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THE ZONED MINERAL DEPOSITS OF THE SCAMANDER-ST HELENS DISTRICT

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ISSUED UNDER THE AUTHORITY OF THE HONOURABLE
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PREFACE

The last comprehensive review of the mineral resources of this area, by W.H. Twelvetrees, was published sixty years ago as Bulletin 9 in this series. The present author has re-mapped the area during the period 1968-1969 and has also examined more recent exploratory work by several mining companies.

The area does not have a high economic potential since the mineralisation is generally low grade. The discovery of further areas of supergene enrichment in the copper zone and of higher grade tin deposits appears to offer the best approach for future exploratory work.

Geochemical studies have shown only a limited correlation between the composition of the ore minerals and the zonal sequence of the mineralisation.

J.G. SYMONS, Director of Mines

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ABSTRACT

A series of small, discontinuous, cross-cutting hydrothermal quartz lodes of variable mineralogy occur in Mathinna Beds and granitic rocks in the Scamander-St Helens area of eastern Tasmania. These lodes exhibit a marked regional mineralogical zonation, similar to that shown by many hydrothermal deposits elsewhere. Wolframite and cassiterite lodes occupy the western part of the area, and Ag-Pb-Zn deposits occur in the eastern coastal zone. A central zone of copper deposits is typified by small, discontinuous, supergene enrichment zones. A small cluster of quartz-gold-silver lodes that occur in the western extremity of the area are probably unrelated to the zoned mineralisation.

Mineralogical and geochemical studies give no indication that the zoned mineralisation was related to more than one source, although these studies do indicate departures from the normal zonal characteristics shown by other hydrothermal deposits in Tasmania. It is probable that the mineralisation phase that resulted in deposition of the wolfram and copper lodes is genetically related to the intrusion of a mass of biotite (muscovite) granite to the west of the mineralised area. The roof of this intrusion possibly extends at shallow depth towards the east, beneath the zone of mineralisation. The origin of the Ag-Pb-Zn deposits is problematical, although the balance of evidence suggests that they represent an outer zone of mineralisation related to the wolfram-tin-copper mineralisation phase, rather than a separate mineralisation phase related to the granodiorite porphyry dyke, in which they commonly occur.

The economic potential of the area is extremely restricted, and few recommendations can be given for further exploration. Induced polarization surveys could be employed to delineate any small, high grade, supergene enrichment zones, similar to the Orieco lode, beneath extensive gossans in the copper zone, and detailed grid drilling of massive quartzite-sandstone sequences at the Great Pyramid mine could be carried out to locate smaller economic prospects than previously considered.

INTRODUCTION

Geological mapping of the Scamander-St Helens area of eastern Tasmania (fig. 1, 2) was largely carried out in late 1968 and early 1969, although visits to the area have been made subsequently to investigate later exploratory work by several companies. Mapping is made difficult by the lack of contoured base maps, the geologic mapping being executed on 1:31,680 plans produced by the Forestry Commission.

This study of the mineralisation of the Scamander district represents part of a wider study of eastern Tasmania designed to determine the associations between mineralisation and the granitic rocks which cover large parts of this region. The mineralisation in eastern Tasmania generally falls into two categories: (*a*) cassiterite and/or wolframite with rare sulphides in greisenized granitic rocks, or in discordant quartz veins adjacent to these granitic rocks, and (*b*) gold-silver with rare sulphides in discordant quartz veins, commonly at considerable distances from granitic rocks. The Scamander district is unusual as it contains some quartz-sulphide veins in which the economic minerals are copper, lead (silver) and zinc sulphides. The zonal character displayed by this mineralisation is unique in NE Tasmania. This report contains a description of the geology and mineralisation of the area and an attempt has been made to determine the nature of the zonation and the source (or sources) of the mineralisation.

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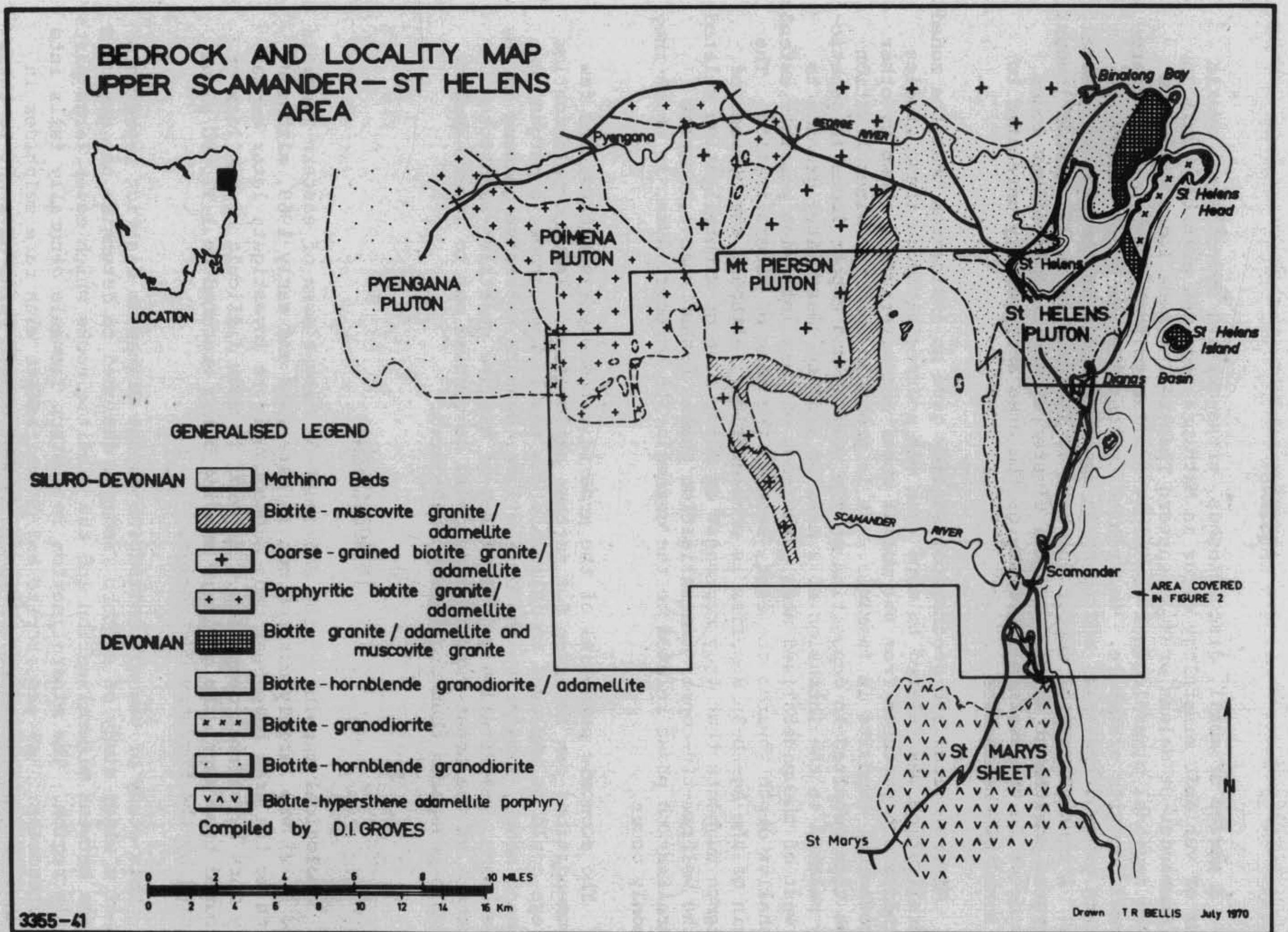

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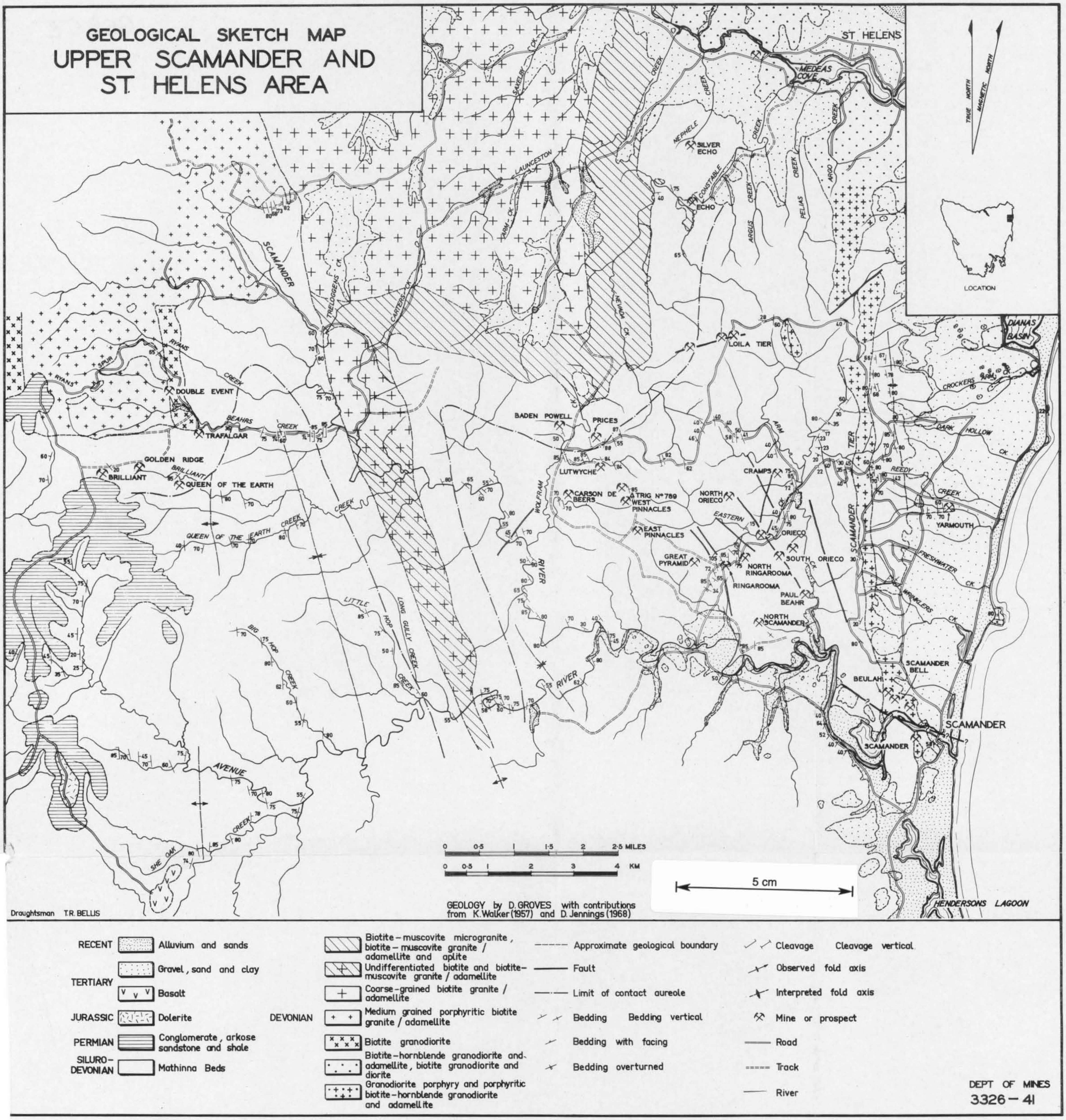
Figure 1.



igure 2. *Geological sketch map, Upper Scamander and St Helens area*

Contributions to the geology and mineralisation of the area have been presented by several authors including Montgomery (1893), Smith (1897), Twelvetrees (1900*a*,*b*), Waller (1901), Twelvetrees (1911), Henderson (1939, 1941), Nye (1941), Walker (1957), Williams (1959), Jack (1964*a*), Jennings (1968), Urquhart (1968) and Groves and Baker (1971). This work is summarised in the following report, and is extended particularly with respect to the mineralisation, from studies by the author and work by exploration companies in the area.

PHYSIOGRAPHY

The physiography of the area has been described by Twelvetrees (1911), Walker (1957) and Jennings (1968), and is only briefly discussed below.

The most easterly physiographic unit is a partly rejuvenated coastal surface that extends from Scamander, where it is 1-2 km wide, to Dianas Basin, where it is 3-5 km wide. The surface dips gently to the east, and is covered by a thin veneer of Tertiary sedimentary rocks that have been partly dissected. The coastal margin is lined with beaches and sand dunes (3-5 m in height) which become more extensive to the north. Several lagoons and barred basins occur to the west of these dunes (Hendersons and Wrinklers Lagoons, and Dianas Basin).

West of the coastal surface a youthful, low mountainous region has been developed by a trellised drainage pattern forming typical V-shaped valleys. The main ridges (*e.g.* Loila and Scamander Tiers) trend northerly to subparallel the structures of the Mathinna Beds. The northern part of the area shown in Figure 2 is an area of low relief comprising granitic rocks with overlying Quaternary and Tertiary sedimentary rocks that represent the south-east extension of Thureau's lead (Jack, 1964*b*). The westernmost area is part of the dissected, flat-lying pre-Permian surface with a thin veneer of Permian sedimentary rocks overlying the Mathinna Beds on the interfluves of several streams. This area also represents the divide between the easterly-flowing streams that are tributaries of the South Esk River.

The granitic rocks in the north-west of the area and the Mathinna Beds are drained by tributaries of the Avenue and Scamander Rivers which unite about 10 km from the sea. Jennings (1968) showed that the present river is only shallowly impressed into the floor of the Scamander River valley, and that its meandering course is caused by resistant bars of Mathinna Beds. Jennings (1968), in agreement with Twelvetrees (1911) and Walker (1957), suggested that when the river previously flowed at a higher level it may have followed a course through Hendersons Lagoon before joining the sea further to the south. These observations have economic implications.

The granitic rocks and overlying Tertiary sedimentary rocks in the northern area are drained by northerly-flowing tributaries of Golden Fleece Rivulet. The Tertiary rocks are thought to fill the course of the former George River and its tributaries; the present George River is situated several kilometres to the north of Medeas Cove.

STRATIGRAPHY

Summary

The oldest rocks exposed are the Mathinna Beds which locally comprise a sandstone and siltstone sequence, exhibiting turbidite structures, with minor interbedded shales. They have been dated in the Scamander area as Lower Devonian. The Mathinna Beds are intruded by a suite of granitic rocks of Upper Devonian age that represent the southernmost extension of the Blue Tier Batholith.

A discontinuous Permian sequence unconformably overlies the Mathinna Beds and the granitic rocks in the west, and is capped by Jurassic dolerite in the south-west of the area.

Tertiary and Quaternary sedimentary rocks, with some basal basalt flows unconformably overlie Mathinna Beds and granitic rocks in the east and north-east parts of the area.

Mathinna Beds

The Mathinna Beds are relatively well exposed in road cuttings and some streams in the Scamander area, and in a coastal section north of Dianas Basin. Elsewhere they are poorly exposed, and occur largely as extensive veneers of angular blocks that migrate down slope. An estimate of their total thickness in the area is impossible because of discontinuous exposure and faulting, but it is at least 200 m along the Upper Scamander road and probably greater than 500 m north of Dianas Basin.

The Mathinna Beds in the mapped area represent the arenite-lutite associations (*e.g.* Banks, 1962) or arenaceous sequence (*e.g.* Marshall, 1970). The major component rock types are layers of essentially unmetamorphosed sandstone or coarse-grained siltstone, generally from 10 cm - 1 m thick, that are commonly graded with fine siltstone or mudstone tops. Sequences of finely laminated mudstone up to 4 m thick occur rarely, and massive, ungraded sandstone or coarse siltstone beds, up to 5 m thick, occur in places. The sand-grade rocks are generally poorly sorted with a high proportion of argillaceous or siliceous matrix, and the most common rock is an impure quartz sandstone or quartz wacke. The degree of development of cleavage is extremely variable, but where well developed it appears to fan about the axial surfaces of folds. Petrological descriptions of these sedimentary rocks from this area are given by Walker (1957) and Williams (1959), and similar rocks from elsewhere are described by Groves (1965) and Marshall (1970), and are not repeated here.

Williams (1959) has described numerous sedimentary structures including flute casts, drag marks, load casts and flame structures, festoon current bedding, and convolute folding from the Upper Scamander Road section. These structures, although less perfectly exposed elsewhere, do generally allow determinations of facing of the beds. Williams (1959) has concluded that the sedimentation features suggest deposition from turbidity currents that came from an area to the south-west of Scamander.

Massive beds of quartzite several metres in thickness occur particularly in areas of mineralisation. Descriptions by Everard (1964) indicate that they represent silicified sandstones, the silicification probably being related to mineralisation.

Evidence of life that existed at the site of deposition is restricted to the presence of worm-like grooves on the surface of mud layers. Transported fragments of vascular plants and fragmented marine fossils including corals, polyzoa, brachiopods and crinoids occur in the graded sandstone beds at Scamander and the presence of *Hostimella* has been taken as indicative of a Silurian or Devonian age for the rocks (see Banks, 1962, p. 184). Subsequently graptolites have been discovered in thin, dark brown mudstone layers exposed along the Forestry Commission roads near the tributaries of Wrinklers Creek. These graptolites include *Monograptus aequabilis* Pribyl which indicates a Lower Devonian age for the sedimentary rocks in this area (M.R. Banks, pers. comm.).

Permian Sedimentary Rocks

Sedimentary rocks of Permian age crop out on the interfluves of several streams in the western part of the mapped area, and were first reported by Twelvetrees (1900*a*). The basal member is either an arkose or a siliceous conglomerate with overlying coarse-grained pebbly sandstone and grit, with extensive siltstones and sandstones at higher levels. The thickness of the sequence has not been measured. Although fossils, particularly brachiopods, have been found the exact age of the sequence is unknown, at Elephant Pass to the south of the mapped area spores from similar basal rocks have been dated as Lower Artinskian.

Tertiary Sedimentary Rocks

Discontinuous patches of partly consolidated Tertiary sedimentary rocks lie unconformably on Mathinna Beds and granitic rocks to the east of Scamander Tier (Twelvetrees, 1911; Walker, 1957; Jennings, 1968). In the coastal area they generally represent a well sorted, relatively unconsolidated beach deposit composed of coarse sand and well rounded quartz and quartzite pebbles. Valley fill deposits consisting of poorly sorted boulders of quartzite and vein matrix in a variable clay, sand or gravel matrix occur in places, particularly near the Scamander River and between Dianas Basin and Medeas Cove. Poorly bedded or cross-bedded, poorly sorted rocks also occur at higher levels along the base of Scamander Tier. These sediments rarely contain blocks of granite and fossiliferous Permian rocks.

The Tertiary rocks south of Golden Fleece Rivulet form part of Thureau's lead, which has been described by Jack (1964*b*). The rocks exposed at the surface are generally stanniferous sandy gravels that were probably formed largely by the reworking of Tertiary sediments during Quaternary times. Boring has revealed sequences up to 90 m thick of interbedded lenses of sand, gravel and clay, with some basalts at the base of the section, which extends to 75 m below sea level near Medeas Cove (Jack, 1964*b*). The dating of spores from Thureau's lead about 9 m above the basal basalt to the north-west of the mapped area has indicated a mid-Tertiary age (Harris, 1968).

Quaternary Sediments

Pleistocene to Recent sediments are represented by the present beach sands and river bars on the coast, and the relatively stable dunes to the west. Alluvial flats occur along the Scamander River and near Medeas Cove and these carry a discontinuous surface cover of blown sand. Boulder beds are common near the present course of the Scamander River, and Recent reworking of the Tertiary sequence has occurred in places.

IGNEOUS GEOLOGY

Upper Devonian Granitic Rocks

The granitic rocks of the area form the southernmost extension of the Blue Tier Batholith, which has been dated as Upper Devonian (McDougall and Leggo, 1965). A detailed discussion of the petrography of the entire batholith is planned by the author, and a structural study of some of the granitic rocks has been completed (Gee and Groves, 1971). The discussion of the granitic rocks presented below is only a broad outline of their petrographic and structural features, particularly those that are pertinent to mineralisation in the area.

St Helens Pluton

The complex of granodiorites, adamellites and diorites in the St Helens area has been called the St Helens Pluton (fig. 1; Gee and Groves, 1971). This pluton and the adjacent granitic rocks have been described in some detail by Walker (1957) and collectively termed the Coastal Range Quartz Monzonite. The main mass consists of biotite-hornblende granodiorite and adamellite, and biotite granodiorite and adamellite, with smaller masses of hornblende-diorite, monzonite and syenite. The granodiorites and adamellites are dark grey rocks consisting of anhedral undulose quartz, zoned subhedral andesine, biotite, and subordinate hornblende, all commonly poikilitically enclosed in microcline which forms large optically continuous crystals in places. A cataclastic foliation occurs in places.

The eastern, southern and northern contacts of the pluton are steeply dipping, but the contact exposed in the tributaries of Launceston Creek is essentially flat-lying with an upper thin layer of microgranite in contact with the Mathinna Beds (J.D. Cocker, pers. comm.).

A long, narrow vertical dyke extends southwards along Scamander Tier from near Medeas Cove. It is concordant to the pre-intrusion structures of the Mathinna Beds, and intrudes about 600 m to the west of one of the regional anticlines (fig. 2). Several sulphide-rich quartz veins occur within the dyke at the Scamander, Beulah and Scamander Bell prospects. The dyke is complex but consists largely of granodiorite porphyry and porphyritic granodiorite, with irregular lenses of porphyritic biotite adamellite and hornblende diorite. It is cut by dykes of quartz-feldspar porphyry, aplite and quartz-dolerite. The major rock type is granodiorite porphyry with phenocrysts of subhedral to euhedral zoned andesine, anhedral quartz and biotite, generally 5 mm in diameter, in a groundmass of quartz, plagioclase, biotite and hornblende, forming clots up to 5 mm in diameter, that are poikilitically enclosed in altered microcline. Large orthoclase microperthite phenocrysts, up to 6 cm in length, are scattered throughout the rock and include numerous subhedral zoned plagioclase crystals that in places form a myrmekitic intergrowth with quartz. Some alignment of phenocrysts subparallel to the dyke walls is evident near the centre of the dyke.

The dyke was probably forcibly intruded with vertical displacement of country rock, as it has dyke-wall irregularities that do not match by lateral restoration, and a blunt southern termination. Some lateral pushing is indicated by local overturning of the strata along the eastern contact (fig. 2).

The swing in strike of the Mathinna Beds to conform with the southwest margin of the pluton suggests lateral shouldering aside by the granodiorite. Locally in the coastal section north of Dianas Basin a discordant contact zone indicates the complex marginal deformation which indicate both lateral and vertical movements as well as demonstrably dilational intrusions into the splayed-out bedding (Gee and Groves, 1971).

Mt Pierson Pluton*

The large mass of coarse-grained biotite granite/adamellite to the west of the St Helens Pluton forms the southwestern part of the Mt Pierson pluton (fig. 1; Gee and Groves, 1971). The main mass consists of deeply

* Now known as Mt Pearson, following a recent decision of the Nomenclature Board of Tasmania.

weathered, pale grey rocks composed of unfoliated coarse-grained aggregates of microcline microperthite, anhedral quartz, subhedral and poorly zoned oligoclase-acid andesine, biotite and rare muscovite. In places these rocks are porphyritic with phenocrysts of orthoclase microperthite that poikilitically enclose biotite and plagioclase.

Fringing the southern contact of the Mt Pierson pluton is a 1 km wide zone of biotite-muscovite microgranites and granites which appear to intrude the normal granite/adamellite of the pluton. These granites are generally pale pink, fine- to medium-grained rocks composed of granular intergrowths of quartz, K-feldspar showing patchy microcline twinning, and acid oligoclase with scattered chloritized biotite and rare muscovite and tourmaline. The relatively flat-roofed isolated patches of these rocks beneath Mathinna Beds in Constable Creek, and the isolated roof of Mathinna Beds above the granite north of the Baden Powell prospect, suggest that these granites may be essentially flat-lying, and shelve beneath the Mathinna Beds to the east and south.

Extending southward from the Mt Pierson Pluton is a concordant, southward tapering dyke that is composed of coarse-grained biotite granite/adamellite in the north, but consists largely of pale pink aplite and microgranite near its southernmost extension where it crosses the Avenue River. The aplites at this locality are pale pink saccharoidal rocks consisting of granular and graphic intergrowths of quartz and K-feldspar with abundant albite-oligoclase and clusters of muscovite with accessory schorlite and corundum.

In contrast to the St Helens Pluton the pre-intrusion structures in the country rock show no marginal distortion related to discordant granite contacts. Fold traces and bedding traces are truncated abruptly, thus ruling out the possibility of forcible intrusion.

Poimena Pluton

The porphyritic biotite granite/adamellite mass in the north-west part of the mapped area is the southernmost extension of the extensive Poimena Pluton (fig. 1; Gee and Groves, 1971). The granite/adamellite is a blue-grey rock comprising large phenocrysts of orthoclase microperthite in a fine- to medium-grained groundmass of quartz, oligoclase-acid andesine, K-feldspar, biotite and minor muscovite. In places the phenocrysts form a flow foliation subparallel to a weak compositional banding, as described by Groves (1968*a*).

A cluster of small, discontinuous bodies of metamorphosed country rock cap the higher ridges just inside the granite contact in the vicinity of Beahrs and Ryans Creeks. The country rocks are extensively metasomatised (generally feldspathised) and there are indications of assimilation by the granite. These features, which are not generally evident on near-vertical side contacts, together with the elevation of the blocks, suggest that they represent remnants of the roof of the granite which shelves downwards with a moderate dip to the south, as first suggested by Twelvetrees (1900*a*). It is evident that there is no marginal distortion of pre-intrusion structures by the porphyritic biotite granite/adamellite.

Part of the eastern contact of the mass is composed of biotite granodiorite which extends as a thin band north from the Trafalgar mine. This granodiorite is similar in composition and texture to the marginal phase of predominantly biotite-hornblende granodiorites which are in contact with rocks of the Poimena Pluton about 1 km west of the mapped area (fig. 1; Gee and Groves, 1971). It is a medium- to coarse-grained, pale grey rock comprising abundant anhedral undulose quartz and subhedral zoned crystals of andesine that are poikilitically enclosed in microcline microperthite. Small clots of biotite, commonly altered to chlorite, are scattered throughout the rock and contain abundant inclusions of magnetite, zircon and apatite. The occurrence of bent cleavage surfaces in andesine, kink bands and bent cleavage in biotite, and undulose quartz indicate that the granodiorite has been deformed. The granodiorite is the host rock to gold-silver mineralisation at the Trafalgar and Double Event mines.

Quartz Dolerite Dykes

Several long, narrow basic dilational dykes intrude the Mathinna Beds along Scamander Tier, at the Great Pyramid mine, and at Dianas Basin, where a dyke also intrudes the biotite-hornblende granodiorite. The dykes are generally altered quartz dolerites (Walker, 1957). They are fine- to medium-grained, dark-grey to black rocks, with an intergranular to sub-ophitic texture, and are composed of about equal proportions of clinopyroxene and plagioclase, with their alteration products. Sulphides are abundant (up to 15%), commonly pyrite with minor chalcopyrite; other minerals present include quartz, magnetite, biotite, apatite and sphene. The pyroxene is altered to fibrous amphibole and chlorite, and the plagioclase is commonly albite associated with tremolite, epidote and calcite, indicating alteration of an original basic plagioclase. It is not apparent with which granitic type they are particularly associated, but it is clear from other exposures in eastern Tasmania that similar rocks are representative of the ultimate stages of granite emplacement.

Other Rocks

A small patch of dark grey granitic rock occurs at the southern end of a small coastal section just north of Wrinkler Lagoon (fig. 2). It is exxentially a hornblende granodiorite or tonalite porphyry with phenocrysts of hornblende and zoned basic andesine, up to 4 mm in length, and minor quartz and chloritised biotite in a fine-grained groundmass of quartz, plagioclase and K-feldspar. It is probably related to granitic rocks of the St Helens Pluton.

Longman (1961) reported the occurrence of hornblende picrite from grid reference [586902]* (*i.e.* Ryans Spur near Ryans Creek). This rock occurs close to local granite contacts with the country rocks which are considered to be remnants of the roof. The rock consists essentially of subhedral crystals of hornblende, up to 2 cm in length, that contain numerous poikilitic inclusions of olivine, hypersthene and malacolite, containing inclusions of magnetite, with interstitial labradorite and biotite. Longman (1961) considered the hornblende picrite to represent one of the earliest differentiates of the granite magma, forming by gravity settling and accumulations of early formed crystals. It is possible that the rock represents an inclusion of material that has no genetic association with the granitic rocks. Whatever its origin it would appear to have been brought up from some considerable depth by the granite, the density contrast indicating considerable upward flow of magma.

Contact Metamorphic Aureoles

Contact metamorphic aureoles of the granitic rocks have restricted widths ranging from 500 m - 2 km. Demonstrable contact metamorphic rocks occur at greater lateral distances from the microgranites fringing the Mt Pierson Pluton, and indicate that this contact may be essentially gently sloping to the south and east. The contact zone of the granodiorite porphyry

* 100 kiloyard grid square 59, zone 7.

dyke extending down Scamander Tier is limited to a few metres thickness.

No detailed petrographic work has been carried out on the contact aureole, but a hornfels close to the contact is typically a fine-grained dark grey recrystallised rock, passing into a spotted hornfels away from the contact. The hornfels consists of varying proportions of even-grained intergrowths of quartz, sodic plagioclase, microcline, biotite, muscovite, chlorite and rarely cordierite. The spots are generally of indeterminate composition or of fine sericite but probably represent the incipient growth of cordierite or andalusite.

At the Dianas Basin contact, discrete bodies of feldspathised rock occur within fold cores in the country rocks. These rocks comprise individual quartz grains, identical with those in the hornfels, and large euhedral zoned plagioclase crystals in a groundmass of biotite and chlorite. These bodies appear to have grown initially in the pockets of low pressure during essentially concentric folding, and appear to have a mixed origin with quartz and biotite derived from disaggregated country rock and the chlorite and plagioclase derived metasomatically from the granodiorite. These bodies contain xenoliths of the hornfelsed country rock. Similar rocks occur in the roof area of the porphyritic biotite granite/adamellite along Ryans Spur, and to the north of Ryans Creek.

At the western end of Medeas Cove some prospecting has been carried out on an elongate block of rock enclosed in the granodiorite. It is probably a large xenolith and consists of a fine-grained, dark green rock that contains small but abundant irregular patches of sphalerite. The rock comprises rare euhedral crystals of brown garnet, generally 0.25 mm in diameter, and irregular patches of quartz in a mass of finely intergrown green hornblende and chlorite with small crystals of zircon and apatite. It was probably originally an impure calcareous sedimentary rock, or a basic igneous rock, both of which are uncommon in the Mathinna Beds.

Jurassic Dolerite

A small isolated block of dolerite caps basal Permian beds in the south-west of the area (fig. 2). It is one of many such cappings exposed on the higher ranges in eastern Tasmania (*e.g.* Threader, 1967). The dolerite has not been studied in detail.

Tertiary Basalt

Small, discontinuous basalt flows have been detected near the base of the Tertiary sequence by drilling in Thureau's lead (Jack, 1964*b*). They occur up to 30 m below present sea level. A small basalt flow also occurs in the south-west of the mapped area near the headwaters of She Oak Creek. The basalts have not been petrologically examined.

STRUCTURAL GEOLOGY

The folding of the Mathinna Beds has been attributed to Tabberabberan orogenesis which has been dated elsewhere (Burns, 1964) as upper Middle Devonian. This is consistent with local evidence as the Mathinna Beds have been dated as Lower Devonian, and most regional folds are truncated by the granitic rocks which have been dated as Upper Devonian (McDougall and Leggo, 1965).

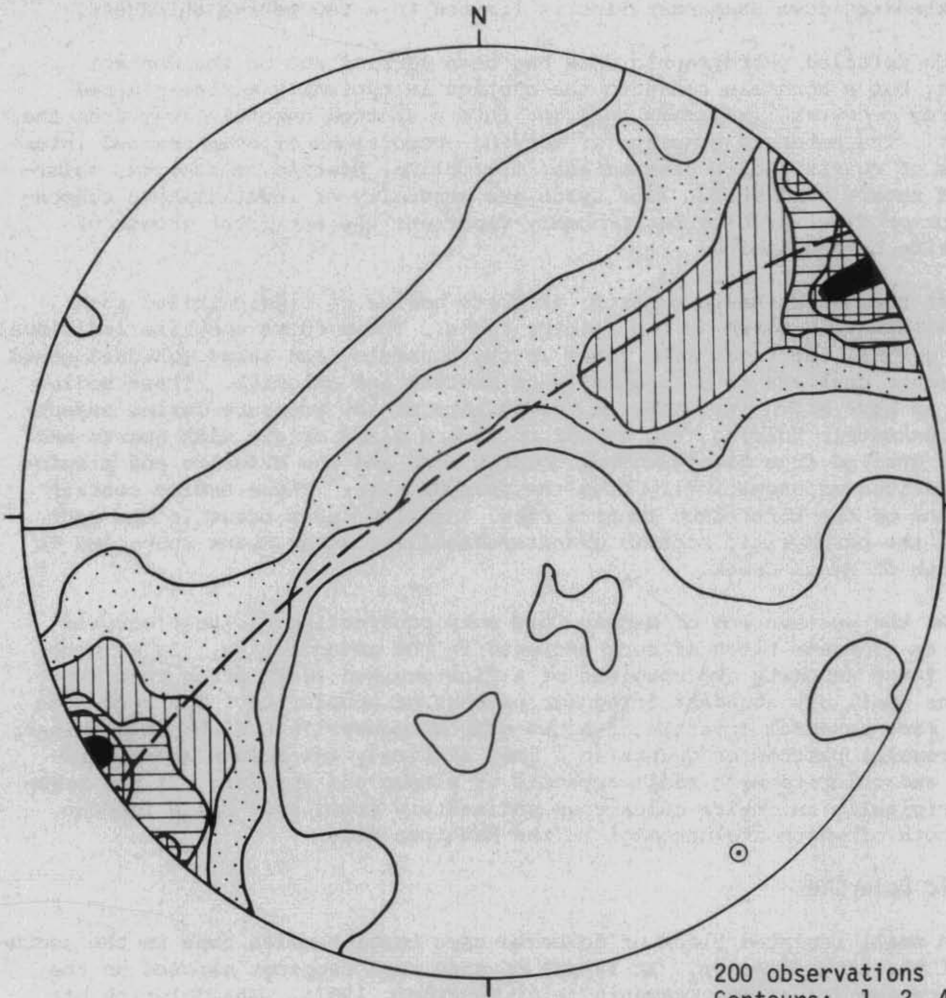


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Figure 3. *Contoured stereographic plot (Lambert projection) of poles to bedding, Scamander - St Helens area*

Folding

Most authors (*e.g.* Lyon, 1957; McNeil, 1965; Longman, 1966; Threader, 1967) have demonstrated that in eastern Tasmania it is common to find a series of major folds, with folds of smaller wavelength superimposed on them. This also appears to be the pattern in the Upper Scamander area, although the existence of major anticlinoria and synclinoria postulated by Carey (1953) is not supported. The major folds in the Scamander area have wavelengths of about 4 km, in close agreement with major folds (λ = 3 km) described by Threader (1967) from the area immediately to the north and west.

A contoured equal area projection of poles to bedding (fig. 3) over the mapped area (fig. 2) shows a girdle distribution, suggesting that bedding has suffered cylindrical folding on a regional scale. Two strong concentrations are shown with a narrow, hardly continuous linking section.

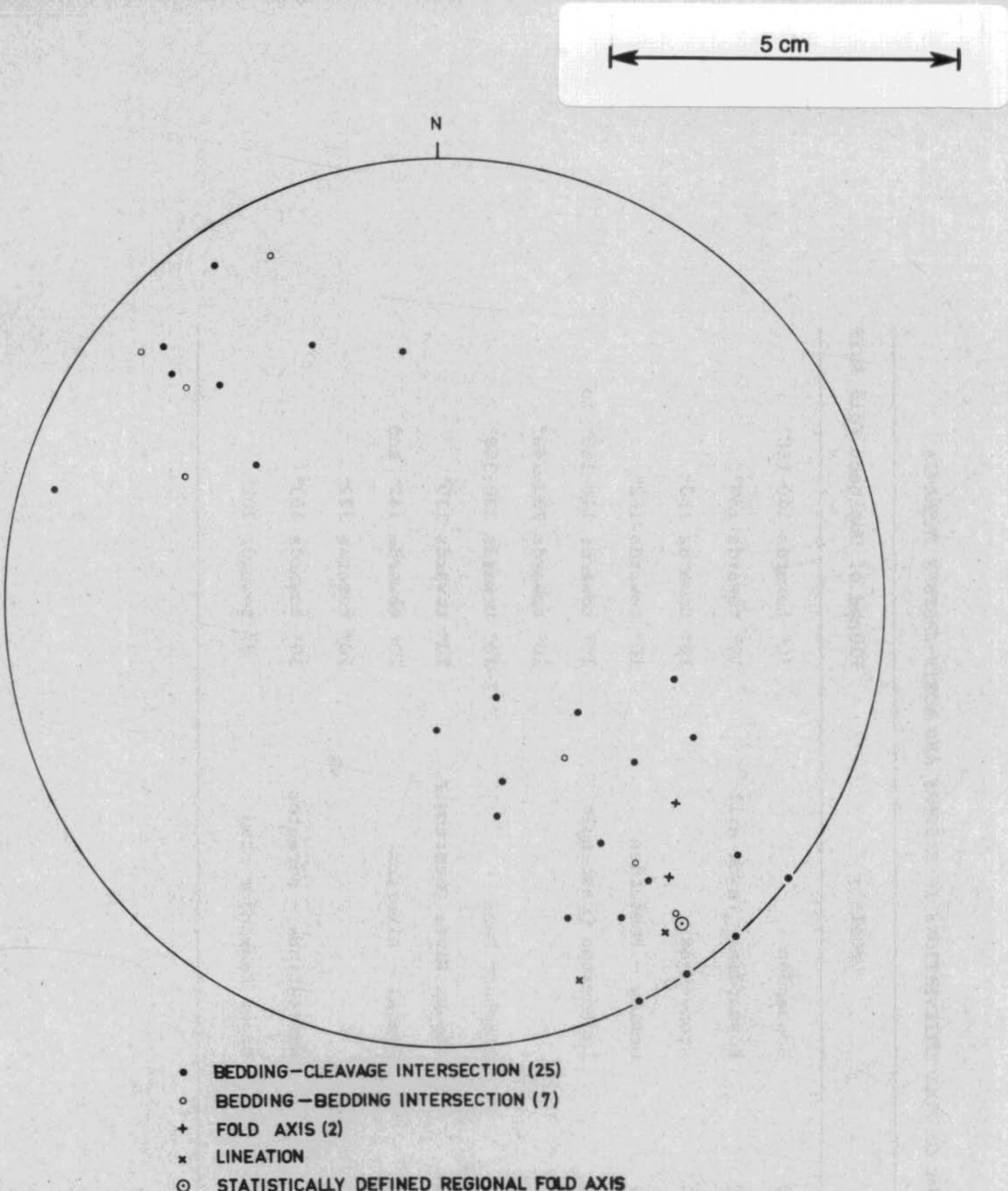


Figure 4. *Stereographic plot (Lambert projection of bedding-bedding intersections, bedding-cleavage intersections, lineations and fold axes, Scamander - St Helens area.*

These characteristics suggest folds with steep axial surfaces, long relatively planar limbs, and sharp closure. These features are typical of folds from most areas in north-east Tasmania (*e.g.* Threader, 1967; Legge, 1968; Marshall, 1970). The normal to the bedding pole girdle is the statistically defined axis of folding. It plunges 10° towards 143°, a similar orientation to that obtained from other areas (table 1). A plot of bedding-bedding intersections, bedding-cleavage intersections, measured lineations and fold axes (fig. 4) demonstrates that the folds are probably gently plunging both to the north-west and to the south-east, although some steep plunges are indicated. The position of the maxima in Figure 3 indicates that the north-east facing limb is slightly steeper, suggesting a regional axial surface dipping steeply

Table 1. SUMMARY OF FOLD ORIENTATIONS IN EASTERN AND NORTH-EASTERN TASMANIA

Author		Locality	Plunge of Dominant Fold Axis
Blissett	(1959)	Rossarden	30° towards 140-150°
Bravo	(1968)	Rossarden - Tower Hill	10° towards 159°
Jennings	(1967)	Stony Head	12° towards 150°
Legge	(1968)	Ormley - Rossarden	10° towards 162°
Longman	(1966)	Launceston Quadrangle	10° towards 140-160° to
			10° towards 320-340°
McNeil	(1965)	Elephant Pass	3-30° towards 320-350°
Marshall	(1970)	Pipers River Quadrangle	10° towards 139°
Threader	(1967)	Fingal - Alberton	20° towards 142° and
			20° towards 322°
		Warrentinna - Forester	30° towards 353°
Williams	(1957)	Upper Scamander road	8° towards 202°

south-west. Complete folds are extremely rare in this area but where developed (*e.g.* Avenue River) they are relatively symmetrical flexural folds with an angular shape (*i.e.* abrupt zones of closure).

Cleavage is present in most exposures of the Mathinna Beds but is indistinct in massive sandstones and in the contact aureoles of the granitic rocks. Bedding is almost without exception the more prominent planar element of the rocks, in contrast to the structure of the lutite associations where cleavage is commonly more prominent (*e.g.* Groves, 1965). In the few closures examined the cleavage fans slightly about the axial planes of the folds. Cleavage generally dips steeply west, although steeply easterly dipping and vertical cleavage occur.

The regional folds have been modified by later folding associated with the intrusion of the granitic rocks of the St Helens Pluton. At Dianas Basin (Gee and Groves, 1971) biotite-hornblende granodiorite/adamellite discordantly intrudes the axial zone of a NW-trending anticline. In the contact zone there is a local swing in the bedding to a N-S direction, about an axis plunging 70° towards 200°, and associated with strong minor flexural folding in the core region. In the zones of stronger deformation, fold axes and axial surfaces become chaotic and bedding traces are diffuse.

Faulting and Fracturing

A series of extensive NW-trending faults or fault zones occur north of the Scamander River in the Orieco area, and extend up to 3 km in length (fig. 2). The nature of these fault zones is shown in the Orieco mine where the fault zone has been driven on for nearly 275 m and is 1.5 - 6 m in width (fig. 9, 10). The fault zone comprises two main subparallel NW-trending, SW-dipping fault surfaces with numerous subparallel, subordinate, fractures. The fault surfaces are covered with fault gouge composed of extremely fine-grained kaolin, mica and quartz grains. Slickensides of several orientations occur, and it is difficult to determine the main direction of movement of the faults, although relative movement of blocks between individual fault surfaces indicate at least some horizontal component of movement. It is apparent (fig. 5) that these faults are subparallel to the mean regional trend of axial surfaces of folds.

The mineralised lodes that fill fractures in the Mathinna Beds have no definite preferred orientation (fig. 5) but have a wide range of orientations between 20° and 100°. These fractures are broadly perpendicular to the spread shown by bedding orientation (fig. 3), and it is probable that they represent tensional fractures (or incipient tensional fractures) related to the regional folding. These fractures may be re-opened during granite intrusion to allow the passage of mineralising fluids.

Several small faults offset the granodiorite porphyry dyke that extends down Scamander Tier and larger faults affect the dyke in Basin Creek, and possibly in the Scamander River (fig. 2). These faults probably have a horizontal component of movement as they displace an essentially vertical dyke. The age of the faults in unknown.

MINERALISATION

Introduction

As recognised by Twelvetrees (1911) and subsequent authors, the mineral occurrences of the Scamander district show a marked mineralogical zonation

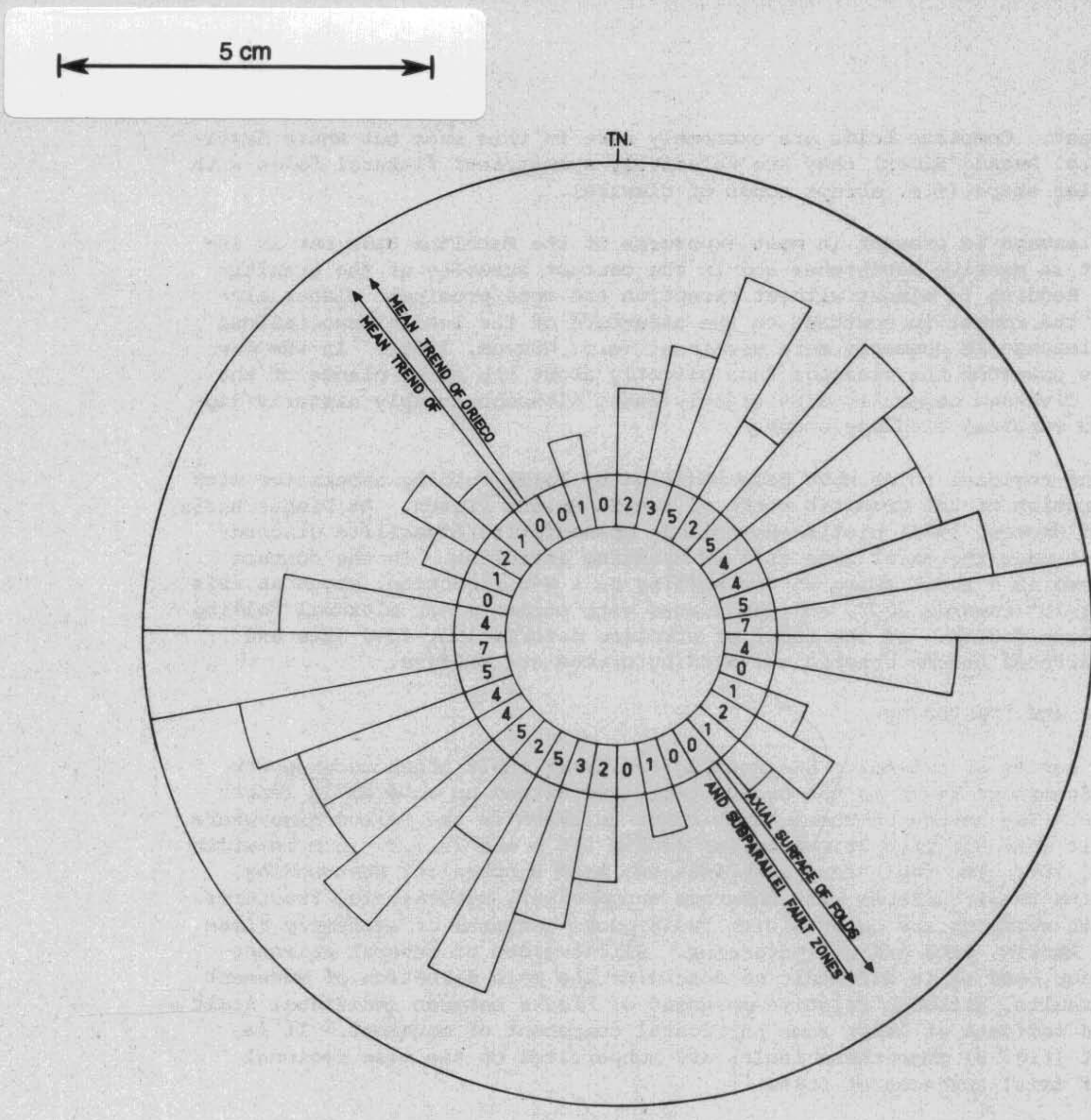


Figure 5. *Rose diagram of trends in mineralised fractures, Scamander - St Helens area.*

(fig. 6). The deposits are firstly described in groups relating to their mineral composition, and secondly the nature of the zonation and the source of the mineralisation is discussed. The deposits may be divided into five main groups: (*a*) wolframite-molybdenite deposits, (*b*) cassiterite deposits, (*c*) chalcopyrite-arsenopyrite-pyrite deposits, (*d*) galena (Ag-bearing)-sphalerite-arsenopyrite-pyrite deposits, and (*e*) gold-silver-arsenopyrite deposits.

Wolframite-Molybdenite Deposits

The wolframite-molybdenite deposits occur in or adjacent to the constant metamorphic aureole of the marginal belt of biotite-muscovite granites and microgranites of the Mt Pierson Pluton. They commonly occur as thin, non-persistent quartz-wolframite veins with variable amounts of molybdenite, cassiterite, bismuthinite, pyrite, chalcopyrite and arsenopyrite. The veins are generally perpendicular to the regional fold axes of the Mathinna Beds,

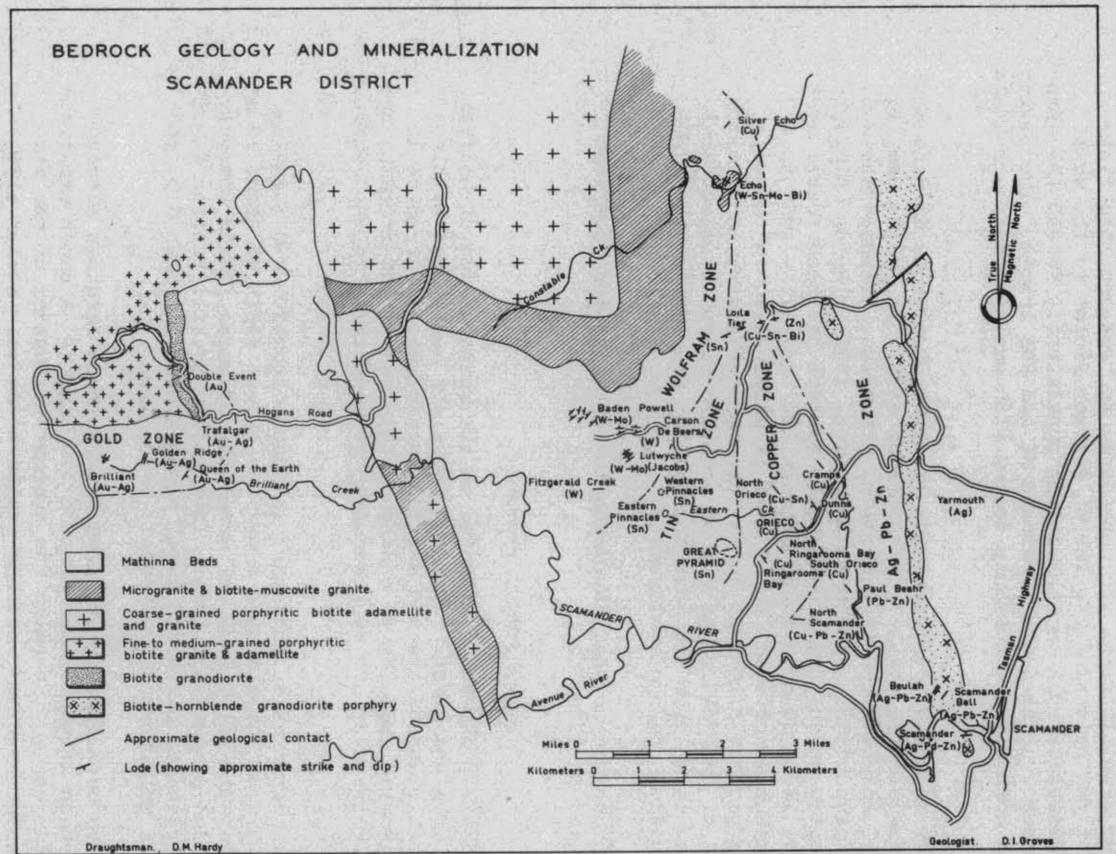


Figure 6. *Bedrock geology and mineralisation, Scamander district, zonal arrangement of mineral occurrences.*

and appear to fill tension fractures in these rocks. The deposits have been previously described by Waller (1901), Twelvetrees (1911), Hills (1916) and Nye (1941).

Echo Prospect

The Echo prospect is situated on Constable Creek about 6 km from St Helens. Biotite-muscovite granites crop out in the creek and for several tens of metres up the steep valley flanks, and are capped by hornfelsed Mathinna Beds. The granitic rocks are considered to represent the flat-lying projection of the belt flanking the Mt Pierson Pluton to the west. The hornfelsed sedimentary rocks strike fairly consistently NW and the granitic rocks are strongly jointed with dominant NE and ESE trends. The joints in the granite and hornfels are commonly coated with small euhedral crystals of cassiterite.

Walker (1957) recorded the occurrence of about 40 steeply dipping mineral veins that consistently strike just south of east. The veins comprise quartz, wolframite, molybdenite, bismuthinite, scheelite, arsenopyrite and pyrite in varying proportions. The main lode (Nye, 1941; plan no. 820/41) which occurs virtually on the granite/hornfels contact has been tested over a distance of about 170 m along a trend between 110° and 120°, and has a proven down-dip extension of 8 m. No. 2 reef is subparallel to the main lode. The veins typically pinch and swell, the main vein varying in width from about 0.3 - 2 m, and the proportion of economic minerals is extremely variable. The production from the main vein, which averaged about 1% WO_3, has amounted to about 1 tonne of wolframite.

A drilling programme to test the deposits was started by Geophoto Resources Consultants in 1969-70.

Baden Powell Prospect

The Baden Powell prospect is situated on the western side of Wolfram Creek about 12 km from Scamander. The host rocks are hornfelsed Mathinna Beds which are locally quartzites and spotted hornfelses. Wolframite is associated with minor molybdenite in bunches within NNE- to NE-trending and NW-dipping quartz veins that are approximately perpendicular to the regional fold axes.

There are six major veins that vary in length from 20 - 90 m and in width from 0.2 to almost 1 m and have a maximum proven depth of about 10 m (Nye, 1941; plan no. 818/41). They are generally elongate lenses commonly with curved sides and pinched-out ends. They appear to fill tension fractures. The veins typically pinch and swell along strike and down dip, and the distribution of wolframite is extremely irregular.

The veins have been largely explored from surface trenches although the main lode has been driven on for part of its length. A short exploratory adit has been driven to intersect the northern extension of the main lode below the present workings, but has failed to do so. Waller (1901) recorded a production of about 1 tonne of wolframite from the workings.

As noted by Waller (1901) the most persistent and extensive veins appear to contain limited wolframite, whereas the impersistent, narrower veins contain quite rich pockets of wolframite.

Price's (Carson de Beers) Prospect

Price's prospect is situated about 1 km ESE of the Baden Powell prospect near the top of a steep E-W trending ridge on the eastern side of Wolfram Creek. A number of small ENE- to E-trending and NNW- to N-dipping quartz veins carrying wolframite cut almost perpendicularly across silicified and tourmalinised sandstone beds which strike NNW to N and dip steeply W. Previous prospecting has been carried out by a series of surface trenches (Nye, 1941; plan no. 819/41), and more recently excavations with a bulldozer have uncovered further small lodes.

The quartz-wolframite veins appear to be of two types. The first type consists of relatively thin, 10 - 35 cm thick, straight-walled veins that cut a number of sedimentary units at a high angle. These are commonly very poor in wolframite. The second type are elongate pod-like veins that are confined to thick silicified sandstone units which they cut at a high angle. They are up to 1 m thick at their widest extension, up to 6 m in length and contain rich bunches of wolframite. In one pit at least five such pods occurred over a distance of less than 30 m along strike in two adjacent silicified sandstone beds. A tunnel has been driven on the northern side of the ridge in a NNW direction along a similar massive sandstone unit for about 75 m, but only a few small quartz veins carrying minor wolframite were intersected. Total production from the prospect has been approximately 1 tonne of wolframite.

Twelvetrees (1911) recorded that several small quartz-wolfram lodes had been opened up to the west of the prospect in tourmalinised and greisenised granite. However, as in the case of the other prospects, the widest and most persistent veins carried the least wolframite.

Lutwyche (Jacobs) Prospect

The Lutwyche prospect is situated on the northern slope of the adjacent parallel ridge about 1 km south of Price's prospect. A series of trenches and small open cuts have exposed several NNE- to ENE-trending and NW- dipping quartz veins carrying varying amounts of wolframite and molybdenite with minor pyrite and chalcopyrite (Nye, 1941; plan no. 819/41). Bedding in indurated sandstones is striking 340° and is vertical. The lodes are again of limited width, 8 - 50 cm thick, with only patchy occurrences of wolframite and molybdenite. A short adit has been driven to intersect the main lode below its exposed level, but has failed to do so.

Fitzgerald Creek Prospect

A small adit has been driven on the north bank of Fitzgerald Creek on a small ENE-trending vein consisting of quartz, pyrite, arsenopyrite and wolframite. Similar small veins occur in fractured quartzite beds in Fitzgerald Creek, but are commonly less than 5 cm in width.

Recommendations

The quartz-wolframite veins are generally too thin, too impersistent, and too impoverished in wolframite to be an economic proposition. The Echo prospect shows some promise because of the occurrence of significant amounts of wolframite, molybdenite and cassiterite in the same deposit. This deposit is being tested by drilling at the present time. The only economic possibility appears to be to locate a high enough density of quartz-wolframite veins in suitable quartzite or massive sandstone horizons to warrant a small open cut along these beds. Where this type of occurrence is exposed at Price's prospect the density of veins and their wolframite content appears too low for such an enterprise.

Cassiterite Deposits

The cassiterite lode deposits of the Great Pyramid-Pinnacles area lie to the south-east of the wolframite deposits described above. The Loila Tier tin prospect occurs just within the contact metamorphic aureole of the granite to the north-east of the wolframite deposits. The cassiterite occurs in thin seams, with or without quartz and sulphides, in probable tension fractures at a high angle to bedding in the host sandstone or quartzite horizons.

Great Pyramid Tin Mine

Previous Work

The Great Pyramid tin mine is at present covered by two mineral leases 23M/62 and 33M/62, totalling 11 ha (28 acres) held by L. Price, H.H. Williams and H.L. Price. The history of the mine, together with detailed geological descriptions and sampling of the exploratory adits, is given by Jack (1964*a*). The following brief discussion of the area is taken from Jack (1964*a*), and later exploratory work of Broken Hill Pty Co. Ltd (Chestnut, 1965*a*).

Production from the mine was limited to a period from 1928 to 1936 when 336 tonnes (331 tons) of ore were treated to give 2.96 tonnes (2.93 tons) of tin, indicating a recovery grade of 0.88% Sn and implying an approximate ore grade of 1.5% tin (Jack, 1964*a*). Assaying carried out in 1909 and 1914 during exploratory work and by the Department of Mines (Keid and Gulline, 1958; Jack, 1964*a*) indicated the limited extent of ore of this grade. It is evident from Figure 7 that areas with proven grades of greater than 0.3% tin also have a limited extent.

Geology of the Mine Area

The host rocks to mineralisation are part of the Mathinna Beds which locally can be broadly grouped into two types of sequence; (*a*) quartzite and sandstone beds with some shale horizons, and (*b*) interbedded shale, siltstone and sandstone with few quartzite beds. Significant mineralisation is almost totally confined to the two sandstone-quartzite sequences exposed in the area, and even in the shale-rich sequences it is normally confined to sandstone or quartzite horizons (Jack, 1964*a*). Percussion boring by Broken Hill Pty Co. Ltd generally confirmed this pattern of mineralisation (fig. 7), and tin mineralisation intersected in their diamond drill hole (D.D.S.1) was also largely confined to quartzite units.

Mineralisation consists of thin veins of fine-grained cassiterite along fractures that are commonly at a high angle to bedding, and in the matrix of breccias of limited extent. The cassiterite is associated with some vein-quartz and limonite with rare specks of pyrite and chalcopyrite. The occurrence of small gossan gappings and the abundance of limonite associated with mineralised zones suggest the subsequent oxidation of previously more abundant sulphides. This is substantiated by the diamond drill hole (D.D.S.1) in which massive sulphides (notable sphalerite) were intersected over a width of 0.3 m at 203 m.

The structure of the mine area is difficult to interpret because of lack of surface outcrop and the varying topographic levels of the exploratory adits, and neither Jack (1964*a*) nor Chestnut (1965*a*) have attempted an interpretation. The western sandstone-quartzite sequence and the immediately

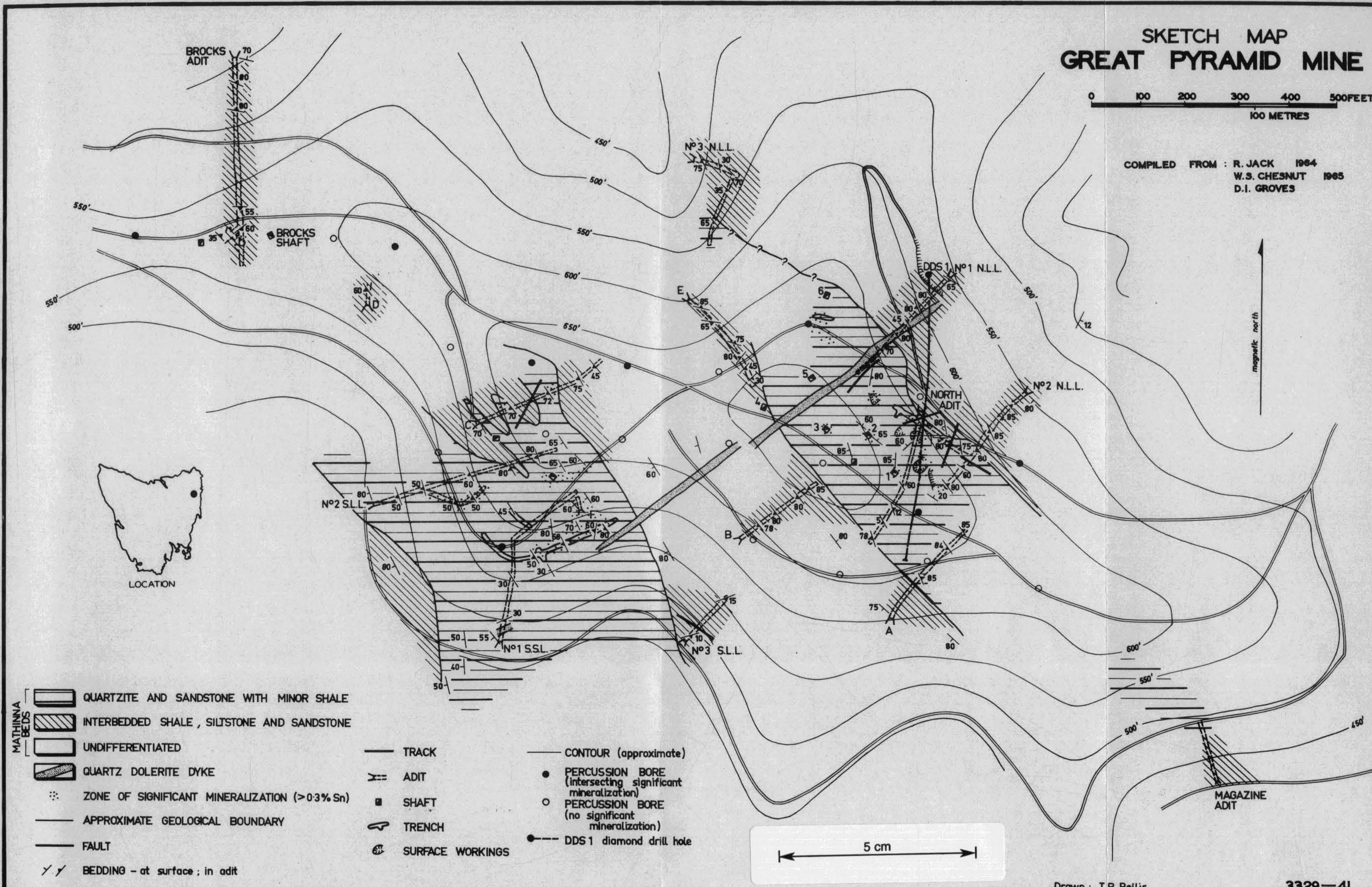


Figure 7. *Geological sketch map, Great Pyramid mine area*

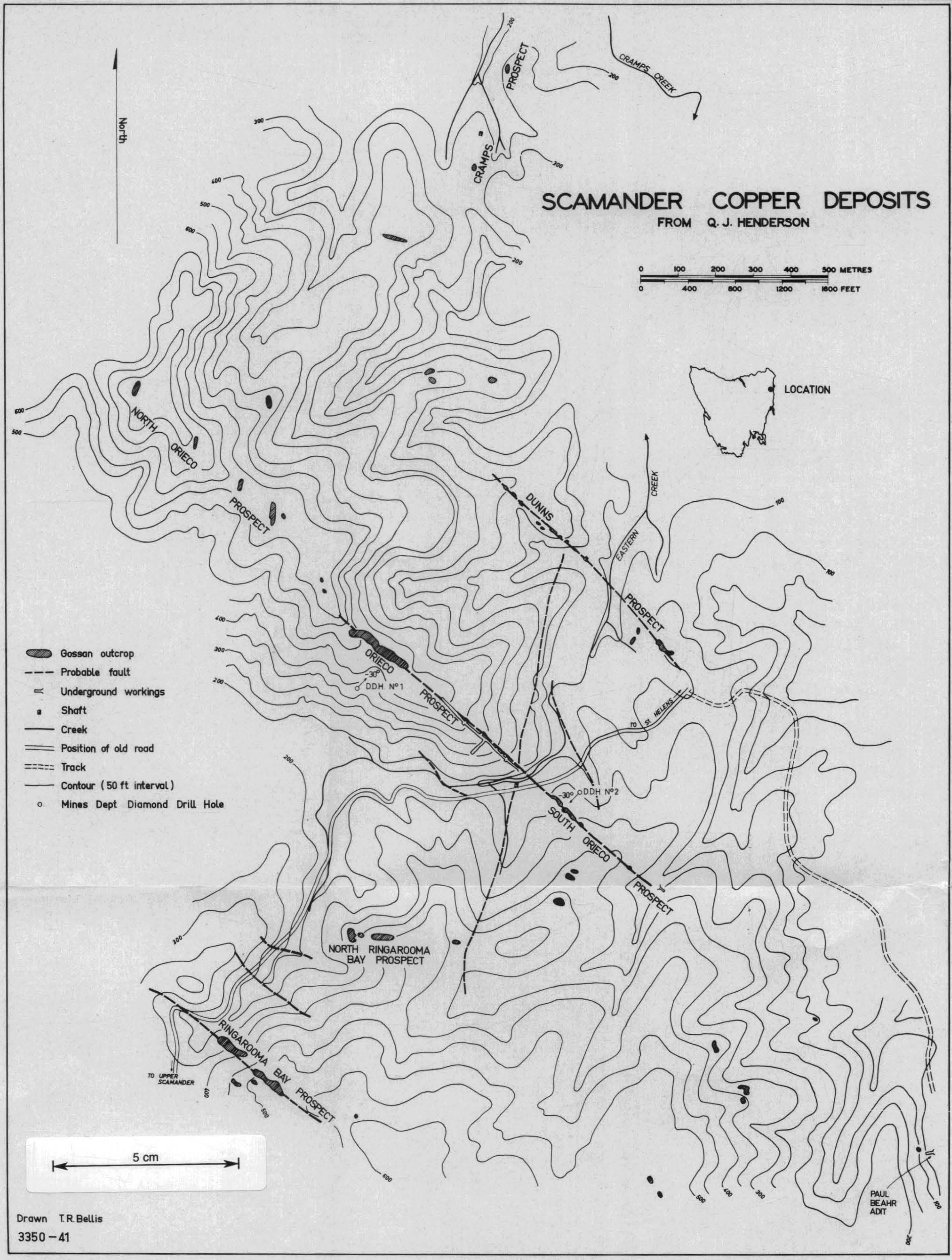


Figure 8. *Scamander copper deposits, showing distribution of gossans and mineralisation*

facing page 25

underlying and overlying shale-sandstone sequences form a continuous NW-trending, SW-dipping sequence with relatively minor faulting (fig. 7). The eastern sandstone-quartzite sequence and the most easterly shale-sandstone sequence have a more complicated structure with a general dip to the north-east, and a possible anticlinal crest just east of the western margin of the sandstone-quartzite sequence. A possible explanation of the rock distribution and bedding variation is for the sandstone-quartzite sequences to be equivalent and represent the limbs of a faulted, NW-trending anticlinal structure, with the western margin of the eastern sequence being a fault surface dipping and downthrowing to the north-east; this fault may be exposed in A adit (Jack, 1964*a*). The anticlinal structure demonstrated in Brock's adit may represent an extension of this structure with a westerly swing in the axial surface. The faulted anticlinal structure may also explain the intensity of fracturing in the mine area.

A NE-trending altered quartz-dolerite dyke (fig. 7) has been delineated partly from sporadic outcrop and partly from an elongate magnetic anomaly (Chestnut, 1965*a*). It cuts almost perpendicularly across the structural trend of the Mathinna Beds, and probably represents the filling of an extensive tensional fracture, related to the folding. Several of the mineralised zones carrying higher tin values extend in a similar direction to the dyke, particularly in the western sandstone-quartzite sequence, and are also probably related to tensional fractures.

It is evident that there is a close relationship between the higher tin values and the occurrence of fractured sandstone-quartzite beds. It is probable that because of their greater competence the sandstone beds formed more continuous, discrete fractures than the shale lenses during folding, and thus allowed the more ready passage of mineralising solutions. The textures of the quartzites (Everard, 1964) and evidence that they merge into sandstone beds (Jack, 1964*a*) suggests that they probably represent original sandstone beds that were silicified during mineralisation. The occurrence of quartzite beds elsewhere may therefore be indicative of further mineralisation.

Recommendations

All published work has shown that the bulk of mineralisation in the area is low grade, although some promising areas occur near North Adit and in the vicinity of F Adit. The economic possibilities of the prospect appear limited, although further percussion drilling on a closer grid may be warranted over the sandstone-quartzite sequences in the areas of known significant mineralisation. Further work could also be carried out to test the potential of the extensions of the sandstone-quartzite sequences to the north-west and south-east of the area covered by previous investigations.

Pinnacles Tin Prospect

The Pinnacles prospect occurs to the west of the Great Pyramid mine on a bold ridge about 370 m a.s.l. (fig. 2). By 1911 some surface trenching had been carried out and a short adit driven to test the West Pinnacles prospect. Subsequently a short adit has been driven to test the East Pinnacles prospect. There is no record of any tin production from either prospect. In 1965 the Broken Hill Pty Co. Ltd drilled six percussion holes over weak magnetic anomalies in the area, but no significant mineralisation was encountered (Chestnut, 1965*b*).

The Mathinna Beds at this prospect comprise fewer massive sandstone and/or quartzite beds than at the Great Pyramid mine. The rocks are poorly exposed but appear to be SW-facing and steeply SW-dipping. Mineralisation is similar to that at the Great Pyramid mine, consisting of thin discontinuous quartz veins carrying minor fine-grained cassiterite in fractures in the quartzite beds. A few blocks from surface rubble are reported to contain high tin values, but an extensive source of this material has not been found.

Loila Tier Prospect

The Loila Tier prospect has been described in some detail by Urquhart (1968). It occupies an extensive fault zone that is probably continuous for over 1.5 km. The mineralogical composition changes from cassiterite-tourmaline-quartz at the western end to sulphide-rich quartz veins containing Cu-sulphides, sphalerite and galena at its eastern extension.

Two pits have been sunk on the western end of the prospect and have revealed a NE-trending, steeply SE-dipping fault zone about 8 m wide. It intersects silicified Mathinna Beds which trend NNW and dip steeply west, and are brecciated and cemented by fine-grained tourmaline and chlorite. Urquhart (1968) considered the fault to be possibly a lateral wrench fault.

Quartz veins fill joints that are subparallel to the fault zone, and cassiterite occurs as encrustations on small vugs, as aggregates of crystals disseminated through the host rocks or in silicified patches of rock. Some cassiterite is associated with tourmaline bands. Urquhart (1968) visually assessed the grade of the tin-bearing rock between 2 - 4% Sn.

About 400 m north-east of the western prospect a similar NE-trending, fault zone, about 2 m thick, containing quartz, arsenopyrite and minor cassiterite is exposed on the ridge. The fault zone can be traced from discontinuous gossan outcrops and small surface excavations in a general north-easterly direction for about 1.5 km. On the western side of the Loila Tier road a shaft has been sunk to a depth of 5 m on a small lode of brecciated rock and vuggy quartz, that contains abundant arsenopyrite, and its oxidation product scorodite, together with minor chalcocite and covellite. H. Williams states that tin and bismuth are also recorded in an assay of material from this shaft. Surface workings from the eastern side of the road have exposed a quartz lode about 0.7 m thick that contains coarse-grained patches of arsenopyrite and sphalerite. The sphalerite (Specimens 69-40, 69-41) contains large blebs and exsolution bodies of chalcopyrite together with minor pyrrhotite and galena, and small veins of covellite.

Copper Deposits

A series of discontinuous gossan cappings occur on the ridges to the east and south of the wolfram and tin zones of mineralisation (fig. 8). The most extensive line of gossans occurs over a NW-trending fault zone up to 3 km long, which includes the Orieco mine. Gossan cappings also occur over subparallel, weakly mineralised fault zones to the north-east and south-west of the Orieco fault zone. The structure within these fault-banded blocks is complex, and poor exposure makes interpretation almost impossible.

The gossan cappings consist of irregular blocks of quartzite cemented by iron oxides, iron-stained kaolin, ferruginous chert and rare embolite (Smith, 1897). They have generally been explored by trenches and small shafts in places, which reveal a strongly leached and oxidised zone with barren quartz veins. The deeper workings at the Orieco mine, and to a lesser extent Dunns adit, have intersected small zones of supergene enrichment of copper around, and slightly above, the level of the present water table. It seems likely that similar restricted zones of supergene enrichment will occur beneath gossans elsewhere in this area.

The oxidised and supergene zones at the Orieco mine have been intensively examined as it is important to determine the type and distribution of minerals which may exist beneath the other gossan cappings in the area. The geology of the Orieco mine is discussed in detail below and the surface indications of the other prospects are briefly described. A detailed discussion of the oxidation and supergene enrichment at the Orieco mine has been given by Ford *et al.* (1970), and the following summary is from this paper.

Orieco Mine

Geology of the Mine Area

The Orieco mine is situated on the southern flank of a steep ridge rising from the northern bank of Eastern Creek (fig. 2), which is the only permanent stream in the area. The permanent water table is between 3.5 - 5 m below the adit level in the mine at the present time.

The Orieco fault zone has been driven on for nearly 275 m (fig. 9) and two shafts have been sunk on the fault zone to the south-east of the adit portal. These shafts are flooded and at present a study of the deeper workings is impossible. The fault zone exposed in the adit varies in width from about 1.5 - 6 m and consists of two main subparallel NW-trending and SW-dipping fault surfaces with numerous subparallel, subordinate fractures (fig. 10). The fault surfaces are covered with gouge composed of kaolin, mica and clay-grade quartz grains. Broadening of X-ray diffraction peaks indicates the fine-grained nature of the material. Several ore shoots were intersected within the fault zone in the adit but only two were of economic grade with copper values ranging from 1.8 - 5.4% (Henderson, 1941).

The first ore shoot was intersected at about 40 m from the portal and extended 18 m along the adit, although it did not persist above adit level (fig. 9). The main ore shoot, which is persistent up to 6.5 m above adit level and is up to 46 m in length, is only partly accessible due to the collapsed condition of the workings adjacent to the main winze and rise (fig. 9).

The workings have been adequately described by Twelvetrees (1911) and this information is not repeated here. Henderson (1941) sampled the available workings and indicated for the first ore shoot at adit level an average grade of 1.82% Cu over a length of 18.3 m, and an average width of about 1.35 m. A sample taken from a small stope about 3 m below the adit level showed a grade of 5.91% Cu over a width of about 1 m. Sampling of the main ore shoot at adit level indicated an average grade of 5.39% Cu over an average width of 2.26 m for a strike length of about 46 m. Small patches of richer ore were encountered below adit level. Production from the mine has been in excess of 446 tonnes (439 tons) of ore assaying between 15 and 28% Cu, most of this being mined before 1911.

The ore shoots consist of quartz-sulphide and sulphide veins that are commonly virtually monomineralic, and have been replaced by supergene copper sulphides throughout the exposed ore shoot and by copper oxides, copper carbonates, and rare pre-mine copper sulphates at adit level (*i.e.* at the top of the ore shoots). Most veins of secondary copper minerals contain remnant primary sulphides.

The hypogene sulphides in approximate order of abundance are; pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, marcasite, pyrrhotite, cubanite, bornite and tetrahedrite. Supergene sulphides are chalcocite,

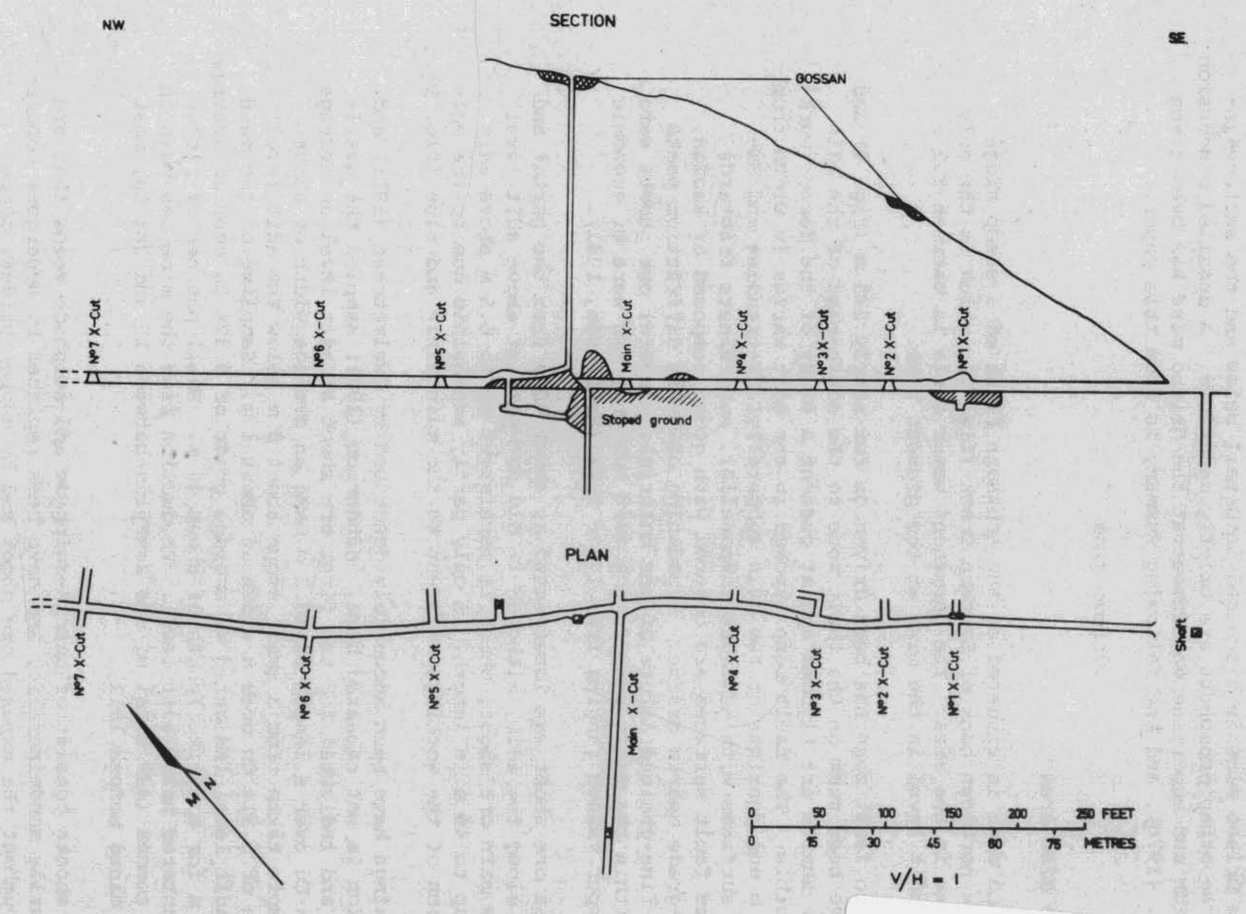


Figure 9. *Plan and section of mine workings, Orieco mine.*

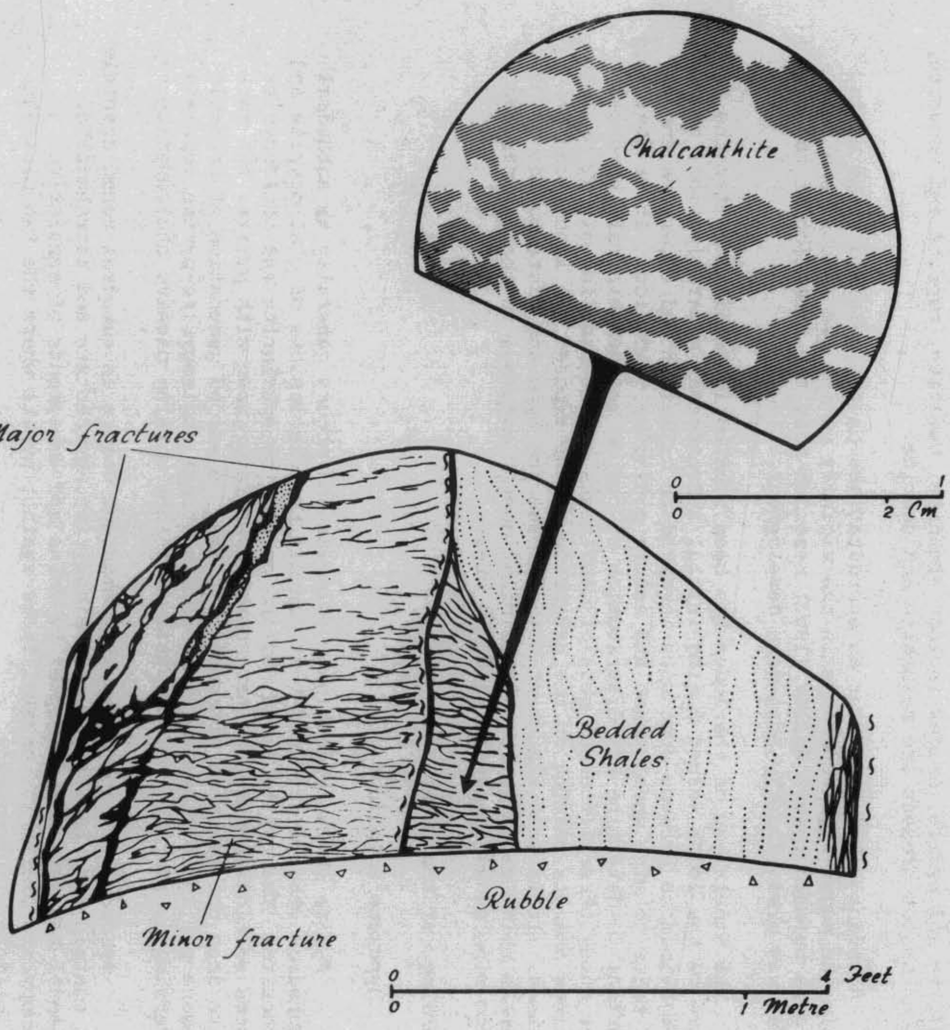


Figure 10. *Cross section through fault zone exposed in stope above No. 4 cross-cut, Orieco mine (from sketch by J. Klomínský).*

covellite and pyrite, oxides include limonite, hematite, cuprite and tenorite, and carbonates present are malachite and azurite.

Abundant sulphates occur as encrustations on the adit and stope walls, within the puggy fault surfaces in the vicinity of the ore shoots, and in the area between them. Waller (1901) recorded that the formation of the sulphates was predominantly post-mine development.

The mineralogy of the lodes has been studied in detail to determine the nature of the lodes formed during initial hydrothermal mineralisation, and to discriminate between processes involved in oxidation and supergene enrichment prior to mine development and active post-mine oxidation. It is obviously important to determine the distribution of copper between minerals produced under these three different sets of conditions before sampling of the present workings and its bearing on the extension of the exposed ore shoots can be assessed. It is also important to determine the type and distribution of minerals which may exist beneath similar gossan cappings to those above the Orieco mine on adjacent hills in the area.

Mineralogy of the Ores

Hypogene Sulphides

Pyrite is the predominant sulphide and occurs generally as subhedral to euhedral cracked crystals that contain rare inclusions of chalcopyrite and pyrrhotite. The pyrite is veined and embayed by sphalerite and chalcopyrite. In some sections patches of marcasite occur intergrown with pyrite, but marcasite does not occur as discrete crystals. A second generation of probable hypogene pyrite is represented by rare multiple chalcopyrite-pyrite veinlets traversing sphalerite, and by pyrite veinlets cutting massive chalcopyrite.

Arsenopyrite is extremely common and occurs as euhedral zoned crystals that contain rare inclusions of chalcopyrite, pyrrhotite and tetrahedrite. The zonal textures are disrupted by veins and embayments of sphalerite. Arsenopyrite exerts its crystal faces against pyrite where the two minerals are intimately intergrown.

Sphalerite occurs commonly as granular interlocking aggregates in large, almost monomineralic veins up to 15 cm wide, or in small patches, up to 5 mm in diameter, in massive quartz veins. The sphalerite apparently replaces arsenopyrite and pyrite, but sphalerite-chalcopyrite interfaces exhibit features akin to mutual boundaries textures. The sphalerite commonly contains numerous exsolution and segregated exsolution bodies of chalcopyrite which occurs as blebs, generally from 0.01 - 0.1 mm diameter, as aligned elongate bodies and as small veinlets and in some sections is strongly aligned along favoured crystallographic directions and cleavages in the sphalerite host. Small blebs of pyrrhotite and pyrrhotite-chalcopyrite also occur in sphalerite and inclusions of cubanite and galena occur more rarely. The multiple pyrrhotite-chalcopyrite bodies commonly have an unusual lamellar habit.

Chalcopyrite is only a minor constituent in the primary sulphide assemblage and occurs predominantly as small anhedral grains, up to 4 mm in diameter, at mineral interfaces, particularly in spaces between euhedral pyrite and/or arsenopyrite crystals. It also occurs as granular aggregates up to 5 mm in diameter in quartz veins and also as inclusions in pyrite, arsenopyrite and sphalerite, as described above. Massive aggregates of chalcopyrite grains rarely form veins up to 30 cm in width. The chalcopyrite is generally free from inclusions except rare pyrite and sphalerite, and exsolution bodies of sphalerite are completely absent. The chalcopyrite rarely forms restricted lamellar intergrowths with bornite.

Galena is a rare constituent of the ore. It is commonly intergrown with sphalerite but textural relationships are not clear because of replacement by secondary copper sulphides at sphalerite-galena interfaces. It also occurs as small skeletal inclusions in arsenopyrite and sphalerite. Other sulphides are relatively rare.

Supergene Sulphides

Chalcocite is the predominant supergene sulphide developed in the ore shoots. It commonly occurs as extremely fine-grained, almost isotropic aggregates that rarely contain coarse-grained crystals at their centres. The chalcocite replaces all the primary sulphides to a variable extent with chalcopyrite being the most strongly replaced followed by sphalerite and arsenopyrite, with pyrite the least replaced. The euhedral, brittle minerals, generally lacking in cleavage, (pyrite, arsenopyrite) have been replaced around crystal faces and along post-crystallisation cracks, with the formation of anastomosing veinlets of chalcocite separating isolated residuals of the host mineral. Chalcocite replaces sphalerite along cleavage surfaces and crystallographic directions within the sphalerite host, producing triangular and sub-rectangular residuals of sphalerite. The replacement of chalcopyrite by chalcocite is more irregular with uneven, sometimes feathery, anastomosing veinlets of chalcocite throughout the chalcopyrite host. Chalcocite also replaces the primary sulphides at interfaces between sulphide pairs.

Covellite is less common than chalcocite. Its most common occurrence is as small intergrowths with chalcocite in chalcocite-rich veins. It also occurs as rims around chalcopyrite grains, as irregular patches in sphalerite that contains abundant chalcopyrite, and filling apparent dilational fractures in pyrite. Irregular, thin, discontinuous veinlets of covellite fill small fractures in quartzite in places.

Supergene Oxides

The supergene oxides; hematite, limonite, cuprite and tenorite are generally restricted in occurrence to the upper parts of the ore shoots.

Hematite occurs as earthy red masses along, and between, fault surfaces near No. 1 cross-cut. It has not been identified in polished sections of sulphide-rich veins.

Limonite is abundant throughout the mine workings. Microscopically it can be seen to consist of botryoidal masses almost completely replacing pyrite in some sections, where it is commonly associated with malachite, azurite and cuprite in veins traversing the host rock.

Cuprite occurs in small irregular veinlets associated with limonite, malachite and azurite. It is relatively rare in the material available for inspection, but Waller (1901) recorded that it was abundant at adit level when the drive was originally opened.

Tenorite (melaconite) was reported to occur commonly by Waller (1901). It was identified in only one section in the present study as twinned irregular crystals in the centre of malachite veins cutting sphalerite and chalcocite. Irregular veins of earthy black minerals resembling tenorite were shown by X-ray diffraction to be covellite.

Supergene Carbonates

Supergene carbonates (malachite, azurite) are also largely restricted in occurrence to the upper parts of the ore shoots.

Malachite is the predominant carbonate. It occurs as veinlets traversing sulphide-rich veins, and as encrustations on fractures in the host rocks. An unusual occurrence is as clusters of rosettes along small fracture surfaces near No. 1 cross-cut. In places malachite forms the centre of anastomosing chalcocite veinlets cutting sulphides. Other associates are azurite, limonite, cuprite and sulphates.

Azurite occurs in minor proportions throughout the adit level. It occurs as intergrowths with malachite in veins traversing sulphide-rich patches.

Supergene Sulphates

Sulphates that can be shown to be definitely pre-mine development are rare. Minor chalcanthite possibly of this generation occurs in veins with associated malachite and azurite in the upper parts of the ore shoots. The arsenates (particularly scorodite and pharmacosiderite) were probably at least partly formed during pre-mine oxidation although criteria for the recognition of their time of formation are not definite. They are described in the following section.

Post-Mine Oxidation

Abundant sulphates and arsenates fill fractures within the main fault zone and coat the adit and stope surfaces for some considerable distance from the sulphide-rich ore shoots. Waller (1901) recorded that the formation of the sulphates was predominantly post-mine construction, and fresh sulphate was observed to have crystallised in the walls and floor of the adit after heavy rain in June 1969.

The sulphates (confirmed by X-ray diffraction) in approximate order of abundance are: chalcanthite, antlerite, brochantite, pisanite, ktenasite, natrojarosite, and gypsum. The arsenates are scorodite and pharmacosiderite. Langite, chenevixite and duftite have been tentatively identified from the presence of their most intense X-ray diffraction peaks, although the patterns were not sufficiently intense to enable recognition of the complete patterns.

Mineralogy

Chalcanthite [$CuSO_4.5H_2O$] is the predominant sulphate mineral throughout the accessible mine workings. It commonly occurs as cross-fibre veinlets, up to 1 cm in width, in fractures that are both perpendicular and parallel to the main fracture surfaces within the fault zone (fig. 10), or as unusual acicular crystals, up to 10 cm in length, that project perpendicularly from the adit and stope walls. Crystalline aggregates commonly consist of wire-like, bent crystals, the colour of the crystal aggregates varying from berlin-blue to sky-blue with different shades.

Antlerite [$CuSO_4.2Cu(OH)_2$] is next in abundance to chalcanthite, and is commonly closely associated with the acicular crystals of this mineral. It also occurs as friable, pale-green encrustations on the walls of the adit.

Brochantite [$CuSO_4.3Cu(OH)_2$] forms fine-grained drusy crusts that are emerald-green in colour. It is generally present as a coating or filling in cavities in quartz-limonite veins. It occurs only rarely in association with chalcanthite, and is more commonly associated with antlerite at some distance from the sulphide veins.

Pisanite [$(Fe,Cu)SO_4.7H_2O$] occurs rarely as greenish-blue felt-like coatings and granular encrustations associated with chalcanthite on the adit walls. It also occurs as sheet-like encrustations on the surface of kaolinite in the mylonitic material of the major fault zones. Pisanite will commonly crystallise on the surface of kaolinite as an almost continuous sky-blue encrustation when the kaolinite is dried.

Ktenasite [$3(Cu,Zn)SO_4.4H_2O$] occurs rarely as pale emerald-green powdery encrustations on quartz veins that commonly also contain azurite.

Langite [$CuSO_4.3Cu(OH)_2.H_2O$] occurs in a single specimen from the Orieco mine. It is present as small greenish-blue fibres that are intergrown with brochantite.

Natrojarosite [$NaFe_3(SO_4)_2(OH)_6$] is abundant throughout the mine workings. It occurs as yellow powdery coatings on the adit walls and within fractures in the fault zone.

Gypsum [$CaSO_4.2H_2O$] occurs rarely as small transparent plates in association with limonite on the walls of small vugs and fractures.

Scorodite [$Fe(AsO_4).2H_2O$] is relatively rare in the mine workings although it occurs commonly in surface trenches that have exposed minor quantities of arsenopyrite. In the mine workings it occurs as pale-green massive encrustations on small veinlets that contain arsenopyrite.

Pharmacosiderite [$KFe_4(AsO_4)_3(OH)_4.6\text{-}7H_2O$] occurs as small irregular olive-green veinlets and powdery coatings associated with arsenopyrite, malachite and azurite.

Chenevixite [$Cu_2Fe_2(AsO_4)_2(OH)_4.H_2O$] and possible *duftite* [$CuPb(AsO_4)(OH)$] occur intergrown as a pale olive-green encrustation on the surface of small arsenopyrite veinlets in a single specimen from the vicinity of the first ore shoot.

Chemistry of Oxidation

The oxidation and subsequent supergene enrichment at the Orieco mine originally developed under conditions which were different from those causing active oxidation at the present time. Prior to mine development the ore shoots consisted of primary sulphides and secondary copper sulphides (chalcocite and covellite) with an upper restricted zone of limonite and hematite together with cuprite, tenorite, malachite, azurite and probable iron arsenates. These ore shoots have been oxidised following mine development with the formation of numerous copper sulphates and iron arsenates. This oxidation has been facilitated by the ready circulation of air and water combined with large free surfaces ideal for evaporation of aqueous solutions. Most ore bodies having a well developed oxidised zone, with abundant sulphates, occur in arid or semi-arid regions (*e.g.* Anderson, 1955), but at the Orieco mine such oxidation is occurring under artificial conditions in a region where there is an annual rainfall of 750-1000 mm.

The chemistry of both oxidation events have been described in detail by Ford *et al.* (1970). The main conclusions of this work are given below.

It is probable that around the initial sulphide-rich zones the activity of the sulphate ions was initially high and that gradually decreased as groundwater containing dissolved atmospheric CO_2 caused dilution, until dissolved carbonate became the dominant anionic species; there is apparently no other source of carbonate in the area. It is significant that the stability field of the main carbonate present, malachite is close to a pH of 6. Thus the development of carbonates was probably most intensive during the latter stages of pre-mine oxidation. Azurite is far less common than malachite and is considered to have occurred in restricted zones where the local carbonate concentration was high.

The absence of native copper in the oxidised zone suggests initially low pH, oxidizing conditions with the oxidation voltage being maintained at least 0.6V above the lower stability limit for water during progressive increases in pH caused by dilution of initial solutions with further groundwaters.

It appears that although sulphates were present as predominantly transient phases during initial oxidation with only minor stability of copper sulphates in the zone of oxidation, the arsenates (pharmacosiderite and scorodite) were stable. This probably results from their lower solubility relative to the sulphates.

The abundance of chalcanthite in the present mine workings suggests that the initial concentration of sulphate ions during post-mine oxidation was very high, with conditions of low pH and relatively high Eh. Under this new set of conditions the previously formed mineral assemblage of the ore shoots is unstable, particularly the Cu-carbonates, and the minerals are reverting to sulphates similar to those from which they were initially derived. The spatial sequence, with respect to the sulphide-rich zones in the Orieco mine, is chalcanthite-antlerite-brochantite (+ duftite) which has commonly been found in other studies (*e.g.* Jarrell, 1944), and it resulted from decreasing sulphate concentrations and increasing pH away from these zones.

North and South Orieco Prospects

Gossan cappings occur on the ridges to the north and south of the Orieco workings. Some minor surface workings have explored the occurrence at the South Orieco prospect (Henderson, 1941), but have been essentially in the oxidation zone and have not fully tested the occurrence. Henderson (1941) recorded the occurrence of the lode formation about 3 m wide consisting of chloritized rock containing arsenopyrite, pyrite and sphalerite in an adjacent creek.

Henderson (1941) planned a series of drill holes to test these prospects (Department of Mines plans no. 806/41, 807/41) but only two modified holes were drilled (fig. 8). The first hole (D.D.H. 1) was drilled to test the large gossan outcrop immediately north of the main Orieco ore shoot. It appears to have intersected the fault zone at about adit level, but was relatively barren of sulphide mineralization. The relative level of intersection of the fault zone appears to have been too high to fully negate the occurrence of a supergene zone below adit level. The second hole (D.D.H. 2) was drilled to test the gossan outcrops immediately south of the Orieco mine and north of the main South Orieco prospect (fig. 8). The hole appears to have intersected a barren fault zone about 30 m below the Orieco adit level but, if the gossans are in situ over the fault zone, it must be dipping steeply NE at this locality and not SE as at the Orieco mine.

Paul Beahr's Prospect

Paul Beahr's prospect is the most easterly working on the Orieco fault zone. It is situated on the western bank of the North Arm of the Scamander River (fig. 2). An adit was driven to intersect the lode but it is now inaccessible. Twelvetrees (1911) recorded a quartzose-pyritic lode carrying galena and sphalerite with minor chalcopyrite and oxidized zinc and copper ores. The lode has been strongly oxidized judging from the accumulation of iron oxides at the mouth of the adit and the water which is charged with yellow iron oxides. A gossanous outcrop is present on the hill slope behind the adit.

Examination of the dumps (Specimens 69-181, 69-182) indicate that the lode was composed predominantly of massive or lamellar intergrowths of pyrite-marcasite in a groundmass of limonite, quartz and scorodite. Pyrrhotite, arsenopyrite, sphalerite, galena and chalcopyrite are scattered through the pyrite-marcasite mass. The sphalerite and pyrite are intergrown in small patches with the galena commonly occurring as wispy or crescent-shaped forms. Massive sphalerite-rich specimens (*e.g.* 69-44) contain abundant inclusions of galena and exsolution bodies of pyrrhotite but contain only minor exsolution bodies of chalcopyrite.

The mineralogy of this lode is more akin to that of the Ag-Pb-Zn lodes of the district than to the copper deposits but there is no record of silver occurrences.

Dunn's Prospect

Dunn's prospect represents a lode subparallel to, and about 175 m north-east of, the Orieco fault zone. Prospecting has been carried out by driving an adit about 30 m in a north-west direction along the lode, and sinking a shaft about 7.5 deep at the adit entrance (Department of Mines plan no. 809/41). The lode is about 0.3 m wide, and Henderson (1941) recorded an assay of 0.15% Cu from a 1.5 m channel sample. Extensive gossanous outcrops occur both to the north and south of Dunn's Prospect but these have not been examined at depth. The deposit appears to represent the impregnation of sedimentary units rather than filling of distinctive fractures.

The adit has clearly intersected the top of a small supergene enrichment zone. The lode material consists of fine-grained quartz, chlorite, scorodite and limonite containing sulphides. The primary sulphides (Specimens 69-176 - 69-178) are predominantly arsenopyrite with minor pyrite-marcasite intergrowths and chalcopyrite patches that have been strongly replaced by scorodite, covellite, chalcocite, cuprite and limonite. Covellite is relatively more abundant than in the Orieco mine, and generally occurs as feathery, anastomosing veinlets scattered throughout the other sulphides.

Cramp's Prospect

A shaft about 30 m deep was sunk to test Cramp's prospect, which appears to be along a NNE-trending line of gossan cappings (fig. 8). Henderson (1941) recorded that no driving was carried out because of an influx of water and poor ventilation. The lode material on the dumps appears to be similar to that from Dunn's prospect.

Ringarooma Bay Prospect

Extensive outcrops of gossan occur on the ridges south-west of the Orieco mine and have been grouped as the Ringarooma Bay prospect (fig. 8). The gossans of the Ringarooma Bay prospect lie in a zone subparallel to the Orieco fault zone and appear to be related to a similar fault zone which is exposed on the road. The gossans of the North Ringarooma Bay prospect appear to lie along a cross-trending structure. A few surface trenches have been cut to test these gossans but they are all in the oxidised zone.

North Scamander Prospect

The North Scamander prospect is situated south-east of the Great Pyramid mine and south-west of Paul Beahr's prospect (fig. 2). The mineralisation appears to be partly replacement of shale horizons, and partly fracture fillings. The mineralised zone trends WNW and has been prospected from two short drives from the creek, several trenches and a small shaft. The Electrolytic Zinc Company of Australasia Limited carried out magnetic and electromagnetic surveys over the area (Paltridge, 1959), and obtained extensive almost coincident anomalies over a length of 100 to 125 m. An induced polarization survey (Gregory, 1961) confirmed the electromagnetic anomaly. Assays of selected samples of dump material were given by Gregory (1961) as:

	Pb %	*Zn* %	*Cu* %	*Ag* g/tonne	*Ag* oz/ton	*Fe* %
High grade specimens	2.5	11.8	1.67	117	3.4	45.6
Medium grade specimens	0.2	5.7	0.92	69	2.0	50.2
Magnetite mineralisation	0.9	1.8	0.30	48	1.4	60.0
Mineralised rock	0.2	2.8	0.20	34	1.0	34.2

A diamond drill hole was drilled to intersect the exposed mineralisation approximately 30 m down dip. Sporadic mineralisation, generally small pyrrhotite veins similar to those in the creek section, was encountered, and the main mineralised zone was intersected between 36.73 and 38.56 m. This consisted predominantly of pyrite, pyrrhotite and magnetite with traces of galena, sphalerite and chalcopyrite, and assayed 1.5% Pb, 4.4% Zn, 0.1% Cu, 34 g/tonne (1 oz/ton) Ag and 35.4% Fe. Gregory (1962) concluded that the mineralisation was too sparse and too low grade to warrant further testing.

A deposit is unusual in several respects and, like Paul Beahr's prospect, appears to be a transitional type between the copper and Ag-Pb-Zn deposits. The occurrence of magnetite is unique to the area. Material taken from the dumps (Specimens 69-54, 69-55, 69-173 - 69-175 and 70-1) indicate scattered crystals of pyrite and arsenopyrite and veinlets of sphalerite, chalcopyrite and galena in a magnetite matrix. Sphalerite is the predominant sulphide mineral, and is unusual in that it is almost devoid of exsolution bodies of chalcopyrite, and pyrrhotite bodies are entirely absent. The small veins that cut the quartzite beds in the area adjacent to the main lode are composed essentially of pyrrhotite which fills microfaults and replaces bedding lamination. The pyrrhotite, which is partially replaced by feathery intergrowths of pyrite-marcasite, contains numerous small inclusions of sphalerite, chalcopyrite and minor galena.

Silver Echo Prospect

The Silver Echo prospect is situated in Nephele Creek about 5 km WSW of St Helens. It is several kilometres north of the main copper zone. The mineralisation occurs on the south-east edge of the contact aureole of the adjacent granitic rocks which include both granodiorites and granites (fig. 2). A trench in the creek has exposed a large quartz lode which is pod-like in form with a maximum width of about 10 m and a NNE elongation. It is probably filling a tensional fracture. Irregular masses of pyrrhotite are exposed in a small shaft at creek level and these contain patches of pyrite, marcasite and chalcopyrite. Small veins of sulphide cut the massive quartz lode in places. A short tunnel has been driven to the east of the shaft but has not intersected the lode although small veinlets of cuprite are present in the country rock. Smith (1897) recorded values of up to 0.3% Cu, and Waller (1901) recorded maximum values of 25.7 g/tonne (15 dwt/ton) Au.

Examination of material from the dumps and the small shaft (Specimens 69-190 to 69-193) shows massive pyrrhotite enclosing quartz, mica and tourmaline crystals with discontinuous masses of chalcopyrite occuring at pyrrhotite-quartz interfaces and along pyrrhotite grain boundaries. The pyrrhotite (hexagonal 2A, 5C and monoclinic 2B, 4C) is partly replaced by anastomosing, feathery veinlets of pyrite-marcasite intergrowths. Some larger irregular masses of pyrite-marcasite occur in places. The deposit is unusual in the proportion of pyrrhotite present and the occurrence of tourmaline and mica associated with the sulphides. Waller (1901) suggested that part of the margin of the lode may be an acid granite dyke, and the deposit certainly exhibits some features akin to those of the Echo prospect, although the same economic minerals are not present.

Recommendations

It is apparent from a study of the deposits of the Orieco copper zone (fig. 8) that only the zones of supergene enrichment are of a high enough grade over the limited length and width of the mineralised zones to warrant further investigation. The oxidised zones of the mineralised areas are commonly barren, and the primary mineralisation appears to be too low grade to be of economic interest.

Despite consistent geological advice to this effect over the last 70 years, exploration in the zone of copper mineralisation has been generally confined to shallow testing of gossan outcrops. These gossans are commonly at a considerable height above the projected position of any supergene zone and such work has only delineated possible mineralised zones and their attitudes. The two bore holes drilled by the Department of Mines in 1942 gave disappointing results, but did not fully test the prospects.

The potential depth of supergene enrichment has never been fully investigated, because the deeper workings at the Orieco mine have either been collapsed or flooded.

Future prospecting should be designed specifically to locate possible supergene enrichment zones beneath exposed gossan cappings. The deeper workings of the Orieco mine should be dewatered and examined to determine the depth, persistence and grade of the supergene zone. Induced polarisation surveys should then be carried out over the more promising surface indications of mineralisation. (*e.g.* Ringarooma Bay, North Orieco, South Orieco) to locate sulphide accumulations close to the water table. A drilling programme could then be planned if the geophysical results warranted it. It must be stressed that any supergene enrichment zones located would probably be small, and economic assessments based on the type of occurrence at the Orieco mine should be carried out before a large expenditure is made on exploration.

The zones of primary mineralisation exposed at the North Scamander and Silver Echo prospects are generally of too low a grade and of too limited an extent to warrant further exploration, although some high grade patches of mineralisation undoubtedly exist.

Silver-Lead-Zinc Deposits

The silver-lead-zinc deposits form the easternmost zone of the Scamander district (fig. 6). The deposits occur largely in quartz veins in fracture zones in granodiorite porphyry, and to a lesser extent in the sedimentary host rocks. The deposits are typified by the occurrence of silver chloride (cerargyrite) and native silver in the oxidised zone. The deposits have been described in detail by Montgomery (1893), Smith (1897), and Twelvetrees (1911).

Scamander River Mine

Geology

The Scamander River mine is situated on the southern bank of the Scamander River about 0.5 km above the bridge. The mineralisation occurs in ENE-trending and NNW-dipping quartz lodes in fine-grained, altered granodiorite and associated quartz-feldspar porphyries that probably represent the southernmost extension of the Scamander Tier dyke. The dyke at the mine is only about 20 m wide (as against 350 m wide on the north shore) and it is possible from this miss-match of the dyke that the river course may follow a fault line (fig. 2).

The workings have been largely inaccessible since 1893 and details of the workings are unknown. A main shaft has been sunk to a depth of about 40 m from the top of the hill and an underlay shaft has been sunk near the river to a depth of about 36 m. Both shafts extend below river level and are partly filled with water. A small adit has been driven from a little above adit level in a WNW direction and has intersected several veins. Montgomery (1893) recorded a zone of mineralised granite and quartz veins up to 3 m thick, but examination of dump material indicates that the individual quartz lodes were generally less than 0.3 m thick. The mineralised quartz contains massive arsenopyrite with various proportions of pyrite, sphalerite, galena and chalcopyrite, and these sulphides are also scattered through the altered granite. Montgomery (1893) quotes assays of the sulphide ore indicating about 6% Pb. The estimate of the silver content of the ore varies from 69 g/tonne (2 oz/ton) - 9.63 kg/tonne (281 oz/ton). The variation is probably related to the presence or absence of cerargyrite and native silver. Montgomery (1893) recorded that all the sulphides were silver-bearing and that a high galena content did not necessarily imply a high silver content. Production from the mine has been at least 51 tonnes (50 tons) of ore averaging 1.13 kg/tonne (33 oz/ton) Ag.

The Scamander River mine is the only Ag-Pb-Zn prospect from which abundant ore specimens can be obtained, and for this reason the mineralogy of the quartz-sulphide deposits was studied as a guide to the possible composition of similar deposits.

Ore Mineralogy

Specimens of quartz-sulphide veins (69-45 - 69-48, 69-189) indicate a commonly banded nature particularly in arsenopyrite-pyrite rich specimens (69-184). The minerals present in approximate order of abundance are: arsenopyrite, pyrite, galena, sphalerite, secondary pyrite-marcasite intergrowths, chalcopyrite, tetrahedrite, pyrrhotite, boulangerite and covellite. The distribution of silver in these minerals has not been studied.

Arsenopyrite generally occurs in bands or clusters as euhedral, cracked crystals of variable size that are commonly partially replaced or veined by galena, sphalerite and secondary pyrite/marcasite. The arsenopyrite contains small inclusions of galena and tetrahedrite in places. The arsenopyrite is commonly oxidised to form scorodite.

Pyrite occurs in a similar form to arsenopyrite but is generally subordinate in both size and abundance. It is commonly veined and replaced by galena and sphalerite. Lamellar marcasite and, or pyrite-marcasite intergrowths occur as a matrix for much of the ore, and vein or replace most of the other sulphides along mineral interfaces and grain boundaries.

Galena occurs as irregular patches that are commonly associated with sphalerite, and have irregular or concave contacts against that mineral. The galena contains inclusions of sphalerite and chalcopyrite, and strongly replaces arsenopyrite and pyrite particularly along fractures. Small globular to rectangular inclusions of tetrahedrite and, or boulangerite up to 0.3 mm in length are scattered throughout most of the galena. The tetrahedrite also commonly occurs at galena-quartz or galena-sulphide boundaries, and forms multiple inclusions with sphalerite and, or chalcopyrite in places. The relatively abundant tetrahedrite may be the source of high silver values of the ore.

Sphalerite occurs as irregular patches that are commonly isolated in quartz, although it also occurs with galena in discontinuous patches throughout arsenopyrite/pyrite specimens. The sphalerite contains numerous, commonly globular, inclusions and exsolution bodies of chalcopyrite and, or pyrrhotite in widely varying proportions. It also contains inclusions of galena and tetrahedrite, and small euhedral crystals of arsenopyrite.

Chalcopyrite occurs as small patches commonly associated with sphalerite. It encloses small euhedral crystals of pyrite and irregular blebs of sphalerite, and is commonly strongly veined by pyrite-marcasite intergrowths. The chalcopyrite appears to be devoid of exsolution bodies, and does not include tetrahedrite.

Pyrrhotite, tetrahedrite and *boulangerite* occur exclusively as inclusions in the more abundant sulphide minerals.

Scamander Bell Prospect

The Scamander Bell prospect is situated about 1 km west of Scamander. The mineralisation is confined to two NNE-trending lodes within the granodiorite porphyry dyke north of the Scamander River. Several shafts have been sunk, but all appear to be in the unmineralised granodiorite porphyry. The two lodes are poorly exposed in surface trenches, and small blocks of gossan and quartz carrying rare sulphides can be found on adjacent small dumps. Smith (1897) recorded the presence of cerargyrite in some specimens but concluded that the lodes exposed were small and patchy.

Examination of material from the dumps (Specimens 69-35, 69-36, 69-39, 69-134) reveals small sulphide patches in milky quartz. The sulphides, which are arsenopyrite, pyrite, galena, sphalerite, chalcopyrite and covellite, have similar textures to those from the Scamander River mine. The galena contains rare inclusions of goulangerite and tetrahedrite, and the sphalerite contains only rare exsolution bodies of chalcopyrite and pyrrhotite. The galena appears to replace all other primary sulphides.

Beulah Prospect

The Beulah prospect is immediately west of the Scamander Bell prospect. Two NNE-trending lodes have been worked from a series of shallow shafts and trenches cut in decomposed granodiorite porphyry. The veins are all less than 0.3 m in width. The eastern lode, the main lode, has been stoped to a depth of about 12 m over a length of 13.5 m, and between 1896 and 1897 about 52 tonnes (51 tons) averaging about 3.17 kg/tonne (92.5 oz/ton) were recovered (Smith, 1897). A shaft was sunk and a cross cut driven to intersect the main lode about 30 m below the surface, but failed to do so. The silver, as in the other prospects, was largely present as cerargyrite filling cavities in the lode material, although Smith (1897) recorded pyrite carrying some silver.

Examination of the dumps reveals mainly small blocks of quartz with abundant iron oxides. Some quartz specimens (69-37, 69-38) contain small patches of sulphides including pyrite, arsenopyrite, sphalerite, galena and chalcopyrite.

Yarmouth Prospect

The Yarmouth prospect is situated in Yarmouth Creek about 1 km from its mouth. The prospect consists of three small NE-trending lodes, varying between 0.1 and 0.6 m in width, which cut hornfelsed Mathinna Beds, and have been explored from several shallow workings. The lodes (Specimens 69-52, 69-53, 69-179, 69-180) consist of quartz carrying massive arsenopyrite that is partly replaced by pyrite, sphalerite and minor galena. The sphalerite contains minor inclusions of pyrrhotite, chalcopyrite and galena. Smith (1897) recorded the presence of patches of chalcopyrite and some malachite. Assays of picked samples of gossan and sulphides indicated between 103 g/tonne (3 oz/ton) and 1.37 kg/tonne (40 oz/ton) Ag.

Recommendations

The deposits are too thin and patchy to warrant any further exploration. It is considered that the high silver values obtained in the oxidised ore above the water table would not continue at depth, as they appear to have been at least partly due to the occurrence of cerargyrite and native silver produced by oxidation of silver-bearing sulphides.

Gold-Silver Deposits

A number of small gold-silver prospects occur near Hogans road along the headwaters of Beahr's and Brilliant Creeks (fig. 2). They have received little attention, the only reports on these prospects are by Twelvetrees (1900*a*, *b*) and Henderson (1935, 1939).

The deposits occur either within a marginal belt of biotite granodiorite on the eastern edge of a porphyritic biotite granite/adamellite mass (Trafalgar, Double Event), or in the roof zone of the gently S-dipping southern margin of this granite mass (Brilliant, Golden Ridge, Queen of the Earth). The deposits typically contain both gold and silver in varying amounts, and Twelvetrees (1900*a*) suggested that these elements were present as electrum. High silver values are common in several other gold prospects in eastern Tasmania (Threader, 1967).

Trafalgar (New Carthage) Prospect

Workings on this prospect include a shaft 60 m deep, a prospecting shaft, two adits, and two prospecting holes. This prospecting work has been carried out adjacent to the granodiorite/Mathinna Beds contact. The mineralisation consisted of an ENE-trending, S-dipping quartzose zone in the granodiorite that reached a maximum of 0.3 m in thickness. Twelvetrees (1900*a*) recorded that the quartz-rich zone contained abundant arsenopyrite and minor galena and had been driven on for about 30 m, but proved to be of very variable width. Production from the prospect is recorded at approximately 46 tonnes (45 tons) averaging about 137 g/tonne (4 oz/ton) Au and Ag.

Examination of material from the dumps (Specimens 69-165 - 69-167, 69-171, 69-172) indicates two varieties of mineralisation. The most prominent type consists of quartz veins carrying abundant arsenopyrite bunches, partly oxidised to scorodite, which contain small inclusions of galena and chalcopyrite and dilational veinlets of quartz, pyrite and minor galena. No gold was seen in these veins. Sulphides, predominantly arsenopyrite with chalcopyrite, pyrite and galena, are also disseminated in altered granodiorite in which the feldspars have been replaced by quartz and sericite and the biotite by chlorite. Small grains of gold are scattered through the arsenopyrite and gold also occurs as smears on fractures in quartz crystals (Specimen 70-72).

Double Event Prospect

The Double Event prospect is situated about 1.5 km NNW of the Trafalgar prospect, and occurs in the same biotite granodiorite mass as the latter. Two shafts have been sunk on two parallel ENE-trending quartz lodes of variable width (up to 1 m width recorded). Gold assays up to 169 g/tonne (4.3 oz/ton) have been reported from the prospect, although gold assays quoted by Twelvetrees (1900*a*) were only 5.6 g/tonne (3.25 dwt/ton).

Brilliant Prospect

The Brilliant prospect is situated at the headwaters of Brilliant Creek. This prospect has been adequately described by Twelvetrees (1900*a*), although several of the workings that are described by him have not been located during the present study. Impersistent quartz veins of extremely variable width occur within massive sandstone and quartzite beds of the Mathinna Beds. These beds strike N - NNE and are generally vertical, and the quartz veins are subparallel to this trend and appear to occur along bedding planes and subparallel joints. Reported gold assays are extremely variable, with a maximum recorded of 69 g/tonne (2 oz/ton). Sulphide could not be found on any of the dumps or workings on this prospect.

Golden Ridge Prospect

The Golden Ridge prospect is situated to the east of the Brilliant prospect. The workings have been adequately described by Twelvetrees (1900*a*) and Henderson (1939). The host rocks are massive sandstones and quartzites similar to those of the Brilliant prospect, and the gold-bearing quartz veins also occur along joint and bedding surfaces as impersistent veins of variable width. The bedding is much flatter than at the Brilliant prospect, and in most of the workings is subhorizontal. The quartz veins carry some arsenopyrite, pyrite and covellite (Specimen 69-170), but the proportion of sulphides is generally small. Systematic sampling by Henderson (1939) indicated generally only traces of gold and silver with maximum combined assays over 3 m lengths of 15.1 g/tonne (8.8 dwt/ton) and 5.4 g/tonne (3.15 dwt/ton) respectively. There is no accurate record of production from the prospect.

Queen of the Earth Prospect

The Queen of the Earth prospect, situated about 3 km downstream from the Brilliant prospect, has been described in detail by Twelvetrees (1900*b*). The host rocks are again massive sandstones and quartzites, and in Brilliant Creek below the prospect there are spotted hornfelses indicating contact metamorphism. The quartzites strike NNE and dip steeply NW, while the main quartz lode trends about 35° (true) and dips at 45-60° SE. This lode, which varies in thickness from about 0.3 - 1.6 m has been worked from an adit and two shafts. The lode contains abundant sulphides, predominantly arsenopyrite (Specimens 69-168, 69-169), with minor pyrite, sphalerite and galena recorded by Twelvetrees (1900*b*). Testing of blocks of ore prior to 1900 indicated grades exceeding 34 g/tonne (1 oz/ton) Au, but records of production from the prospect indicate a total of 196 tonnes (193 tons) treated for a return of 3.42 kg (99.65 oz), an average grade of 22.4 g/tonne (0.52 oz/ton).

Recommendations

The deposits are generally too thin and low grade to warrant any further prospecting. Additional problems in assessing the prospects include the unpredictable structure of the lodes themselves and their extremely variable grade.

ZONING OF MINERAL OCCURRENCES

Introduction

It is important to examine the hydrothermal mineralisation of the Scamander - St Helens area in relation to the larger framework of mineralisation in eastern Tasmania. This hydrothermal mineralisation generally falls into two categories: (*a*) cassiterite (and/or wolframite and molybdenite) with rare sulphides in greisenised granitic rocks, or in discordant quartz veins adjacent to these granitic rocks, and (*b*) gold (and silver) with rare sulphides in discordant quartz veins, commonly at considerable distances from granitic rocks. A genetic relationship between hydrothermal mineralisation and the Upper Devonian granitic rocks of the area has been accepted by most authors.

The close association of tin, wolfram and molybdenite deposits with biotite granite (and adamellite) and biotite-muscovite granite (and adamellite) has been noted by many authors and a genetic relationship between them appears probable (see Klominsky and Groves, 1970). Although the evidence is not conclusive several authors (*e.g.* Twelvetrees, 1909; Reid and Henderson, 1929; Carey, 1947; Hughes, 1947; Klominsky and Groves, 1970; Groves and Baker, 1971) have suggested a genetic relationship between the gold deposits and hornblende-bearing granodiorites.

The unusual mineralogy of the Scamander - St Helens mineral occurrences with respect to other occurrences in eastern Tasmania, and their zonal configuration (fig. 6) were first recognised by Twelvetrees (1911). He considered the Ag-bearing lodes of the easternmost zone to be possibly related more closely to the arsenopyrite-gold veins of eastern Tasmania than to the other mineralisation in the area. Carey (1947) suggested that both the copper and Ag-Pb-Zn mineralisation were genetically related to gold mineralisation and the hornblende-bearing granitic rocks of the St Helens Pluton, and were not related to the more westerly wolfram and tin mineralisation. These deposits have received little subsequent attention.

The apparent mineralogical zonal sequence from west to east in this area (fig. 6) is similar to the consistent sequence shown by many other zoned hydrothermal deposits (Both and Williams, 1968). This zonation is generally thought to result from changing physical and chemical conditions (the most universally accepted being decreasing temperature and pressure) as the ore fluids migrate from their source. If the concept of zoning is valid the mineralogical changes shown by the Scamander - St Helens occurrences indicate that the source of the mineralisation is probably the marginal phase of the Mt Pierson Pluton (*i.e.* to the west of the wolfram zone). The occurrence of mineralisation exclusively to the west of the Mt Pierson Pluton could be explained if the eastern and south-eastern margins of this pluton were shallowly dipping. This possibility is enhanced by the isolated flat-topped occurrences of granite in Constable Creek, and north of the Baden Powell prospect and the recognition of sheet-like bodies composed of similar granite types elsewhere in NE Tasmania (Gee and Groves, 1971). There are however some objections to a single phase of mineralisation and these are discussed below.

Field and Empirical Relationships

The wolfram (and molybdenite) deposits of the area occur within, or in the contact aureole of, the belt of biotite (muscovite) granites and adamellites that fringe the eastern and southern margins of the Mt Pierson Pluton. These fine- to medium-grained granites appear to be related to, but slightly later than the intrusion of the coarse-grained biotite granite/adamellite that forms the bulk of the pluton. Microgranites associated with the granodiorites of the St Helens Pluton occur near Launceston Creek (fig. 2), but the granitic rocks adjacent to the Echo wolfram prospect in Constable Creek appear more similar to the broader bands of granites that crop out further upstream and extend within about 1 km of the Baden Powell and Price's wolfram prospects. The spatial association of the wolfram (molybdenum plus minor tin) deposits to the biotite (muscovite) granites, and the similarity of these granites to those of other tin- and wolfram-bearing areas (Klomínský and Groves, 1970), suggest a genetic association. The tin mineralisation of the Great Pyramid mine and the Loila Tier prospect are also probably related to the biotite (muscovite) granites on the basis of similar associations elsewhere, although there is no direct evidence for the association in this area.

The Loila Tier prospect provides an example of zoning on a local scale, as along an apparently continuous structure the mineralisation changes from cassiterite-rich and sulphide-deficient at its western extremity to sphalerite- and arsenopyrite-rich at its eastern extremity with intermediate copper sulphide-rich patches.

The copper mineralisation of the Orieco area appears to merge with the tin mineralisation in the vicinity of the Great Pyramid mine. Gossan cappings of similar type occur in both areas, and some patches of massive sulphide have been recorded from the Great Pyramid mine. Small, but significant, amounts of tin have also been recorded from the gossans of the North Orieco and Ringarooma Bay prospects. It appears likely that the tin and copper mineralisation are genetically related. The copper deposits of the Orieco fault zone also show a zonal trend with Pb-Zn mineralisation occurring at the eastern extremity (Paul Beahr's adit).

The relationship of the Ag-Pb-Zn deposits of the easternmost zone to the granitic rocks is problematical. Their apatial position relative to the wolfram, tin and copper mineralisation is consistent with the normal zonal pattern, and is suggestive of a common origin. However, with the exception of the Yarmouth prospect, the mineralisation occurs within the dyke of granodiorite porphyry and associated rocks extending down the Coastal Range. Their position could be exclusively structurally controlled, although alteration of the granitic rocks at the Scamander prospect may be indicative of a local source. The relative ages of the biotite (muscovite) granites of the Mt Pierson Pluton and the granodiorite porphyry of the St Helens Pluton are obviously important in solving this problem. If the granodiorite porphyry was younger than the biotite granite, there would be the unique solution of an association between mineralisation and the granodiorite porphyry, but if

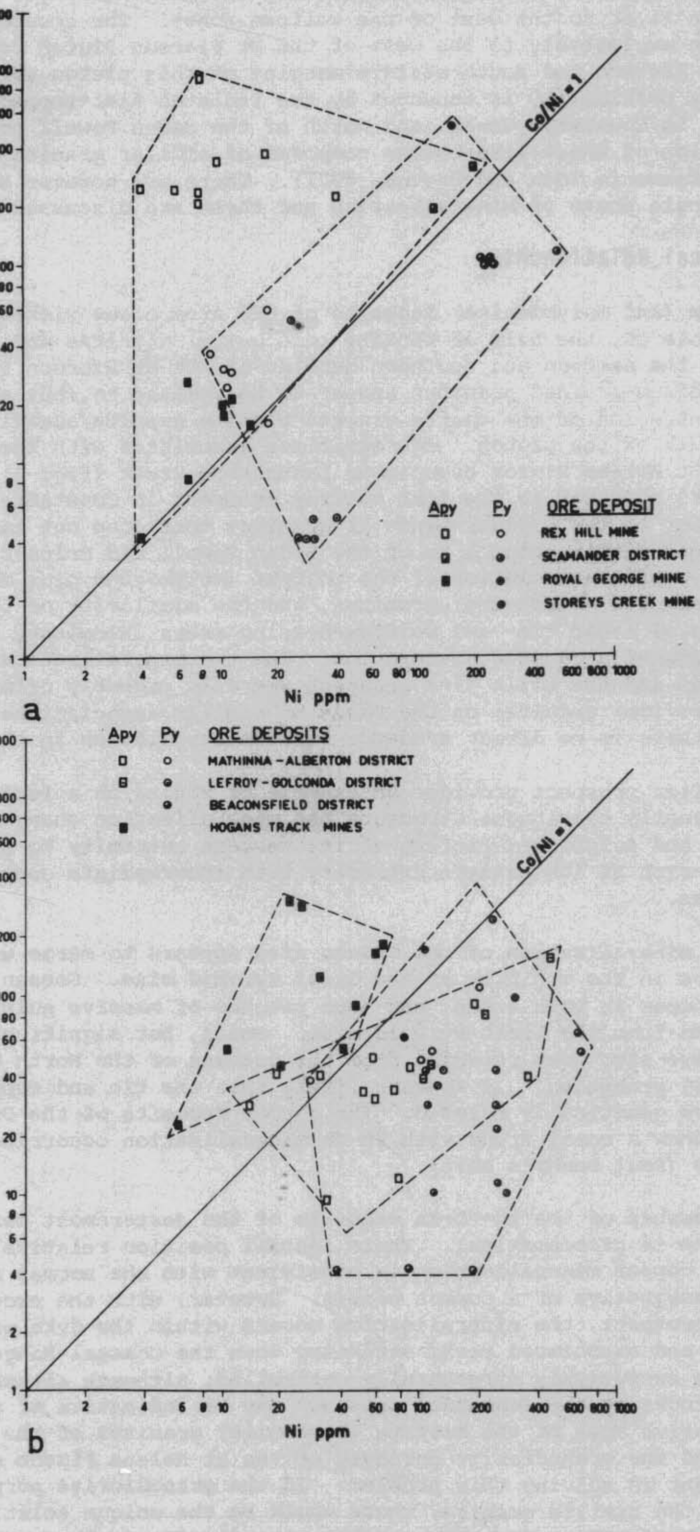
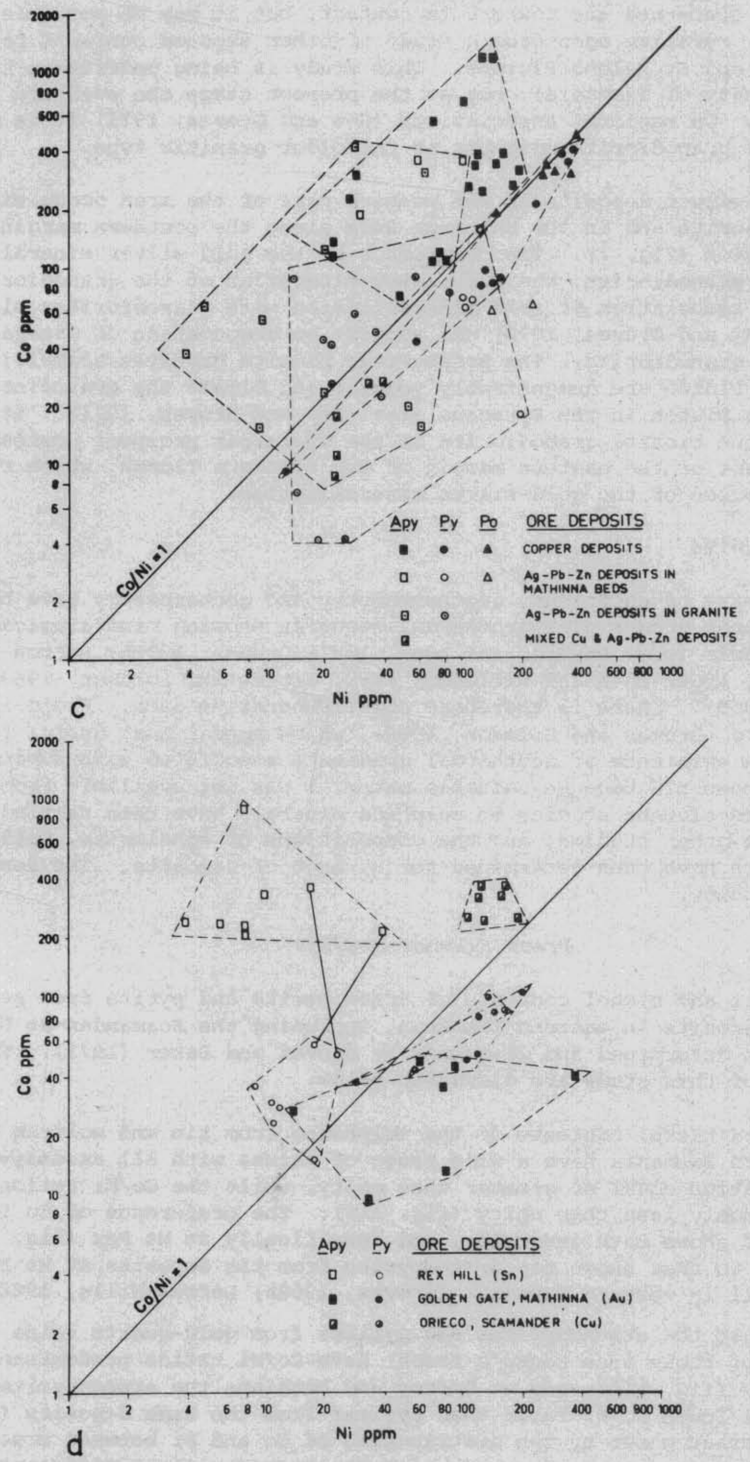


Figure 11. *Distribution of Co and Ni in sulphides from gold and tin deposits.*



in eastern Tasmania, and from the zoned deposits of the Scamander area.

the reverse situation existed the problem would still be present. The two granitic types concerned are nowhere in contact, but it may be possible to determine their relative ages from a study of other exposed contacts between the Mt Pierson and St Helens Plutons. This study is being undertaken by J.D. Cocker (University of Tasmania), but at the present stage the evidence is not conclusive. On regional associations (Gee and Groves, 1971) it is more likely that the granodiorite porphyry is the older granitic type.

The gold-silver deposits in the western part of the area occur within biotite granodiorite and in the Mathinna Beds along the southern margin of the Poimena Pluton (fig. 1). The occurrence of the gold-silver mineralisation within the granodiorite, the associated alteration of the granodiorite, and the common association of gold mineralisation with granodiorites elsewhere (Klominsky and Groves, 1970) all support an association of mineralisation with the granodiorite. The porphyritic biotite granites/adamellites of the Poimena Pluton are demonstrably younger and dilate the granodiorites of the Pyengana Pluton in the Pyengana area (Gee and Groves, 1971). It is possible that the biotite granodiorite at the Trafalgar prospect represents a fragmented part of the eastern margin of the Pyengana Pluton, which represented the source of the gold-silver mineralisation.

Geochemical Studies

Geochemistry of sulphides, geothermometry and geobarometry have been studied on several groups of hydrothermal deposits showing mineralogical zoning in Tasmania (*e.g.* Edwards and Lyon, 1957; Groves, 1968*b*; Loftus-Hills, 1968; Williams, 1968; Both and Williams, 1968; Groves and Solomon, 1969; Both *et al.*, 1969). There is therefore some comparative data. Fluid inclusion studies (*e.g.* Groves and Solomon, 1969), which appear most useful for determining the existence of geothermal gradients associated with zoning, have not been possible because suitable material was not available from most deposits. Trace element studies on sulphide minerals have been carried out and compared to other studies, and the compositions of sphalerite, wolframite and arsenopyrite have been determined for a range of deposits. The results are discussed below.

Trace Element Studies

The cobalt and nickel contents of arsenopyrite and pyrite from several hydrothermal deposits in eastern Tasmania, including the Scamander-St Helens area, have been determined and discussed by Groves and Baker (1971). The main features of this study are discussed below.

Cobalt and nickel contents of the sulphides from tin and wolfram deposits in eastern Tasmania have a wide range of values with all arsenopyrites having Co/Ni ratios equal or greater than unity, while the Co/Ni ratios of pyrite are commonly less than unity (fig. 11*a*). The preference of Co for arsenopyrite is shown both generally, and specifically at Mt Rex (fig. 11*d*), and is similar to that shown for arsenopyrite from tin deposits at Mt Bischoff and Renison Bell in western Tasmania (Groves, 1968*b*; Loftus-Hills, 1968).

In contrast the arsenopyrites and pyrites from gold-quartz veins (with the exception of those from Hogan's track) have Co/Ni ratios predominantly less than unity (fig. 11*b*), and at Lefroy and Mathinna the arsenopyrites have an overall lower Co/Ni ratio than pyrites from the same deposits (fig. 11*d*). The contrast shown by the distribution of Co and Ni between arsenopyrite and pyrite from the two groups of deposits may reflect different mineralisation sources, different deposition temperature ranges, or different crystallisation sequences as equilibrium has not been demonstrated.

The Co and Ni contents of arsenopyrites and pyrites from the copper and Ag-Pb-Zn deposits of the Scamander-St Helens area are similar to those from the tin and wolfram deposits (fig. 11*c*), and have the same preference of Co for arsenopyrite from the Orieco, Beulah and Scamander prospects (fig. 11*d*). This suggests a correlation with the tin and wolfram deposits rather than the gold deposits. Further the Co content of pyrite decreases from the copper deposits to the Ag-Pb-Zn deposits, a trend common to other zoned deposits at Storeys Creek (Loftus-Hills, 1968), Zeehan (Williams, 1968) and Mount Bischoff (Groves, 1968*b*; Loftus-Hills, 1968). The behaviour of Ni varies between these deposits and the Scamander-St Helens deposits. The scanty data available for pyrrhotites from the Scamander-St Helens area show a similar trend to the pyrites with respect to Co (fig. 11*c*).

The distribution of Co and Ni between arsenopyrite and pyrite is not available for the gold-silver deposits from Hogan's track because of the lack of pyrite. The Co/Ni ratios of arsenopyrite are higher than for other gold deposits in north-east Tasmania and are similar to those of other mineralisation in the Scamander-St Helens area (fig. 11*b*), but the available evidence is not diagnostic of any association.

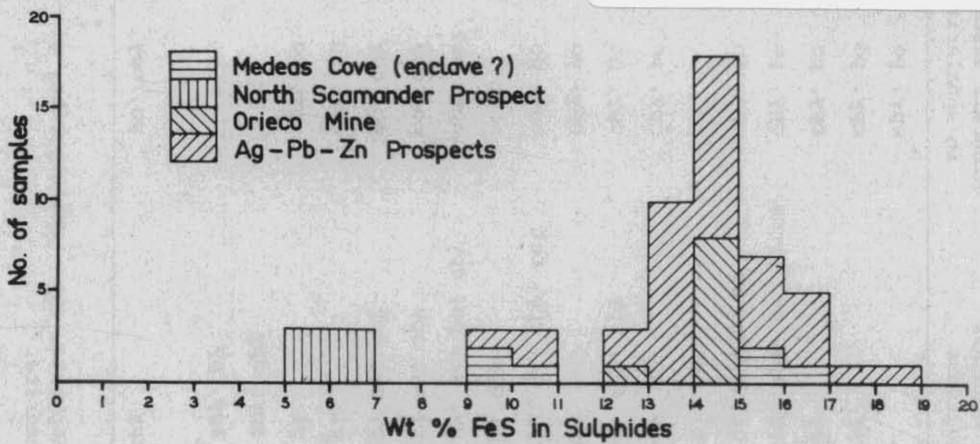


Figure 12. *Histogram showing distribution of FeS in sphalerites from the Scamander - St Helens area.*

Composition of Sphalerite

The sphalerites were analysed for Fe and Mn by electron microprobe techniques (Williams, 1967) with pure metals as standards. In all samples two or three analyses were made on separate grains within the area of each polished sections. The precision of analyses for Fe and Mn are ±0.1 and ±0.5% respectively. Variation in the FeS and MnS contents of sphalerite within polished sections is much less than the total variation between samples. The composition of the sphalerites varies from 6.2-16.7 wt% FeS and 0.04-0.42 wt% MnS (table 2, fig. 12).

The significance of exsolution bodies of pyrrhotite in the sphalerite with respect to equilibrium in the system Fe-Zn-S is not fully understood (*e.g.* Williams, 1968). It is apparent that the sphalerites with the lowest FeS contents (Specimens 69-50, 69-54, 69-55) have no exsolved pyrrhotite,

Table 2. *THE FeS AND MnS CONTENTS OF SPHALERITES FROM THE SCAMANDER DISTRICT*

Specimen No.	Locality	Other minerals in sections	Minerals exsolved in sphalerite	Wt% FeS	Wt% MnS
69-42	Orieco Mine	py	cpy, po	14.1, 12.2, 14.6	0.07, 0.07, 0.06
69-43	Orieco Mine	py, cpy	cpy, po	14.6, 14.4, 14.8	0.09, 0.07, 0.07
69-49	Orieco Mine	gl, cpy	cpy, po	14.1, 14.4, 14.5	0.07, 0.07, 0.06
69-45	Scamander Mine	gl, cpy, apy, py, py-ma	cpy, po	14.2, 15.3, 14.8	0.05, 0.05, 0.05
69-46	Scamander Mine	cpy, gl, py, py-ma	cpy, po	14.5, 14.2, 13.5	0.05, 0.05, 0.05
69-47	Scamander Mine	apy, gl, tet	po	10.5, 10.0, 10.6	0.07, 0.06, 0.07
69-48	Scamander Mine	py, apy, cpy	cpy, po	14.8, 15.6, 14.5	0.15, 0.32, 0.10
69-35	Scamander Bell Prospect	gl, py, apy, cpy	cpy, po	13.9, 14.8, 15.1	0.05, 0.06, 0.07
69-36	Scamander Bell Prospect	gl, apy	cpy, po	15.7, 15.5, 15.6	0.07, 0.06, 0.08
69-39	Scamander Bell Prospect	py, apy, gl, cpy, tet	cpy, po	13.7, 13.2	0.05, 0.06
69-38	Beulah Mine	py, gl, cpy	-	13.4, 13.8	0.07, 0.06
69-52	Yarmouth Mine	apy, py, gl, po, cpy	cpy, po?	15.3, 16.2, 16.3	0.25, 0.26, 0.28
69-53	Yarmouth Mine	apy, py-ma, cpy	po, cpy	16.4, 16.9, 15.8	0.29, 0.29, 0.29
69-44	Paul Beahr's Prospect	gl, po, py, cpy	po, cpy	13.4, 12.5, 13.8	0.35, 0.36, 0.42
69-40	Loila Tier (E)	cpy, gl	cpy, po	13.7, 13.2, 13.0	0.05, 0.06, 0.07
69-41	Loila Tier (E)	cpy, gl	cpy, po	18.2, 17.1, 17.0	0.17, 0.17, 0.17
69-54	North Scamander Prospect	mag, apy, cpy	-	6.4, 6.7, 6.2	0.05, 0.05, 0.05
69-55	North Scamander Prospect	mag, apy, py	-	7.3, 7.2, 7.3	0.05, 0.04, 0.05
69-50	Medeas Cove (enclave?)	cpy	-	10.1, 10.0, 10.0	0.22, 0.22, 0.23
69-51	Medeas Cove (enclave?)	po, cpy	po, cpy	16.0, 16.0, 16.7	0.31, 0.33, 0.35

Analysts: K.L. Williams and D.I. Groves.

Electron-probe microanalysis: apy - arsenopyrite, cpy - chalcopyrite, gl - galena, ma - marcasite, mag - magnetite, po - pyrrhotite, py - pyrite, tet - tetrahedrite.

Table 3. COMPOSITIONS OF WOLFRAMITES FROM SCAMANDER COMPARED TO THOSE FROM THE ABERFOYLE AREA

Locality	No. of Samples	Range $\frac{\text{Wt\% MnO}}{\text{Wt\% MnO+FeO}} \times 100$	Average $\frac{\text{Wt\% MnO}}{\text{Wt\% MnO+FeO}} \times 100$
Echo Prospect	3	21.7 - 22.3	22.0
Baden Powell Prospect	4	26.9 - 29.0	28.0
Lutwyche Prospect	4	21.5 - 28.0	21.5
Price's Prospect	5	21.1 - 32.4	27.5
Mt Rex Mine	1	-	40.5
Aberfoyle (Edwards and Lyon, 1957)	17	47.2 - 71.2	53.9

Analyst: W.E. Baker. Atomic absorption spectrophotometry and that the sphalerites with abundant exsolved pyrrhotite (Specimens 69-36, 69-39, 69-44, 69-53) commonly have average to high values, although Specimen 69-47 has abundant exsolved pyrrhotite and a low FeS content. If the samples with unusual mineralogy are neglected (*i.e.* from the North Scamander prospect and Medeas Cove) the sphalerites show a relatively restricted compositional range between 9-19 wt% FeS with a mode at about 14 wt% FeS. Although relatively few samples have been analysed in this study the distribution is similar to that for sphalerites from the pyritic zone of the Zeehan field (Both and Williams, 1968), an environment in which pyrite is also common but pyrrhotite is only present as an exsolution product. There is no significant systematic variation in FeS content of sphalerites throughout the Scamander-St Helens area.

The compositions of the sphalerites do not approach compositions of sphalerite-pyrrhotite-pyrite equilibrium mixtures calculated by Einaudi (1968) and determined experimentally by Chernyshev *et al.* (1968) at geologically reasonable temperatures, and therefore have no thermometric significance. The relative consistency of the results probably reflects a relatively constant activity of FeS during sulphide formation.

There is only a weak positive correlation between FeS and MnS contents of the sphalerites. It is interesting that only two analyses from a total of twenty-two analyses of sphalerites from deposits within the granodiorite porphyry dyke have values outside the range 0.05 to 0.10 wt% MnS, whereas twelve out of twenty-four analyses of sphalerites from veins in the Mathinna Beds fall outside this range. This may be a reflection of availability of Mn at different sources, or may be a function of host rock type. The high values of MnS obtained for sphalerites from the Yarmouth prospect, which is considered to be similar to the deposits in the granodiorite porphyry, suggest that the latter explanation is more likely.

Composition of Wolframite

The composition of wolframite was determined initially from the $d_{(200)}$ reflection by X-ray diffraction (Berman and Campbell, 1957). The determination is accurate to about ±8 mole % MnO.

As these results showed a rough trend, the wolframites were analysed by atomic absorption spectrophotometry to provide more accurate results. The possible wide range of compositions shown by the X-ray diffraction method were not borne out in detail by the later analyses although the results showed a similar trend. Composition ranges expressed as (wt% MnO/wt% FeO + MnO) x 100 are 21.1-32.4%, with average compositions for individual deposits ranging from 21.5-28% (table 3). These wolframites are markedly less MnO-rich than wolframites from Aberfoyle and Story's Creek (Edwards and Lyon, 1957; Patterson, 1968) and Mount Rex (table 3), and approach more closely the ferberite end of the ferberite-huebnerite solid solution. The Scamander-St Helens area appears to be a Mn-deficient area in general as both wolframite and sphalerite from the Aberfoyle and Mt Rex areas (Edwards and Lyon, 1957; Groves *et al.*, 1970) are richer in manganese than the equivalent minerals from this area.

Several European authors (*e.g.* Khasin, 1949; Leutwein, 1952) have suggested that high temperature wolframite is richer in manganese than low temperature wolframite, whereas several studies in the U.S.S.R. (*e.g.* Churikov, 1959; Ganeev and Sechina, 1960) have shown the reverse relationship. Taylor and Hosking (1970) obtained conflicting trends at the South Crofty mine, Cornwall. Edwards and Lyon (1957) showed some zonal arrangement at Aberfoyle with higher manganese wolframites near the centres of the veins than at the extremities, and some indication of an increase in MnO content with depth.

Table 4. COMPOSITIONS OF ARSENOPYRITES FROM THE SCAMANDER DISTRICT

Locality	No. of Samples	Range in $d_{(131)}$	Average $d_{(131)}$	Average Composition (Atomic% As)
Copper deposits				
Orieco Mine	5	1.6258 - 1.6326	1.6293	29.5
Cramps Shaft	2	1.6308	1.6308	31.0
Dunns Adit	2	1.6263 - 1.6298	1.6280	27.5
Loila Tier	1	1.6282	1.6282	28.0
Ag-Pb-Zn deposits				
Scamander Mine	6	1.6300 - 1.6316	1.6309	31.0
Loila Tier Prospect	3	1.6294 - 1.6310	1.6305	30.5
Yarmouth Prospect	2	1.6313	1.6313	31.5
Gold deposits				
Trafalgar	5	1.6265 - 1.6286	1.6278	27.5
Queen of the Earth	2	1.6292 - 1.6310	1.6299	30.0

Analyst: D.I. Groves. X-ray diffraction

Patterson (1968) showed that the compositions of wolframites from Storeys Creek and Aberfoyle were rather erratic, but showed a tendency towards MnO enrichment with depth in the Aberfoyle mine. It is apparent that the wolframites from the Scamander-St Helens area have varied compositions that show no consistent relationship to their spatial positions.

Composition of Arsenopyrite

Clark (1960) has shown that in an anhydrous Fe-As-S system although arsenopyrite is stable up to 702°C and pyrite up to 743°C, the minerals are not stable as a pair above about 491°C. Therefore if arsenopyrite coexists with pyrite in the presence of vapour at least one of the minerals was deposited below 491°C. Clark (1960) and Morimoto and Clark (1961) found that the sulphur content of arsenopyrite in equilibrium with pyrite and liquid varied with temperature and pressure and that the $d_{(131)}$ spacing could be used as a measure of the sulphur content.

The arsenopyrite and pyrite present in the mineralised veins in the Scamander-St Helens area are commonly intergrown and there is no definite evidence to suggest that they were deposited at different times. Therefore it is likely that at least one of the sulphides was deposited below about 491°C. The average $d_{(131)}$ spacings or arsenopyrites from several deposits vary from 1.6278-1.6319 Å, *i.e.* very sulphur-rich compositions. It is impossible to assign geothermometric significance to these values as the overburden pressure is unknown. The arsenopyrites from the copper deposits have slightly higher sulphur (*i.e.* lower arsenic) contents than arsenopyrites from the Ag-Pb-Zn deposits (table 4). This may have resulted from a lower temperature of formation, or a higher confining pressure, for the arsenopyrites from the copper deposits than from the Ag-Pb-Zn deposits. There is insufficient evidence to determine which is the major controlling factor in determining the composition of the arsenopyrite. The arsenopyrites from the gold-silver deposits, that are close to the roof of the granitic body, have similar values to those from the copper deposits.

Conclusions

There are some indications but no conclusive evidence to support the zonal hypothesis from geochemical studies, and some minor features show the reverse to normal behaviour in zoned deposits. The trace element studies alone suggest an association with tin mineralisation in eastern Tasmania, although the gold-silver deposits of this area are also similar from available evidence. There is no evidence to suggest multiple phases of mineralisation in the Scamander-St Helens area. It must be concluded that geochemical studies have proved a poor discriminant of ore genesis in this area.

Some of the comparative data is quite interesting, including the similar distribution of FeS in sphalerite to that shown by sphalerite from the pyritic zone of the Zeehan field, and the overall deficiency in manganese relative to other areas of hydrothermal deposits in Tasmania. It is hoped that the data may be more useful when further studies have been carried out elsewhere in Tasmania.

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