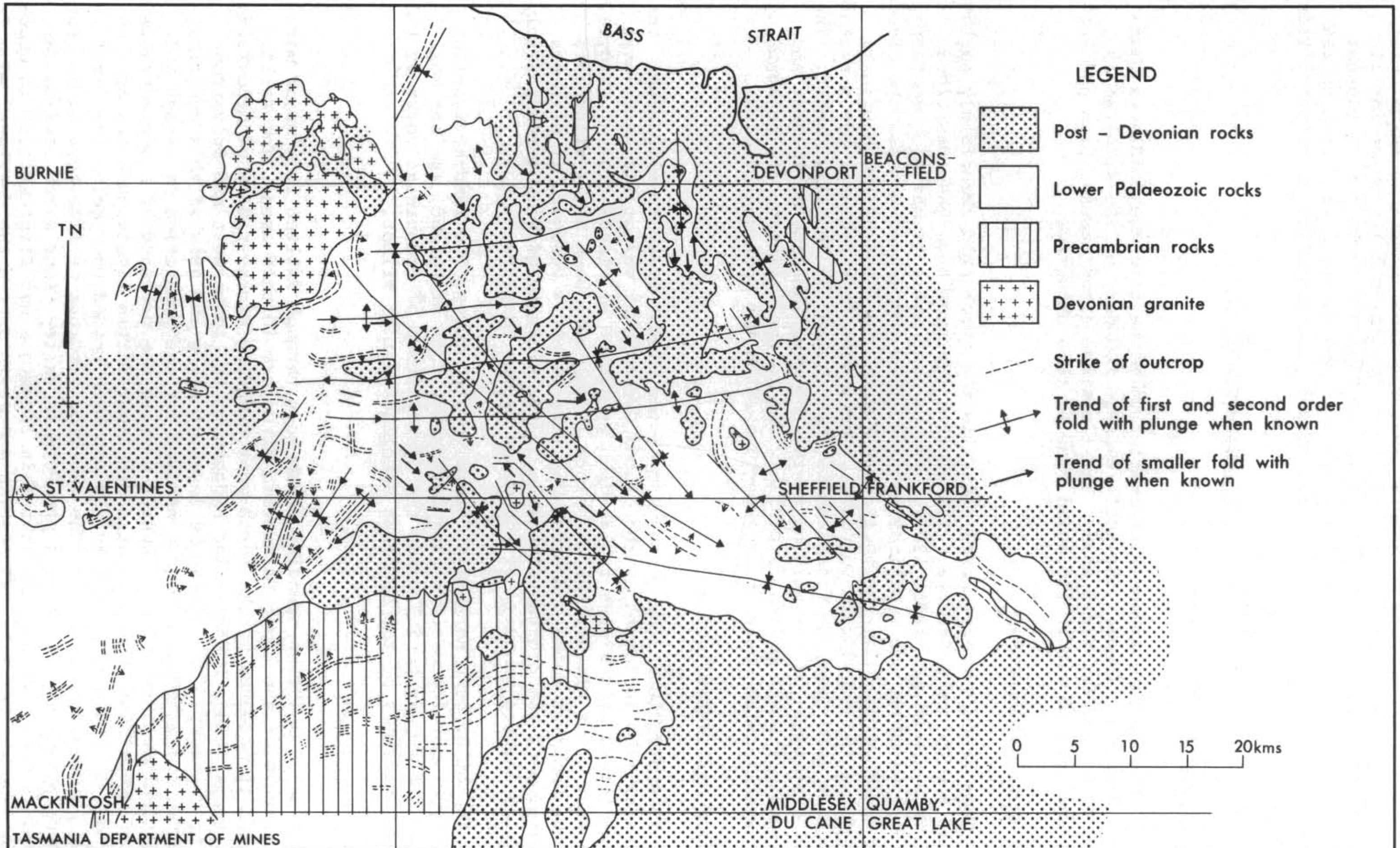


Figure 7. *Structural trends, Sheffield area.*

5 cm

ridge forming The Badgers. North of this syncline, a further large anticline trends eastward from the vicinity of Nietta, but its extension is somewhat difficult to establish within the Cambrian rocks; it is thought to trend through the centre of the basin, crossing the River Forth in the vicinity of Barrington. A further syncline, the Gunns Plains Syncline lies to the north.

NORTH-WEST TRENDING STRUCTURES

Lorinna Syncline

This structure trends south-east from Moina into the Middlesex Quadrangle (Jennings, 1963). The north-eastern boundary of the syncline is formed by a powerful fault zone. The limestone areas around Moina and Iris River are located within the axial zone of this structure.

Round Mount Synclinorium

This feature trends north-west into the quadrangle immediately north-east of the Dolcoath Granite. Its general features have been described previously (Jennings, 1958, 1963). In the area where it has been most extensively studied, the synclinorium is tightly compressed between the Claude Creek Fault which forms the north-east boundary and the Dolcoath Granite which forms the south-west boundary. North-west from Cethana, the structure disappears into Cambrian rocks and is then covered by Tertiary basalt. The marked distortion of the margins of the Loongana Syncline north-west and south-east of South Nietta is probably due to the influence of the Round Mount Synclinorium where it is superimposed on the Loongana Syncline.

Standard Hill Anticlinorium

This structure lies north-west of the Claude Creek Synclinorium. The south-west limb is formed by the Claude Creek Fault whilst the north-east limb is formed by a wrench fault which separates Mt Claude from Mt Vandyke. North-west of Mt Claude, the structure is not well seen as it disappears into the Cambrian rocks and under Tertiary basalt. However, it distorts the margins of the Loongana Syncline in the vicinity of Wilmot and possibly forms the eastern boundary of the Gunns Plains Syncline.

The other main north-west trending structures, the Vandyke Syncline and a synclinal feature trending north-west from Mt Roland, are not well exposed but appear to influence the distribution of Ordovician rocks at the eastern extremity of the Loongana Syncline east of Wilmot.

Railton Syncline

A major syncline trending north-west through Railton is a major marginal feature of the Lower Palaeozoic structure in this area. The Railton Syncline is bordered by the north-west trending strike ridges of Ordovician conglomerate and sandstone, The Badgers to the south-west and Dulverton Hill to the east. The limestone deposits along the axis of this syncline have been exploited as a source of lime for the production of cement and for agricultural purposes. However despite the presence of a considerable belt of Ordovician limestone at depth, very little limestone crops out, as the floor of the Railton valley has not been eroded much below the level of the Permian unconformity. The existing outcrops of limestone at Railton are merely remnants of the old pre-Permian valley floor which have so far escaped erosion. It appears that this limestone was first exposed to erosion between the Devonian and Permian and again during the Tertiary, when it was covered by basalt. In post-Tertiary time, the old valley has been exhumed and erosion is currently excavating the Ordovician rocks. To the north, the Railton Syncline is cut off by a number of north-east trending post-Permian faults downthrowing generally to the north-west. The south-west boundary of the limestone is formed by a large north-west trending fault which downthrows to the north-east. This fault is probably of Tabberabberan age but has been reactivated during post-Permian time.

ECONOMIC GEOLOGY

Metallic minerals

P.L.F. Collins

The Sheffield Quadrangle contains a variety of metallic mineral deposits, the majority of which are situated in the Moina and Round Mount districts in the south-west within an area of about 25 km^2 between Mount Claude and the River Lea and bounded to the north by Bell Mount (fig. 8).

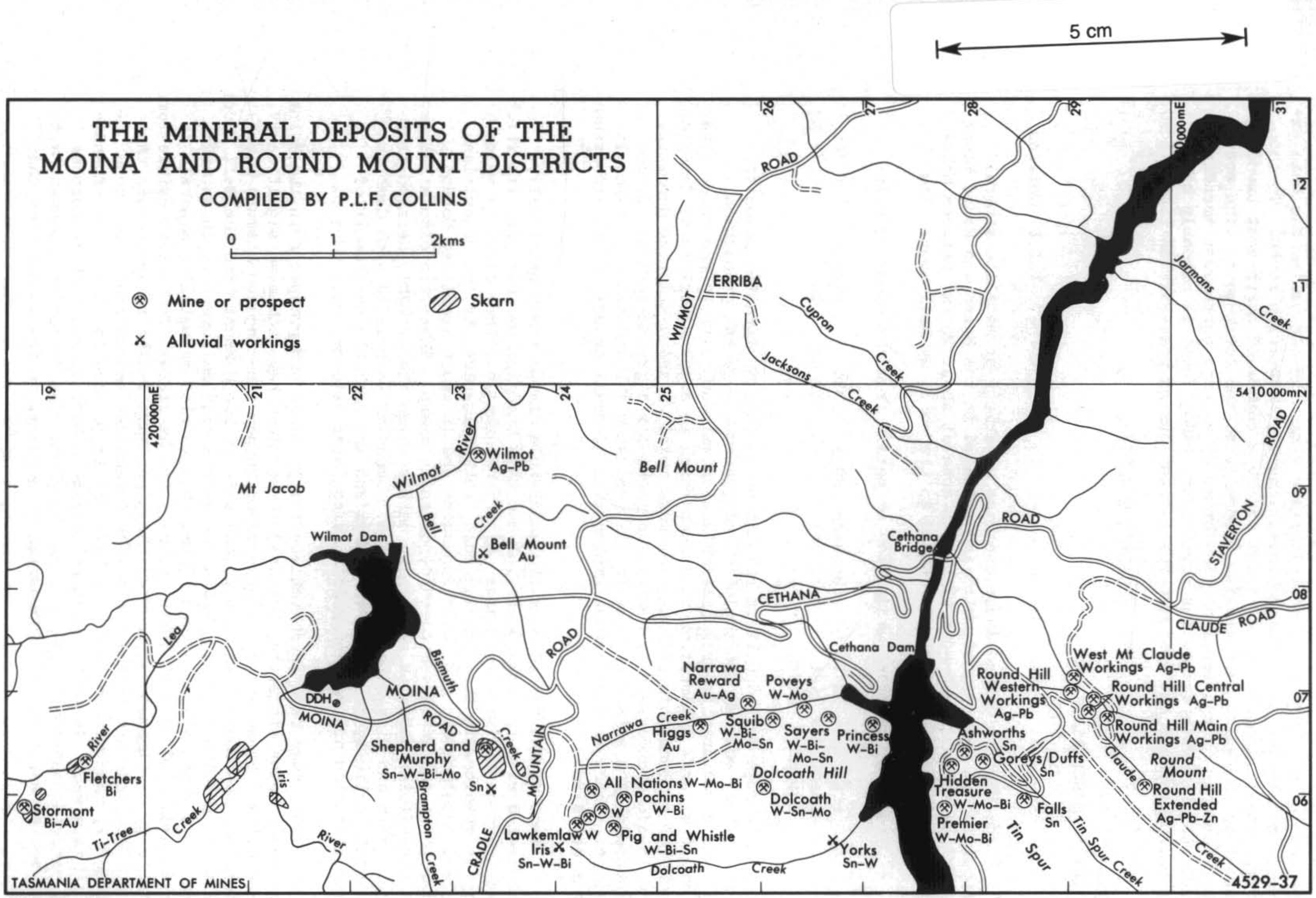
The total recorded production of metals from the quadrangle is;

tin	537t	tungsten (WO_3)	332t	bismuth	76t
lead	4 748t	silver	10 810 kg	gold	175 kg
copper	0.5t				

Although molybdenite is ubiquitous to the tin-tungsten deposits, there is no recorded production of molybdenum. Present production is limited to wolframite from small mines on vein deposits in the Moina area. Current mineral exploration is concentrated in areas underlain by Cambrian rocks of volcanogenic affinity for base metal, massive sulphide deposits, and in areas underlain by Ordovician rocks for skarn in replaced Gordon Limestone as a potential host for disseminated tin and tungsten mineralisation. There is also active exploration by small groups for tin-tungsten vein deposits.

Most of the deposits in the quadrangle are probably genetically associated with the emplacement of the Late Devonian Dolcoath Granite which crops out on the southern margin of the quadrangle. They occur as veins in the granite, in the Cambrian Bull Creek Volcanics, in the Ordovician Roland Conglomerate and Moina Sandstone and in skarn (replaced Gordon Limestone) and as disseminated deposits in skarn. There are also a number of superficial deposits containing metals which are probably derived from these vein and disseminated deposits. Deposits associated with Cambrian volcanic activity are minor in number and are probably the result of remobilisation and concentration during later deformation.

There have been approximately thirty mines and prospects in the Moina and Round Mount districts, but only three mines have achieved significant production. These are the Shepherd and Murphy tin-tungsten-bismuth mine at Moina, the Round Hill silver-lead mine at Round Mount, and the Bell Mount alluvial goldfield. The reasons for such a high failure rate in an area which, at first glance, appears particularly rich in metallic minerals is best summarised by Reid (1919, p.66), when he states 'Those responsible for the early development of many of the mines have failed to appreciate the peculiar structure of the geological formations encountered here, consequently many mining companies have little to show for the heavy expenditure incurred. In some instances companies were formed for the purpose of carrying out operations on sections which were pegged in alignment with ore-bodies existing on neighbouring properties, on the supposition that


5 cm
THE MINERAL DEPOSITS OF THE MOINA AND ROUND MOUNT DISTRICTS
COMPILED BY P.L.F. COLLINS
0 1 2kms
Mine or prospect
Skarn
Alluvial workings
Wilmot Ag-Pb
Bell Mount Au
Mt Jacob
Bell Mount
Wilmot Dam
MOINA
DDH
Shepherd and Murphy Sn-W-Bi-Mo
Fletchers Bi
Stormont Bi-Au
Narrawa Reward Au-Ag
Poveys W-Mo
Higgs Au
Squib W-Bi-Mo-Sn
Sayers W-Bi-Mo-Sn
Princess W-Bi
All Nations W-Mo-Bi
Pochins W-Bi
Pig and Whistle W-Bi-Sn
Lawkemlaw W
Iris Sn-W-Bi
Dolcoath Hill
Dolcoath W-Sn-Mo
Yorks Sn-W
Cethana Bridge
Cethana Dam
Ashworths Sn
Goreys/Duffs Sn
Hidden Treasure W-Mo-Bi
Premier W-Mo-Bi
Falls Sn
Round Hill Western Workings Ag-Pb
West Mt Claude Workings Ag-Pb
Round Hill Central Workings Ag-Pb
Round Hill Main Workings Ag-Pb
Round Mount
Round Hill Extended Ag-Pb-Zn
ERRIBA
WILMOT ROAD
CETHANA ROAD
CLAUDE ROAD
STAVERTON ROAD
CRADLE MOUNTAIN ROAD
MOINA ROAD
Tin Spur
Tin Spur Creek
Claude Creek
Dolcoath Creek
Narrawa Creek
Cupron Creek
Jacksons Creek
Jarmans Creek
Bismuth Creek
Brampton Creek
Ti-Tree Creek
Iris River
Lea River
Wilmot River
Bell Creek
420000mE
5410000mN
TASMANIA DEPARTMENT OF MINES
4529-37
Figure 8.

the ore-bodies would be continuous and pass into them. At the time of the gold-mining boom in this locality metallurgical plants for the treatment of the ores were erected before they were warranted by developed ore reserves. Plants were erected even on the supposition that the gold content and the size of the veins would increase with depth; in other cases this procedure was followed for purely speculative purposes. This policy, naturally, has had a ruinous effect on the mining industry, the direct result being the abandonment of the fields before extensive developmental work had been carried out.'

RELATIONSHIP OF DEPOSITS TO THE DOLCOATH GRANITE

It has been previously postulated (Gee, 1966) that the Dolcoath Granite plunges shallowly westwards from where it crops out on Dolcoath Hill to extend beneath Moina and continue further west at relatively shallow depths to beneath the River Lea. Diamond drilling has confirmed the presence of granite below Moina (Reid, 1971). There are three general, interrelated features of the mineral deposits in the Moina and Round Mount districts which reflect the relationship of these deposits to the granite and also reflect the shape of the granite body. These are:-

(*a*) zonation of the mineralisation,

(*b*) linearity of the vein deposits and

(*c*) extent of the skarn deposits.

The deposits genetically associated with the emplacement of the Dolcoath Granite exhibit a distinct metal zonation, particularly evident in the Round Mount district (fig. 8). The deposits within and nearest to the granite contain tungsten, bismuth, molybdenum and tin. The tin content appears to increase away from the probable granitic source. For example, the vein deposits at the lowest level and furthest within the granite mass (*e.g.* Princess, Premier) do not contain cassiterite, whereas at the Shepherd and Murphy mine, which is probably the most distant of the tin-tungsten vein deposits from the granite, cassiterite is a major constituent. The outer zone contains silver, lead, gold, copper and zinc (*e.g.* Round Hill mine). The presence of the Round Hill silver-lead deposits in such relatively close proximity to the eastern contact of the Dolcoath Granite possibly reflects a steep eastern margin to the granite mass compared with the shallowly plunging western margin where silver-lead mineralisation is scarce.

There are two distinct trends in the linearity of the vein deposits, also confined to the two major metal zones. The tin-tungsten veins occurring within the granite and in the older intruded rock have a general east-west trend. The fractures in which these deposits formed are probably related to deformation during and soon after the emplacement of the granite, the mineralisation being a final phase of the intrusion process. At the Squib mine for example, quartz veins traverse unbroken the granite/quartzite contact. The silver-lead deposits in the Round Mount district have a general north-west - south-east trend, paralleling the regional structure. The deposits occur in structures pre-existing the emplacement of the Dolcoath Granite. These structures provided suitable channels for the ore solutions and repositories for the mineralisation.

The presence of skarn deposits up to 8 km west of the Dolcoath Granite where it crops out on Dolcoath Hill probably reflects the shape of the intrusive body plunging shallowly westwards from Dolcoath Hill.

The skarn occurrences in the Ti-Tree Creek-Stormont and Moina areas are probably due to the presence of cupola-like extensions above the main granite mass. The intrusion of such a small cupola-like body beneath the Shepherd and Murphy mine at Moina may have caused the sheeted fracture system (in association with weaknesses caused by folding), providing suitable channels for mineralising solutions. The presence of unaltered basal sections of Gordon Limestone in Claude Creek, less than 2 km east of the Dolcoath Granite, indicates a steep eastern margin, as is also implied by the close proximity of the silver-lead deposits.

PREVIOUS LITERATURE

The first report on mineral deposits in the Sheffield Quadrangle is by Thureau (1881), describing gold deposits south of the Minnow River, silver-lead deposits on Mount Roland and Mount Claude and in Claude Creek, and the Barrington copper deposits. The silver-lead deposits in Claude Creek are the subject of a later report by Thureau in 1885.

The first mention of mineral deposits to the west of the River Forth is in a report by Montgomery (1894), referring to the silver-lead deposits in Claude Creek and the tin-tungsten deposits at the Iris, Dolcoath and Shepherd and Murphy mines. Smith (1897) described the early workings of the Shepherd and Murphy mine, with further detailed descriptions of this mine being given by Smith in his report on the Bell Mount and Middlesex mineral fields (Smith, 1899), which also includes descriptions of the Claude Creek deposits.

Waller (1901) described the Shepherd and Murphy, Bell Mount and Iris mines, while the copper deposits in the vicinity of the River Leven and Alma (Barrington) were described by Twelvetrees (1903, 1906). In a later report, Twelvetrees (1908) concluded that the Bell Mount mineral field (the Moina and Round Mount districts) on the whole would probably prove to be one with numerous small, but rich lodes.

The first major report on the mineral deposits in the Moina and Round Mount districts is by Twelvetrees (1913). Twelvetrees was the first to recognise the genetic relationships of these deposits to the Dolcoath granite and the zonation of metals around the granite. In his conclusions, Twelvetrees states that 'the deposits of tin, wolfram and bismuth ores are in the pneumatolytic zone within the granite itself and the surrounding mantle of sediments, while auriferous silver-lead and zinc blende (sphalerite), with free gold released from them, are found in the outside zone at a greater distance from the magmatic reservoir' (Twelvetrees, 1913, p.130). Summary descriptions of the Shepherd and Murphy mine and the All Nations mine, and other mines in the vicinity are given by Hills (1916).

The next major report is by Reid (1919) who mentions that with the exception of such mines as the Shepherd and Murphy, All Nations, Squib and Round Hill, little additional development had taken place at most of the prospects since the early reports by Smith and Twelvetrees. Reid gives detailed descriptions of most of the deposits in the Moina and Round Mount districts, in particular the two major producers in the area, the Shepherd and Murphy and Round Hill mines.

Since Reid's (1919) report there have been numerous reports on individual mines, in particular the silver-lead deposits in the vicinity of Round Mount (*e.g.* Hughes, 1948; Jennings, 1958) and the tin-tungsten deposits in the Moina area (*e.g.* Broadhurst, 1934; Keid, 1943; Nixon, 1954; Blake, 1956; Robinson, 1958; Williams, 1958).

Recently, the geology and mineral deposits in the Moina and Round Mount districts were investigated by Gee (1966), with summary descriptions given by Elliston (1953*b*) and Jennings (1965). The skarn deposits within the contact aureole of the Dolcoath Granite have been investigated in detail by Webb (1974) and are currently being evaluated by Comalco Limited.

GOLD

Varying amounts of gold have been recovered from most of the mines in the Moina and Round Mount areas, but there are only two mines, Higgs and Devonport, from which gold was exclusively mined. The major alluvial workings were on the Bell Mount goldfield, 1.5 km north of Moina. Deposits of alluvium in the valleys of the River Forth (*e.g.* Cooper-Smiths) and Minnow River have also been prospected for gold.

The total gold production from the Sheffield Quadrangle is in excess of 175 kg, the main producers being the Higgs gold mine (28.35 kg), the Bell Mount goldfield (113.4 kg) and the Round Hill silver-lead mine (31.46 kg).

Higgs (Sunrise) [48/097911]

This mine is situated on the south bank of Narrawa Creek, approximately 2.5 km east of Moina (fig. 8). The deposit was reported on by Blake (1937*b*), Keid (1947) (referring to the Sunrise mine) and by Jack (1961), from which the following description has been summarised.

Gold was first discovered in the area in 1893 but it was not until 1934 that mining began, continuing intermittently until 1947. Production during the period 1935 - 1941 was 18.96 kg of gold (Keid, 1947). Jack (1961) estimated that a total of 28.35 kg of gold had been recovered by underground mining and surface sluicing during the period 1893-1947. Since 1947 the mine has been abandoned.

The mine is located on the southern limb of a small syncline in the Ordovician Moina Sandstone. At the mine, the sandstone is altered to metaquartzite, and bands of impure dolomite within the sandstone have been altered to skarn containing garnet, diopside and quartz. The alteration, mineralisation and minor faulting and shearing near the mine are attributed to the intrusion of the Devonian Dolcoath Granite to the east.

The mineralisation occurs in three sub-parallel north-west trending shear zones, two of which are narrow and have not been worked. The main lode, worked from two adit levels and stoped through to the surface, occurs as an intensely crushed zone up to three metres thick between two well defined shears dipping 70° NE, parallel to the bedding. The crushed metaquartzite between the shears served as a favourable site for deposition of pyrite and minor galena, arsenopyrite and chalcopyrite. The gold is apparently contained in the pyrite and has been concentrated in a shallow oxidised zone of surface enrichment. This is reflected in lengthening of the stope, together with higher assay values (Keid, 1947) from the lower adit to the surface. Hematite is common in the oxidised zone.

Devonport [48/005919]

The Devonport gold mine is situated on the west bank of Devonport Creek, approximately 6 km west of Moina. In the first report on the mine, Twelvetrees (1913) described a discontinuous series of quartz and gossanous formations and suggested that the encouraging gold assays obtained in surface outcrops were the result of secondary enrichment and could not be expected at depth. Similar conclusions were later reached by Broadhurst (1934) and Henderson (1939). Collins (1975*a*) suggested the irregular nature of the quartz lenses was another major deterrent to mining.

The gold occurs in a series of short quartz lenses which have filled an anastomosing system of fractures associated with the major fault between the Ordovician Roland Conglomerate to the west and Moina Sandstone to the east. Henderson (1939) reports the quartz veins to be sub-parallel to the bedding with a slightly shallower dip than the country rock, and as being difficult to trace.

Assays of samples collected by Henderson (1939) from surface gossan and lode quartz and underground lode quartz indicate a possible enrichment of gold in the ferruginous lodes and a decrease in gold values with depth, as originally suggested by Twelvetrees (1913). This surface enrichment, particularly in the gossanous formations, is attributed to the liberation of gold during decomposition of pyrite.

The deposit has been prospected by means of a small open cut located about 25 m above a 44 m long adit, and several small trenches (Collins, 1975*a*).

Narrawa Reward [48/105913]

Situated on the north bank of Narrawa Creek, about nine metres above the creek, a tunnel has been driven 47 m on a bearing of 335°. The poorly defined lode apparently consists of very fine grained arsenopyrite, pyrite, chalcopyrite and galena disseminated through meta-quartzite adjacent to a quartz-feldspar porphyry dyke (?) trending about 290° and dipping steeply to the south-west (Twelvetrees, 1913; Reid, 1919). The sulphide ore reportedly assayed up to 6 g/t Au and 91.8 g/t Ag. The workings were apparently abandoned well before Twelvetree's (1913) inspection.

In the vicinity of the prospect are quartz veins containing wolframite and molybdenite.

Star of the West [48/315935]

Thureau (1881) records the discovery of alluvial gold in gravel on the banks of the Minnow River and in surface specimens from the slopes to the south of the Minnow River, near the Star of the West workings.

At the Star of the West prospect, a shaft 17.4 m deep with a six metre long south cross cut at the bottom was sunk on the southern contact between a feldspar-hornblende porphyry dyke (?) and slate. The contact dips about 50°S. Thureau reports gold occurring in lenticular quartz-veins within the porphyry and perpendicular to the contact and also in the weathered matrix of the porphyry. The average yield from the shaft is reported to be 4.5 g/t Au.

To the west of the shaft in the slate to the south of the porphyry is a tunnel 67 m long. To the east of the shaft is another tunnel 99 m long (Star of the East workings), which passes through the porphyry dyke from north to south. The dyke here is greater than 60 m thick and is traversed by quartz veins with similar gold values to the Star of the West (Thureau, 1881).

Bell Mount [48/075930]

The Bell Mount alluvial goldfield is situated approximately one kilometre south-west of Bell Mount in the headwaters of Bell Creek (fig. 8). Gold was discovered in the area in 1892 and the field was almost worked out within two years. Since then the field has received intermittent attention from prospectors. Twelvetrees (1913) estimated 113.4 kg of gold was recovered during the first two years.

The first report on the Bell Mount goldfield is by Montgomery (1894), who suggested that the gold originated either from the slopes of Bell Mount to the north, or from rewashing of older gravel belonging to the river system obliterated by the Tertiary basalt. The general consensus of opinion in later reports such as those by Waller (1901), Twelvetrees (1913), Reid (1919) and Broadhurst (1934) is that the gold is close to its source, and that the gold and alluvium probably originated from the south and south-west slopes of Bell Mount. Twelvetrees (1913) notes that had the gold originated from the south or south-east of the field, then cassiterite and wolframite would also be present in the wash.

The main workings are in Bell Creek (Broadhurst, 1934) where recent alluvium covers Ordovician Gordon Limestone and Moina Sandstone. Most of the gold reportedly was recovered from the basal 150 mm of the alluvium. The gold occurs as flat nuggets commonly weighing 85 g, with the largest nugget weighing 624 g. The shape of the nuggets, flat and smooth on one side and rounded or bulbous on the other side, suggests the gold originally occupied joint planes or small veinlets in the host rock (Broadhurst, 1934).

Cooper - Smiths [49/235180]

Twelvetrees (1906) reported that alluvial gold had been recovered from the alluvial flats near the Paloona Bridge, at the confluence of the Forth and Wilmot Rivers. The gold occurs in the pre-Tertiary basalt alluvium, which consists of large rounded boulders resting on a bedrock of Precambrian quartzite and schist. Twelvetrees suggests it is possible to distinguish this older alluvium, carrying the gold, from the recent river gravel deposited by the present River Forth.

SILVER-LEAD

Silver and lead have been mined in significant economic quantities in the quadrangle. Nearly all the silver and lead produced has come from mines in the Round Mount district and most of this from the Round Hill Main (or Eastern) workings during the period 1908-1927. Minor amounts of silver and lead have been produced from two other small silver-lead deposits (Wilmot, Prestons) and minor amounts of silver have been produced from some of the tin-tungsten and copper deposits.

Although the deposits in the Round Mount district have always been known to contain varying amounts of sphalerite, these deposits were mainly mined for their silver and lead content, and to a lesser extent their gold content.

*ROUND MOUNT DISTRICT**

The discovery of silver-lead deposits in the bed of Claude Creek north of Round Mount was made by two prospectors, Shepherd and Weeks, about

* After Jennings (1958)

1878. Whilst early developments of these deposits did not immediately disclose any large rich ore bodies, they stimulated the search for further deposits in the vicinity. Within a few years of the original discovery further metalliferous deposits were discovered at the Round Hill Extended, Round Hill Western and Tin Spur workings, together with a number of other small prospects in the general area.

Development of these deposits proceeded sporadically for about the next 30 years. However to date, the original deposits at Round Mount (the Round Hill Main workings) are the only ore bodies which have achieved any important production. The structure of the Round Mount lodes proved extremely puzzling to the early workers and although a great deal of prospecting was carried out much of this proved to be misguided.

Despite a number of set-backs, prospecting and development was pushed on and eventually a number of large high-grade ore bodies were located by driving south under Round Mount from the original lodes discovered in Claude Creek. The period 1913-1925 was the hey-day of the Round Hill Silver-Lead Company and some of the lodes discovered were exceedingly rich. One parcel of several tonnes of ore assayed at 6 mass% Cu, 50 mass% Pb, 11 633 g/t Ag and 31.1 g/t Au, whilst some specimens of galena assayed from 11 020-27 552 g/t Ag.

The Round Hill Silver-Lead Company ceased operations in 1927, by which time the majority of the large ore bodies had been worked out. Even at this stage the structure of the ore bodies was still not clearly understood, and to a large extent this severely hampered the mining operations in the area. The West Mt Claude Mining Syndicate took up the leases in 1948 and carried out further exploration work and erected a small mill which operated until 1951. Again, much of this work was misguided due to a non-appreciation of the structural problems involved and work ceased about 1954.

Round Hill (West Mt Claude)

The Round Hill or West Mt Claude silver-lead mine comprised several workings closely spaced along the banks of Claude Creek, to the north-west of Round Mount (fig. 8). The geology in the vicinity of this mine, the various workings and the nature and structural control of the ore bodies have been described in detail in a report on the Round Mount district by Jennings (1958). The following descriptions of the Round Hill mine, the Round Hill Extended and the Tin Spur deposits are based on his report.

History and previous literature. A detailed account of the history of the Round Hill mine is given in the report by Jennings (1958) and is not repeated here.

The various workings of the Round Hill mine have been examined by several geologists. The first reports are those of Thureau (1881, 1885), when most of the work was centred around the no. 3 adit at the Central workings. Thureau recommended that this adit be abandoned, at least temporarily, and that open cut mining methods be applied to known ore bodies near Claude Creek.

Montgomery inspected the mine in 1893, but at that time development was still concentrated on the Central workings, largely the no. 3 adit and his report (Montgomery, 1894), consequently, is not optimistic. In 1898, Smith examined the workings but only a small amount of prospecting was being carried on and he too was not optimistic (Smith, 1899).

The first major description of the mine is by Twelvetrees (1913). He gave a brief description of the geology and structure and a detailed account of the mine workings at that date. By this time the Central workings had been abandoned, the Western workings had reached their maximum development and at the Main (or Eastern) workings the no. 1 adit had been driven 58 m and the no. 2 adit about 23 m. Twelvetrees also pointed out the anticlinal control of the ore bodies.

Reid's (1919) report describes the Main workings which were then at an advanced stage of development with several ore bodies exposed. Reid gives an account of the mineralogy and structure of these ore bodies, this being the only real description of the lodes as most of the workings have been inaccessible to later geologists. Reid noted the anticlinal control of the ore bodies and suggested that they were related to the softer bands interbedded with the quartzite. He also introduced the idea of the ore bodies pitching conformably with the folds. Neither Twelvetrees nor Reid attempted any structural mapping in the vicinity of the deposits.

Hughes (1948) made the first attempt at mapping the folds in which the ore bodies are contained. Hughes pictured the ore bodies as being contained in vertical fracture zones in the axial planes of the anticlines. He also concluded that the axial planes of the folds were vertical and that the folds had no appreciable plunge; the general sequence of events was thrust faulting, folding and ore deposition.

Jennings (1958) presents the results of detailed structural mapping and an interpretation of the structure of the Round Mount district. Jennings concluded that there are at least three factors controlling the deposition of the large ore shoots; anticlines, soft beds and small thrust faults. Where these three factors are localised the main ore bodies have developed.

Development. At the workings of the Round Hill or West Mt Claude silver-lead mine, there are 12 adit levels, and one internal level in the Main workings, scattered along the banks of Claude Creek. Jennings (1958) conveniently divides the various workings into the following four groups (fig. 8);

(*a*) Main (or Eastern workings) [48/142901] - comprising three adit levels (no. 1, 2 and 7) and an internal level connected by shaft to the main adit level. The bulk of the production has come from these workings.

(*b*) Central workings [48/140912] - comprising two short adits (no. 1a and 8) and one adit in excess of 245 m in length (no. 3 adit) from which little or no ore has been produced.

(*c*) Western workings [48/137914] - comprising four short adits (no. 4, 6, 9 and 10) from which a small quantity of ore has been obtained.

(*d*) West Mt Claude workings [48/138915] - comprising three adits (no. 11, 12 and 13) from which about 20 t of ore has been produced.

The early workings are described in detail by Twelvetrees (1913) and development to 1918 is described by Reid (1919). Development and mining during the period 1918-1927 is described by Hughes (1948). Detailed plans and descriptions of all the various workings are provided in the report by Jennings (1958).

Table 3. SILVER, LEAD AND GOLD PRODUCTION FROM THE ROUND HILL MINE FOR THE PERIOD 1908-1927

Year	Ore milled (t)	Concentrates (t)	Au (kg)	Ag (kg)	Pb (t)
1908-1916	-	1 879.0	-	2 402.248	1 061.4
1917	7 020	775.8	3.175	976.102	416.6
1918	6 415	543.6	1.443	586.409	268.4
1919	7 015	751.9	2.807	1 454.442	370.9
1920	8 269	1 229.4	5.925	1 482.480	684.8
1921	-	-	-	321.653	167.6
1922	-	-	-	403.697	183.1
1923	5 385	546.6	4.536	761.893	301.8
1924	7 779	648.2	3.430	685.179	373.9
1925	7 615	638.1	4.026	679.821	365.8
1926	8 420	647.2	3.657	687.135	387.1
1927	-	-	2.461	369.167	141.9
	57 918	7 659.8	31.460	10 810.226	4 723.3

An exploratory diamond drilling programme of six horizontal and inclined holes was undertaken by the West Mt Claude Mining syndicate prior to 1958, but failed to locate any significant mineralisation.

Production. Recorded production of silver, lead and gold from the Round Hill mine during the period 1908-1927 is listed in Table 3. There was apparently no production during the period 1928-1948 and Jennings (1958) estimates 20 t of lead have been produced since 1948, containing small amounts of silver and gold.

Geology. The deposits occur within interbedded sandstone, quartzite, grit and shale of the Ordovician Moina Sandstone. There are no deposits in the Gordon Limestone or Roland Conglomerate, occurring stratigraphically above and below the sandstone respectively.

The geological structure of the Round Mount district is most complex, but is of considerable importance to both the formation of the deposits and the exploration for further deposits. Jennings (1958) defines four orders of fold structures, forming part of a major complex synclinorium and a series of associated thrust faults. There is a marked orientation of the structures. All the major fold axes and the minor structures and most of the faults trend about north-west. A set of smaller faults trend about north-east.

The four fold groups are;

Order	*Name*	*Magnitude*	*Workings*
1st	Round Mount Synclinorium	6 km	
2nd	Claude Creek Synclinorium	600 m	
	Cockatoo Ridge Anticlinorium		
3rd	Main Anticline	60 m	Main (or Eastern)
	Sales Anticline		Western
	Falls Anticline		Central
4th	Small drag folds on 3rd order folds	6 m	

All the deposits are associated with the third order structures occurring as drag folds and associated thrust faults on the limbs of the second order folds. At the Round Hill mine, Jennings distinguishes three anticlines on the north-east limb of the Claude Creek Synclinorium. The Round Hill Main workings are located on the Main Anticline. Minor mineralisation was explored on the Sales and Falls Anticlines (the Western and Central workings) but Jennings suggests that the lack of major ore bodies on these anticlines is due to a regional dip south from the Main Anticline to the centre of the Claude Creek Synclinorium, such that the soft beds which may carry the ore bodies are approximately 40 m beneath Claude Creek at Sales Anticline and 60 m beneath the creek at the Falls Anticline.

Structure of the ore bodies. Jennings (1958) described two distinct types of ore bodies at Round Mount, firstly thin galena veins lying parallel to the bedding and secondly the large deposits mined in no. 1 and 2 adits. Examples of the first type are exposed in many of the workings, *e.g.* adit no. 3, 7, 11, 12 and 13. Characteristically, these veins are thin and irregular but usually contain clean ore.

Examples of the second and more important type of ore bodies are no longer exposed as the Main workings have collapsed. However Reid visited the mine while such lodes were being worked and gives the following description (Reid, 1919, p. 131);

'The ore bodies follow the pitch of the fold and as they are brought down they are carried north-westward. The principal mineralisation has taken place at the apices of the anticlines, but solutions have migrated also along the bedding planes. Deposition has taken place in the weaker beds. ....As these layers are rarely more than 20 feet (6 m) thick the depth of the ore shoot is limited to this extent ...... The ore bodies are thus contained in shoots about 25 feet (7.6 m) wide, 20 feet (6 m) deep (measured at right angles to the pitch) and of (as yet) indeterminate length along the pitch. Mineralisation has also taken place but to a minor extent, along cleavage planes and joints .... but the main channel of access was along the flowage planes of the crushed beds.'

All writers agree on the localisation of these bodies in the axis of the Main Anticline and that mineralisation, if it occurs in the intervening syncline, is slight and unimportant. Two of the old stopes of the Main workings still accessible to Jennings bear out Reid's description of the ore bodies. They indicate that the ore bodies were roughly conformable to the bedding and pitched north-west along the axis of the fold. Reid (1919) gave the dimensions of the ore body as 6 metres deep at right angles to the pitch. He also states that the first ore shoot in no. 1 adit came in at 17.4 m along the drive and continued for 22.9 m. From these dimensions, the ore shoot must pitch north-west at 16°. Jennings (1958) measured a pitch of 15° for the Main Anticline in this locality.

Reid's (1919) description of the ore bodies emphasises the importance of the softer beds within the quartzite beds in localising the ore shoots. The soft beds have flowed up into the anticlinal crest forming roughly saddle-like bodies having similar dimensions to the ore bodies described by Reid. Jennings (1958) notes that the true thickness of such beds would be very much less than 6 metres, but they are exaggerated in the anticlinal axis by their incompetent behaviour. Thus there are two factors controlling the structure of these ore bodies, the anticlinal crest and the behaviour of the incompetent beds. Obviously there are further controlling factors since there are examples of soft beds localised in the anticlines but with no ore of importance contained in them.

A further factor in the formation of these ore bodies lies in the small thrust faults. The Main Anticline is cut by at least three such faults which run up the north limb of the fold nearly parallel to the bedding and then cut across the crest of the fold. Where these faults encountered the beds on the south limb of the fold, the beds are rolled back and overturned. Some of these thrust faults act as channels for the ore-bearing solutions and where they encounter a soft bed at the crest of the anticline an ore body has been formed. As the fault cuts across the beds on the south limb of the fold, the beds have been opened up slightly and thin veins of ore have been deposited along the bedding planes.

Several features of the ore bodies at the Round Hill mine are explained by this interpretation;

(*a*) The ore shoots are confined to soft beds which pitch north-west at about 15°. However, the mineralisation does not extend indefinitely along the beds as evidenced by the smaller size of the lodes in the shaft level. This is due to the fact that since the folds have an appreciable pitch, the soft beds are only cut for a portion of their length. Mineralisation extends out from this zone but becomes weaker and eventually dies out unless the beds are cut by another such mineralising fault.

(*b*) The small 'bedding plane' veins are usually located on the limb of the anticline cut at a strong angle by the thrust faults. These veins could lie some distance beyond the axis and may be 30 m or more in depth.

(*c*) The Western workings are located on one of these mineralised thrust faults, but the lithology there is not favourable to the formation of a large deposit.

It seems that all the three main factors (*i.e.* fold, soft bed, thrust fault) must be present before an ore body of appreciable size developed. There are several instances where two such features are present and no major ore body is present. Doubtless not all such intersections were productive. There is evidence to suggest that the ore deposition was a late phase of the structural history. In this case, it may be that only some of the later faults are likely to be mineral bearing at such intersections. It is, however, significant that such small thrust faults are present in close relationship to all the known ore occurrences.

Another factor which may be important in this area is the pitch of the folds. However, there is not enough evidence to draw any definite conclusions on this point. It is likely that changes in pitch of the folds would affect concentration of the softer beds and hence be more favourable points for ore deposition. North-west of no. 1 adit the pitch of the Main Anticline has been measured at 10°, indicating some flattening in this direction. However, at this point the fold has been displaced by a low angle thrust fault which could cause a local variation.

The formation of the ore bodies as envisaged by Jennings (1958) is illustrated in Figure 9. This shows the relationship of the major deposits to the bedding plane veins. The two types of deposits are thus related to one another and are part of the same stress environment. Some workers have postulated replacement on a large scale to account for such deposits. Whilst there is undoubtedly some replacement in this area it has been on a minor scale only.

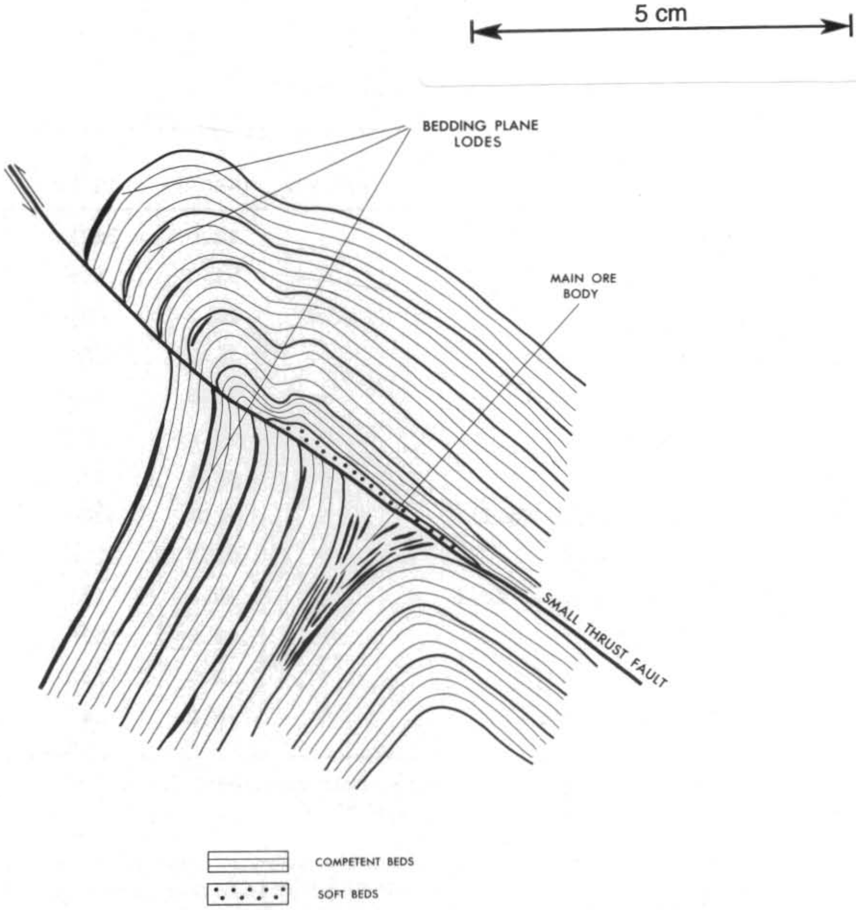


Figure 9. *Sketch section to illustrate the formation of the ore deposits at Round Hill (after Jennings, 1958).*

Mineralisation. The mineralogy of the bedding plane lodes is relatively simple. The ore is massive and consists of galena and pyrite with subordinate sphalerite and occasional blebs of chalcopyrite. The gangue, if present, is dominantly quartz, usually milky but sometimes iron stained and rarely crystalline. The galena may be fine-grained or coarsely crystallised.

The mineralogy of the major deposits has been described by Reid (1919). Briefly, these ore bodies consist of galena, both fine-grained and coarse, with abundant chalcopyrite, a little pyrite, sphalerite and siderite, together with small amounts of bismuthinite, pinite (muscovite) and quartz. The gangue is never abundant and the quartz is usually opaque. Pyrite tends to be deposited first, but in general the deposition was contemporaneous.

The silver content is variable, being as high as 27 552 g/t. However, generally speaking, it averages about 30 g of silver per unit of lead. Similarly the gold content is erratic but is said to average 3 - 4 g/t in ore containing 50 mass% lead. Bismuthinite, although present only in very small amounts, always accompanies the rich silver-bearing ore. Assay results of ore samples are given in Table 4.

Table 4. METAL CONTENT OF ORE, ROUND MOUNT.

Sample description	Zn (mass%)	Pb (mass%)	Ag (g/t)	Au (g/t)
Ore, Main tunnel	-	42.0	2602	4.6
Selected ore, no. 7 adit	-	54.3	116	-
Selected ore, no. 7 adit	1.5	10.2	85	1.1
Selected ore, no. 7 adit	-	61.2	205	-
Selected ore, no. 7 adit	-	59.8	122	-
Ore, Claude Creek	*	57.1	364	1.2
Ore, no. 3 adit	-	21.6	376	0.8
Ore, no. 9 adit (south wall)	*	31.6	306	1.2
Ore, dump, no. 9 adit	†	28.5	156	trace
Mineralised zone, no. 11 adit	2.7	5.4	141	6.9
Vein, no. 11 adit	*	42.5	1026	trace
Galena vein, no. 12 adit	*	52.3	1133	3.7
Galena vein, no. 13 adit	*	76.1	1347	trace

(*= plus zinc and copper; †= plus zinc and molybdenum)
Assays from Hughes, 1948; Jennings, 1958.

Genesis. Although there is no direct evidence, the most likely origin of these deposits is that they formed by precipitation from mineralising solutions emanating from the Dolcoath Granite. The only other possible origin could be that there was pre-existing mineralisation occurring within the underlying Cambrian volcanogenic sequences and the sulphide mineralisation was remobilised and redeposited in the Ordovician rocks during later deformation of the area. Such an origin would certainly explain the lack of gangue minerals, but the distances involved are probably prohibitive for such genesis.

Assuming the mineralisation is genetically associated with the emplacement of the Dolcoath Granite, then the conditions prevailing during ore deposition are probably as described by Jennings (1958). At the time of ore deposition the thrust faults were active and where they cut across the anticlinal axis a zone of low pressure occurred. The flowage of the soft beds into the fold axis, purely as a part of the folding process, indicates a pressure gradient acting towards the apices of the folds. This does not imply that actual openings existed but that this area was at a lower pressure than the surrounding country. Also, as the faults cross the fold axis, the beds on the other sides of the folds would tend to be opened up slightly by the fault movement. Again, no actual openings may have been present. Fluids travelling along the thrust planes would naturally migrate to these areas of lower pressure depositing metallic and gangue minerals from solution due to the lower pressures prevailing. Since the fluids themselves were also under pressure, there is no reason to postulate that openings ever existed but rather that there were low pressure areas or 'potential openings'.

Round Hill Extended [48/146903]

This mine is situated about one kilometre south-east of the Round Hill Main workings on the south bank of Claude Creek (fig. 8). Silver-lead ore was discovered here about 1880 and although the deposit was developed by an open cut and three exploration adits, no production is recorded from this mine. The workings are described by Reid (1919) and Jennings (1958).

All the mineralisation is related to a faulted anticline, which appears to plunge gently (about 5°) north-west and occurs on the south-west limb of the Claude Creek Synclinorium (Jennings, 1958). The host rock for the mineralisation is the Moina Sandstone and the puggy mineralised fault zone itself forms the main ore body. Ore deposition has also extended into the softer beds, interbedded with the quartzite, on either side of the fault. The predominant minerals are galena and sphalerite with chalcopyrite, pyrite, quartz, calcite and pinite (muscovite). The silver content is about 40g per unit of lead. Samples of the ore from the open cut workings assay (from Jennings, 1958):-

Zn (mass%)	Pb (mass%)	Ag (g/t)	Au (g/t)
2.2	4.0	166	0.4
2.6	3.2	122	trace

Jennings (1958) concluded that the mineralisation apparently represents the remnants of more extensive deposits which have been largely removed by denudation, and that the dominantly massive quartzite beneath the workings is not a favourable host rock for further deposits in the vicinity.

OTHER SILVER-LEAD DEPOSITS

Wilmot (Washington) [48/075940]

This prospect, later known as the Washington silver-lead mine (Scott, 1927*a*), is situated on the east bank of the Wilmot River about two kilometres west of Bell Mount and one kilometre north-east of the Wilmot Dam (fig. 8). Irregular veinlets of galena and chalcopyrite within tubicolar sandstone and quartzite of the Moina Sandstone were discovered here in 1893 during the boom days of the Bell Mount goldfield. The veinlets are probably either fillings of fractures in the quartzite or replacement along bedding planes, on the south-west limb of a north-west trending anticline, adjacent to a major fault. Scott (1927*a*) described a north trending lode, 600-700 mm thick, consisting of quartzite containing galena as impregnations and as veinlets 50-75 mm thick. The galena assays up to 6200 g/t Ag (Scott, 1927*a*), and assays of the mineralisation collected by Reid (1919) indicated:-

	Pb (mass%)	Cu (mass%)	Ag (g/t)	Au (g/t)
Galena ore	73.5	-	1775	trace
Galena-chalcopyrite	42.6	3.5	1837	3.1

The lode has been worked on two adit levels, from which 5.1 t of galena has been produced (Scott, 1927*a*). The mineralisation probably has a similar origin to the silver-lead deposits in the Round Mount district.

Prestons [*49/072120*]

Located in a creek in the headwaters of the West Gawler River about three kilometres south of Preston are parallel lines of lode consisting of galena, sphalerite and pyrite in cleavage planes and joints in slate within the Cambrian Gog Range Greywacke, adjacent to the faulted contact with the Ordovician Dial Range Conglomerate. Twelvetrees (1909*b*) described a shaft 4.6 m deep on the south bank of the creek, which exposed pockets of pug with slugs of galena. It is possible that this prospect is on the same fault zone as the Copper Creek mine.

Mt Roland and Mt Claude prospects

Thureau (1881) described three isolated occurrences of argentiferous galena on the northern slopes of the range between Mount Claude and Mount Roland, but was not optimistic about the economic potential of these deposits. The prospects are apparently within Cambrian schist of volcanogenic origin and just below the unconformity at the base of the Roland Conglomerate. Thureau suggested that the mineralisation formed subsequent to deposition of the conglomerate, as the conglomerate is also impregnated with argentiferous galena.

On the north-west flank of Mount Roland, the Mount Roland silver-lead mine was established upon a formation within Cambrian schist carrying impregnations of galena and sphalerite associated with calcite and siderite. An adit 21.3 m long was driven into this formation and at the end of the tunnel encountered a second similar formation, striking 060°, in sandstone. Further west, at Atkinsons prospect, an adit six metres long was driven on narrow, irregular veins of galena and pyrite within Cambrian schist.

To the north of Mount Claude, at Gilberts prospect [about 48/195912], Thureau (1881) described pyrite, siderite, calcite and galena occurring in veins of white quartz within Cambrian schist. These early discoveries led to further, but unsuccessful exploration in the area that is later referred to by Reid (1919) as the Mount Vandyke prospect. The later work disclosed sparsely disseminated galena, chalcopyrite (some altered to covellite) and pyrite in schistose feldspar porphyry, and quartz-calcite veins 150-200 mm thick containing galena, chalcopyrite, pyrite and a little silver and gold.

TIN - TUNGSTEN - BISMUTH - MOLYBDENUM

All the tin - tungsten - bismuth - molybdenum deposits are located in the Moina and Round Mount areas, in the south-west corner of the quadrangle (fig. 8). The main producer was the Shepherd and Murphy mine at Moina, which operated intermittently between 1893 and 1957.

These metals are usually all found in the same deposit, but often in varying proportions. Wolframite is the dominant ore mineral in all deposits with cassiterite, bismuth ores (bismuthinite and minor native bismuth and bismutite) and molybdenite in lesser but variable quantities. Minor amounts of gold and silver have also been recovered from most of these deposits.

It is convenient to divide deposits containing these metals into groups according to the nature of their occurrence:

(*a*) Greisen and quartz veins in greisenised granite (*e.g*. Dolcoath, Sayers, Princess, Premier, Hidden Treasure and Squib).

(*b*) Quartz veins (*e.g.* Shepherd and Murphy, All Nations, Pig and Whistle, Lawkemlaw, Pochins, Squib).

(*c*) Disseminations in skarn equivalent to replaced Gordon Limestone (*e.g.* Shepherd and Murphy, Ti-Tree Creek, Stormont, Fletchers, Tin Spur Creek).

(*d*) Secondary enrichment in detritus (*e.g.* Tin Spur) and alluvial deposits (*e.g.* Iris, All Nations, Yorks, Shepherd and Murphy).

GREISEN DEPOSITS

At several localities within the Dolcoath Granite wolframite, bismuthinite, molybdenite and cassiterite occur in greisenised granite and in quartz veins within greisen. Wolframite is the dominant ore mineral in all of these deposits. Cassiterite has not been detected at the Princess, Hidden Treasure and Premier deposits. The mineralised quartz veins at the Squib mine traverse the granite/quartzite contact, most mining having been undertaken in the quartzite. In addition to the prospects described here, Twelvetrees (1913) and Reid (1919) refer to several other minor vein deposits, particularly in the vicinity of the Premier and Hidden Treasure lodes.

Dolcoath (Auldana) [48/106905]

Situated on the south flank of Dolcoath Hill, just below the summit (fig. 8), the mineralisation at the Dolcoath prospect was discovered in 1891 and is hailed as the first discovery of cassiterite and wolframite in the Moina district (Reid, 1919).

Reid (1919) described irregular quartz veins 25-100 mm thick with wolframite and minor cassiterite and molybdenite occurring within greisenised granite consisting of quartz, topaz, muscovite and disseminated pyrite and arsenopyrite. The quartz veins also contain topaz, pyrite and arsenopyrite and have a muscovite selvage. The veins trend north-northwest and dip 45°S. Twelvetrees (1913) described molybdenite also occurring on joint faces in the greisen.

During Reid's visit the veins were developed by means of a small open cut and a 14.5 m cross cut tunnel with a short drive on one vein. Since then, the adit has been lengthened to 60 m, exposing several quartz veins up to 150 mm thick, and on two of them, short levels have been driven (Keid, 1943).

Sayers [48/114910]

A zone of mineralisation, approximately 600 m in length and trending east-west, has been prospected on the steep north-east flank of Dolcoath Hill between Narrawa Creek and Lake Cethana (fig. 8). The numerous veins within the zone, collectively known as Sayers prospect, have been explored by a number of shallow shafts and short adits and numerous trenches. Detailed descriptions of the various early exploratory workings are given by Twelvetrees (1913) and Reid (1919), whilst later development is described by Elliston (1953*a*).

The lodes consist of a series of subparallel quartz veins up to 200 mm thick, but generally 50 mm and less, in aplitic and greisenised granite. The veins contain dominantly wolframite with minor bismuthinite, cassiterite and sparsely disseminated molybdenite in association with fluorite, beryl, topaz and muscovite. A feature of the veins is coarsely crystalline beryl occurring as crystals up to 100 mm in length (Reid, 1919), but Elliston (1953*a*) suggested this would only constitute a by-product of the wolframite if mined.

Elliston (1953*a*) concluded that although the veins are numerous, they are of insufficient number and size and too low in wolfram content to warrant exploitation. Several of the veins are aplitic variants of the granite carrying only specks of wolframite.

Princess (Urquharts) [48/118910]

This prospect, referred to as Urquharts prospect by Twelvetrees (1913), is situated on the east flank of Dolcoath Hill (fig. 8) where two intersecting pegmatitic quartz veins were discovered in 1908.

The main vein, 50 - 100 mm thick, consists of quartz, topaz, fluorite, wolframite and bismuth minerals enclosed in greisenised granite bearing topaz and fluorite. Reid (1919) reports tungstite and ferritungstite in oxidised portions of the veins. The main vein trends 310° and dips 45° SW and a second similar vein, 75 mm thick, trends 350° and dips 60°W.

The veins are particularly rich in bismuth, occurring as bismuthinite and bismutite. An assay of a sample of the main vein collected by Reid (1919) indicated 3.36 mass% WO_3 and 2.86 mass% Bi. Another feature of the prospect is coarse quartz crystals up to 150 mm long.

The veins have been developed by means of a tunnel driven 21 m on the main vein and a six metre drive on the second vein, and a 3.5 m deep open cut 12 m above the tunnel. There are also several trenches described by Twelvetrees (1913).

Premier [48/123902]

At the Premier mine, situated on the east side of Lake Cethana (fig. 8), numerous quartz veins 75 - 200 mm thick occur within greisenised pegmatite dykes near the eastern boundary of the Dolcoath Granite. Only the major veins have been explored by a six metre deep open cut and a 3.5 m drive at the eastern end of a second open cut (Reid, 1919).

The veins consist of coarsely crystalline quartz with wolframite, molybdenite, bismuthinite, native bismuth, pyrite, chalcopyrite and arsenopyrite associated with fluorite, topaz and muscovite. In one vein, 50 - 150 mm thick, Reid (1919) reports large molybdenite flakes up to 25 mm in diameter in both the lode and the adjacent granite. Another quartz vein, 75 - 200 mm thick, contains bismuthinite and minor molybdenite but no wolframite.

Hidden Treasure [48/123905]

Discovered about 1890, the Hidden Treasure lodes are situated adjacent to the old Lorinna Road on the north-west tip of Tin Spur (fig. 8). Only the two main veins have been explored by two small open cuts and a five metre drive at the end of one of the open cuts. Reid (1919) reports 1.524 t of ore containing over 20 mass% WO_3 was produced from the small workings.

Numerous quartz veins, up to 300 mm thick, contain wolframite and molybdenite with bismuthinite, pyrite and chalcopyrite and accessory fluorite, topaz and muscovite. The veins occur in greisenised granite which also contains wolframite, molybdenite and bismuthinite. In the main workings, consisting of a nine metre long open cut and short drive, a 200 mm thick quartz vein trending north-west and dipping 60° SW is contained in greisenised granite one metre wide. This vein, exposed in the drive at the end of a nine metre long open cut, reportedly assayed at 5.9 mass% WO_3 and 8.05 mass% Mo (Reid, 1919). Other veins in the immediate area also indicated high metal values of 3.4 - 10.2 mass% WO_3. The 250-300 mm thick quartz vein in the second open cut assayed 1 mass% WO_3 and 0.15 mass% Mo (Reid, 1919).

Squib (Gurrs) [48/100912]

Located on the north flank of Dolcoath Hill about 45 m above Narrawa Creek (fig. 8) the Squib mine, referred to as Gurrs mine and Packetts workings by Twelvetrees (1913) occurs on the contact between the Dolcoath Granite and the Moina Sandstone.

Quartz veins contain dominantly wolframite with molybdenite, bismuthinite and bismutite, cassiterite, gold, pyrite, chalcopyrite, sphalerite and arsenopyrite in association with topaz, fluorite, beryl, monazite and muscovite (gilbertite). The veins, trending 320° and dipping 40° - 50° SW, traverse unbroken the greisenised granite and quartzite with very little variation in size or composition, although the richest ore apparently occurs in the quartz veins in the quartzite (Reid, 1919).

The principal developments at this mine have been on two levels 36 m apart (Reid, 1919). On the upper level, an open cut 7.6 m deep has been excavated in greisenised granite carrying numerous quartz veinlets, 25-125 mm thick, bearing wolframite, bismuthinite, bismutite and molybdenite, and which also occur in the enclosing greisen. The open cut was enlarged during a later, unsuccessful attempt to mine the veins (Keid, 1943). A crosscut adit, 4.5 m below the open cut, intersects these veins, which have been driven both east and west of the adit and pass unaltered from granite into quartzite. The veins are generally of low grade, although one vein 150 mm thick assayed 3.10 mass% WO_3 (Keid, 1943).

In the lower level, two sub-parallel veins diverge at a point 30.5 m from the entrance of the main tunnel and each vein has been developed separately. The east vein, 75-200 mm thick, has been developed for a further 88 m and the west vein 200-300 mm thick, for a further 78 m. The veins in these workings are in quartzite. The east vein in the main tunnel splits into a number of veinlets at the end of the drive and although not established, Reid (1919) suggests that the veins exposed in the open cut and main tunnel are the same.

Subsequent to Reid's visit, the veins have been stoped to the surface, the lower workings now appearing as a long open cut more than 60 m in length (Keid, 1943). A second adit, 12 m below the main adit and connected to it by a rise, was driven on a lode up to 4.3 m thick and described by Keid (1943) to be heavily pyritic and containing an appreciable amount of galena with some sphalerite.

In addition, two other adits 32.6 m long (Truscotts workings) and 45.7 m long (Sparks drive) have been driven on smaller quartz veins parallel to the main lode. These veins also contain wolframite, bismuthinite, molybdenite, pyrite and sphalerite, and occur at the contact between quartzite and granite (Reid, 1919).

Packetts workings. These workings are located in a small gully to the south-west of the Squib mine, where a trench 30.5 m long and 4.2 m deep has been cut along the course of narrow wolframite bearing quartz veins. These veins also contain cassiterite and bismuthinite. Reid (1919) reported that pyrite in these veins contains 3.1 g/t Au.

QUARTZ VEINS

Quartz veins bearing wolframite, cassiterite, bismuthinite and molybdenite penetrate Cambrian quartz-feldspar porphyry (Bull Creek Formation), Ordovician lenticular pebble conglomerate (Roland Conglomerate) and tubicolar quartzite and shale (Moina Sandstone) and skarn equivalent to the Gordon Limestone. The principal deposit is at the Shepherd and Murphy mine, Moina, about 2.5 km west of the Dolcoath Granite. Other significant deposits are at the All Nations mine and at the Squib mine (described in the previous section) located 1.5 km west of, and on the edge of the Dolcoath Granite respectively.

Shepherd and Murphy [48/074909]

The Shepherd and Murphy mine, later referred to as the Moina Tungsten-Tin mine, is situated on the south bank of Bismuth Creek at Moina (fig. 8).

This mine has contributed the greatest part of the total production of tin, tungsten and bismuth from the Moina and Round Mount districts. During periods of intermittent production between 1893 and 1957, an estimated 525 t Sn, 255 t WO_3 and 71 t Bi have been recovered from the underground and surface workings at this mine.

History. The lode deposits of the Shepherd and Murphy mine were discovered in 1893 by Thomas Shepherd and Thomas Murphy. Shepherd was also one of the discoverers of the silver-lead deposits in Claude Creek (later to become the Round Hill mine). During the early stages of prospecting and mine development, production was intermittent, but from 1907 to 1918 regular production of tin, tungsten and bismuth was maintained. Prior to 1914, mining was confined to the lodes above no. 3 adit, but by 1915 the main shaft had been sunk below that level to a depth of 52 m. From this period up to 1919, no. 4 and 6 lodes, together with the north-west branch of the latter, were developed from the shaft levels, the greater part of the stoping being carried out on no. 6 lode. In 1919 a bushfire destroyed the milling plant and the mine closed down.

The erection of a new mill commenced in 1921 by the Shepherd and Murphy Syndicate Limited and was completed in the following year by the New Shepherd and Murphy Mining Company. The latter company milled some 2 000 t of ore, principally from broken material in stopes above no. 3 adit and from surface dumps, for a return of approximately 22 t of concentrate. The shaft levels were not de-watered and operations ceased in 1924.

Between 1933 and 1950, J.P. Godwin carried out intermittent sluicing operations on alluvial and detrital deposits and a limited amount of underground stoping and prospecting.

In 1953, the Moina Tungsten Tin Mining Co. N.L. was formed and by 1954 had de-watered the mine, erected a new treatment plant and had treated some 2540 t of ore. Production continued for the next two years, but in 1957 production ceased and the company was placed in liquidation.

In the petition to the court for liquidation, the directors stated that due to low metal prices they were unable to operate at a profit.

The mine has been abandoned since 1957, but sporadic interest has been shown in the deposit (*e.g.* Reid, 1971). The main potential for the mine now appears to be in the skarn which is one of the host rocks for the veins.

Previous Literature. Several geological examinations have been made during the life of the Shepherd and Murphy mine. Since the underground workings are inaccessible, and have been so since 1957, it is necessary to draw upon the previous literature for descriptions of the mine and of the various lodes.

The first report on the mine is a brief note by Montgomery (1894), soon after discovery of alluvial cassiterite and gold and lodes containing cassiterite, bismutite and bismuthinite in small creeks flowing north into Seven-mile Creek (now Bismuth Creek). Descriptions of the early workings are given in reports by Smith (1897, 1899) and Waller (1901). Between Smith's visits, the operations at the mine were transferred from surface trenching to underground development from two adits (no. 1 and 2).

A comprehensive description of the lodes, the milling and mining methods, and of the then innovative process of electromagnetic separation of the cassiterite, wolframite and bismuthinite is contained in the report by Twelvetrees (1913). At the time of this inspection, no. 2,4,5 and 6 lodes were being worked from no. 1 and 3 adits and no. 4 creek drive. By the time of Reid's (1919) inspection the workings were at a most advanced stage, with development and mining being undertaken on most levels to the no. 3 shaft level.

Keid inspected the mine in 1943, but the operations then were directed towards recovery of alluvial cassiterite, wolframite and bismuth-inite.

After the underground workings were re-opened in 1953, the mine was inspected by Blake (1956), who concluded that the lodes exposed in the lowest level were contracting and the grade decreasing laterally in either direction. When it was known that operations at the mine were about to cease once again, much of the available information on the underground workings was recorded in a report by Robinson (1958) and the mineralogy of the lodes recorded by Williams (1958).

Development. From the surface down to a depth of 103 m no. 2,4,5, and 6 lodes have been worked from four adits (no. 1,2 and 3 adits and no. 4 creek drive, fig. 10). Below no. 3 adit, which is the lowest and in the later workings is referred to as no. 1 shaft level, the lodes have been developed to a further depth of 46 m, in two levels 23 m apart, from the main shaft (no. 2 and 3 shaft level) which was sunk on 6 lode.

Above no. 3 adit (no. 1 shaft level) the lodes have been almost completely stoped out to the surface. On no. 3 shaft level all four lodes together with the north-west branch lode have been developed, and on no. 2 shaft level only the 6 lode and the north-west branch lode have been developed.

Detailed plans of all the various levels and longitudinal sections of the lodes are included in reports by Blake (1956) and Robinson (1958). The early workings, above no. 3 adit level are described in detail by

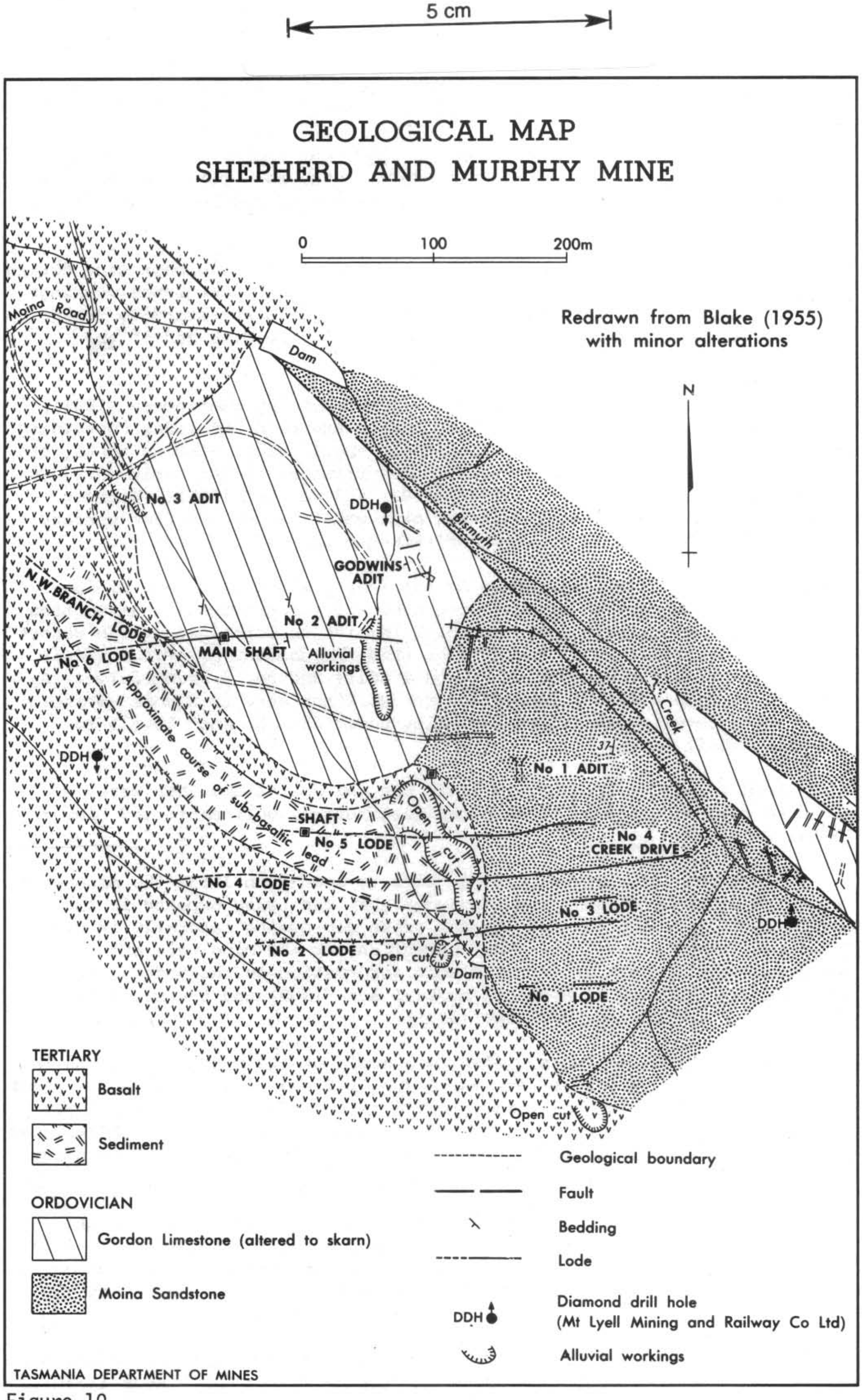

5 cm
GEOLOGICAL MAP
SHEPHERD AND MURPHY MINE
0
100
200m
Redrawn from Blake (1955)
with minor alterations
N
Moina Road
Dam
No 3 ADIT
DDH
Bismuth
GODWINS ADIT
N.W. BRANCH LODE
No 2 ADIT
MAIN SHAFT
Alluvial workings
No 6 LODE
Approximate course of sub-basaltic lead
Creek
DDH
No 1 ADIT
SHAFT
Open cut
No 5 LODE
No 4 CREEK DRIVE
No 4 LODE
No 3 LODE
DDH
No 2 LODE
Open cut
Dam
No 1 LODE
Open cut
TERTIARY
Basalt
Sediment
ORDOVICIAN
Gordon Limestone (altered to skarn)
Moina Sandstone
Geological boundary
Fault
Bedding
Lode
Diamond drill hole
(Mt Lyell Mining and Railway Co Ltd)
DDH
Alluvial workings
TASMANIA DEPARTMENT OF MINES

Figure 10.

Twelvetrees (1913) and the shaft levels by Reid (1919). Most of the development and mining was undertaken prior to 1920.

The only other major development is Godwins adit, situated approximately 55 m north-east of no. 2 adit (fig. 10). The adit extends south-east for 24 m and intersects four east-west trending quartz veins carrying wolframite and minor cassiterite and molybdenite (Blake, 1956). The veins vary from 50 - 180 mm thick. A fifth vein at the end of the adit trends north-south.

On the steep slopes east of Bismuth Creek, opposite the entrance to no. 4 creek drive, several north-west trending quartz veins containing a little cassiterite and wolframite have been cut in a series of prospecting trenches located on either side of the Bismuth Creek Fault.

Production. There are no production figures available prior to 1907. Production during the period 1907 - 1920 amounted to 479 t of tin (metal), 305 t of wolfram (concentrate) and 69 t of bismuth (metal)(Table 5). For the period 1920 - 1952 the production records are incomplete, but at least 8.17 t Sn, 8.56 t WO_3 and 1.9 t Bi were produced from the underground workings and from surface sluicing operations.

During 1953 - 1956, some 18 580 t of ore was treated, of which 15 784.4 t of ore treated during 1955-56 produced 53.821 t of tin concentrate and 31.374 t of wolfram concentrate (Table 5).

Table 5. TIN, TUNGSTEN AND BISMUTH PRODUCTION FROM THE SHEPHERD AND MURPHY MINE.

Year	Sn (conc.) (t)	Sn (metal) (t)	WO_3 (conc.) (t)	Bi (metal) (t)
1907	30.380	19.139	15.495	-
1908	91.393	57.577	0.914	3.455
1909	85.145	53.641	6.147	2.947
1910	39.778	25.060	20.981	10.872
1911	39.453	24.855	22.851	14.601
1912	49.360	31.096	23.207	7.610
1913	57.315	36.108	29.211	5.111
1914	37.873	23.860	24.070	5.349
1915	71.530	45.064	36.222	5.207
1916	68.329	43.047	33.682	3.516
1917	69.955	44.071	37.086	4.217
1918	60.201	37.926	31.152	4.116
1919	-	36.974	23.775	1.595
1920	-	0.457	0.406	-
Total	700.712	478.875	305.199	68.596
1955	22.654	-	22.737	-
1956	32.031	-	9.140	-
Total	755.397	478.875	337.076	68.596

Ore reserves. Robinson (1958) calculated a total of 43 000 t of probable ore and 35 100 t of possible ore at an estimated extractable grade of 0.21 mass% Sn and 0.37 mass% WO_3. The probable ore reserves are almost exclusively above the backs of already started stopes.

Robinson (1958) suggested that the above reserves, though not very large, might be increased by further exploration. However, Blake (1956) suggested that there is an indication of a decline in the overall grade of the lodes towards the no. 3 shaft level and that this decline is particularly noticeable at the extremities of the drives.

Geology. The host rocks for the mineralised quartz veins are the Moina Sandstone and the overlying altered equivalent of the Gordon Limestone (fig. 10). The Ordovician rocks generally dip 30°-40° north-west. Tertiary olivine basalt and underlying tin-bearing sediments effectively blanket much of the mine area.

The Late Devonian Dolcoath Granite, which is the most likely source of the mineralising fluids, has been intersected 200 - 220 m below the surface at the mine in two diamond drill holes (McKibben, 1971*a*). Gee (1966) suggested that the Dolcoath Granite plunges shallowly westwards from where it crops out on Dolcoath Hill, 3 km east of the mine, to extend beneath Moina, where it is now postulated that a cupola-like body has intruded above the main granite mass (Reid, 1971; Collins, 1975*c*), causing the east-west fracture system which served as channels for the mineralising fluids.

Beneath the mine, only the Moina Sandstone has been intruded by the Dolcoath Granite causing induration and recrystallisation of the sandstone to dense, grey quartzite. The overlying Gordon Limestone has been metamorphosed and metasomatised to magnetiferous skarn and garnetiferous (or calc-silicate) skarn (Collins, 1975*c*; Webb, 1974). The lodes traverse unbroken the quartzite and the skarn.

Coinciding with the course of Bismuth Creek is a near vertical fault, the Bismuth Creek Fault, on which the movement is accepted as south-block down (Robinson, 1958). Blake (1956) commented that the age of the Bismuth Creek Fault is post-mineralisation on the basis of off-set veins. Although the correlation of such veins is difficult, Robinson (1958) agrees that the overall impression is that the fault is post-mineralisation.

Mineralisation. The lodes of the Shepherd and Murphy mine are essentially quartz fillings of tension fractures, occurring as a series of almost vertical (dip about 85°S), east-west trending quartz veins up to 395 m in length and varying up to 900 mm thick, but generally 350 - 500 mm thick. Six parallel veins, numbered from south to north, occur within a width of 275 m (fig. 10). Of these, no. 2,4,5 and 6 have been developed and worked. An additional vein, the north-west branch lode, trends north-west and intersects the no. 6 lode west of the main shaft. The veins penetrate the dense quartzite and overlying skarn, traversing the contact unbroken.

The veins consist predominantly of quartz with fluorite, topaz, phlogopite, muscovite, chlorite, laumontite, calcite, siderite and beryl as accessory gangue minerals. The metallic minerals of economic importance comprise cassiterite, wolframite and bismuthinite. Subordinate metallic minerals include pyrite, marcasite, magnetite, hematite, pyrrhotite, arsenopyrite, molybdenite, chalcopyrite, sphalerite, galena and scheelite (as an alteration product after wolframite). Native bismuth and bismutite also occur near the surface (Blake, 1956; Williams, 1958). A detailed description of the mineralogy of the veins is given by Williams (1958). Wall-rock alteration is a minor and occasional feature (Blake, 1956; Robinson, 1958).

In addition to the main east-west lodes there are two other lodes, 'banded lodes' and north-west branch lodes. The 'banded lodes' consist mainly of quartz with some chalcopyrite and fluorite and are frequently banded, consisting of laminations of fine siltstone and quartz varying from 3 - 12 mm thick (Burns, 1958*a*). The banding is interpreted by Burns to be silicification of fracture cleavage in shale bands interbedded with the quartzite. The 'banded lodes' are considered to be contemporaneous with the east-west lodes (Burns, 1958*a*).

The north-west branch lodes are considered to be mineralised transverse faults which generally cause negligible displacement of the east-west veins. Only two of these faults are mineralised, the north-west branch of 6 lode and a similar branch of 5 lode. Burns (1958*a*) attempted to establish the relationship between the 5 north-west branch and 5 lode and considered the north-west branch to be later than the 'banded lodes'. The relationships are confused by later faulting sub-parallel to the 5 north-west branch lode.

Genesis. The most probable source of the mineralising fluids is the Dolcoath Granite and more particularly through the cupola-like body beneath the mine. The granite here appears greisenised, consisting of 50 - 60 modal% quartz, 30 - 50% total feldspar and up to 20% mica (phlogopite), with accessory fluorite, topaz and magnetite (Webb, 1974). It is not known whether the veins penetrate the granite.

Several conclusions have been drawn from previous investigations (*e.g.* Williams, 1958; Webb, 1974) relating to the sequence and conditions of deposition of the lodes.

Firstly, considerable evidence is presented by Williams (1958) to indicate that the limestone was contact metamorphosed before the material now filling the veins was introduced. Webb (1974) postulates two phases of metamorphism and metasomatism of the limestone to produce initially a garnetiferous (or calc-silicate) skarn which was then transformed, in part, by a second phase of iron-rich metasomatic fluid into a magnetiferous skarn.

This second phase of metasomatism coincides roughly with Williams' 'halide stage' of mineralisation from which cassiterite, wolframite, magnetite and topaz were deposited during interaction between the metamorphosed limestone wall rocks and gaseous halide-rich mineralising fluids to form the magnetiferous skarn (tactite).

Following deposition of the cassiterite, wolframite and fluorine-bearing minerals, the bulk of the sulphide minerals and quartz were introduced. Pyrite and arsenopyrite were deposited first, followed by molybdenite, then pyrrhotite, chalcopyrite and sphalerite and finally bismuthinite and galena (Williams, 1958).

In the final stage of mineralisation, Williams (1958) envisages the introduction of carbonate rich solutions. During this stage, decomposition of pyrrhotite to pyrite and marcasite occurred, with accompanying formation of iron oxides and partial decomposition of bismuthinite and formation of native bismuth.

All Nations (Lady Barron) [48/086904]

Early reports of the All Nations mine, situated at the head of

Narrawa Creek about 1.5 km east of Moina (fig. 8), were prepared by Twelvetrees (1908, 1913), referring to the Lady Barron workings, Reid (1919), Keid (1943) and Nixon (1954).

The veins have been worked over a considerable distance, the surface workings extending for approximately 350 m as a long open cut (or underhand stope). The veins have also been mined from two adit levels, with stopes extending to the surface, and a third internal level connected to the surface by a shaft. Detailed plans of the workings were prepared by Nixon (1954), with more recent development described by Collins (1978). Recorded production from the All Nations mine is 36.253 t WO_3 and 0.528 t Bi during the period 1910 - 1942.

Quartz veins bearing dominantly wolframite and minor bismuth, molybdenite, muscovite and pyrite occur entirely within quartzite and siltstone of the Moina Sandstone. The veins range from 10 - 400 mm thick, strike about 105° and dip 75° - 80° S. They occur in an *en echelon* pattern with their extremities overlapping. At least three parallel veins are recognised with an average thickness of about 200 mm. The veins are dislocated at the eastern end of the workings by a low angle reverse fault striking about 090° and dipping 20° - 25° N. This thrust fault consists of a brecciated zone with included vein fragments and a series of parallel faults over a thickness of about two metres. Drag on bedding indicates the hanging wall moved south relative to the footwall (Nixon, 1954), but the magnitude of the displacement is not known. The fault is also reported to have been intersected at the end of a 10 m drive to the east of the bottom of the main shaft in the centre of the workings.

In the western end of the lode, the wolframite is reported to be finer grained than in the eastern end and the vein of lower grade. Twelvetrees (1908) suggested the All Nations lode possibly connects with the no. 6 lode at the Shepherd and Murphy mine.

Cassiterite has not been detected in the veins at the All Nations mine but does occur in alluvial workings immediately to the north. Twelvetrees (1913) and Reid (1919) suggest the origin of this cassiterite is from smaller quartz veins 50 - 100 mm thick carrying wolframite and cassiterite, occurring about 60 m south of the All Nations lode. Reid (1919) described bismutite and gold 25 - 75 mm thick occurring on the hanging wall selvage, with one sample of this selvage material assaying 4.8 mass% Bi, 17.1 g/t Au, 6.2 g/t Ag.

Exposed in a trench on the summit of the hill approximately 200 m south-east of the All Nations mine [48/088902] are several quartz veins with minor wolframite occurring within massive white conglomerate (Twelvetrees, 1913; Reid, 1919).

Pig and Whistle (Lawson and Rileys) [48/090900]

At the Pig and Whistle workings, situated about 500 m south-east of the All Nations mine (fig. 8), two intersecting vein systems have been developed on two adit levels 9 m apart. Detailed plans of the workings, which are now inaccessible, have been prepared by Nixon (1954). Recorded production is 0.9 t WO_3.

The 75 - 250 mm thick quartz veins contain dominantly wolframite with minor cassiterite, bismuthinite and bismutite, pyrite and arsenopyrite and accessory abundant topaz and fluorite, tourmaline and muscovite. The veins occur within decomposed quartz-feldspar porphyry.

Within a distance of 100 m north of the Pig and Whistle workings, Reid (1919) describes wolframite bearing lode material occurring as a horizontal lode between the conglomerate and the porphyry.

Pochins [48/091904]

An adit, 30.5 m in length, has been driven on a series of rich pockets and short irregular veinlets, 50 - 150 mm thick, containing wolframite and occurring in gritty sandstone and conglomerate overlying quartz-feldspar porphyry. The veins were originally considered to be the eastern extension of the All Nations lode (Twelvetrees, 1913; Reid, 1919) but this is not possible as the low angle reverse fault which dislocates the veins at the All Nations mine intersects the surface between the two deposits.

Lawkemlaw (Burford and Bilson) [48/086901]

Situated approximately 250 m south of the All Nations mine, on the crest of the hill, are the inaccessible workings of the Lawkemlaw mine (fig. 8).

These workings consist of 5 shafts spread over a distance of 100 m along a general bearing of 290°. Blake (1937*c*), referring to the Burford and Bilson mine, reported that the two eastern and the central shafts were connected by a drive 56 m long and eight metres below the surface. The lode above this drive is apparently stoped out, nearly to the surface. The two western shafts (about 9 m deep) apparently are not connected, but there is evidence to suggest that there has been some stoping of the lode to the west of the central shaft. To the west of the most western shaft, surface trenching over a distance of 65 m indicates the existence of a second parallel lode, occurring as a vein 75 - 150 mm thick (Blake, 1937*c*).

From near the central shaft, a cross cut sent in south apparently intersected a vein at about 3.5 m and this vein was driven on to the west (and probably east) and most of the available ore appears to have been stoped out. At the western end of this stoped block a rise has recently been converted into a shaft. To the west of this new shaft, the vein has been driven on for about 10 m.

The vein exposed in this drive averages about 50 mm thick, but thins to 10 - 20 mm thick in the face of the drive. The vein consists predominantly of smoky quartz and pale blue topaz with wolframite and minor sulphides. The vein strikes 275° and dips 80° - 85° N, and is probably a branch of the main vein (striking about 290°). The host rock is decomposed Cambrian quartz-feldspar porphyry overlain immediately to the north by siliceous conglomerate (Roland Conglomerate). Recorded production from the Lawkemlaw mine is 23.2 t WO_3 during the period 1935 - 1939.

Immediately to the south-west of the Lawkemlaw mine are several prospecting trenches along the course of quartz veins carrying wolframite, and also trenches across the general trend of the lodes. These workings are referred to as the Nicholls and Smith tribute by Nixon (1954).

Povey and Johnsons (Sullivans) [48/111913]

To the north of Sayers prospect, on the south bank of Narrawa Creek, is a quartz vein, 75 - 200 mm thick, carrying wolframite and a little molybdenite in quartzite of the Moina Sandstone. The vein strikes 335° and dips 45-60° S. It has been explored by a 10 m cross cut adit driven in a southerly direction, from which the vein has been developed along its strike for a distance of 10.6 m to the west and 26.2 m east. Throughout this length the vein has been stoped to within about one metre of the surface (Keid, 1943). The grade of the vein is apparently reasonably high.

On the steep spur to the north of the creek, Reid (1919) described very thin veinlets of cassiterite and wolframite in quartzite.

Fletchers [48/032907]

Cropping out on rock benches cut in the banks of the River Lea near Fletchers adit (fig. 8) are several veins carrying varying amounts of bismuthinite, wolframite, sphalerite, galena, chalcopyrite and pyrite, with reportedly a little silver and gold. The veins occur in folded and faulted quartzite and shale (Moina Sandstone) and in the overlying Gordon Limestone which has been converted to magnetite and garnet skarn.

The veins strike north-west, parallel to small folds and to a major thrust fault at Fletchers adit. In the quartzite, the veins are *en echelon* in plan, occurring as tension fillings along the crests of small folds. The veins in the magnetite skarn occupy one member of a set of conjugate shear-joints concordant with the axis of a major syncline (Burns, 1959). The veins are 50 - 100 mm thick and are of no economic significance (Reid, 1927; Keid, 1943; Burns, 1959).

SKARN DEPOSITS

Skarn occurs at several localities in the Moina area and is equivalent to the basal sections of the Gordon Limestone and possibly the uppermost beds of the Moina Sandstone. Development of the skarn is attributed to the emplacement of the late Devonian Dolcoath Granite which crops out between Dolcoath Hill and Tin Spur. Despite its stock-like appearance at the surface, Gee (1966) suggested that the Dolcoath Granite plunges shallowly westwards from Dolcoath Hill to extend beneath Moina, where granite has since been intersected 200 - 220 m below the surface in diamond drill holes (McKibben, 1971*a*). Granite is also considered to occur at relatively shallow depths beneath the skarn in the Stormont and Ti-Tree Creek areas (Reid, 1971; Collins, 1975*c*).

The main occurrences of skarn (fig. 8) are in the River Lea in the Stormont area, at Ti-Tree Creek, Moina (Shepherd and Murphy mine) and in Tin Spur Creek. Minor occurrences of skarn are located in the Iris River and in a diamond drill hole collared on the southern shore of Lake Gairdner (Collins, 1975*c*). Jack (1961) described bands of impure dolomite within the quartzite at Higgs gold mine which had been altered to skarn containing garnet, diopside and quartz.

The only locality at which skarn has been mined for metallic minerals is at the Stormont bismuth mine, situated in Castle Creek, a tributary of the River Lea. At the other localities, metallic minerals do not occur in sufficient quantity to have warranted previous exploitation. However, these skarn deposits have significant potential as possible hosts for disseminated metallic mineralisation, in particular scheelite, wolframite, cassiterite, molybdenite, bismuth ores and chalcopyrite and possibly as sources of iron ore. The metallic content of the skarn in the Moina and Ti-Tree Creek areas is indicated in Table 8. At the present time, the main potential of the skarn is as a source of non-metallic minerals (*e.g.* fluorite, garnet and magnetite) for metallurgical and industrial use.

The skarn can be divided into two dominant types (based on the Moina and Ti-Tree Creek areas), a garnet (or calc-silicate) skarn and a magnetite-fluorite skarn. The metallic minerals generally appear to be more concentrated in the magnetite-fluorite skarn than in the garnet skarn (Table 8), although at the Stormont mine the bismuth apparently occurred in garnet skarn in preference to magnetite skarn (Broadhurst, 1934). The above two types of skarn are described in detail by Webb (1974) and a summary description is given in a later section.

The occurrence in Tin Spur Creek near its confluence with the River Forth (now submerged beneath Lake Cethana) is described by Jennings (1958) as composed of garnet (probably grossularite), pyroxene (probably ferro-augite) and epidote.

Stormont area

There are two occurrences of bismuth bearing skarn in the valley of the River Lea, about 3.5 km west of Moina. These are at the Stormont bismuth mine, located on the west bank of Castle Creek [48/026903] and immediately south-west of Fletchers adit [48/032907] on the banks of the River Lea for a distance of about 65 m.

The bismuth ores occur disseminated in skarn or in thin veins near Fletchers adit. Only the disseminated ore in the skarn at Castle Creek has been mined. Production for the period 1928-1934 amounted to 6.325 t of bismuth concentrate containing 51-67 mass% Bi, 164 - 1234 g/t Au and 214 - 360 g/t Ag (Burns, 1959). Some of the early concentrates also contained lead. Keid (1943) records that 4.348 t bismuth and 1831 g of gold were produced during 1930-1933.

The skarn here is formed from the lowest horizons in the Gordon Limestone, with perhaps the top shale beds of the Moina Sandstone (Broadhurst, 1934; Keid 1943). There are several occurrences of skarn controlled by the folding and faulting of the rocks in this area. The skarn south-west of Fletchers adit is the flat-lying centre of a syncline, as probably is the skarn to the north-east of the Castle Creek workings. The Castle Creek deposit is also parallel to bedding which is here steeply dragged against the fault immediately east of the open cut workings, giving a vertical orebody running obliquely into the fault (Burns, 1959).

The Castle Creek deposit was worked from an open cut, from which several short exploratory adits and shafts were driven. The only estimate of the grade of the deposit are two assays of crude ore mill feed at 1.01 and 0.92 mass% Bi (Burns, 1959). The bismuth occurs as bismuthinite interstitial between the garnet in the garnet skarn, in preference to a magnetiferous skarn in which garnets occur sparingly (Broadhurst, 1934).

At Fletchers adit, samples of skarn collected by Keid (1943) assayed 0.13 - 1.28 mass% Bi (average 0.57 mass% Bi), and a chip sample across about 300 mm of the face of the open cut above Fletchers adit assayed 2.52 mass% Bi and 7.1 g/t Au (Burns, 1959).

ALLUVIAL AND DETRITAL DEPOSITS

Detrital and alluvial deposits in the vicinity of the vein deposits have been worked for tin, tungsten and bismuth. The main alluvial workings are the Iris mine at the head of Dolcoath Creek, Yorks workings lower down Dolcoath Creek, at the All Nations mine and at the Shepherd and Murphy mine.

Sluicing has also been conducted in the creeks and gullies in close proximity to the Dolcoath, Squib and Narrawa workings.

On Tin Spur, several small tin prospects are located beneath the scarp of Tin Spur Creek Fault. Most of the cassiterite here is a secondary enrichment formed by gravity concentration in the detritus below the scarp.

Iris (Kemps Rainbow, Red Robin) [48/083898]

Cassiterite, wolframite and bismuthinite occur in the basal 0.5 - 1 m of detrital and alluvial material occupying a gently south sloping area immediately south-west of the All Nations group of lodes (fig. 8). The alluvium is composed of boulders of quartzite, conglomerate, quartz feldspar porphyry and white vein quartz and overlies the Moina Sandstone and Bull Creek Volcanics, straddling the Bismuth Creek Fault. The mineralised alluvium is overlain by up to 1.5 m of barren material. To the south, the alluvium is overlain by Tertiary basalt.

The ore minerals are not water worn, indicating a close proximity to their source which is probably the mineralised quartz veins to the north.

Recorded production during intermittent periods of mining between 1912 and 1942 is 15.966 t WO_3, 15.658 t Sn, 0.016 t Bi, of which 74% of the tungsten, 82% of the tin and all of the bismuth was recovered during the period 1912-1918 (Keid, 1943).

Yorks [48/117902]

Minor amounts of cassiterite and wolframite have been sluiced from a flat area in the valley of Dolcoath Creek which was probably an old terrace of the River Forth (fig. 8). The alluvial wash, 1.8 m thick and composed of pebbles and boulders of granite and quartz-feldspar porphyry and a little vein quartz, lies beneath 1.5 m of overburden (Twelvetrees, 1913; Reid, 1919). At the bottom of the alluvium is a clay layer which probably rests on granite bedrock.

A little wolframite is also reported to have been recovered from workings in the creek further to the west.

All Nations [48/086905]

Sluicing of alluvial material, 1 - 2.5 m deep, has been undertaken along the course of Narrawa Creek beginning a few metres to the north of the All Nations mine and extending for some 120 m. The coarse-grained wolframite, cassiterite and bismuthinite in the wash are derived from the All Nations lode and other smaller lodes to the south. The origin of the cassiterite is from these smaller lodes and also probably from erosion of higher levels of the All Nations veins which, at their present level, are barren of cassiterite.

Reid (1919) estimated the grade of this alluvial deposit to be 6.5 kg/m^3 wolframite, 0.5 kg/m^3 cassiterite and 0.3 kg/m^3 bismuth in 3 500 m^3 of wash.

Shepherd and Murphy [48/070906]

Generally narrow and shallow deposits of alluvial and detrital cassiterite, wolframite and bismuth along the course of Bismuth Creek have been worked by sluicing methods (Blake, 1956).

Up the hill and above the main Shepherd and Murphy mine workings is a sub-basalt alluvial deposit which has been worked for cassiterite, principally from a large open cut at the south-east end of the lead (fig. 10). The alluvium consists of basaltic soil and rubble, 4.6 m thick, carrying a little cassiterite overlying bedded alluvial stanniferous sediment, 7.6 m thick, dipping to the west and resting on quartzite of the Moina Sandstone. The upper layers of the alluvium near the contact with the overlying basalt have been silicified (greybilly).

Twelvetrees (1913) and Blake (1956) report that the stanniferous unit as a whole was not payable, but a basal layer of rubbly wash, 200 - 300 mm thick, immediately above the bedrock was payable. Crystals of cassiterite and topaz occur as thin beds of coarser and finer grains within sand containing a little monazite, bismuthinite, wolframite and gold, and also a little black coniferous timber. The sub-basalt alluvial lead has been intersected at five localities in the underground workings, all at the western end of drives along lodes.

The old gully probably rises to the south-east and falls to the west towards other Tertiary gullies (deep leads) known to occur in the Moina area (fig. 5). Greybilly occurs extensively throughout the Moina area beneath the Tertiary basalt.

Tin Spur deposits

Jennings (1958) has fully described the tin deposits on the north flank of Tin Spur and the following description is based on this report. Twelvetrees (1913), Reid (1919, 1923) and Scott (1927*b*) have also reported on these deposits.

Since most of the workings which were open at the time of Reid's visits have since collapsed, it is convenient to group them into two sets of workings; those around Falls mine [48/133902] and the Lower workings, comprising Goreys tunnel and Duffs shaft [48/127906] and Ashworths workings [48/126907].

Geology and mineralisation. The Moina Sandstone, here consisting of dense, white quartzite and friable sandstone often packed with tubicolar casts, underlies most of this area. The remainder is underlain by Roland Conglomerate except for a small area of Cambrian porphyry exposed beneath the scarp of the Tin Spur Creek Fault, on the upthrown block. Talus and fluvioglacial deposits blanket much of the area. Reid (1919, 1923) refers to porphyry sills within the Moina Sandstone. However, Jennings (1958) suggests these porphyries are in fact beds of grit. Reid also reports that skarn (a garnet-epidote rock) occurs in association with some of these deposits.

The main fault is the Tin Spur Creek Fault, a large thrust fault trending north-west and dipping south-west at 30° to 35°. In general there is comparatively little folding in the rocks on the upper plane of this fault but the rocks beneath the thrust plane are folded into a series of north-west trending anticlines and synclines.

There is a persistent zone of tin bearing rocks in the area paralleling the Tin Spur Creek Fault for over one kilometre. The actual fault plane is not well exposed, but it is possible to locate it within a few metres at most points (Jennings, 1958). There is no evidence as to whether the fault zone has acted as a lode channel or whether payable deposits of primary ore may be found within the fault zone itself.

The tin which has been produced in this area has been largely derived from secondary deposits, which could be easily worked by prospectors. The thickest superficial deposits are those lying below the scarp of Tin Spur Creek Fault. The majority of these deposits have not been tested and it is therefore possible that further small enriched patches may occur to the north-west and south-east of the Falls mine.

There is also some primary tin mineralisation occurring as disseminated cassiterite with pyrite in friable beds in the Moina Sandstone and as facings on joints in quartzite near the fault.

Falls mine [48/133902]

The discovery of tin at this locality was made about 1918. The mine is situated just above a road cutting on Olivers Road, about 100 m west of Tin Spur Creek. The original outcrop was described by Reid (1919) as 'a lode consisting of gossanous material carrying tinstone in considerable quantity'. The original lode has since been removed in the open cut workings.

The property was originally worked by driving a crosscut adit for about 7.6 m under the gossanous material and driving along the lode for about 12 m. Only a few metres of these workings are now visible in the open cut. The rocks in the cut are deeply weathered and covered by the toe of extensive talus accumulations from the scarp of the Tin Spur Creek Fault which lies about 60 m up the hill south of the open cut.

The gossanous lode material was described by Reid (1919) to 'contain a good deal of silica and undecomposed porphyry'. However Jennings (1958) found the rocks in the cut at the Falls mine to consist of deeply weathered, ferruginous sandstone and siltstone, with numerous porphyry boulders in the overlying talus. The only porphyry in this area is that lying unconformably beneath the Roland Conglomerate and exposed by the upthrown block of the Tin Spur Creek Fault.

Jennings (1958) reported that small quantities of cassiterite could be washed from the material forming the face of the open cut, but none of this is in commercial quantities. The two 'lodes' in this cut are separated by a barren zone and contain only traces of tin. Small quantities of cassiterite can also be obtained by washing the detritus from many parts of the hill-side. Tiny black cassiterite crystals associated with quartz occur on the faces of major joints associated with the Tin Spur Creek Fault.

Jennings (1958) concluded that the concentration of tin which led to the establishment of the Falls mine was probably due to gravity concentration of cassiterite in the detritus below the scarp of the Tin Spur Creek Fault. The Moina Sandstone on the downthrown side of the fault at the mine has been slightly mineralised and carries pyrite, cassiterite and quartz in friable sandy beds. However, it is only when the weathering products of these rocks have been concentrated in talus accumulations that they may become payable. Such concentrations are extremely erratic and unlikely to be of economic importance.

Lower Workings

The majority of the work carried out at Tin Spur was in connection with these deposits. A number of lodes were worked in the vicinity of the old road on the western side of Tin Spur (Ashworths) and also on the nose of Tin Spur itself between the old and the new roads (Goreys and Duffs). Reid (1919) described another lode, the Star of Peace lode, which contained rich pockets of gold.

The original discovery of tin in this vicinity was made about 1889 and the ore bodies were explored sporadically for about 35 years before being finally abandoned. The lodes have been regarded as an extension of the Falls line of lode. However, it is unlikely that those lodes persist for this distance, and the deposits are more likely to be isolated ones associated with fractures and brecciation close to the Tin Spur Creek Fault.

The workings have long been abandoned and are now inaccessible. Goreys tunnel was blocked by a fall at the entrance but was cleared out and re-examined by Jennings (1958). Reid (1919) reported skarn in Goreys tunnel but Jennings (1958) found only sheared, heavily iron-stained quartzite which may superficially resemble skarn at the point where skarn is reported to occur.

Reid (1919) lists assays from Duffs shaft and Ashworths workings which appear attractive (0.16 - 2.70 mass% Sn), but these workings have long since been abandoned. It seems likely that the ore bodies were rich in the detrital material at the surface but that at depth they were uneconomic. Such tin as can be found around Duffs shaft and the nearby sluicings consists of very fine grained cassiterite along joints and fractures.

As with Falls mine, the only payable tin recovered in this area was probably concentrations in the superficial deposits formed by weathering of the quartzite and sandstone (Jennings, 1958). The parent rocks carry small quantities of disseminated cassiterite and pyrite in certain beds, and similar to the Falls mine, there is a fairly persistent zone near the Tin Spur Creek Fault where primary tin occurs along joints. These primary 'ore bodies' are not economic, but where concentration of the weathered sandstone occurs, reasonably rich pockets of tin could occur locally.

COPPER

Several small copper deposits occur within Cambrian sedimentary and volcanogenic sequences to the north-east of Gunns Plains, in the north-west corner of the quadrangle and at the Barrington (or Alma) copper mine located on the ridge between the Forth and Wilmot Rivers. These deposits are probably of volcanogenic origin occurring as disseminations within Cambrian volcanogenic rocks and later remobilised into shear zones during post-volcanism deformation.

Barrington (Alma) [49/219141]

The Barrington (or Alma) copper mine is situated on the north bank of Barrington Creek about 500 m upstream from its confluence with the River Forth (Lake Paloona). The mine was reported on by Thureau (1881) and Twelvetrees (1906, 1909*b*) and by Blake (1928), when reporting on barite occurrences in Tasmania. The deposit has been explored and developed by means of a shallow shaft and an adit driven 130 m into the hillside in a north-westerly direction and from which three short crosscuts were driven in a south-westerly direction. A second smaller adit (the Devonport tunnel) is located 50 m upstream from the main adit. The only recorded production is 457 kg of copper ore (Twelvetrees, 1906).

The sulphide mineralisation is apparently confined to black slate between two pebbly sandstone/mudstone units, each about 15 m thick, within the Cambrian Gog Range Greywacke. Cromer (1973) suggested that the two units are the same horizon folded into a syncline. Twelvetrees (1909*b*) described barite-quartz-siderite veins containing chalcopyrite and pyrite in the greywacke and slate and disseminated chalcopyrite in the pebbly sandstone.

At several localities on the surface, gossan has developed over the pebbly sandstone, and can be traced along strike for at least one kilometre, and it was this feature that initiated prospecting in the area in 1880. A soil geochemical survey by Cromer (1973) failed to indicate a relationship between copper, lead and zinc and the gossanous zone.

The mine is presently more renowned for barite which is relatively common throughout the area, occurring as small veins and as irregular masses in excess of 2 m thick.

Other gossanous formations

Lucas and Perrys lodes are situated about 1.5 km south-west of the Barrington mine [about 49/205130]. A shaft about 12 m deep has been sunk on each of two outcrops of gossan up to 6 m wide and about 40 m apart. The gossanous occurrences, trending north-west, are located in slate within the Barrington Chert. A sample of the eastern gossan collected by Twelvetrees (1909*b*) assayed 9.2 g/t Ag and the western gossan assayed 3.1 g/t Ag.

Crawfords lodes, situated near Alma at the confluence of the Wilmot and Forth Rivers, consist of gossanous formations in slate veined with calcite and containing disseminated pyrite and traces of gold (Twelvetrees, 1909*b*).

Copper Creek [49/037197]

The Copper Creek mine is located on the west bank of Walloa Creek (originally known as Copper Creek) about 1.5 km upstream from its confluence with the River Leven.

Twelvetrees (1909*b*) described bands of copper bearing calcareous slate exposed in a small open cut, an upper adit 18.9 m long and a lower adit 85.3 m long and 50-60 m below the upper adit. These workings have exposed a lode 0.9-1.5 m thick consisting of quartz and calcite veinlets carrying pyrite, chalcopyrite, covellite, hematite and minor amounts of gold and silver in brecciated slate. The lode is vertical and trends 345° and probably represents fissure fillings in a major fault between the Ordovician Dial Range Conglomerate and Cambrian sedimentary and volcanic rock.

In addition to copper, the lodes were also prospected for their gold and silver content as indicated in the following assays (from Twelvetrees, 1909*b*);

Sample description	*Cu (mass%)*	*Au (g/t)*	*Ag (g/t)*
Outcrop	4.8	-	61.2
Outcrop	2.3	-	300.0
Gossan	0.75	1.5	-
Gossan	-	1.1	1.2
Lode, upper adit	2.9	-	73.5
Lode, lower adit	1.6	-	2.5

River Leven prospects

Twelvetrees (1909*b*) described several minor prospects on the banks of the River Leven in the gorge downstream from Gunns Plains, where the river passes through the Cambrian Gog Range Greywacke and Minnow Keratophyre.

Radfords Reef [49/063184], situated about 7 m above the north bank of the River Leven, consists of disseminated pyrite and chalcopyrite lining quartz crystals in cavities in sandstone adjacent to an intrusive porphyry.

Browns Blow [49/064183] is situated on the south bank of the River Leven, opposite Radfords Reef. Here flinty slate is impregnated with quartz and a little specular iron adjacent to the contact with an eruptive unit.

At Colbourns Show [49/067185] a gossanous breccia is composed of tuffaceous and igneous rock and disseminated pyrite.

IRON

Potential iron ore deposits are restricted to the skarn occurrences in the Stormont-Moina area in the south-west corner of the quadrangle. The only other iron deposit of note is approximately 750 m north of the Paloona Bridge, where Twelvetrees (1906) described outcrops of ferruginous quartzite within Precambrian quartzite and schist.

Magnetite is a common constituent of the skarn exposed at Stormont, Ti-Tree Creek and Moina. The iron content of magnetite-fluorite rich skarn in the Moina and Ti-Tree Creek areas ranges from about 10 mass% Fe up to 38 mass% Fe, equivalent to 13.8-52.5 mass% Fe_3O_4 (Collins 1975*c*), but generally contains 15-25 mass% Fe (Table 8). These skarns are described under fluorite.

Non-metallic minerals

INDUSTRIAL MINERALS AND ROCKS

T.G. Summons

Many industrial minerals and rocks occur in the Sheffield Quadrangle but their economic viability is largely unknown. The main occurrences are listed in Table 6, together with an arbitrary classification of the status of the deposit.

Table 6. INDUSTRIAL MINERALS AND ROCKS, SHEFFIELD QUADRANGLE.

Mineral	Common usage	Active mine	Abandoned mine	Prospect*	Occurrence
Asbestos	Insulation, cement, fabrics				Cethana
Barite	Pigments, weighting material, filler		Lower Beulah	Lower Barrington, Lower Wilmot, Mt Roland, Central Castra	Paloona
Fluorite	Metallurgical, chemical and ceramic			Moina	Moina area
Garnet	Abrasive				Moina area
Limestone	Metallurgical, lime, cement	Railton		Gunns Plains	Loongana, Moina area, Paloona
Magnetite	Abrasive, heavy media liquid				Moina area
Beryl	Source of Be, refractory				Moina area
Lithium	Ceramic, glass making				Moina area
Monazite	Source of rare earth elements				Moina area
Topaz	Refractory (mullite)				Moina area
Wollas-tonite	Ceramic, filler				Moina area
Zeolite group	Molecular sieve, adsorbent, base exchange				Sheffield, Bell Mount, Moina

* A prospect is defined as 'an area that is a potential site of mineral deposits, based on preliminary exploration; it is distinct from a mine in that it is non-producing'.

ASBESTOS

Reid (1919) refers to an altered dolerite approximately 1.5 km north-east of Cethana, which hosts irregular masses of 'asbestos ..... of the hornblende type'. It appears likely that he is referring to actinolite asbestos and he states that the fibre is 'short and brittle', with epidote and quartz veins scattered through the asbestos in an irregular manner.

The outcrop is now obscured by road works. Actinolite asbestos is of minimal commercial importance.

BARITE

Barite is reported from several localities in the quadrangle. All occurrences consist of barite veins in Cambrian host rocks.

Lower Beulah

Barite occurs about 800 m east of Lower Beulah [48/378928] as veins parallel to the schistosity in a broad sheared zone encompassing the boundary between andesitic extrusives of the Beulah Formation and sandstone/shale of the Gog Range Greywacke.

The sheared host rocks consist of muscovite schist, schistose andesite and foliated quartz-feldspar-muscovite rock. The barite veins range in width from 0.1 - 1.2 m and show variable contamination by galena, sphalerite, pyrite, chalcopyrite and tetrahedrite. The maximum sulphide impurity occurs in veins immediately adjacent to Clearwater Creek, where it is approximately 20 mass%.

Barite was mined intermittently between 1911 and 1920 from the two largest veins (ranging in width from 0.3 - 1.2 m), predominantly by the Electrolytic Zinc Company of Australasia Limited. Production totalled approximately 635 tonnes.

Following a gravity survey of the area, Leaman (1975) reported an inferred figure of 37 000 tonnes of 'barite rich rock' remaining on the site (*i.e.* possible ore). Analyses (of indeterminate reliability) are shown in Table 7 as a guide to the quality of the barite.

Lower Barrington

Barite occurs 3.2 km west of Lower Barrington, associated with Fe-Cu sulphide mineralisation at the abandoned Barrington (Alma) copper mine. The host rock is pebbly sandstone/mudstone units of the Gog Range Greywacke. These pebbly clastic units form the limbs of a south-west plunging syncline (Cromer, 1973) and host both barite and quartz veins and masses in association with chalcopyrite, pyrite, siderite, dolomite and malachite. According to Twelvetrees (1909*b*), one of the adits in the Barrington copper mine intersected a barite lode approximately 2.5 m in width.

Outcrop data reported by Blake (1928) implies that the barite veins and masses coalesce to form lodes ranging in width from 0.5 to 2.5 m. Cromer (1973) refers to anomalous Ba values obtained in a soil sampling program in a non-outcrop area east of the main adit in the Barrington copper mine, but reports a poor Ba geochemical response over the gossanous pebbly clastic units.

Analyses of similar status to those for the Lower Beulah occurrence are shown in Table 7.

Mt Roland

Barite occurs as two parallel veins in the Gog Range Greywacke approximately 3 km west of Paradise on the northern flanks of Mt Roland. The veins are up to 300 mm thick and combine to form a north-west trending lode ranging in width from 1.5 - 1.8 m.

The analysis shown in Table 7 is of indeterminate reliability and is presented only as a guide to the quality of the barite.

Table 7. ANALYSES OF BARITE, SHEFFIELD QUADRANGLE (ADAPTED FROM BLAKE, 1928).

Analysis	1	2	3	4	5	6
$BaSO_4$	98.2	88.8	86.4	96.4	70.5	92.0
SiO_2	1.1	4.2	1.7	0.9	0.7	5.3
Fe_2O_3 + Al_2O_3	0.2	-	-	1.1	2.36	1.88
Fe^{++}	-	0.5	-	-	3.61	-
Pb	-	-	1.05	-	-	-
Zn	-	-	5.45	-	-	-
Ca	-	-	-	tr	5.72	-
Mg	-	-	-	0.13	2.07	-
CO_2+ Ignition loss	0.38	-	-	0.9	9.5	1.3

1. Trench sample, Lower Beulah.
2. Average assay value of samples, E.Z. Co., Lower Beulah.
3. Assay values, E.Z. Co., Lower Beulah.
4. Hole above 'Copper Creek', Alma mine area, Lower Beulah.
5. Slate band in 'Copper Creek', Alma mine area, Lower Beulah.
6. Trench sample, Mt Roland.

Lower Wilmot

A barite prospect occurs in Gog Range Greywacke approximately 2.4 km south-west of Lower Wilmot. No further details are known about this occurrence.

Central Castra

A barite prospect occurs in Gog Range Greywacke about 2.5 km south-east of Central Castra and 1.5 km south of McPhersons copper mine. No further details are available for this occurrence.

Paloona

Barite veins in trachyte (Minnow Keratophyre) overlying Gog Range Greywacke are recorded about 2.5 km south-west of Paloona, upstream from the Paloona Bridge.

The veins occur as fracture fillings but no further details about the occurrence are available.

FLUORITE

Fluorite is a relatively common mineral in the Moina area, occurring in several different rock types.

Table 8. COMPARATIVE ANALYSES OF GORDON LIMESTONE, GARNET SKARN AND MAGNETITE-FLUORITE SKARN

Element	Gordon Limestone	Garnet skarn (calc-silicate rock)		Magnetite-fluorite skarn			
	1	2	3	4	5	6	7
Si (%)	8.56		18.93	10.33			11.30
Al (%)	0.91		2.22	2.41			3.90
Na (ppm)	400		1100	927			
K (ppm)	5800		1900	13 800			
Rb (ppm)	60		61	603			
Be (ppm)							30
Mg (%)	1.63		1.66	1.46			1.40
Ca (%)	28.50		20.78	10.12			15.20
Sr (ppm)	283		33	2			
Ba (ppm)	105		81	47			
Ti (ppm)	1000		2300	659			
Mn (ppm)	800		12 200	3408			
Fe (%)	0.72	5.72	5.39	14.83	20.10	24.00	20.70
Cu (ppm)	24	58	28	76	253	42	120
Zn (ppm)	10	125	129	285	304	237	810
Pb (ppm)		61			245	27	75
Sn (ppm)		293			787	2050	2250
W (ppm)	18	12	61	344	172	2375	1400
Bi (ppm)		81			654	342	350
Mo (ppm)		11			12	592	115
Ag (ppm)		2			4	3	0.10
Au (ppm)							0.035
P (ppm)	100		300	109			
Sb (ppm)							45
Y (ppm)	7		22	1361			
Zr (ppm)	58		85	24			
F (%)		0.48			1.70	10.70	9.90

1. Average of 8 samples from DDH DOM1 (Webb, 1974). Webb describes these samples as 'unaltered limestone', although Collins (1975*c*) records minor recrystallisation of the Gordon Limestone in DDH DOM1.
2. Average of 15 samples from DDH DOM1, 2 and 3 (Collins, 1975*c*; Askins, 1978).
3. Average of 13 samples from DDH DOM1 and ML3 (Webb, 1974).
4. Average of 7 samples from DDH ML3 (Webb, 1974). Assay results for columns 3 and 4 are slightly inaccurate, (particularly those shown in column 4), because F was not determined.
5. Average of 23 samples from DDH DOM1, 2 and 3 (Collins, 1975*c*; Askins, 1978).
6. Average of 2 chip samples from Shepherd and Murphy mine (Collins, 1975*c*; Askins, 1978). Collins suggests the W result is not necessarily representative of the magnetite-fluorite skarn.
7. Bulk sample from mullock dumps at Shepherd and Murphy mine (Askins, 1978).

Ordovician host rocks

Moina Sandstone.

Fluorite occurs in quartz-chlorite-magnetite-fluorite veins, in greisen veinlets composed of quartz-muscovite-fluorite and as an interstitial mineral to quartz grains in Moina Sandstone adjacent to the Dolcoath Granite.

Gordon Limestone

In the Moina area, the basal sections of the Gordon Limestone and the underlying transition zone beds (above the Moina Sandstone) have been metamorphosed and metasomatised to skarn containing significant quantities of magnetite, garnet and fluorite.

Fluorite bearing skarn occurs in the Stormont, Ti-Tree Creek and Moina areas, the most important being at the Shepherd and Murphy mine, where two main skarn types are recognised.

Garnet skarn (equivalent to Gordon Limestone). Webb (1974) observed fluorite in the following situations:

(*a*) Fluorite interstitial to garnet and pyroxene.
(*b*) Fluorite replacing garnet.
(*c*) Quartz-epidote-magnetite-fluorite assemblages replacing quartzite bands at the base of the Gordon Limestone.
(*d*) Epidote-fluorite pods.

Further details are provided in Table 8.

Magnetite (-Fluorite) skarn (equivalent to Gordon Limestone). The presence of significant concentrations of fluorite in the skarn at Moina was first recognised by Twelvetrees in 1913, although he did not distinguish between the types of skarn. Williams (1958) differentiated the skarn and reported a high proportion of fluorite in the magnetite skarn.

However, it is only recently that the magnetite skarn has been investigated as a source of fluorite; Comalco Limited began systematic exploration in 1974. As a result of this work, summarised by Askins (1978), and the work of Webb (1974), this skarn is more accurately described as a magnetite-fluorite skarn.

The texture and complex mineralogy of the magnetite-fluorite skarn is briefly described in the section on magnetite.

Askins (1978) and Webb (1974) record fluorite in the magnetite-fluorite skarn in fine layers of fluorite alternating with magnetite, interstitial to magnetite and epidote in magnetite-epidote-fluorite bands, coarse-grained intergrowths of ferrohastingsite-fluorite-garnet-magnetite-pyroxene and veinlets of quartz-fluorite, adularia-fluorite, andesine-fluorite and muscovite-quartz-fluorite-oligoclase. Fluorite constitutes approximately 20 mass% of the magnetite-fluorite skarn and is fine-grained (ranging in size from several microns to 3 mm).

The geochemical trends associated with the alteration of the Gordon Limestone to garnet skarn and magnetite-fluorite skarn are readily apparent from the data shown in Table 8.

Devonian host rocks

Quartz Veins.

These consist of a quartz-fluorite-topaz-muscovite-beryl assemblage, hosting Sn-W-Bi-Mo mineralisation. The veins are tension fracture in-fillings and cut both Cambrian and Ordovician country rocks (*e.g.* Shepherd and Murphy, All Nations, Lawkemlaw and Squib mines) and the pegmatitic, aplitic and greisenised modifications of the Devonian Dolcoath Granite (*e.g.* Sayers, Dolcoath, Princess, Premier and Hidden Treasure mines).

The fluorite generally occurs in equal proportions with topaz in the veins; benefication studies on the ore from the Shepherd and Murphy mine by Hills (*in* Twelvetrees, 1913) indicate a fluorite concentration in fresh rock veins of >5 mass%.

Pegmatite and aplite.

Reid (1919) and Jennings (1963) refer to fluorite as an accessory mineral in the pegmatite rocks containing the quartz veins described previously, particularly in the pegmatite at the Princess mine.

Reid (1919) and Elliston (1953*b*) describe fluorite bearing aplite in the Dolcoath Granite.

Granite and greisen.

Portions of the Dolcoath Granite have been strongly greisenised and contain accessory fluorite (Jennings, 1955). Reid (1919), Elliston (1953*b*), Reid (1967) and Webb (1974) report the presence of fluorite as an accessory mineral in the Dolcoath Granite.

GARNET

Garnet is a particularly common mineral in the Stormont-Moina area where, as the result of the contact metamorphic and metasomatic processes associated with the intrusion of the Dolcoath Granite, the transition zone beds (consisting of limestone with narrow bands of siltstone and calcareous dolomitic siltstone) at the base of the Gordon Limestone have been converted to a garnet skarn (garnet calc-silicate rock). The garnet skarn occurs in four main areas;

(*a*) Stormont mine - Fletchers adit;
(*b*) Ti-Tree Creek;
(*c*) Shepherd and Murphy mine (Moina);
(*d*) Tin Spur Creek

The garnet species are reported to range from andradite in the Stormont mine (Webb, 1974) to andradite-grossular in the Shepherd and Murphy mine (Reid, 1919; Williams, 1958; Gee, 1966; Webb, 1974; Askins, 1978). The characteristics of the garnet skarn are summarised in Table 9.

LIMESTONE

The Ordovician Gordon Limestone represents an important mineral commodity in the Sheffield Quadrangle. The main occurrences are in the Loongana, Gunns Plains, Paloona, Railton and Moina areas.

History

Agricultural and other uses.

The earliest recorded commercial usage of limestone is in the Railton area (Twelvetrees, 1909*b*), where it was quarried and used for the manufacture of lime in 1851.

Table 9. MINERALOGY OF GARNET SKARN, MOINA AREA

Locality	Dominant calc silicate minerals	Garnet comp. (vol %)	Garnet size range (mm)	Garnet shape range	Accessory minerals in skarn	Author
Stormont	garnet-actinolite	80-95 andradite 20-50 grossular	1-120 ave.5	?	quartz, calcite epidote, fluorite, talc, chlorite	Webb, 1974
Ti-Tree Creek	garnet-diopside/ hedenbergite	andradite > grossular	?	?	quartz, calcite, fluorite, epidote, actinolite, magnetite, clinozoisite	Webb, 1974
Shepherd and Murphy mine	garnet-diopside/ hedenbergite	50-60 andradite 40-50 grossular with minor pyrope and spessartine	⩽ 5	Xenoblastic subidioblastic	quartz, fluorite, epidote, actinolite ferrohastingsite, magnetite, K feldspar, biotite, wollastonite, vesuvianite, talc, chlorite	Askins, 1978
Tin Spur Creek	garnet-epidote-pyroxene	?? grossular	?	?	?	Jennings, 1958

This quarry was purchased by J. Blenkhorn in 1885, who continued mining the limestone for the production of both lime and crushed limestone until 1945, when mining operations ceased. Blenkhorn's quarry is at present the site of the Railton Lime Works which purchases its raw limestone from the neighbouring Goliath Portland Cement Company Limited.

Several smaller quarries, such as Dalley's and Wooley's (Haines Siding) were probably in operation at the same time as Blenkhorn's quarry, but no detailed information about them is known.

Twelvetrees (1909*b*) refers to a 'small lime burning industry' at Gunns Plains and that 'the stone is also used for metalling roads at the Plains'.

In 1951, the North Western Farmers Lime Company Limited commenced an investigation of the limestone at Gunns Plains and eventually drilled several holes in an outcrop north of the River Leven, on what was known as Winduss' Property. Although encouraging results were obtained with respect to the limestone grades, non-geological factors precluded mining of the limestone at the time.

Minor quarrying of limestone has occurred in the Loongana area for use as construction materials.

Cement manufacture.

Twelvetrees (1911) records a borehole put down approximately 50 m west of the railway line at Railton which intersected limestone over a vertical distance of 168 m, the hole finishing in limestone.

At approximately the same time, tests on samples of limestone from Blenkhorn's quarry indicated that it would be suitable for the manufacture of Portland cement, with the qualification that additional clay (to that forming the acid insoluble residue), would be required to increase the Al_2O_3 content of the limestone.

In 1923, the Tasmanian Portland Cement Company Pty Ltd began construction of a cement works at Railton and by June 1926 had commenced production of Portland cement.

This company changed its name to the Goliath Portland Cement Company Limited in 1928 and since the cessation of operations by the National Portland Cement Company on Maria Island in 1930, it has been the sole producer of Portland cement in Tasmania.

Production for the 1977-1978 financial year by the Goliath Company amounted to 452 222 t of limestone mined, of which 421 018 t was assigned for the manufacture of Portland cement, 22 665 t was used for agricultural purposes and 8 539 t were sold to the Railton Limeworks.

Gross structural features

Loongana.

The Gordon Limestone appears to range in thickness from 450 - 600 m and has been folded into an asymmetric syncline with the axis striking approximately 090°. Parasitic folds and minor faulting have resulted in local offsetting of the limestone.

Gunns Plains.

The Gordon Limestone is approximately 1000 m thick at this locality and has been folded into a major asymmetric syncline, with the axis striking approximately 120°. Parasitic folds and minor faulting similar to those at Loongana also occur.

Paloona.

A small area of Gordon Limestone occurs in the Paloona district, as the southern extension of the limestone cropping out in the Melrose Syncline.

Railton.

The Gordon Limestone in the vicinity of the Goliath Portland Cement Company quarry appears to range in thickness from 600 - 1000 m. The quarry is located on the eastern limb of a syncline, with the axis striking approximately 160°.

Moina district.

Gordon Limestone approximately 200 m in thickness occurs in a topographic and structural basin in the Moina area. The basal 50 m have been converted to garnet and magnetite-fluorite skarn.

Similar alteration of the limestone can be seen at adjacent localities such as Stormont, Ti-Tree Creek, Tin Spur and Round Mount.

Composition

Geochemical data for the Gordon Limestone in the Sheffield Quadrangle as presented by Hughes (1957) cannot be meaningfully utilised in quantitative terms for the following reasons;

(*a*) The method of sample collection is frequently not reported;
(*b*) The methods of sampling adopted (where stated) are inconsistent, both at a given locality and between localities;
(*c*) The relationship between sampling lines and the strike of the limestone strata is not stated;
(*d*) The variation of apparent widths of strata as exposed in outcrop due to:-

 (i) folding - causing dip reversals;
 (ii) topography - variable slope inclinations are not stated, nor can they be deduced from the data.

(*e*) The analyses refer only to small areas within the entire limestone occurrence and statements concerning the overall grade of an occurrence cannot be made until extensive systematic sampling has been performed over the area.

These factors preclude the presentation of the geochemical data as weighted average assays and the data shown in Table 10 is of semi-quantitative status only.

Table 10. ANALYSES OF GORDON LIMESTONE

Locality	No. samples*	$CaCO_3$ (%)	$MgCO_3$ (%)	Acid insol. residue (%)	Fe_2O_3 + Al_2O_3 (%)	P_2O_5 (%)	S (%)
Loongana	7	84.2-94.4	2.5- 5.2	3.2-11.6	0.4-1.0	?	?
Gunns Plains	46	69.4-94.8	1.2-12.6	2.6-19.4	0.3-4.6	?	0.1-0.23
Paloona (Melrose)	14	73.1-91.7	0.8- 3.8	3.6-20.6	0.5-3.1	0.01-0.04	0.03-0.48
Railton	15	60.9-94.6	0.5- 5.0	3.0-29.7	1.6-6.9	?	?
Moina area	12	29.8-84.6	1.9-11.6	9.2-61.8	1.8-10.8	0.03-0.12	?

* 12 samples from Moina district taken from Webb (1974) (8 samples) and Jennings *in* Hughes (1957) (4 samples).

All data from remaining areas taken from Hughes (1957). The analyses presented are of indeterminate reliability and in most case are probably not representative of the limestone at those localities.

Information provided by the Goliath Portland Cement Company at Railton indicates the average grade of limestone quarried in 1978 (based on grab samples) is approximately 89% $CaCO_3$, 6% SiO_2 and 4% ($MgCO_3$ + Fe_2O_3 + Al_2O_3 + MnO_2 + Na_2O + K_2O). These figures appear to correlate with the 'high grade stone' described by Jennings (1960), which averaged 88.3% $CaCO_3$, 2.7% $MgCO_3$, 5.3% SiO_2, 1.2% Fe_2O_3 and 2.2% Al_2O_3.

MAGNETITE

Similarly to garnet, magnetite is a common mineral in the Stormont-Moina area, although it is also widely distributed in other areas as an accessory mineral in host rocks ranging in age from Cambrian to Devonian.

The most significant occurrences of magnetite are in the magnetite skarn at Stormont, Ti-Tree Creek and Moina, which were formed by the metasomatic alteration of the Ordovician Gordon Limestone in stratigraphic horizons generally higher than the garnet calc-silicate rocks described previously. The magnetite skarn is closely associated with the garnet skarn and similarly to the latter, was formed by hydrothermal fluids associated with the intrusion of the Dolcoath Granite. The magnetite skarn in the Moina area has been subject to detailed examination in recent years by Webb (1974) and Askins (1978) and is more appropriately described as a magnetite-fluorite skarn, due to the high fluorite content. The main constituents of this skarn are magnetite and fluorite (with average concentrations of 40 mass% and 20 mass% respectively), with accessory K-feldspar, plagioclase, ferrohastingsite, epidote, biotite, vesuvianite, sericite, chlorite, pyrite, pyrrhotite and arsenopyrite. The magnetite skarn is also host rock for disseminated base metal minerals, with cassiterite, scheelite, bismuthinite, molybdenite, sphalerite, galena and chalcopyrite being reported by various authors. Gold and silver are reported from the Stormont mine, in association with bismuthinite in a garnet-magnetite host rock.

Askins (1978) describes the magnetite-fluorite skarn at Moina as having a distinctive finely layered contorted texture, with the layers being analagous to Liesegang Rings, formed by diffusion of fluids from porous permeable lithologies or from fractures in the rocks.

The magnetite grain size in this skarn ranges from several microns to approximately 3 mm.

BERYL

Beryl is a minor accessory mineral in the quartz veins hosting the Sn-W-Bi-Mo mineralisation in the Moina-Dolcoath Hill area. Reid (1967) refers to beryl as an accessory constituent in the Dolcoath Granite.

Twelvetrees (1913) reported significant concentrations of beryl in some of the lodes of Sayers mine, where it occurs as individual veins with crystals ranging in size from 70 - 100 mm and as quartz-beryl-wolframite veins.

However conflicting, less optimistic, reports on the occurrence of beryl in Sayers mine by subsequent authors are probably indicative of the erratic distribution of the beryl. Numerous references to massive sericite (muscovite, gilbertite, pinite) in the quartz veins, in conjunction with the reported occurrence of phenacite (Be_2SiO_4) in Sayers mine and the replacement of beryl by 'massive mica, fluorite and chlorite' (Twelvetrees, 1913) imply that at least some of the beryl has been altered to sericite and kaolin as a result of metasomatic processes.

LITHIUM MINERALS

Twelvetrees (1908) reported that in the no. 6 lode of the Shepherd and Murphy mine at Moina 'the gangue is quartz, accompanied by ..... occasionally spodumene .....', and that the 'hydrated mica' in the lodes of the same mine was possibly derived from spodumene ($LiAlSi_2O_6$).

Petterd (*in* Twelvetrees, 1908) in his examination of 'altered spodumene' from the Shepherd and Murphy mine, appears to have described a mixture of spodumene(?) and lithium muscovite/lepidolite, with the latter possibly pseudomorphing the former. Reid (1919) refers to 'lithia bearing white mica' in greisenised granite in the adit of the Dolcoath mine.

He also states that 'a lithia bearing mica (lepidolite) is found accompanying the ore' in the Squib, Dolcoath, Sayers, Princess, Premier and Hidden Treasure mines. It would appear that at least one lithium mineral is present in the area, which is probably lithium muscovite.

MONAZITE

Monazite is recorded by Twelvetrees (1913) and Reid (1919) as occurring in the lodes of the Shepherd and Murphy, All Nations, Squib, Dolcoath, Sayers, Princess, Premier, Hidden Treasure and Devonian mines. Hills (*in* Twelvetrees, 1913), in his benefication studies of the ore from the Shepherd and Murphy mine, reported 2 mass% of monazite in fresh rock, but does not state whether its mode of occurrence is in the quartz lodes or in the skarn country rocks, parts of which were extracted with the ore.

However, it is believed that the monazite occurs predominantly in the quartz veins and has been derived partly from the relatively P and rare earth rich garnet skarn and partly from the rare earth and F rich fluids responsible for the formation of the magnetite-fluorite skarn.

Twelvetrees (1913) described monazite in the deep lead quartz-cassiterite-topaz sand encountered in the workings of the Shepherd and Murphy mine.

TOPAZ

Topaz is a common mineral in the Moina-Dolcoath Hill area, where it is closely associated with fluorite. It has several modes of occurrence.

Quartz veins.

These consist of a quartz-fluorite/topaz-muscovite-beryl assemblage, hosting the Sn-W-Bi-Mo mineralisation in the area.

Pegmatite and aplite.

Reid (1919) described topaz as 'a most common component' of the pegmatite and aplite enclosing the lodes of the Sayers, Princess, Premier and Hidden Treasure mines.

Granite and greisen.

Reid (1967) and Webb (1974) describe topaz as an accessory mineral in the Dolcoath Granite. Greisenised granite enclosing the lodes of the Sayers, Dolcoath and Premier mines contains accessory topaz.

Deep lead and alluvial deposits.

Twelvetrees (1913) described unconsolidated deep lead quartz-cassiterite-topaz sand in the workings of the Shepherd and Murphy mine. He also referred to silicified alluvial gravel containing topaz adjacent to the same mine. This silicified gravel corresponds to the Tertiary grey-billy/silcrete of Collins (1975*c*). Significant concentrations of topaz are reported from the alluvial Iris mine, which is located in alluvium of Recent age. Topaz is also recorded in alluvium at Bell Mount (Montgomery, 1894).

WOLLASTONITE

Wollastonite was first reported by Twelvetrees (1908) in both the skarn rocks and the quartz veins (no. 6 Lode) of the Shepherd and Murphy mine. Although the occurrence in the quartz veins seems unlikely, recent work by Askins (1978) has revealed the presence of minor wollastonite in garnet calc-silicate rock at Moina.

Several factors appear to have influenced the minor formation of wollastonite at Moina, the most likely being:

(*a*) replacement of wollastonite by fluorite and quartz, under conditions of high F chemical activity;
(*b*) inversion of wollastonite to calcite and quartz, under conditions of lower temperature and localised high P_{CO_2};
(*c*) replacement of wollastonite by garnet.

The potential for locating wollastonite away from the immediate Moina (Shepherd and Murphy mine) area has yet to be determined.

ZEOLITE GROUP

Several species of zeolite are reported from the Moina-Sheffield area.

5 cm

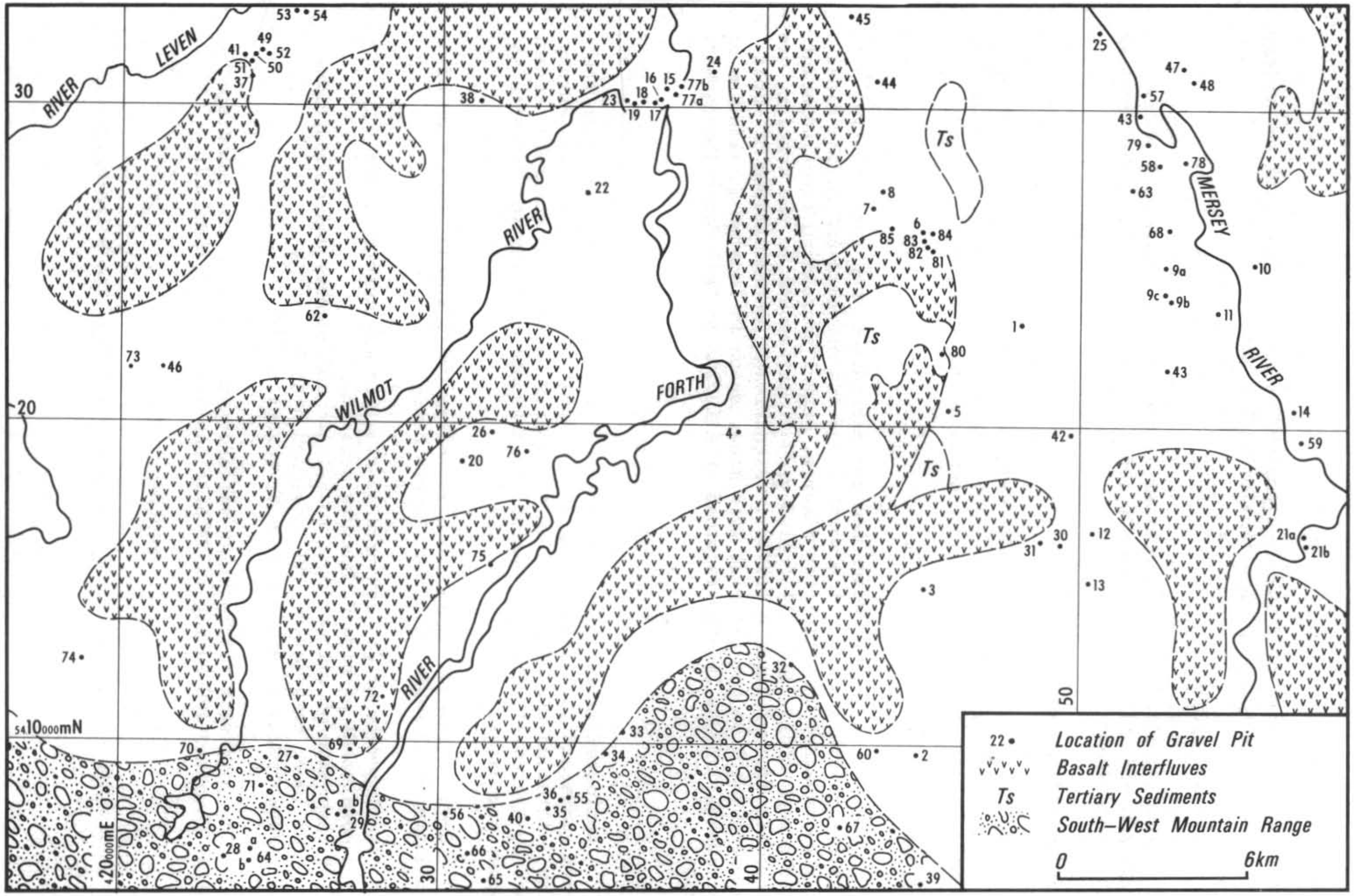


Figure 11. *Physiographic units and quarry locations, Sheffield Quadrangle.*

Devonian host rocks.

Laumontite is present as an accessory mineral in the quartz lodes (particularly in the north-west branch and no. 6) of the Shepherd and Murphy mine at Moina, where it occurs as veinlets and masses of radiating crystals $\leqslant$ 3 mm in length. The presence of Hg in a sample of laumontite analysed in 1917, in conjunction with its mode of occurrence, suggests a late stage hydrothermal origin of Devonian age.

Tertiary host rocks.

At Sheffield, thompsonite, phillipsite and chabazite are reported in Tertiary basalt.

At Bell Mount, phillipsite, chabazite, stilbite, gmelinite, (and the feldspathoid/zeolite analcite), occur in amygdaloidal basalt of Tertiary age; the chabazite is reported to occur in crystals up to 15 mm in diameter.

Reid (1919) reports chabazite 'filling geodes in basaltic glass' as being abundant near Moina; these occurrences are assumed to be of Tertiary age.

CONSTRUCTION MATERIALS

V.M. Threader

The Sheffield Quadrangle can be divided into three main physiographic units (fig. 11):

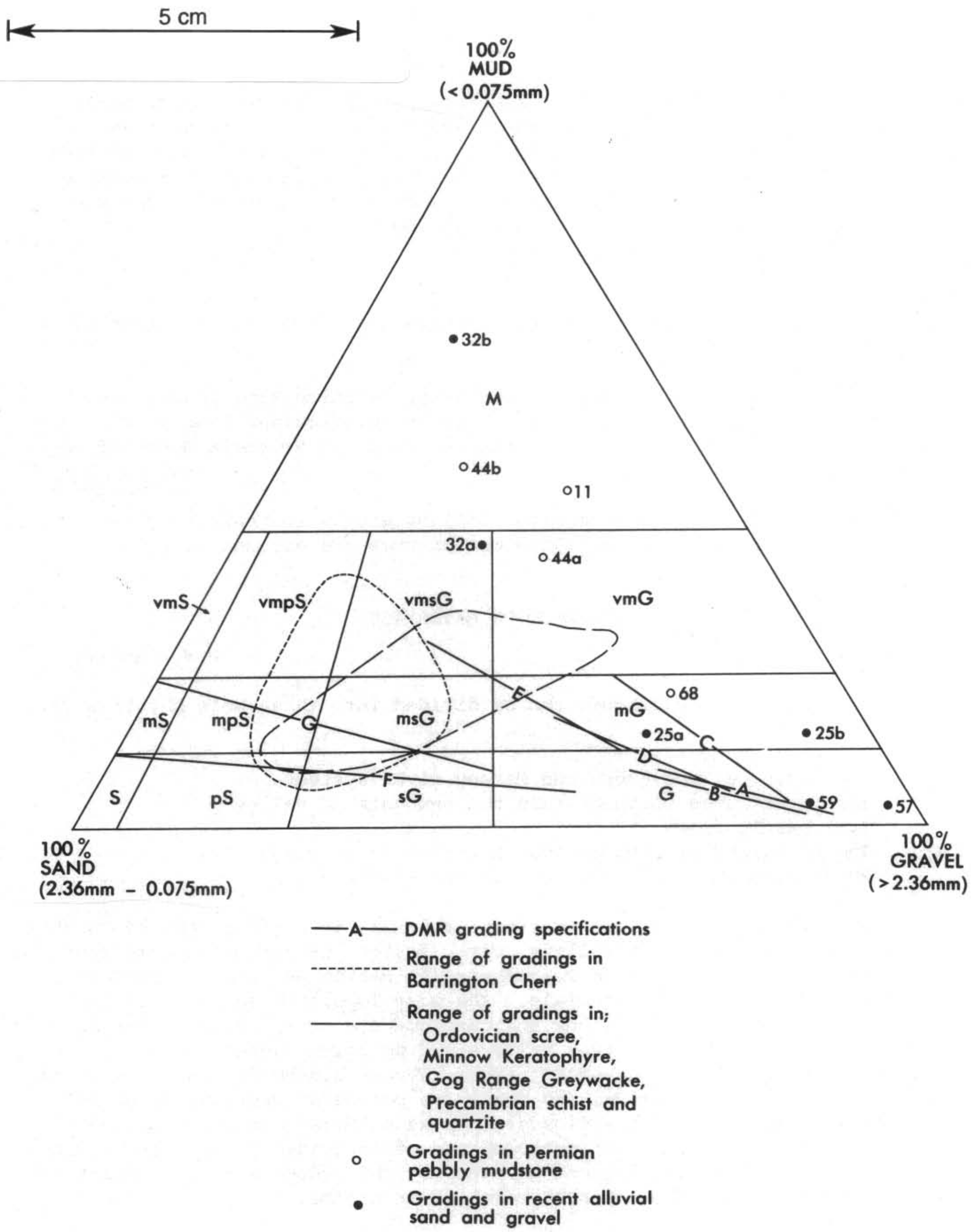
(*a*) The Leven, Wilmot-Forth and Mersey river systems.
(*b*) The interfluves which contain the remnants of valley fill basalt flows.
(*c*) The Mt Roland-Mt Claude-Round Mount-Mt Jacob range which occupies the south-west of the quadrangle.

The distribution of construction materials is closely related to this subdivision. In the river valleys, river action has exposed and redeposited sediments ranging in age from Precambrian to Recent and which have been quarried for road making materials. The most important source of these deposits is Ordovician sandstone and conglomerate scree which occurs in several localities in the river valleys and as scree slopes on the flanks of the south-west mountain range. Recent sediments contain workable quantities of sand and gravel and there are potential reserves of gravel underlying some of the river floodplains, as at Merseylea where Leaman (1973*b*) estimated one million cubic metres of doleritic gravel underlying the alluvium. Large quantities were used by the Hydro-Electric Commission during construction of the Mersey-Forth power scheme.

Basalt from the interfluves is quarried at one locality only (locality 85, fig. 11) where it is crushed for road sealing and concrete aggregate. The reserves of this material are considerable but unassessed, although environmental and agricultural considerations would limit the choice of sites. Pre- and intra-basalt sediments of Tertiary age also occur. These consist of sand, clay and pebble beds, but are of little or no commercial value.

Material quality

The locations of working and disused quarries and pits are shown



vmS	very muddy sand	msG	muddy sandy gravel
vmpS	very muddy pebbly sand	mG	muddy gravel
vmsG	very muddy sandy gravel	S	sand
vmG	very muddy gravel	pS	pebbly sand
mS	muddy sand	sG	sandy gravel
mpS	muddy pebbly sand	G	gravel
Non-mineral	unsuitable for use as aggregate		

Figure 12. *Grain size distribution of gravel, Sheffield Quadrangle*

Table 11 SUMMARY OF CONSTRUCTION MATERIALS, SHEFFIELD QUADRANGLE.

Age	Rock type	Pit number*	Remarks
Cainozoic	Alluvial sand and gravel	14, 25, 32, 43, 57, 59, 77.	Variable quality with excessive range of particle size.
Permian	Basal beds, pebbly mudstone	11, 44, 68.	As above
Ordovician	Scree slopes of mixed Moina Sandstone and Roland Conglomerate	1, 5, 6, 9, 12, 13, 21, 29, 30, 31, 33, 34, 35, 36, 39, 40, 42, 46, 55, 56, 60, 63, 64, 65, 66, 67, 70, 75, 76, 80, 81, 82, 83, 84.	The most important material. Huge reserves especially in the south of the quadrangle
Cambrian	Minnow Keratophyre	2, 3, 27, 61, 69, 71, 72.	Acceptable to marginally acceptable and of minor importance
	Gog Range Greywacke	20, 26, 38, 62, 73, 74.	
	Bott Conglomerate	7, 8, 45.	
	Barrington Chert	4, 15, 16, 17, 18, 19, 22, 23, 24, 37, 41, 49, 50, 51, 52, 53, 54.	An important material but tends to be deficient in coarse fraction
Precambrian	Quartzite and schist	10, 47, 48, 58, 78, 79.	Acceptable to marginal material

* For pit locations see Figure 11 and Table 12.

in Figure 11. The type and quality of materials are summarised in Tables 11 and 12, with grain size distributions shown in Figure 12. The bulk of the materials tested range from very muddy gravel to pebbly sand with silt and clay fractions ranging up to 30%. The range of gradings of DMR specifications A to G indicate that many of the materials tested are sub-standard, being deficient in the coarse sizes and extreme in fines content.

CLAY

Bell Mount

Burns (1958*b*) examined a bed of white clay overlying graphitic shale in the Bell Mount goldfield. This material is the weathering product of the underlying limestone and was stated to be about 4.8 m thick, covering an area of about 8 ha (*i.e.* a volume of 400 000 m^3). No uses for this material were stated, but similar clay has been used elsewhere in the world as a source of expanded aggregate. The white clay is stated to be of limited extent, with an estimated volume of 20 000 - 100 000 m^3. No analyses are available, but the size of the deposit would limit its use

Table 12. SIZING ANALYSIS AND PHYSICAL PROPERTIES OF CONSTRUCTION MATERIALS, SHEFFIELD QUADRANGLE.

No.+	AMG Reference	ANG Reference	Sizing Analysis Cumulative % passing (*mm*) 75	53	37.5	26.5	19	9.53	4.76	2.36	1.18	0.6	0.425	0.30	0.15	0.075	0.038	Gravel: Sand: Silt & Clay
1*	DQ482231	49/349087			100	97	90	76	59	48			33			16		52:30:18
2*	DQ448098	48/310942				100	99	85	71	66			56			47		34:19:47
						100	98	83	67	60			52			43		40:17:43
3	DQ450150	48/313999				100	99	91	77	63			47			33		37:30:33
				100	99	98	96	84	71	60			40			29		40:31:29
4*	DQ392189	49/250043					100	91	67	47			27			22		53:25:22
							100	90	64	47			31			27		53:20:27
						100	99	80	48	29			12			8		71:21: 8
5*	DQ456204	49/320058			100	99	91	62	42	32			22			10		68:22:10
						100	98	74	49	30			19			12		70:18:12
6*	DQ449261	49/314121			100	98	94	80	68	62			50			29		38:33:29
					100	99	95	78	68	63			52			29		37:34:29
					100	97	92	70	55	44			30			17		56:27:17
					100	99	94	61	39	29			19			8		71:21: 8
7*	DQ433268	49/296128					100	96	90	82			48			23		18:59:23
8*	DQ436272	49/299133					100	95	83	70			42			21		30:49:21
9*a*	DQ525250	49/397108			100	99	96	85	69	59			41			16		41:43:16
9*b*	DQ527239	49/399096			100	99	97	84	60	45			27			12		55:33:12
9*c*	DQ525241	49/396098			100	97	94	76	57	43			26			9		57:34: 9
10	DQ554251	49/428108			100	98	96	74	56	47			33			22		53:25:22
11	DQ542232	49/415088			100	97	90	77	69	64			58			46		36:18:46
12	DQ504167	49/373017			100	99	94	79	60	50			37			14		50:36:14
					100	98	90	74	57	35			21			11		65:24:11
13*	DQ501152	49/369001		100	93	92	87	74	56	44			29			16		56:28:16
14	DQ565205	49/440058																
15	DQ368304	49/225169				100	97	80	52	29			13			9		71:20: 9
16	DQ367301	49/224165				100	99	82	55	40			26			21		60:19:21
17*	DQ365301	49/222165			100	99	98	78	51	40			31			27		60:13:27
18	DQ363301	49/220165					100	79	56	48			42			36		52:12:36

+ Pit locations on Sheffield construction materials map (fig.11)

* working

Table 12. (continued)

No.	Name	Locality	Dust Ratio	Liquid Limit	Plast. Index	Linear Shrink.	Classi-fication†	Material	Age#	Est. Prod. (m^3)	Res.x
1	Elliott	Railton	0.49		Non-plastic		SMD	Quartzite	O	>10 000	L
2	Dawson	Paradise	0.83	46	20	9	GC-GL	Mudstone	C	10 000	L
			0.83	44	16	8	CMU	Mudstone	C		
3	Kentish Council	Duck Marsh pit	0.69	40	14	9	SMU	Mudstone	C	12 000	M
			0.72	34	10	5	SMU	Mudstone	C		
4	DMR	Nowhere Else	0.79	25	4	2	SM-SC	Siltstone	C	>10 000	L
			0.87	32	11	5	SC	Siltstone	C		
			0.71	28	7	3	GP-GC	Siltstone	C		
5	Kentish Council, DMR	The Badgers pit	0.45		Non-plastic		GP-GM	Quartz	O	>20 000	L
			0.60	19	0	2	GP-GM	Quartz	O		
6	DMR and others	The Badgers (north)	0.58		Non-plastic		SMD	Quartz	O	>10 000	L
			0.56		Non-plastic		SMD	Quartz	O		
			0.58		Non-plastic		GMD	Quartz	O		
			0.43		Non-plastic		GP-GM	Quartz	O		
7	Williams Bros.	Barren Hill	0.48		Non-plastic		SMD	Quartz	C	>10 000	L
8	Williams, Kentish Coun.	Barren Hill	0.49		Non-plastic		SMD	Quartz	C	>10 000	U
9*a*	Kentish Council	Railton pits	0.40		Non-plastic		SMD	Quartz	O	7 500	L
9*b*		Railton pits	0.43		Non-plastic		SW-SM	Quartz	O	10 000	M
9*c*		Railton pits	0.33		Non-plastic		SW-SM	Quartz	O	13 000	M
10		Railton	0.66	36	13	6	GC	Schist	E	700	L
11		Railton	0.79	33	12	7	GC	Gravel	P	-	U
12		Stoodley	0.36		Non-plastic		SMD	Quartz	O	2 000	M
			0.51	22	3		GP-GM	Quartz	O	10 000	L
13	Kentish Council	Frankcombs pit	0.54	21	1	1	GMD	Quartz	O		
14	Readymix	Merseylea						Riverwash	Q	>50 000	M
15	George	Alma Bridge	0.68	44	20	11	GP-GC	Siltstone	C	600	L
16	George	Alma Bridge	0.80	55	31	15	GC	Mudstone	C	10 800	L
17	George	Alma Bridge	0.89	50	25	11	GC	Mudstone	C	3 000	L
18	George	Alma Bridge	0.86	51	26	73	GC	Mudstone	C	1 800	L

† S = sand, C = clay, G = gravel, W = well graded, P = poorly graded, L = low plasticity, M = mixed non-clay fines, D = suitable plasticity, U = unsuitable plasticity

\# E = Precambrian, C = Cambrian, O = Ordovician, P = Permian, T = Tertiary, Q = Quaternary

x Reserves, L = large, M = moderate, S = small, U = unknown

Table 12. (continued)

No.+	AMG Reference	ANG Reference	Sizing Analysis Cumulative % passing (*mm*) 75	53	37.5	26.5	19	9.53	4.76	2.36	1.18	0.6	0.425	0.3	0.15	0.075	0.038	Gravel: Sand: Silt & Clay
19	DQ361301	49/218165				100	97	62	30	31			25			20		69:11:20
20	DQ306187	49/156041			100	99	97	83	64	59			55			50		41: 9:50
21*a*	DQ568165	49/443014	100		67		55	43	35	27	23	21		19	17	13	10	73:15:12
21*b*	DQ570163	49/445012	100		96		90	84	80	75	70	64		57	50	42	34	25:33:42
22	DQ345264	49/200125				100	99	83	59	46			30			21		54:25:21
23	DQ357302	49/213167					100	72	45	32			23			16		68:16:16
24*	DQ384310	49/243175			100		95	86	69	50	40	36		32	30	24	22	51:26:23
25*	DQ505324	49/376189	100		91		59	49	43	40	35	28		21	17	13.7	11	61:26:13
			95	84	72	54	42	25	20	18			13			10		82: 8:10
26	DQ317198	49/168053			100	99	97	66	47	37			20			12		63:25:12
27	DQ254095	48/098941	100		89		78	67	56	47	46	36		31	22	15	11	53:33:14
					100	98	95	71	51	35		22				13		65:22:13
28	DQ231066	48/073910						100	56	29		7				4		71:25: 4
29a*	DQ269079	48/114924	100		93		71	60	51	46	42	39		34	26	14	5	55:32:13
					100	98	94	66	50	42			33			13		58:29:13
29*b*	DQ272080	48/118925																
29*c*	DQ267078	48/112923		100	99	98	98	82	70	67			37			26		33:41:26
30*	DQ491163	49/358013			100	99	95	71	52	44			29			13		56:31:13
					100	99	92	54	34	28			19			9		72:19: 9
31*	DQ487164	49/354014				100	95	67	46	36			23			15		64:21:15
					100	99	91	63	45	35			22			10		65:25:10
32	DQ409125	48/268972	100		86		82	81	80	70	65	62		60	54	48	41	30:22:48
						100	98	98	95	87			78			66		13:21:66
33	DQ356103	48/210949				100	95	66	46	35			24			12		65:23:12
34	DQ354101	48/208947			100	99	96	73	50	36			21			11		64:25:11
					100	98	93	65	42	29			15			6		71:23: 6
35	DQ333080	48/184924			100	97	89	70	53	46			32			19		54:27:19
36	DQ335083	48/187927			100	98	91	69	50	38			24			14		62:24:14

+ Pit locations on Sheffield construction materials map (fig.11)

* Working

Table 12 . (continued)

No.	Name	Locality	Dust Ratio	Liquid Limit	Plast. Index	Linear Shrink.	Classi- fication†	Material	Age#	Est. Prod. (m^3)	Res.[x]
19	George	Alma Bridge	0.81	46	23	11	GC	Mudstone	C	3 000	L
20	George	Wilmot	0.91	46	17	8	ML	Sandy Clay	C	10 800	L
21*a*	R. W. Loone	Kimberley						Quartzite	O	500	Nil
21*b*	R. W. Loone	Kimberley						Clay/sand- stone	Q/O	5 000	M
22		Lower Wilmot	0.72	51	25	12	GC	Mudstone	C	450	L
23	George	Alma Bridge	0.69	48	23	11	GC	Mudstone	C	10 000	L
24		Paloona						Siltstone	C	2 000	M
25	French	Latrobe	0.74	21	3	-	SP	River wash	Q	10 000	M
26	Richards	Wilmot	0.59	43	5	3	GP-GC	Mudstone	C	5 000	L
27	Forestry Commission	Bell Mount	0.58	26	5	3	GM-GC	Mudstone	C	5 000	S
28		Moina	0.53	24	9	4	SP	Tailings		10 000	M
29*a*	HEC	Cethana Road	0.40		Non-plastic		GMD	Sandstone	O	>10 000	L
29*b*	HEC	Cethana Road						Sandstone	O	6 000	M
29*c*	HEC	Cethana Road	0.45		Non-plastic		SMD	Sandstone	O	4 000	M
30	Frankcomb	Blackberry Hill	0.46		Non-plastic		GMD	Quartz	O	>10 000	S
			0.46		Non-plastic		GP-GM	Quartz	O		
31	Frankcomb	Blackberry Hill	0.64	23	7	4	GM-GC	Quartz	O	>10 000	S
			0.45	17	0	-	GU-GM	Quartz	O		
32		Claude Road	0.85	50	19	10	MS-ML	Grav-Clay	Q	5 000	M
33		Gowrie Park	0.52		Non-plastic		GP-GM	Quartz	O	>10 000	M
34		Gowrie Park	0.50		Non-plastic		GP-GM	Quartz	O	>10 000	M
			0.37		Non-plastic		GP-GM	Quartz	O		
35		Gowrie Park	0.59	19	0	-	GMD	Quartz	O	5 000	M
36		Gowrie Park	0.58		Non-plastic		GMD	Quartz	O	5 000	S

† S = sand, C = clay, G = gravel, W = well graded, P = poorly graded, L = low plasticity, M = mixed non-clay fines, D = suitable plasticity, U = unsuitable plasticity

\# E = Precambrian, C = Cambrian, O = Ordovician, P = Permian, T = Tertiary, Q = Quaternary

x Reserves, L = large, M = moderate, S = small, U = unknown

Table 12. (continued)

No.[+]	AMG Reference	ANG Reference	Sizing Analysis Cumulative % passing (*mm*) 75	53	37.5	26.5	19	9.53	4.76	2.36	1.18	0.6	0.425	0.30	0.15	0.075	0.038	Gravel: Sand: Silt & Clay
37*	DQ240309	49/086176			100	98	97	76	58	38			16			10		62:28:10
							100	71	38	24			12			8		76:16: 8
38*	DQ311301	49/163166		100	87	82	71	50	39	33			20			10		67:23:10
39*	DQ448056	48/310896		100	98	93	90	74	59	49			31			15		51:34:15
40	DQ327078	48/178922		100	89	81	72	61	51	46			35			21		54:25:21
41*	DQ238315	49/083182			100		97	88	73	54	39	30		22	18	15	13	46:38:16
42	DQ496198	49/364051					100	82	67	59			48			26		41:33:26
43	DQ517297	49/388159																
44*	DQ433308	49/297172				100	98	89	75	62			50			36		38:26:36
							100	93	84	77			65			48		23:29:48
45*	DQ424328	49/287194				100	99	80	62	54			41			13		46:41:13
							100	93	81	70			51			33		30:37:33
						100	97	88	76	64			47			30		36:34:30
						100	98	77	58	45			22			10		55:35:10
46*	DQ212217	49/054075				100	99	87	72	60			32			15		40:45:15
47*	DQ530311	49/403174	85		71		57	43	32	25	20	17		14	11	10	8	74:16:10
48*	DQ533308	49/406171	100		82		75	64	55	45	38	31		25	20	18	16	56:26:18
49	DQ242316	49/088183			100	99	96	79	56	37			16			10		63:27:10
50	DQ241314	49/087181				100	99	74	49	31			14			9		69:22: 9
51	DQ240313	49/086180				100	96	80	55	40			22			15		60:25:15
52*	DQ245316	49/091183			100	99	96	73	45	30			15			11		70:19:11
53*	DQ253330	49/100199				100	97	82	57	35			11			6		65:29: 6
54*	DQ254330	49/101199			100	99	98	83	59	40			16			8		60:32: 8
55	DQ337082	48/189926			100	96	91	71	55	46			33			20		54:26:20
56	DQ300076	48/148920			100	97	92	71	52	41			24			11		59:30:11
57	DQ515301	49/386164			100	98	91	38	10	6			6			2		94: 4: 2
58*	DQ524281	49/396142	88		69		59	46	40	34	29	26		22	20	17	14	65:20:15
59	DQ564198	49/439050	76		52		39	27	19	14	11	8		4	2	2	1	86:12: 2
60	DQ435098	48/296942																

+ Pit locations on Sheffield construction materials map (fig.11)

* Working

Table 12. (continued)

No.	Name	Locality	Dust Ratio	Liquid Limit	Plast. Index	Linear Shrink.	Classi-fication†	Material	Age#	Est. Prod. (m^3)	Res.x
37	Forestry Commission	Preston	0.60	27	4	2	GP-GC	Siltstone	C	22 000	S
38	Forestry Commission	Sprent	0.69	33	6	4	GP-GM	Siltstone	C	1 520	M
39	Forestry Commission	Union Bridge Rd.	0.15	18	0	0.5	SMD	Silt/q'zite	O/C	>10 000	L
40	Kauri Timber	Gowrie Park	0.60	20	1	1	GMD	Sandy qtz	O	7 000	L
41	Smith	Preston						Chert	C	56 000	L
42		Railton	0.55	22	6	4	SM-SC	Q'ite talus	O/Q	10 000	L
43	Crown Land	Shale Road						Sand	Q	>10 000	S
44	Holyman	Lwr Barrington	0.72	39	20	10	SC	Sandy clay	P	12 000	L
			0.73	50	25	13	SC	Sandy clay	P		
45	Jerand	Buster Road	0.32		Non-plastic		SMD	Quartz	C	40 000	L
			0.66	31	9	5	SC	Quartz	C		
			0.64	32	14	8	SC	Quartz	C		
			0.44	24	6	3	SW-SC	Clay sand	C		
46	Crown Land	Nietta	0.47	21	5	3	SM-SC	Quartz	O	4 000	L
47	Latrobe Council	Old Deloraine Rd						Phyllite	E	7 500	M
48		Old Deloraine Rd						Qtz/phyll.	E	37 500	M
49	Crown Land	Preston	0.62	28	9	4	SP-SC	Grav./sand	C	10 000	U
50	Crown Land	Preston	0.65	22	3	1	GP-GM	Grav./sand	C	5 000	L
51	Crown Land	Preston	0.68	33	10	5	GC	Siltstone	C	4 800	L
52	Ulverstone Council	Preston	0.75	21	Non-plastic		GP-GM	Siltstone	C	12 000	L
53	West	Preston	0.51		Non-plastic		SW-SM	Siltstone	C	6 400	L
54	Ulverstone Council	Preston	0.53		Non-plastic		SP-SM	Siltstone	C	4 000	L
55	HEC	Gowrie Park	0.60	23	4	2	GM-GC	Quartz	O	>10 000	M
56		Cethana	0.43		Non-plastic		GP-GM	Quartz	O	10 000	M
57		Latrobe	0.26	22	2	2	CP	River wash	Q	10 500	S
58	Forestry Commission	China Bush						Phyllite	E	4 000	S
59	McBain (Stone)	Merseylea						River wash	Q	16 000	L
60	Forestry Commission	Paradise						Conglomerate	O	800	S

† S = sand, C = clay, G = gravel, W = well graded, P = poorly graded, L = low plasticity, M = mixed non-clay fines, D = suitable plasticity, U = unsuitable plasticity

\# E = Precambrian, C = Cambrian, O = Ordovician, P = Permian, T = Tertiary, Q = Quaternary

x Reserves, L = large, M = moderate, S = small, U = unknown

Table 12. (continued)

No.+	AMG Reference	ANG Reference	Sizing Analysis Cumulative % passing (*mm*) 75	53	37.5	26.5	19	9.53	4.76	2.36	1.18	0.6	0.425	0.30	0.15	0.075	0.038	Gravel: Sand: Silt & Clay
61*	DQ229127	48/071977					100	94	88	75	63	55		47	39	27	20	26:47:27
62*	DQ263232	49/110091		96	87	79	69	56	46	39			24			13		57:26:13
63*	DQ515275	49/386135		100	98	94	87	74	63	56			41			28		44:28:28
64*a**	DQ240063	48/082907		97	85	77	67	52	38	31			23			11		69:20:11
64*b**	DQ240065	48/082909		100	98	95	78	46	31	25			18			11		75:14:11
65	DQ313058	48/162900		100	95	88	81	69	57	48			37			18		52:30:18
66	DQ307066	48/156909			100	99	94	79	50	34			20			11		66:23:11
67*	DQ425075	48/285917	100		94		80	72	66	62	58	54		47	38	23	11	38:39:23
68	DQ525261	49/397120	100		87		70	54	43	37	33	31		28	24	18	11	62:21:17
69	DQ271098	48/117945																
70	DQ224097	48/065944																
71*	DQ243088	48/086934			100		93	86	77	63	55	47		40	34	29	24	37:34:29
72*	DQ282116	48/129964	100		85		83	76	66	54	42	33		25	18	14	12	47:40:13
73*	DQ202218	49/043077	100		76		61	50	43	33	26	20		15	11	9	8	68:23: 9
74*	DQ186127	48/024977	100		87		80	62	51	41	34	28		22	17	14	12	60:28:12
75	DQ315165	49/166017			100		91	83	81	78	74	71		67	47	24	14	22:52:36
76	DQ327193	49/179048			100		84	71	61	52	45	40		36	30	17	10	48:36:18
77*a**	DQ372303	49/230168																
77*b**	DQ373307	49/231172																
78*	DQ531283	49/404144	100		98		90	80	71	64	56	49		43	37	30	22	37:32:31
79	DQ519289	49/390150			100		94	81	67	53	43	37		32	28	25	21	35:39:26
80*	DQ455223	49/320079	100		90		82	68	54	44	37	31		25	20	16	12	54:31:15
81*	DQ453254	49/318113			100		88	70	49	39	32	27		21	15	11	7	60:30:10
82*	DQ449256	49/313115																
83*	DQ449258	49/314117																
84*	DQ452258	49/317117	100		85		70	60	52	46	41	36		31	24	17	11	53:30:17
85*	DQ439262	49/303122																

+ Pit locations on Sheffield construction materials map (fig.11)

* working

Table 12. (continued)

No.	Name	Locality	Dust Ratio	Liquid Limit	Plast. Index	Linear Shrink.	Classification†	Material	Age#	Est. Prod. (m^3)	Res.x
61	Forestry Commission	Smiths Plain						Siltstone/ Sandstone	C	800	M
62	Forestry Commission	Upper Castra	0.55	41	17	10	GC	Mudstone	C	1 529	S
63	Forestry Commission	China Bush	0.67	18	1	1	GMD	Siltstone	O	5 000	L
64*a*	Kentish Council	Moina	0.47	18	0	0.5	GP-GM	Quartz	O	30 000	L
64*b*	Kentish Council	Moina	0.59	25	3	1.5	GP-GM	Quartzite	O	2 000	L
65	HEC	Lemonthyme Rd	0.50	18	0	0	GMD	Sandy quartz	O	2 000	L
66	HEC	Lemonthyme Rd	0.56	19	3	1	GP-GM	Quartzite	O	15 000	
67	Forestry Commission	Paradise						Conglom. scree	Q/O	600	L
68	Forestry Commission	Tasmanite Plant.						Mudstone	P	5 000	Nil
69	Forestry Commission	Wilmot						Schist	C	Nil	M
70	Forestry Commission	Mt Jacob						Q'ite, schist	O	Nil	L
71		Bell Creek						Volcanics	C	600	L
72	Forestry Commission	Wilmot						Qtz porphyry	C	900	M
73		Buttons Rivulet						Mudstone	C	110	M
74	Forestry Commission	Smiths Plains						Mudstone/ Greywacke	C	3 000	M
75	Maxwell	Sth Wilmot						Sandstone	O	4 000	S
76	Crown Land	Nth Wilmot						Sandstone/ Conglomerate	O	25 000	M
77*a*	HEC	Paloona Bridge						River wash	Q	2 000	L
77*b*	HEC	Paloona Bridge						River wash	Q	500	M
78	Forestry Commission	The Great Bend						Qtz/phyll.	E	1 500	S
79	Forestry Commission	The Great Bend						Phyllite	E	800	S
80	Gerke	Nook						Conglom. scree	Q/O	500	L
81	Kentish Council	The Badgers						Conglomerate	O	8 000	L
82	Devonport Council	The Badgers						Conglomerate	O	80 000	L
83	Latrobe Council	The Badgers						Conglomerate	O	20 000	L
84	DMR	The Badgers						Conglomerate	O	100 000	L
84	DMR	The Badgers						Conglomerate	O	24 000	L
85	Stone	Barren Hill						Basalt	T	24 000	L

† S = sand, C = clay, G = gravel, W = well graded, P = poorly graded, L = low plasticity, M = mixed non-clay fines, D = suitable plasticity, U = unsuitable plasticity

E = Precambrian, C = Cambrian, O = Ordovician, P = Permian, T = Tertiary, Q = Quaternary

x Reserves, L = large, M = moderate, S = small, U = unknown

to home potters. Sub-basaltic and intra-basaltic clay also occurs in small deposits and is used similarly.

Railton

Residual clay overlies the Gordon Limestone from which it was derived (Jennings, 1960). This material represents the insoluble residue after weathering of the parent limestone and would average around 10 mass% of the total. There is an admixture of dolerite, basalt and Permian scree from the higher ground to the east and west. The thickness of overburden on the limestone ranges from nil to more than 60 m, but is usually between 10 and 30 m thick. This clay was used extensively in cement manufacture at Railton, but the use of coal instead of oil for lime burning and utilisation of coal ash has caused an appreciable drop in clay utilisation.

Clay from 17.67 m of auger drilling in the clay overburden was tested for ceramic properties. The top 3.12 m contained 90% of +20 µm material and was unsuitable. The remainder of the hole was sandy clay with 48% of +20 µm material. This proved to be a satisfactory brick material when fired at 1000°C.

Haines Siding

Brick making materials were quarried from Lower Permian pebbly mudstone (Quamby Formation) adjacent to Zolati's brick factory. Current material is now won from a new clay pit on the western side of Caroline Creek. This clay is of Permian origin but contains an admixture of Quaternary and possibly Tertiary alluvium. The Department of Mines drilled 8 auger holes in 1969 to test the deposit (Threader, 1971). Reserves of brick making material were estimated to be 430 000 m^3, sufficient for 75 years at present production rates.

Dulverton

A bed of fireclay was worked and made into firebricks in 1897 (Smith, 1898). It was thought that an industry of some permanence would develop but the deposit was too small. It was described as a 'seat earth', as is found underlying northern hemisphere coal seams. It was not intersected in any of the boreholes drilled in the area (Threader, 1968) and it may have been a sub-basalt clay lens. Lucks Brick Works prospected the clay in 1967 but did not find any additional reserves.

FUEL MINERALS

OIL SHALE

Oil shale rich in the alga *Tasmanites punctatus* Newton occurs around Dulverton, Latrobe, Kimberley and Beulah in the Sheffield Quadrangle. This horizon also occurs at Quamby Brook in the Quamby Quadrangle, Oonah in the Burnie Quadrangle and Chudleigh in the Middlesex Quadrangle.

The shale horizon lies between 9 and 15 m above the base of Quamby Group and is up to 1.8 m thick, although 1.5 m is the more usual thickness. The average thickness and yield of the horizon is;

	Thickness (m)	Oil Yield (l/t)
Top band	0.6	184
Middle band	0.4	37
Bottom band	0.5	138
Total	1.5	120 approx. average

The oil shale was worked intermittently near Latrobe from 1910 - 1935, about 1.6 *Ml* of oil having been distilled from about 34 500 t of shale.

Prospecting

Many bores and shafts were sunk in the period 1884 - 1924 (Reid, 1924). Reid's geological sketch map of the Railton-Latrobe district shows the location of these, but it should be noted that Burns (1963*b*) found many errors in Reid's locations of boreholes in the Devonport Quadrangle. At the present time the most promising areas are held under exploration licence by Endeavour Resources Ltd.

Reserves

The total reserves of oil shale in Tasmania, most of which lies in the Sheffield Quadrangle, was estimated by Reid (1924) to be around 30 million tonnes. There has not been any more recent estimate published.

Uses

It was stated by Reid (1924) that the crude oil distilled from the oil shale was similar physically and chemically to natural petroleum and 'of higher quality than some especially as regards the amount and quality of the motor fuel fraction'. More recently, the heavy distillation fraction has been tested for making bitumen for road sealing with satisfactory results.

The CSIRO has made a preliminary study of the Tasmanite oil shale and has suggested concentration by froth flotation and some small scale pyrolysis, solvent treatment and hydrogenation tests. The research team considered that the small reserves precluded a liquid fuel industry, but that the economic extraction of bitumen warranted further work.

The permission of Endeavour Resources Ltd to quote from the CSIRO report is acknowledged.

COAL

M.J. Dix

Thin seams of coal occur in the Mersey Coal Measures in the Railton - Dulverton and Nook areas. These seams are the southerly extension of the Mersey coalfield (Burns, 1965) and have been worked intermittently between 1850 and 1944. The geology of the coal measures is described by Jennings (this volume, p.29) and Burns (1965, p. 88).

Mining

There are few records of coal mining in the Sheffield Quadrangle and those that do exist give little information, especially in the period 1850

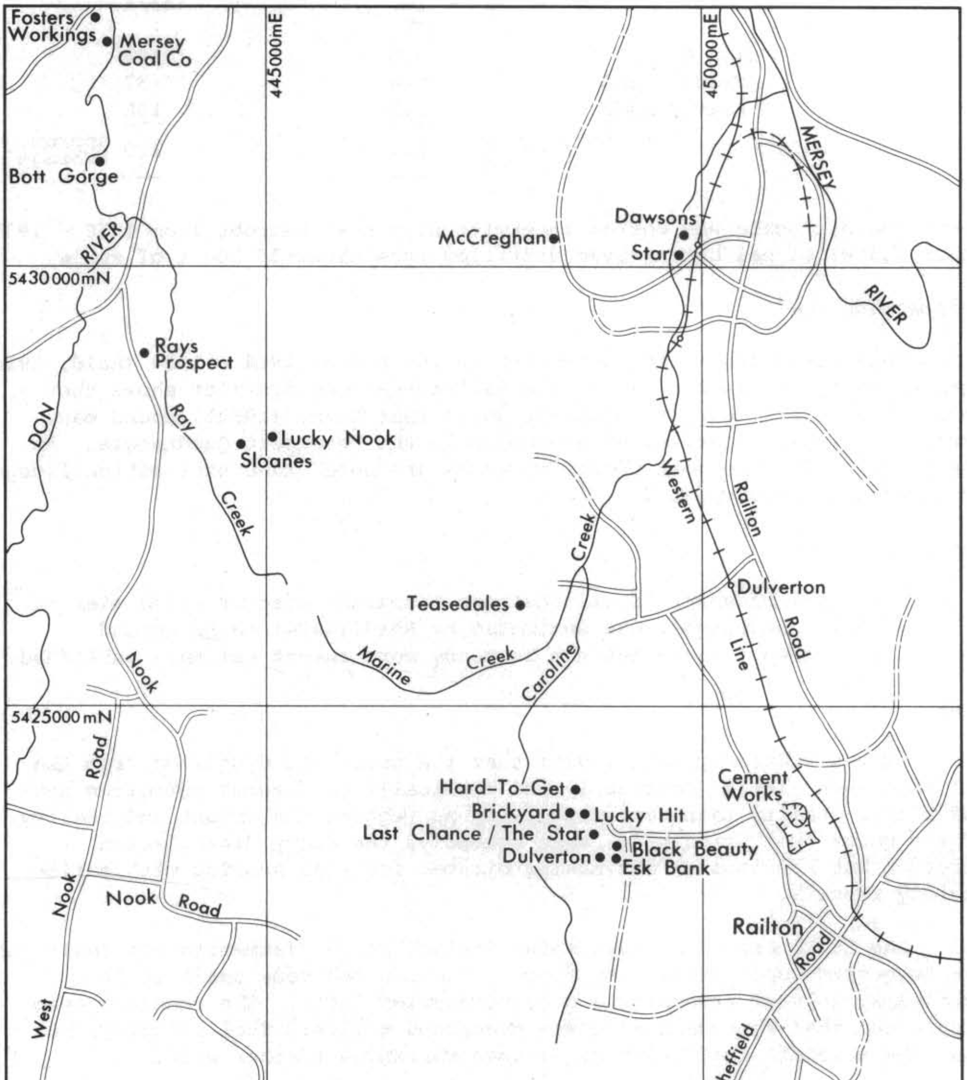


Figure 13.

5 cm

to 1920. The exact location of many mines is difficult, if not impossible to ascertain, due mainly to the limited records but also to the duplication of names, the small and spasmodic nature of the workings, standard of mapping and confusion in some maps. For example the Dulverton mine existed on the same lease area for at least 1888 - 1908 and 1931 - 1939, although the Dulverton Coal Mining Company was operating in the same area in 1883 (Thureau, 1883). However Hills *et al*. (1922, fig. 34) record the Dulverton coal mine on the western bank of Caroline Creek, in approximately the same position as Teasdales lease (451 M), although neither the Dulverton mine nor Teasdales were operating at that time. Thomas Teasdale was also manager of the Dulverton Colliery from 1893 to 1895. Production in the Sheffield Quadrangle can be conveniently split into two periods.

1850 - 1920

The first discovery of coal in the Mersey district was in the Bott Gorge in 1850. Only six drayloads of coal were produced from this location, although further mining was carried on in the Denny Gorge area further north (Fenton, 1891; Burns, 1965). Gould (1861) records that coal was struck in a shaft at the Sherwood (Dawsons) Colliery at the mouth of Caroline Creek, although the mine was not working because of problems with right of way. The mine was connected to the port of Sherwood by a 5 km long tramway. Only a small amount of coal had been raised in 1861 but Hills *et al*. (1922) record that 'for a time the rate of production was quite high'.

The Dulverton Coal Mining Company was in operation at least as early as 1883, as Thureau (1883) gives a diagrammatic section of the mine and took samples for testing. Lease records show that the two leases (318 M, 433 M) were surveyed in late 1882. A large number of leases were taken up in the Dulverton area in the 1880s, but most were only held for a short period before being relinquished. Many of these leases were incorporated in new leases covering slightly different areas, resulting in a confusing array of lease numbers, lease holders and lease areas. The amount of coal produced from these leases is unknown, as reliable statistics are lacking before 1898. Production statistics show that only three mines operated in the 1898 - 1910 period; Dulverton from 1898 - 1906 (at least 3 300 t of coal produced), Teasdales from 1903 - 1905 (822 t produced) and Brightburn in 1905 (300 t produced). The location of the latter mine is unknown. The coal produced was used for the manufacture of town gas in Latrobe. The Latrobe gasworks were opened in April 1888, initially using Newcastle coal, but were using coal from the Latrobe and Dulverton fields by 1899. The production of town gas in Latrobe ceased in 1917 (Keating, 1974).

Twelvetrees (1911) records that 'a seam of coal has recently been worked by Mr Crocker west of Caroline Creek at the foot of Brown Mountain'. Little is known of this mine or of other discoveries in the Nook area, notably Sloanes coal mine, which appears on one map (Hills *et al*. 1922) but not in production records or any literature. Burns (1957) recorded five small workings in the Denny Gorge - Nook area, but no production records are known.

1920 - 1945

A new pit was opened by J. Allison at Dawsons Siding in 1923. This was sold to J.A. Wauchope of the Mersey Valley Oil Company in 1924 but closed in 1925. 411 t of coal were produced.

Expansion of the Goliath Portland Cement Company's works in 1929 - 1930, with additional kiln units in operation and a projected demand of up

TABLE 13. COAL PRODUCTION IN SHEFFIELD QUADRANGLE, 1931-1944

Mine	Production by year (t)													
	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
New Bed														
Dulverton	1095	818	722	1211	1452	1267	559	583	167					
Lucky Hit	353	613	734	653	806	747	575	229						
Hard-To-Get	261	387	353	412	205	87	150							
Esk Bank	710	607	792	785	559	555	633(?)	191						
Black Beauty			260	419	664	507	461	955	1212	487(?)	517	430	334	89
Last Chance }	147	316	45											
The Star }				208	527	299	74							
Dulverton Tribute (?)			313	205										
Brickyard					81	176								
Shepheard and Party								318						
Dawsons Siding														
Star	92	284												
McCreghan & Sons							51	41						
Sheehans								10						
Nook														
Lucky Nook	89													
Botts								23	152					
Botts No. 2									66(?)	388	485	287		
G. Jeffrey								33						
H. Bott & Jeffrey Bros.								89	81					
J. Bott									137					

No attempt has been made to total production for various mines and years due to discrepancy in some recorded figures. The major discrepancies occur in the figures for Esk Bank (1937: 633 or 307 t) and Black Beauty (1940: 487 or 365 t). Official production total for the 'Dulverton coal mines' for the period 1921-1944 is 30 062 t.

to 40 000 t of coal per year, promoted a resurgence of interest in coal mining. Despite depressed building conditions and a consequent drop in the production of cement, the use of coal mined from the Mersey coalfield commenced. Several small collieries were opened, with the miners preferring to work the small seams available than go on the dole. The seam worked was small, varying from 400 - 550 mm thick, being badly faulted and having many small rolls.

Mining was concentrated on the New Bed coalfield 4 km west of Railton, with at least six mines operating, although the exact number is unknown due to the proliferation of leases and short tenures. The Department of Mines drilled seven holes in the coalfield in 1934 in an attempt to prove the extent of the field, intersecting coal in five holes and concluding that sufficient coal existed for many years mining. A total of ten holes were drilled in the 1934 - 1935 period. The last operating mine at New Bed was Black Beauty, which closed in 1944. Some mining was also carried out at Dawsons Siding and Nook in the same period. The production figures for the coal mines (1930 - 1945 period) are summarised in Table 13, with approximate locations of mines (where known) shown in Figure 13.

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APPENDIX 1

Transformation of grid references

The Australian National Grid (ANG), in which coordinates are given in yards, is used on the Sheffield geological map sheet and ANG references are given in this report. The ANG is now obsolete and has been superseded by the metric Australian Map Grid (AMG). When using this report in conjunction with later maps printed with the AMG the equivalent references may be found by consulting the following table:

ANG 100-yard reference	*AMG 100-metre reference*	*ANG 100-yard reference*	*AMG 100-metre reference*
48/005919	DQ169073	48/339940	DQ474096
48/026903	DQ188059	48/342946	DQ477102
48/032907	DQ194063	48/344961	DQ479115
48/070906	DQ229062	48/354966	DQ488120
48/074909	DQ232065	48/355955	DQ489110
48/075930	DQ233084	48/360930	DQ493087
48/075940	DQ233093	48/367960	DQ500115
48/083898	DQ241055	48/375955	DQ507110
48/086901	DQ243058	48/378928	DQ510086
48/086904	DQ243061	48/398990	DQ527142
48/086905	DQ243062	48/413948	DQ542104
48/088902	DQ245059	49/000070	DQ163211
48/090900	DQ247057	49/037197	DQ195328
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48/097911	DQ253067	49/064183	DQ220315
48/100912	DQ256068	49/067185	DQ223317
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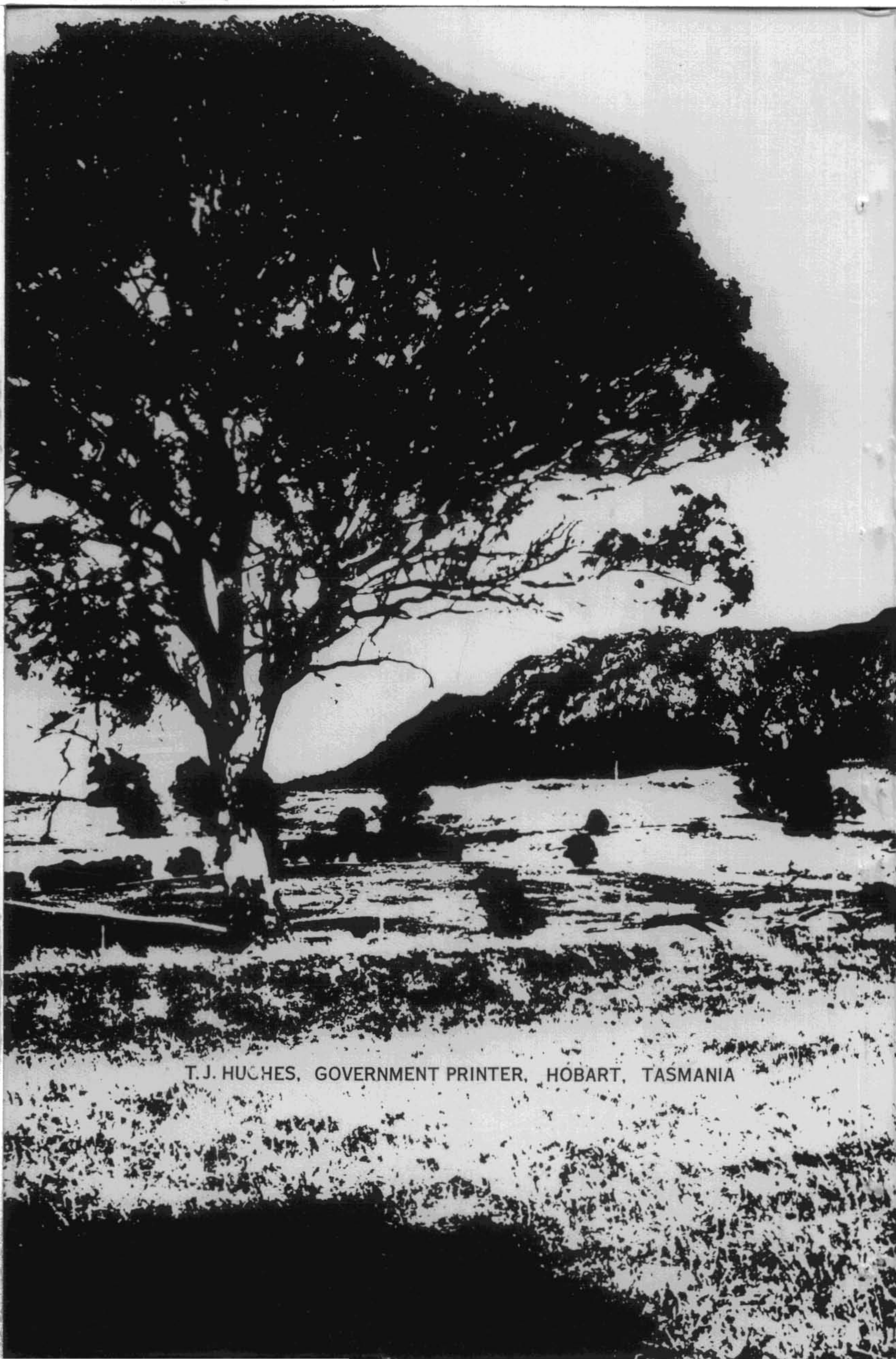

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