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MINERALOGY OF THE MINES AND PROSPECTS OF THE ZEEHAN FIELD

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ISSUED UNDER THE AUTHORITY OF THE HONOURABLE
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PREFACE

This Record is complementary to the Explanatory Report for the Zeehan geological map by A.H. Blissett, 1962, and the authors' papers on the mineralogical zoning of the lead-zinc ores, published in 1968 (*J. geol.Soc.Aust.* 15:121-137; 217-244).

The mineralogical descriptions are based on the microscopic examination of approximately 600 polished and thin sections of specimens collected by the authors at over fifty mines and prospects, and in available museum specimens.

Although the authors of this work are not members of the staff of the Department of Mines it is felt that the results of their research should be made available to those interested in the mineralogy and mineragraphy of the ores of the Zeehan district. The Department is pleased to be given the opportunity to publish this important contribution in this field.

J.G. SYMONS, Director of Mines

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INTRODUCTION

The Zeehan mineral field is located in the vicinity of the township of Zeehan (lat. 41°53′S, long. 145°20′E) in the West Coast region of Tasmania. The field covers an area of approximately 65 km^2, between the south-eastern margin of the Heemskirk Granite and the township itself. Within and adjacent to the granite are the tin deposits of the Heemskirk mineral field, while to the east and north-east are the Dundas, Renison Bell and Rosebery fields.

Between 1887 and 1913 the Zeehan district was a flourishing, though small-scale producer of silver-lead ores. Activity since 1913 has been only intermittent, and with one minor exception, the field has been dormant since the closure of the Oceana mine in 1960. Following recent exploration activity at least one mine is expected to be re-opened. Despite their relative lack of economic success, however, the Zeehan ore deposits have long been of geological interest, since they have been widely quoted as classic examples of zoned hydrothermal ores (*e.g.* Park, 1955; Bateman, 1956). Their reputation in this respect rests largely on the excellent descriptions of Waller (1903, 1904) and Twelvetrees and Ward (1910). The mineralogy of the Zeehan field in relation to the zonal distribution of the ore-types has been discussed elsewhere (Both and Williams, 1968).

This report includes mineralogical data compiled for over fifty of the mines and prospects in the Zeehan field. These descriptions are based on the microscopic examination of approximately 600 polished and thin sections of ore and gangue minerals. The samples studied were collected from the dumps (or, in some cases, outcrop or accessible workings) of most of the mines, and museum specimens were used for the remainder. Only primary ore and gangue minerals are discussed; secondary minerals found in the oxidised lode cappings have been listed by Both (1966).

The geology of the area is illustrated in Figure 1 and mine prospect localities are shown in Figure 2.

For ease of reference, individual deposits are discussed alphabetically, using the mine and prospect names shown in Figure 2. Where one name has been used for several deposits (*e.g.* No. 1 Montana, Montana Silver-Lead), all such deposits are grouped together, even though they may be geographically remote from each other.

MINERALOGICAL DESCRIPTIONS

Argent Mines

The Argent lodes can be grouped in two principal sets, one striking approximately N 30° W and a second, perhaps somewhat stronger, striking N to N 40° E. The host rocks consist of faulted and sheared Cambrian greywacke, mudstone and shale, faulted against the Proterozoic or Lower Cambrian quartzite and slate of Queen Hill to the north and Florence Quartzite to the east of the No. 6 Argent shaft. The orebodies are described by Blissett (1962) as 'fissure veins of siderite and quartz with bands and irregular masses or lenses of galena, sphalerite and pyrite'; considerable variation, particularly in gangue mineralogy, was noted in the present study and is described below. Most of the workings are now inaccessible, and the present observations are based almost entirely on dump samples and some museum specimens.

No. 1 Argent

The two principal lodes strike NNE with steep easterly dips. They

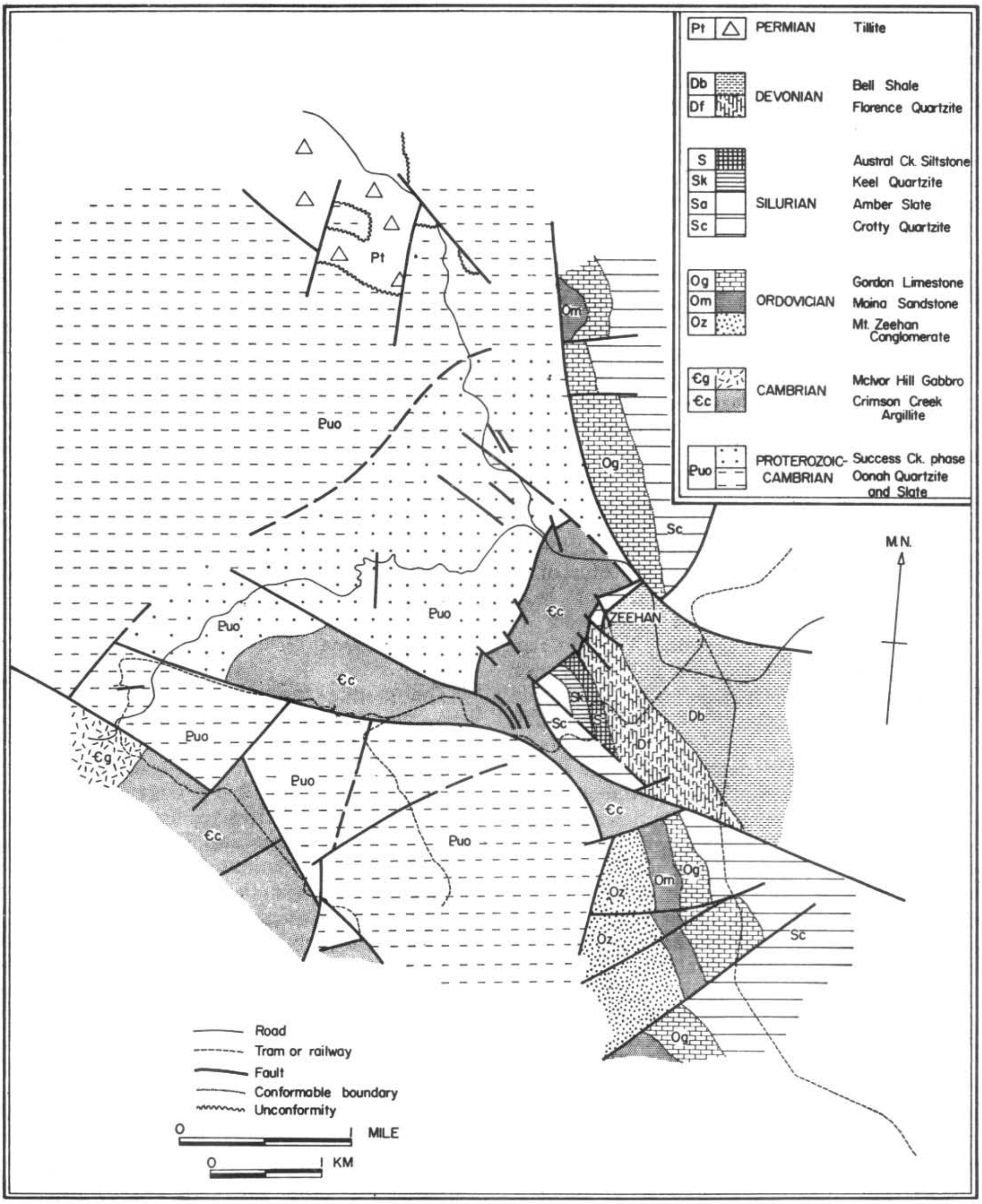

Figure 1. *Geology of the Zeehan field*

5 cm

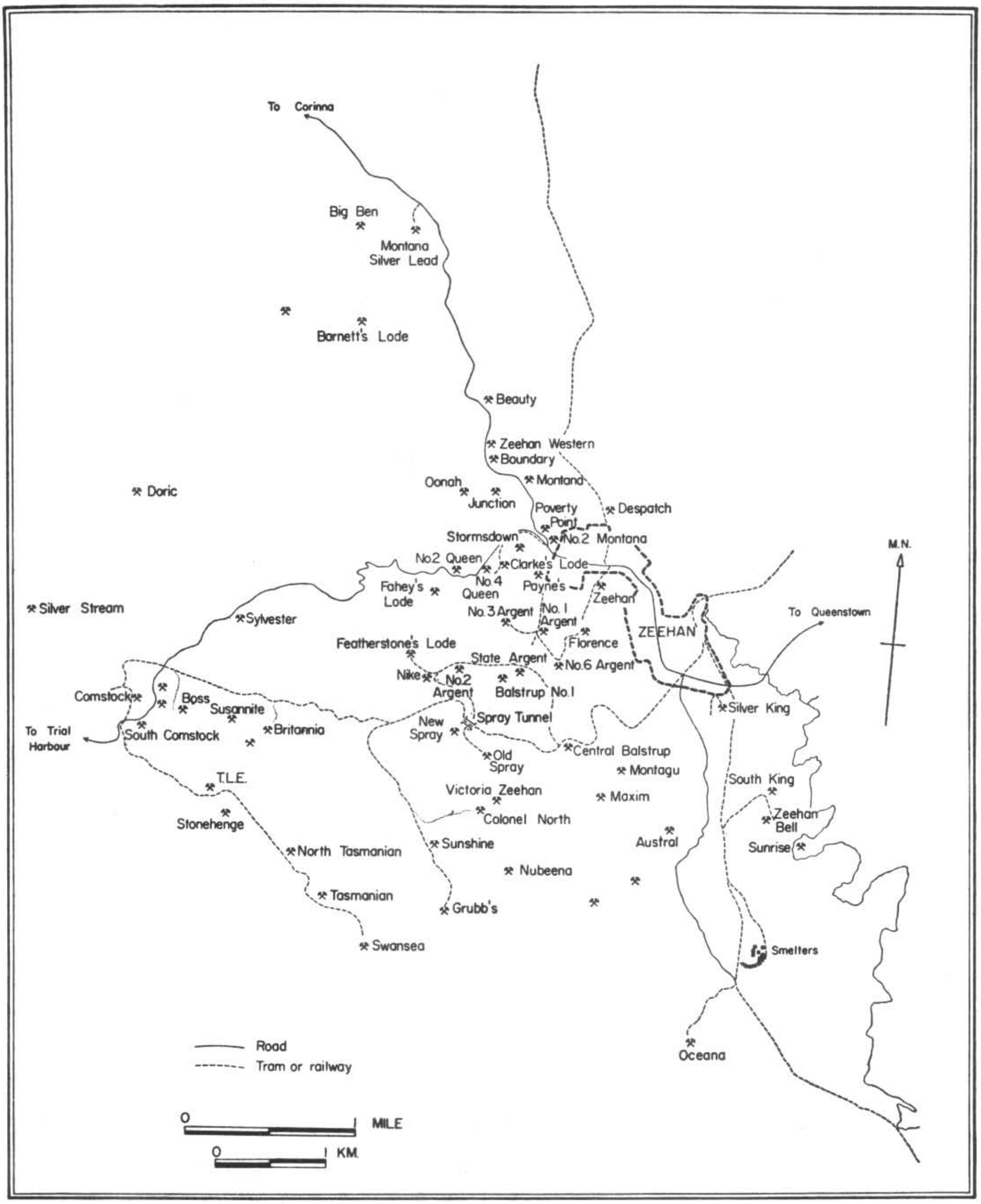

Figure 2. *Mine and prospect localities*

5 cm

Figures 1 and 2 were originally published in Volume 15 of the Journal of the Geological Society of Australia. They are reproduced here with the permission of the Editor.

consisted of weakly mineralised sideritic veins with patches of galena, sphalerite and pyrite (Montgomery, 1895). The workings are now flooded and inaccessible and no well authenticated sample material was obtained from this locality. The adjacent dumps contain small amounts of galena, and rare sphalerite, chalcopyrite, arsenopyrite and tetrahedrite. Both siderite and pyrite are present; the former being the more abundant.

Microscopically, pyrite occurs as granular aggregates up to several millimetres in diameter, intergrown with euhedral and subhedral crystals, up to 200μ wide, of arsenopyrite. Smaller crystals of arsenopyrite also occur in veinlets of late quartz and tetrahedrite, and appear to constitute a second generation. The pyrite-arsenopyrite intergrowths are veined by siderite, with some replacement evident. The pyrite-arsenopyrite-siderite assemblages are in turn moderately brecciated, and the fractures are 'healed' by chalcopyrite, quartz and galena, and occasionally abundant tetrahedrite; irregular late quartz-tetrahedrite and quartz-galena veinlets are common.

Where tetrahedrite is relatively abundant, it occurs as comparatively coarse patches up to 500μ wide, interstitially in, or as irregular veinlets traversing and partly corroding, pyrite and arsenopyrite. Its age relationships with siderite are difficult to establish with certainty, but in places it appears to be contemporaneous with or younger than quartz which in turn is definitely younger than siderite. It contains fine inclusions and narrow, irregular veinlets of chalcopyrite and, less commonly, stannite; chalcopyrite often forms a rim between stannite and enclosing tetrahedrite.

Sphalerite and galena are both relatively rare in the samples studied, occurring largely as wisps or small patchy inclusions in tetrahedrite and chalcopyrite.

Some small veins are crudely crustified, showing a sequence pyrite-arsenopyrite → siderite → quartz-arsenopyrite, with tetrahedrite and chalcopyrite as seams within the quartz; minerals of the latter group also occur as cleavage fracture fillings in siderite and in grain interstices in the pyrite-arsenopyrite aggregates. Generally, however, the 'crustification' sequences are complex and difficult or impossible to unravel.

No. 2 Argent

The wallrocks are laminated quartzite, shale and slate of the Success Creek phase, close to the faulted junction with the Cambrian Crimson Creek sediments.

Small amounts of galena are associated with a gangue of siderite, minor pyrite and quartz. Pyrite occurs as sub-framboidal or micro-spherular particles, up to 30μ wide, disseminated throughout the host slates etc., and also as aggregates of small anhedral grains up to 0.2 mm wide. The pyrite grains frequently show an internal zoning of orientated rows of pits up to 5μ in diameter; high magnification optical and electron microprobe examinations showed no identifiable material in these pits, and their origin and significance remain uncertain.

Galena occurs intergrown with fine grained quartz as irregular ramifying veinlets, up to 2 mm wide, or as disseminated flecks, up to 0.4 mm wide, in the host rocks. It contains rare, small inclusions of sphalerite, which in turn are frequently studded with minute, apparently exsolved, inclusions of chalcopyrite and, less commonly, stannite*. Pyrargyrite is present within

* Stillwell (1950) recorded stannite intimately associated with chalcopyrite and sphalerite in ore from 'Argent Flat'.

galena in some samples, as small ovate inclusions. Some galena also occurs in the interstices of the pyrite aggregates.

No. 3 Argent

No specific description of these workings, situated on the southern flank of Queen Hill, could be located; probably they were part of the old Silver Queen Extended lease included in Consolidated Lease 77M/48 (see Blissett, 1962, p. 174). An old shaft is presently flooded, but portion of an adit driven on a northerly trending lode is accessible. The latter contains galena, sphalerite and chalcopyrite in a gangue of pyrite and quartz, with less abundant siderite; the host rocks are severely contorted phyllitic slates.

The pyrite occurs as massive aggregates of subhedral grains averaging 0.1-0.2 mm in diameter. Galena occurs in the interstices of these aggregates and as narrow veinlets, to 20μ wide, transecting the pyrite grains. Sphalerite also occurs interstitially intergrown with the pyrite, and as irregular patches up to several millimetres in diameter. These contain abundant minute blebs of galena (up to 5μ diameter), occurring discontinuously along the grain boundaries, and larger, continuous grain boundary penetrations of galena.

Siderite occurs in the interstices of the pyrite grains and irregularly intergrown with the sphalerite. It is penetrated along cleavages by galena and quartz. Quartz also occurs interstitially intergrown with pyrite.

In some specimens, the pyrite occurs as corroded but crudely elongated aggregates which show a sub-parallel or roughly en echelon relationship to each other, or a 'swirling' texture; in both cases the matrix is predominantly sphalerite but also consists in part of siderite. The sphalerite is fine grained, strongly twinned and extensively permeated along the grain boundaries by wisp-like inclusions of galena. This texture is interpreted as deformation banding (Edwards, 1954) of pyrite-sphalerite aggregates prior to, or contemporaneous with, deposition of the siderite, which displays evidence of less severe deformation. The shattering of both phases has in places localised subsequent replacement by galena.

Some of the sphalerite is studded by minute anhedral to subhedral grains of pyrite, generally less than 10μ but occasionally up to 40μ in diameter. These inclusions, which superficially resemble products of exsolution, have been interpreted as having been produced by post-crystallisation re-equilibration (Both and Williams, 1968).

No. 5 Argent (State Argent Flat)

The lodes contained siderite, pyrite and lesser quartz, with varying amounts of galena and minor sphalerite, marcasite, arsenopyrite, pyrrhotite, chalcopyrite, tetrahedrite, boulangerite, bournonite, and stannite.

Pyrite occurs again as subhedral grains and granular aggregates, up to several millimetres wide. Interstices in the pyrite aggregates are filled with siderite, and both pyrite and siderite are veined and partly replaced by quartz, galena and several sulphosalts (see below). Fractures in the pyrite grains are 'healed' by veins of galena and tetrahedrite. Sphalerite is not particularly common in the specimens studied, occurring only as ragged inclusions, up to 0.3 mm wide, generally in galena, but sometimes enclosed in siderite. Occasionally the sphalerite contains small grain boundary inclusions of galena, and it also includes rare blebs of pyrrhotite. Some of the sphalerite is studded with abundant exsolved chalcopyrite but other areas are completely free of visible inclusions.

Galena heals fractures in pyrite, and penetrates siderite along the cleavages. It contains abundant inclusions of tetrahedrite, bournonite and boulangerite; the sulphosalts are similar in form (rounded, bleb-like inclusions up to 0.2 mm wide) and when fine-grained may be difficult to distinguish. They are disseminated more or less uniformly throughout the galena, possibly with a tendency for tetrahedrite to be more common in the vicinity of galena - siderite boundaries; age relationshps between all four minerals are inconclusive. Larger areas of both boulangerite and bournonite frequently appear to be nuclei around which irregular and incomplete veins of tetrahedrite are moulded.

Waller (1904) reported No. 15 Lode, Argent Flat, to contain 'considerable capillary and felty jamesonite'; Tasmanian Museum Specimen X 3456, answering this description, has been X-rayed and found to consist of boulangerite. Despite many references in the literature to occurrences of jamesonite in the Zeehan field, the present authors have not been able to identify it, at this or other localities, and these references to its presence are assumed to be in error.

Marcasite is common in several of the sections studied. Some of it occurs interstitially in pyrite aggregates; most, however is found in lacy networks of fine anhedral crystals in cleavages and fractures in siderite and in galena adjacent to galena-siderite boundaries. In the latter case, the marcasite often occurs as seams in the galena which are extensions of veinlets in siderite; the marcasite is evidently younger than the siderite, but its age relationships with the galena are less clear. It was observed that marcasite grains are in general most common near galena-siderite replacement contacts. Where pyrite occurs in the vicinity of such contacts, it is often intergrown with, and perhaps partly converted to, marcasite.

Some of the marcasite also shows a distinctly different texture - it occurs as bladed aggregates of characteristically lamellar form. Marcasite of this type is invariably accompanied by pyrrhotite and appears to have formed by alteration of the latter.

Arsenopyrite also occurs in two forms: as euhedral crystals intergrown with pyrite, and as fine aggregates in late quartz-galena veinlets transecting pyrite and siderite. These appear to represent two distinct generations.

Apart from occurring as exsolved inclusions in sphalerite, chalcopyrite also occurs in intimate 'mutual boundaries' intergrowths with galena, tetrahedrite, bournonite and minor stannite, often as a matrix for microbrecciated siderite fragments.

No. 6 Argent

These workings are presently inaccessible, but examination of the dumps yielded some small specimens of massive galena and, more commonly, siderite with narrow (up to 5 mm wide) branching veinlets of galena. Pyrite appears to be rare, consisting largely of disseminated subhedral crystals partly replaced by sphalerite and siderite, and extensively replaced by galena. The latter contains abundant inclusions of tetrahedrite and boulangerite, and rare inclusions of bournonite; it closely resembles the galena from No. 5 Argent, except that the boulangerite, where present, shows a more distinct tendency to occur as needle- or rod-like inclusions rather than as rounded blebs.

Sphalerite is not abundant; it occurs as rounded inclusions in galena and irregularly intergrown with siderite. It is rather dark in colour, apparently due to the presence of ubiquitous bleb-like inclusions of chalcopyrite and, less commonly, stannite.

Arsenopyrite is common in most sections studied, occurring either as relatively large (50-300μ) subhedral crystals, partly replaced by siderite and sphalerite, or as clusters of smaller euhedral crystals in veins of galena or late quartz traversing the siderite or siderite-sphalerite intergrowths. This again suggests the possibility of a second generation of arsenopyrite, contemporaneous with the galena, quartz and the sulphosalts.

Minor chalcopyrite occurs either as very fine bleb-like inclusions in sphalerite or, more commonly, as larger inclusions (to 500μ), intimately intergrown with galena, tetrahedrite and quartz, often in veinlets which clearly transect sphalerite-siderite intergrowths, or penetrate siderite along the cleavages.

Austral and North Austral Mines

Producing mines in the Austral Valley area included the Central Balstrup (*q.v.*), Maxim, Watt and McAuliffe's, North Austral, Austral and Montagu. During the present investigation, samples were collected from the Austral and North Austral localities and from several small exploration workings along the south arm of the Austral Valley, towards Mt Zeehan. Several museum specimens from the Maxim and Montagu mines were also studied, but field examination of these localities proved fruitless.

The host rocks for the mineralisation in this area range from deeply weathered Cambrian Crimson Creek siltstone, mudstone and argillite to Ordovician Mt Zeehan conglomerate (to the south), Caroline Creek Sandstone (in the Austral Valley itself, overlain to the east, in the vicinity of the smelters, by Gordon Limestone), and Crotty Quartzite (separated, to the north, from further Crimson Creek exposures by the major Balstrup Fault). These rocks are generally disturbed and complexly faulted, with extensive brecciation in the vicinity of some mineralised veins. The veins themselves are in part brecciated, suggesting that some of the faulting may have accompanied or postdated the mineralisation.

The orebodies are narrow, sharply defined fissure lodes containing abundant siderite with irregularly distributed galena, small patches of sphalerite, and minor amounts of tetrahedrite, chalcopyrite, pyrite, bournonite, and boulangerite.

Sphalerite occurs as residuals extensively replaced by galena, also as irregular patches and bands intergrown with siderite. It is generally pale to mid-brown in colour and shows obvious inhomogeneities which are generally of irregular form and rarely show well defined banding or growth zoning; heavily weathered samples are of darker colour, due to finely intergrown iron and manganese oxides (derived at least in part by weathering of the associated siderite). The sphalerite contains sporadically distributed fine blebs of chalcopyrite, but no pyrrhotite inclusions were observed; instead some samples contain clusters of small (up to 25μ) pyrite grains. Further pyrite occurs as larger (to 150μ) subhedral grains enclosed in sphalerite, galena and siderite; it is, however, an insignificant gangue constituent by comparison with siderite.

Most of the galena contains inclusions of tetrahedrite, generally of bleb-like form, up to 50μ in diameter. Occasional larger areas (up to 300μ across) consist of myrmekitic or 'eutectoid' intergrowths of galena and tetrahedrite.

Platy or rod-like inclusions, up to 30μ in length, of bournonite in galena are less common, but boulangerite blebs are abundant (although by no means ubiquitous). Tetrahedrite, which is distinctly coarser, displays a marked tendency to be concentrated near siderite-galena grain boundaries or to be moulded on siderite or sphalerite inclusions within the galena; neither bournonite nor boulangerite shows these relationships. Where tetrahedrite occurs against siderite, the two are often separated by a thin discontinuous film of chalcopyrite, possibly produced as a reaction rim or by exsolution from the tetrahedrite.

Within the galena, several small (up to 30μ) inclusions of a white highly reflecting mineral were observed. This mineral has a polishing hardness approximately that of pyrite and is strongly anisotropic; it resembles arsenopyrite, but its grey to brown polarisation colours are atypical. It was tentatively identified as rammelsbergite.

Balstrup's No. 1 Adit

In August 1965, a portion of the old workings was cleaned out for examination by Placer Development Ltd, and the authors were able to collect some fresh material underground. The wallrocks are described by Blissett as fissured and sheared greywacke, siltstone, mudstone and shale of the Crimson Creek Formation. Underground they show remarkably little evidence of any hydrothermal alteration associated with the mineralisation.

The samples collected consist of strongly sideritic veins transected by narrow veins of galena and quartz. Patches of the galena contain abundant acicular or platy inclusions of boulangerite, which also preserves its acicular habit where it is enclosed in quartz. Sphalerite occurs as rare inclusions in both galena and quartz; where it is replaced by galena it usually contains blebs of chalcopyrite, giving the impression that the 'unmixing' was produced during the replacement.

Barnett's Lode

The lode occurs in quartzite, micaceous schist, and partly graphitic phyllite and slate of the Oonah Quartzite and Slate. The outcrop consists of siliceous pyritic ore with some galena, occurring in a brecciated vein striking a few degrees east of north, and apparently more or less vertically disposed. Sphalerite is rare in the exposures and dump material, but was reported to be more abundant in the northern portion of the sheet (Twelvetrees and Ward, 1910).

The vein material consists of aggregates of subhedral pyrite grains which have been mildly brecciated and extensively penetrated by siderite and sphalerite. The sphalerite contains abundant fine inclusions of chalcopyrite, and some also contains disseminated small (1-5μ) inclusions of pyrite. In one section a series of electron probe microanalyses of such pyrite-bearing sphalerite yielded results ranging from 2.8-3.7% FeS; by contrast, pyrite-free sphalerites in the same section varied from 10.2-16.7% FeS.

Textural relationships between siderite and sphalerite observed in sections from this locality are typical of those seen in ore from many parts of the Zeehan field. In some sections sphalerite appears to replace siderite along grain boundaries (although this relation might be interpreted as co-crystallisation). More significantly, occasional 'reaction rims' of fine euhedral to subhedral pyrite are observed in sphalerite, adjacent to sphalerite-siderite contacts or surrounding somewhat tattered inclusions of siderite in sphalerite. These appear to be analagous to the pyrite rims at galena-siderite boundaries observed elsewhere, and may be due to replacement of siderite by sphalerite or *vice versa*. On the other hand several instances of veinlets of finely crystalline siderite transecting large areas of sphalerite were observed, suggesting the sphalerite to be older.

These relationships, together with the repetitive banding of sphalerite and siderite noted at several localities (*e.g.* Boundary Mine), suggest that both minerals were deposited more or less contemporaneously, with minor local variations only.

Beauty Mine

The shaft was sunk in shale and slate of the Oonah Quartzite and Slate Formation or the Success Creek phase (Solomon, 1965). No details of ore intersections are available, but samples of lead-zinc mineralisation were collected from the dumps. These consist essentially of patchy areas of galena and siderite-sphalerite intergrowths. The galena contains abundant small inclusions (up to 200μ wide) of tetrahedrite; most are rounded or form sub-graphic intergrowths with the galena, but some are rod-like or platy in shape. Cleavages in the galena are filled with quartz, and also with chalcopyrite and tetrahedrite. Tetrahedrite is commonly irregularly moulded around sphalerite residuals in the galena.

Sphalerite occurs irregularly intergrown with siderite and is evidently more or less contemporaneous with it. Both are veined by galena and minor chalcopyrite. Sphalerite contains relatively little exsolved chalcopyrite but is intergrown with larger areas to 0.3 mm wide with 'mutual boundaries' which may have resulted from complete unmixing (Brett, 1964) but cannot be interpreted with certainty.

Pyrite is rare, occurring only as a few small corroded residuals in galena.

Big Ben Mine

The Big Ben lode occurs in faulted Oonah Quartzite and Slate.

Dump samples from this locality consist of pyrite, sphalerite, siderite, galena, and quartz, with minor amounts of chalcopyrite, arsenopyrite, tetrahedrite and bournonite. Pyrite occurs as several distinctive varieties:

(1) Aggregates of relatively coarse subhedral crystals, up to 1 mm wide, veined, corroded and replaced by sphalerite, chalcopyrite, galena and siderite: this variety is typical of the paragenetically early pyrite of many of the Zeehan lodes.

(2) Stringers of fine subhedral crystals (to 15μ) in the grain boundaries of sphalerite and occasionally studded through sphalerite grains in a fashion resembling 'exsolved' blebs. This pyrite is believed to have originated as a result of alteration of the sphalerite (Both and Williams, 1968). Clusters of similar small subhedral crystals are also common along galena-sphalerite replacement contacts, and suggest that alteration took place contemporaneously with the replacement.

(3) Irregular dusty inclusions, seldom more than 50μ in diameter, in fragments of the country rock slate enclosed in the ore. This pyrite frequently displays microspherular or framboidal form, and is probably unrelated to the mineralisation.

(4) Euhedral or subhedral crystals, often displaying 'atoll' textures due either to part replacement by galena or to the expression of crystalloblastic tendencies during contemporaneous crystallisation. These crystals

show a strong tendency to be concentrated along galena-siderite replacement boundaries, and possibly were produced by precipitation of iron released during the replacement.

The sphalerite is a mid-brown, resinous variety which often contains blebs, lamellae and occasionally segregation veinlets of chalcopyrite. It is extensively replaced by galena, but its textural relationships with siderite are inconclusive.

Siderite is clearly veined by galena, often along cleavage fractures with parallel walls, but also often with corroded replacement contacts lined with abundant pyrite (see above). Lack of pyrite along the cleavage fractures suggests that this texture may not be as clearly diagnostic of younger galena as appears at first sight; it may well have been produced by flowage of the galena during post-depositional deformation. Nevertheless, the replacement relationships between galena and siderite, and galena and sphalerite, clearly indicate that galena is younger. It generally contains scattered blebs of tetrahedrite and rare bournonite.

Chalcopyrite occurs as blebs and lamellae in sphalerite, and as segregation veinlets which normally terminate abruptly against galena contacts, suggesting that unmixing took place before deposition of the galena or was genetically related to it. The galena also contains rare, narrow veinlets of chalcopyrite which occupy cleavage fractures; their origin is uncertain, but they may also have been produced by flowage during post-depositional deformation.

Arsenopyrite is not common; it occurs as euhedral crystals, up to 0.1 mm wide, enclosed in and partly replaced by siderite.

Boss Mine

The host rocks are quartzite, slate, graphitic slate and phyllite of the Oonah Quartzite and Slate Formation. These are contorted, fractured and in places brecciated, probably as a consequence of their proximity to the major Balstrup Fault. The lodes were described as consisting of pyritic sphalerite with quartz and minor galena, which is in good agreement with the abundant material on the dumps and exposed in portions of the old workings. Sphalerite and pyrite are common, but galena is relatively rare and no siderite was observed. The veins were reported to range from several centimetres up to 5 m in width, but they do not appear to have been adequately tested in depth, partly because of the low galena content, and partly because the topography would have demanded exploration shafts instead of the cheaper adits prior to the introduction of diamond drilling.

Pyrite occurs as large euhedral crystals, up to 500μ wide, enclosed in quartz and dark reddish brown sphalerite. The pyrite crystals are frequently zoned, with the apparent zoning arising from the presence in polished surfaces of bands containing small pits, individually less than 2μ wide. Optical and electron microprobe examinations could detect no inclusions remaining within these pits, and their origin remains at present unexplained. In places, the pitted zones have been preferentially replaced by both sphalerite and quartz. Many of the pyrite crystals have also been corroded and partly replaced elsewhere by sphalerite and, less commonly, quartz.

Sphalerite occurs as massive aggregates of anhedral grains, individually up to 1 mm wide. It contains few inclusions other than those of pyrite and quartz; a few minor blebs of chalcopyrite and rare small inclusions of pyrrhotite were observed.

The distribution of quartz noticeably parallels that of pyrite; in fact the pyrite generally tends to occur in areas of quartz which are in turn enclosed in sphalerite matrix. At first impression it seems that the quartz was deposited more or less contemporaneously with the pyrite, and the sphalerite was introduced later. However, detailed examination suggests that the pyrite was formed first, followed by the sphalerite. Deposition of quartz was preceded by a period of deformation, to which the pyritic areas seem to have been particularly susceptible; the sphalerite was apparently present prior to shattering of the pyrite and crystallisation of the quartz.

Galena is rare in all the sections examined, occurring only as isolated, minute inclusions in sphalerite grain boundaries. No sulphosalts were observed.

Boundary Mine

This name has been applied to a shallow inclined shaft and several pits put down in the western portion of the Zeehan Western leases, just east of the present Corinna track and near the old Zeehan-Montana boundary. Small amounts of ore were produced by tributors from these workings, but no descriptions of the lodes or of the workings could be located. Dump material consists principally of siderite, with minor amounts of sphalerite; galena is rare, but its absence from the dumps cannot be taken as an indication of its abundance in the lodes relative to sphalerite and siderite, since both of the latter would have been discarded as waste and tributing parties were particularly efficient at sorting ore.

Some of the dump samples were found to be crustified, with alternate layers about 5 mm thick of siderite and sphalerite; the general contemporaneity of these two minerals at this locality is thus established. The siderite frequently occurs as euhedral or subhedral crystals, establishing the time sequence in the crustification; it was observed that these euhedral crystals are often separated from the succeeding layer of sphalerite by a thin irregular band of calcite.

Sphalerite is homogeneous and free of inclusions near its contacts with older carbonate layers; however, interesting relationships were observed in narrow zones adjacent to younger siderite bands. Here the sphalerite contains scattered blebs of chalcopyrite, together with semi-regular cloudy zones, more or less parallel to the siderite contact. Textural detail could not be resolved under high magnification, and the cloudiness was interpreted as incipient exsolution of stannite or tetrahedrite. Positive identification as stannite was made by electron probe analysis.

Britannia Mine

The orebodies occur within faulted and sheared, contorted fissile slate, shale and micaceous quartzite of the Oonah Quartzite and Slate, a short distance from the Balstrup Fault. The lodes proved to be irregular in form, consisting principally of massive pyritic gangue with patchy and impersistent masses of sphalerite and bands or disseminations of galena.

Dump sampling yielded abundant pyrite and dark sphalerite, with minor galena. Pyrite and sphalerite are intimately intergrown, often in a crudely banded fashion which superficially resembles veins of pyrite transecting sphalerite. Under the microscope, however, the pyrite 'veins' are seen to consist of aggregates of euhedral and subhedral crystals, 10-500μ wide, and often corroded and extensively replaced by sphalerite; the texture is interpreted as deformation banding. Both pyrite and sphalerite, but particularly the former, contain interstitial quartz; presumably the more brittle pyrite was more intensively brecciated during deformation and prior to deposition of the quartz.

The pyrite is also characteristically studded with rounded inclusions of quartz, up to 50μ wide. These are distributed in a crudely zonal fashion and were presumably deposited contemporaneously with their pyrite hosts. Minor arsenopyrite is also intergrown with the pyrite.

The sphalerite contains scattered blebs of chalcopyrite and pyrrhotite, with minor inclusions of pyrite and rare tetrahedrite. In some sections both sphalerite and pyrite are brecciated, with a matrix of galena and quartz. Galena-sphalerite contacts are usually 'tattered' due to irregular penetration by replacing galena; 'reaction rims' of pyrite are frequently observed.

The galena in some samples contains abundant ovate inclusions of tetrahedrite and ovate or acicular inclusions of boulangerite.

Central Balstrup Mine

The host rocks are highly disturbed sediments of the Crotty Quartzite, faulted to the west and south against the Crimson Creek Formation.

The lodes were apparently found to be poor fissure veins of siderite with impersistent bands and masses of galena. Principal mineralogical interest in the Central Balstrup mine stems from Twelvetrees and Ward's description (1910, p. 123) of unoxidised ore from a shallow shaft south of Austral Creek containing niccolite and ruby silver with 'galena and some antimonial lead ore in a gangue of siderite'. Petterd (1910) also reported breithauptite and chloanthite from this locality.

Despite careful examination, no samples resembling these descriptions could be located during the present investigation. However, one of the writers has previously described (Williams, 1958, 1959) Specimens 5269 and 9561 from the collections of the National Museum, Melbourne (both specimens thought to be from this locality), and the other (Both, 1966) has described two specimens from the collections of the Tasmanian Museum including Specimen X 314 from the Petterd Collection. The following is a condensed version of these descriptions.

The most abundant mineral in these specimens is niccolite, occurring as mosaics of interlocking grains 0.1-0.3 mm in diameter and often with nodular or nodular aggregate habit. Intergrown with the niccolite are patchy areas, up to 0.5 mm wide, of maucherite.

Both niccolite and maucherite contain long, irregular veinlets, up to 150μ wide, (and occasionally myriads of tiny rounded or elongated blebs 5-10μ wide) of gersdorffite. Nodular niccolite aggregates are surrounded and partly replaced by gersdorffite or by zoned gersdorffite-ullmannite intergrowths resembling the 'corynite' from the Rocky River mine, west of Waratah (Williams, 1958, p. 275-278). Associated with these rims are patches of rammelsbergite, which also occurs as the cores of the zoned gersdorffite-ullmannite intergrowths.

Cracks and open spaces in the niccolite are almost invariably bordered by narrow zones of gersdorffite or gersdorffite-ullmannite intergrowths, suggesting that the latter minerals formed by reaction with sulphur introduced during the later phases of the mineralisation, according to the reaction:

$$NiAs + S \rightarrow NiAsS$$

It is uncertain whether the antimony required for the ullmannite molecule was introduced with the sulphur or was originally present in solid solution in the niccolite.

A narrow veinlet of violarite, evidently pseudomorphous after pentlandite, was observed in one section prepared from National Museum Specimen 5269. Small areas and veinlets of a mineral tentatively identified as hauchecornite were also observed in some of the niccolite aggregates; the status of this mineral was reviewed in the original description (Williams, 1958, p. 272-274).

Associated with the nickel arsenides are small amounts of pyrite, marcasite, sphalerite, chalcopyrite and galena. The galena contains a few small inclusions of tetrahedrite and some minute inclusions of a bireflecting mineral with reddish internal reflections tentatively identified by Both (1966) as proustite.

The Petterd Collection specimen (Tasmanian Museum Specimen X 314) labelled 'breithauptite and chloanthite' was found to consist of niccolite and gersdorffite-ullmannite; the occurrence of breithauptite and chloanthite at this locality is therefore doubtful.

Although small amounts of ullmannite have been identified during the present study from other Zeehan localities (*e.g.* Sylvester mine) the niccolite-gersdorffite assemblage is unique and difficult to reconcile with the zonal concept of Twelvetrees and Ward (1910). However, although the Central Balstrup exposures could not be studied in satisfactory detail, it may be of significance that serpentine is exposed nearby in the Summit Cutting of the Comstock Tramway, and the unusual nickel-bearing assemblage may thus be a consequence of contamination of the mineralising fluids. The association with galena, sphalerite and a predominantly siderite gangue relates the otherwise unusual assemblage to the lead-zinc mineralisation as a whole. Waller (1904, p. 82) described a similar unusual deposit (Moyle's Lode) a short distance to the west. On Section 195/87M, dolomite and serpentine, with splashes of galena, were intersected in a shallow shaft. Crocoite was reported in the gossan. To the west of Moyle's lode, Waller reported a small deposit of 'nickeliferous and cupriferous pyrites' close to a serpentine dyke on the southern bank of the Summit tunnel; the ore assayed high in both copper and nickel. Waller suggested that these various relationships resulted from the intersection of lode fissures with earlier (Cambrian) serpentine dykes.

The samples studied by Williams (1958) are thinly coated with annabergite, a common alteration product of nickel arsenides.

Colonel North Mines

The Colonel North Mines and Railway Co. N.L. held at different times several leases in the area between the Spray and Swansea Mines. Between 1888 and 1911 prospecting activity was intensive, as is reflected by literature references to a large number of 'mines' in this area, including Grubb's, Colonel North, Victoria Zeehan, Silver Foam, Silver Wave, Silver Beach, Sunshine, Chloride Lode, Tramway Formation, Pyritic Formation, Cross Chloride Lode and several others. Most of these were evidently shallow workings on impersistent lodes; they are poorly documented, and many of them could not be located in the field. In at least some cases, confusion has arisen from the use of different names for the same workings (*e.g.* 'Office adit', Silver Beach adit').

The Colonel North Silver Mining Co. N.L. was originally formed in 1894 to work Sections 1584/91M and 1585/91M, acquired from the Queen and Balstrup's

Junction Silver Mining Co. N.L. Section 861/93M was taken over in 1897 and Section 4316/93M was added in 1899. The Company was reorganised in 1900 as the Colonel North Mines and Railway Co. N.L., and in 1903 Sections 1562/87M and 1674/87M were acquired from the Grubb's Silver Mining Co. N.L. (the latter lease having formerly been held by the North Grubb's Silver Mining Co. N.L.). In 1906 the Victoria-Zeehan Silver-Lead Mining Co. N.L. was formed to work Section 1585/91M and 861/93M transferred from the Colonel North Mines and Railway Co. These transactions are summarised here because they account for some of the confusion of nomenclature in published maps and reports. The name 'Colonel North mine' in particular has been variously applied to the Victoria-Zeehan shaft (south of the Spray mine; see fig. 2), the original (1900) Colonel North shaft (in the northern portion of Section 1585/91M, 320 m south-west of the Victoria-Zeehan shaft) and Grubb's shaft (about 1 km to the SSW, and approximately 350 m north-east of the Swansea mine).

In the present study, the terminology indicated in the latter sentence has been adopted to avoid confusion; the Colonel North, Grubb's and Sunshine workings are described separately. A description of the Victoria-Zeehan is not included, since no samples could be located for examination during the present study.

The original Colonel North shaft was sunk to a depth of 60 m in folded shale, slate and quartzite of the Oonah Quartzite and Slate Formation. In a brief description, Twelvetrees and Ward (1910, p. 118) mention a crosscut driven north-east for a total of 135 m from the bottom of the shaft which intersected only two barren lodes of siderite and quartz.

Records available do not differentiate Company production from the Colonel North and Grubb's workings; production from the former, however, appears to have been relatively small, and no sample material could be found in dumps or workings during the present investigation.

Comstock and South Comstock Mines

The Comstock lodes occur in a contorted and sheared succession of schist, phyllite, slate, quartzite and greywacke, believed to constitute the upper part of the Oonah Quartzite and Slate (Blissett, 1962). Intercalated limestone and calcareous siltstone crop out near Comstock Creek, north of the Trial Harbour road; Waller (1903) recorded 'a large amount of wallrock replacement; especially in limestone', and noted the development of talc and tremolite in limestone, adjacent to the lode, in the lower adit. This constitutes one of the rare recorded observations of significant wallrock alteration in the Zeehan field.

Mineralogically, the Comstock ores differ from most of the other Zeehan types in the presence of (former) pyrrhotite, which occurred originally in coarsely crystalline granular intergrowths with pyrite but was subsequently extensively altered to lamellar aggregates of marcasite (or, less commonly, secondary pyrite) with intimately intergrown carbonate inclusions. Although pyrrhotite is not mentioned in the early reports, it was observed in several of the polished sections from this locality examined during the present study.

Pyrite occurs as euhedral and subhedral crystals intergrown with altered pyrrhotite, and as massive granular aggregates partly replaced by sphalerite and galena, through all stages to extremely corroded residuals 'sieved' with inclusions of galena, sphalerite and, less commonly, quartz. Deposition of the bulk of the quartz appears to have overlapped that of the pyrite; both minerals are evidently older than the sphalerite.

Several specimens examined in the present study display a crude pyrite-sphalerite-galena banding which is interpreted as crustification banding, in the light of Waller's (1903) description. In these specimens, shale and sub-greywacke host rocks are commonly bordered with a seam, up to several millimetres wide, of pyrite and quartz. These marginal seams sometimes appear to have formed by alteration of the wallrocks which also commonly contain disseminated subhedral pyrite grains and are partly silicified.

Occasional euhedral grains of arsenopyrite are intergrown with a little pyrite and pyrrhotite.

The marginal pyrite seams either merge into pyrite-pyrrhotite intergrowths, or give way abruptly to massive sphalerite. The sphalerite occurs as seams up to 1 cm wide, which in turn are succeeded by seams of galena. Additional finer grained, subhedral pyrite is often noticeably concentrated (but is far from ubiquitous) along galena-sphalerite boundaries; it may have formed by precipitation of iron released during partial replacement of the sphalerite.

Comstock sphalerite is uniformly dark in colour, due to high contents of both iron and manganese (Both and Williams, 1968). It is in general relatively free of inclusions, except where it contains isolated residuals of pyrite and/or quartz, or in narrow bands (up to 100μ across) immediately adjacent to sphalerite-pyrite or sphalerite-galena boundaries, where it often contains scattered small blebs and lath-like inclusions of pyrrhotite and chalcopyrite.

Carbonates (principally siderite) are sporadic in their distribution, and are much less abundant than pyrite. They are common, however, where pyrrhotite has altered to marcasite; here they occur as seams up to several millimetres wide, replacing sphalerite and pyrrhotite, as small inclusions intimately intergrown with marcasite, and as narrow veinlets (up to 15μ wide) about which the pyrrhotite alteration is crudely symmetrical.

The paragenetic relationships between the carbonates and the sulphides could not be established with certainty, but in places the coarser siderite seams penetrate sphalerite along grain boundaries and therefore may possibly be younger.

Galena is also relatively free of inclusions, except in the vicinity of carbonate seams, which it partly replaces. Here small blebs of tetrahedrite and boulangerite are almost invariably observed, and are often abundant. The somewhat sporadic distribution of carbonates is therefore presumably paralleled by a sporadic distribution of tetrahedrite, and this may account, at least in part, for the variable assays discussed above. No bournonite was observed.

Narrow zones in the sphalerite adjacent to carbonate contacts also often contain minute blebs of pyrrhotite. Microprobe analyses of the sphalerite in these zones show iron contents distinctly higher than those in areas free of inclusions; most of the Comstock sphalerite was found to contain 11-13% FeS. rising to 15-16% in these marginal zones.

Crown Mine

The workings are situated in strongly folded sediments of the Success Creek phase, and east of a NNW trending fault, in Gordon Limestone. The lodes were described by Montgomery (1890, 1893, 1895, 1896) as fissure veins containing galena and sphalerite in a siderite gangue.

Although intermittent activity on these leases continued until 1956, samples of the vein material proved difficult to locate. Those studied by the present authors consist principally of corroded residuals of sphalerite in a matrix of intergrown siderite and quartz. They contain a few irregular patches, up to several millimetres across, of galena with sporadic inclusions of boulangerite and tetrahedrite. The sphalerite, which is extensively replaced by galena, contains scattered minute inclusions of chalcopyrite and, rarely, of pyrite.

Sphalerite, siderite and quartz all show evidence of deformation; the siderite in particular is extensively recrystallised, while both sphalerite and quartz show microbrecciation textures. Galena cleavages show no evidence of 'bending', which may indicate either that the galena post-dated the deformation or that its recrystallisation was complete. This and other examples (*e.g.* Boss mine) of deformation textures in ores adjacent to major faults is supporting evidence for at least some post-mineralisation movement on the latter.

Despatch Mine

The shaft was sunk in Gordon Limestone. Waller (1904) described 'three large parallel lodes striking 30° W of N' and dipping to the west.

Specimens from the Despatch mine examined during this investigation consist of sideritic ore with seams of galena, up to 2 cm wide. The siderite contains ragged inclusions of intergrown pyrite and arsenopyrite with some minor marcasite. The arsenopyrite inclusions in particular are extensively replaced and 'sieved' with inclusions of finely crystalline siderite.

The siderite also contains patchy, ragged and microbrecciated inclusions of yellow to orange brown sphalerite. These commonly contain clusters and narrow veinlets of minute subhedral crystals of pyrite in the sphalerite grain boundaries. Scattered blebs of chalcopyrite and rare pyrrhotite occur within the sphalerite grains.

The galena seams contain abundant, large (to 5 mm wide) subhedral crystals of pyrite which are corroded and partly replaced and which are often 'sieved' with inclusions of quartz. The galena also contains corroded residuals of siderite and sphalerite, and rare inclusions, up to 100μ wide, of pyrrhotite. Rare boulangerite was observed in galena from this locality.

Doric Mine

The host rocks are sheared black slate and quartzite (Oonah Quartzite and Slate).

Dump material consists largely of pyrite and sphalerite, with minor siderite and galena. Most of the pyrite occurs as more or less massive aggregates of euhedral to subhedral crystals up to 500μ in diameter. These are corroded and partly replaced by both sphalerite and galena. Some pyrite, together with minor marcasite, also occurs as small crystals and thin discontinuous veinlets transecting or filling grain boundaries in sphalerite; this type is clearly younger than sphalerite and represents a second generation.

The dark coloured sphalerite is characterised by extreme abundance of orientated and sub-orientated rods and blebs of pyrrhotite, up to 30μ wide. Where sphalerite is veined by galena, the latter tends to penetrate along grain boundaries, and a marked selective replacement of pyrrhotite is noted. Replacement is complete near the galena-sphalerite boundary and is not observed more than 100-200μ from the contact. These relationships, which are not typical of the Zeehan ores, are interpreted as strong evidence of a paragenetic break between sphalerite and galena, since both pyrrhotite and sphalerite must have been present during crystallisation of the galena. Similar but less abundant inclusions of chalcopyrite are also widespread.

The galena contains rare, minute inclusions of tetrahedrite.

Florence Mine

The main workings are within greywacke, siltstone and slate of the Crimson Creek Formation, which are faulted to the east against sandstones, grits and shales of the Crotty Quartzite.

The ore consists of closely intergrown siderite and sphalerite, both minerals being extensively veined and partly replaced by galena - often along grain boundaries. Age relationships between siderite and sphalerite are uncertain; in places sphalerite is veined by finely recrystallised siderite, but this may have been due to post-mineralisation deformation.

The sphalerite contains abundant exsolved blebs of chalcopyrite; some similar bleb-like inclusions also appear to consist of tetrahedrite, but they are too small ($<3\mu$) for certain identification.

The galena contains abundant inclusions of tetrahedrite and boulangerite, with minor bournonite. These range in size from a few microns up to several hundred microns wide. Tetrahedrite is distinctly coarser grained than boulangerite, and occasionally contains inclusions and narrow veinlets of chalcopyrite. Some at least of the chalcopyrite appears to be younger than galena; narrow chalcopyrite veinlets are continuous across intergrown sphalerite, siderite, galena and tetrahedrite. Again this may have resulted from minor 'mobilisation' during post-crystallisation deformation.

Much of the tetrahedrite occurs along galena-siderite contacts; although it occurs in the galena, it appears to be 'moulded' on the siderite.

Siderite-galena intergrowths are often pseudo-myrmekitic, apparently resulting from particularly extensive cleavage-controlled veining and replacement.

The galena contains rare, small inclusions (up to 50μ wide) of a bright white mineral superficially resembling arsenopyrite, but having a higher reflectivity and relatively weak anisotropism. This phase in turn contains smaller inclusions (up to 10μ wide) of a slightly greyer, strongly anisotropic phase. Neither of these rare minerals was identified.

Grubb's Mine

The lode, which varies from several centimetres up to about one metre in width, occurs in faulted, contorted and silicified quartzite, sandstone and slate of the Oonah Quartzite and Slate Formation. Veinlets of milky white quartz, up to several centimetres wide and up to one metre long, are common in the folded slates.

Barite and quartz were reported from a crosscut on No. 4 Level; the occurrence of barite is confirmed by Specimen X 3048 in the Tasmanian Museum collection.

Ore samples examined in the present study consist generally of granular intergrowths of early quartz and pyrite, veined by siderite with irregular patches of sphalerite. The latter minerals are in turn veined and partly replaced by intergrowths of galena and quartz. Most of the siderite, sphalerite, galena and later quartz contain abundant acicular inclusions of boulangerite; the galena also contains patches of bournonite and minor tetrahedrite.

The sphalerite, which varies from orange-red to dark brown in colour, contains a few blebs of exsolved chalcopyrite together with rare inclusions of pyrrhotite.

Scattered euhedral crystals of arsenopyrite occur in the siderite; much of the galena also contains abundant, intimately intergrown arsenopyrite and marcasite.

Rare, irregular inclusions (up to 25µ wide) of pyrargyrite occur in galena or, very rarely, intergrown with boulangerite.

The most notable feature of this ore is the relative abundance of quartz, which apparently occurred in quantities at least comparable with those of siderite and pyrite. Although quartz is a more or less ubiquitous gangue mineral in the Zeehan lodes, it is seldom one of the major vein constituents. The presence of abundant quartz veins in the Grubb's host rocks has been noted above, but it is not obvious whether or not it is of hydrothermal origin.

Junction Mine

The Junction mine lies within rocks of the Success Creek phase. The ore consists of stringers and irregular aggregates of brecciated, subhedral pyrite crystals, up to 1 mm wide, in a matrix of quartz. The pyrite-quartz intergrowth is veined, and the pyrite in particular extensively replaced, by massive aggregates of coarsely crystalline siderite.

Irregular veinlets of galena are up to several millimetres wide; occasionally the galena forms larger patches up to several centimetres wide. These contain abundant corroded residuals of pyrite and quartz, together with sporadic ragged residuals of sphalerite, which is only a minor constituent of the samples examined. Galena is distinctly younger than both pyrite and quartz, and is also younger than siderite, which it replaces and penetrates along rhombohedral cleavages.

The siderite is also extensively penetrated, along cleavages and minute fractures, and partly replaced by chalcopyrite, which is intimately intergrown with patches of tetrahedrite. Chalcopyrite, tetrahedrite and galena occur as sieve-like inclusions in pyrite, as well as extensively penetrating pyrite aggregates along grain boundaries. The sieve textures merge into atoll textures where the pyrite residuals are enclosed in massive galena.

The larger areas of galena also contain abundant fine inclusions of tetrahedrite, boulangerite and bournonite. The tetrahedrite bodies, which are up to 100µ in diameter, are irregular in shape, showing mutual boundaries against the enclosing galena; some show pseudo-myrmekitic or graphic intergrowths with chalcopyrite. Boulangerite occurs as smaller, acicular crystals disseminated throughout the galena or aggregating into patches up to 1 mm across. Bournonite is much less abundant, occurring as scattered rounded blebs up to 15µ across.

One section contained several small inclusions, up to 20µ wide, of argentite in pyrite.

South of the Junction shaft, the southern extension of the lode was intersected in an adit known as 'Hanrahan's adit' or 'Gossan tunnel'. Mineralisation was poor at the intersection, but 24 m along a northerly drive an unusual sheet of pyritic ore containing argentite and pyrargyrite was found (Waller, 1904). This sheet was rich in silver, with reported assays up to 513 oz Ag/ton, but petered out passing northwards into low grade sideritic lead ore typical of the Junction workings. The only specimen of ore from Hanrahan's adit located during the present study, consists of galena in a siderite-quartz gangue, with minor inclusions of tetrahedrite, boulangerite, pyrargyrite and argentite. This specimen does not match Waller's description of the pyritic silver sheet, and the observation of argentite in ore from the Junction workings suggests that it may be slightly atypical sideritic lead ore. The pyritic sheet is reported to have been worked out, and it seems unlikely that further samples of this unusual assemblage will be forthcoming.

Montagu Mine

The mine shaft was sunk in Crotty Quartzite. Sample material is rare, and consists mostly of massive pale siderite enclosing irregular, ragged inclusions of very pale to mid-brown sphalerite. Most of the sphalerite inclusions are of 'shredded' form, and the complete absence of any regular equilibrium configuration of triple junctions (Stanton, 1964) involving both sphalerite and siderite grains suggests that the sphalerite may be paragenetically earlier; however in view of the limited sample material the evidence is not conclusive.

The sphalerite-siderite intergrowths are seamed with narrow (up to 2 mm wide) veinlets and irregular patches of galena with minor tetrahedrite and chalcopyrite. Both tetrahedrite and chalcopyrite also occur, together with some galena, as thin, curving wisp-like inclusions in sphalerite.

Sphalerite and siderite are mildly brecciated and healed with galena and minor tetrahedrite.

Montana Mines

Montana No. 1. (Montana, Zeehan Montana)

The lodes consisted of sideritic fissure veins in intensely folded and faulted dark slate, siltstone and quartzite of the Success Creek phase. The stratigraphic sequence here is characterised by interbedded spilites and spilitic tuffs; Waller (1904) also describes 'melaphyre dykes'. Following Waller, King (1961) drew attention to the relative intensity of mineralisation in the vicinity of spilitic host rocks (approximately 85% of the total Zeehan production was derived from lodes in this environment) and suggested the possibility of a significant host rock control. In the absence of accessible exposures, detailed studies to test this hypothesis cannot at present be made, but in this connection Waller (1904, p. 37) noted that the lode fissures 'usually traverse the slates and melaphyres without being materially influenced by the change of country. Sometimes the metal appears to cut out when a change takes place, as in the case of a lode passing out of melaphyre into slate. But in other instances this is not the case. There appears to be no rule to guide one as to where ore may be expected'.

The Montana lodes strike more or less N-S, but are extensively dislocated by a series of cross faults or 'slides'. The lode fissures are frequently drag folded in the immediate vicinity of the faults, and the only recorded ore from the fault zones appears to have been drag-breccia fragments; nevertheless both Waller (1904) and Twelvetrees and Ward (1910) strongly support a pre-mineralisation age for the faulting. Their reasoning appears to be based principally on marked splitting and branching of the lodes as they approach the faults, with concomitant increases in ore grade, and on the lack of obvious faulting of the lodes themselves; since the faults appear to have pronouncedly affected the distribution of ore, it was concluded that they are of similar or older age.

By contrast, Blissett (1962, p. 141) states 'There is much evidence that [the faults] are post-mineralisation and that the orebodies have been dislocated...The writer would suggest that by comparison with the thrusting near the Montana Silver-Lead mine, faults in the Montana workings may be Tertiary thrusts on which transcurrent movement has also taken place...'.

Blissett's suggestion does not account satisfactorily for the close spatial relation between faulting and high grade mineralisation which so impressed Waller and Twelvetrees and Ward. The present authors prefer a compromise to the effect that initial faulting was penecontemporaneous with the mineralisation, but the recurrent post-mineralisation movement has taken place, possibly continuing at least into the Tertiary. Similar considerations are thought to apply to many, if not all, of the major faults in the Zeehan field. Textural evidence for contemporaneous and post-mineralisation deformation of the ores is abundant and there is some geochemical evidence for substantial post-mineralisation fault movement (Williams, 1968).

The lodes consisted of sideritic lead ore, with some quartz. Below the 500-foot level the proportion of galena declined markedly, and there is some suggestion that the proportion of sphalerite increased somewhat. Twelvetrees and Ward (1910, p. 108) observed that the 'silver ratio' did not vary significantly with depth; reported assays range up to 67% Pb and 115 oz Ag/ton.

Samples of Montana ore examined in the present study consisted principally of galena, sphalerite and minor pyrite in a gangue of siderite and quartz. The pyrite occurs in several different forms. Relatively large (up to 200μ wide) subhedral grains are sporadically disseminated in the sphalerite and galena, or occasionally aggregated into larger masses with a predominantly quartz matrix. These larger aggregates often consist of subhedral or anhedral grains which have been extensively microbrecciated and are veined with quartz, chalcopyrite and minor galena. The pyrite is partly replaced by both chalcopyrite and galena.

Sphalerite is also studded with minute, subhedral pyrite grains, up to 10μ wide, which are characteristically distributed in grain or, more rarely, twin boundaries.

Pyrite is also common, but far from ubiquitous, as thin, discontinuous 'reaction rims' consisting of aggregates of subhedral crystals along galena-siderite replacement boundaries; this variety appears to have formed by sulphide precipitation of iron set free during the replacement.

The distribution of sphalerite is rather variable. Some samples consist almost entirely of massive sphalerite with subordinate pyrite, siderite and galena; in others sphalerite occurs only as small, extensively replaced residuals in galena. Exsolved blebs of chalcopyrite are common in both types, often showing a pronounced concentration in the cores of grains; larger areas of chalcopyrite in the grain boundaries suggest that the grain rims have been 'drained' by diffusion in the early stages of unmixing.

The sphalerite also contains bands of incipiently exsolving stannite similar to that observed in the ore from the Boundary mine (*q.v.*), ranging from regularly orientated cloudy patches and bands to sharply lamellar bodies. Occasionally cloudy areas contain more sharply defined inclusions of stannite. The stannite is noticeably more common in the vicinity of areas of siderite.

Much of the siderite occurs, intergrown with quartz, in well-defined veinlets transecting aggregates of sphalerite; elsewhere sphalerite-siderite intergrowths provide no conclusive textural evidence of age relationships. While there appears to have been some overlap, at least part of the siderite is distinctly younger than the sphalerite. Disseminated euhedral crystals of arsenopyrite, up to 100μ in diameter, are common in the siderite.

The galena contains scattered ovoid, lamellar, or acicular inclusions of tetrahedrite and boulangerite, with some minor bournonite. In some cases, the boulangerite inclusions form aggregate seams and patches up to 500μ across.

Montana Silver-Lead (Montana Western)

The rocks in the vicinity of the mine are tightly folded quartzite, siltstone and slate of the Oonah Quartzite and Slate, unconformably overlain by Permian tillite.

Pyrite occurs as scattered subhedral grains, partly replaced by galena and, less commonly, by sphalerite. Pyrite aggregates up to 500μ wide are veined by quartz, sphalerite, and galena. Euhedral crystals, up to 500μ wide, of both pyrite and arsenopyrite are common in slate fragments enclosed within the ore and adjacent to the lode.

Sphalerite varies in colour from pale to dark brown and occasionally shows a crude zonal texture. It usually contains abundant exsolved blebs and veinlets of chalcopyrite and, less commonly, tetrahedrite which occurs as minute disseminated blebs and larger, irregular coalesced areas up to 50μ wide. In several polished sections minor cloudy areas appear; by analogy with similar sections from the Boundary and Montana No. 1 mines, these are thought to represent incipient exsolution of small amounts of stannite.

Much of the sphalerite occurs as scattered 'splashes', up to 5 mm wide, enclosed in and partly replaced by massive, white to yellowish white quartz. The quartz embays the sphalerite along grain boundaries, and similar grain boundary replacement by galena is also common. Sphalerite aggregates are veined by quartz, chalcopyrite, galena and tetrahedrite.

Siderite is less abundant than quartz, and occurs mostly as small patches irregularly intergrown with sphalerite.

Although some of the galena is free of inclusions, much of it is richly studded with blebs, up to 250μ in diameter, of tetrahedrite, bournonite, and minor chalcopyrite. Tetrahedrite and galena frequently form sub-graphic 'mutual boundaries' intergrowths suggestive of contemporaneous deposition.

Nike Mine

The irregular narrow lodes consisted principally of galena and sphalerite in a gangue of siderite and quartz, in fractured quartzite and sheared phyllitic slate of the Success Creek phase.

No. 1 Lode

Abundant low grade material on the Nike mine dumps contains scattered subhedral crystals, up to 100μ in diameter, of pyrite enclosed in siderite or occurring as ragged, extensively replaced inclusions in galena. The siderite occurs as massive aggregates irregularly intergrown with sphalerite and occasionally apparently replacing it. Much of the siderite is characterised by unusual needle-like inclusions of boulangerite, which have only been observed elsewhere in this field at the Spray mine, and by scattered euhedral crystals, up to 100μ wide of arsenopyrite.

Most of the sphalerite contains exsolved inclusions of chalcopyrite; some also contain very fine-grained, apparently exsolved inclusions of stannite.

Seams of galena, up to 5 mm wide, are often separated from siderite by bands of quartz up to 2 mm wide; both galena and quartz are also characterised by abundant inclusions of boulangerite. Often the sulphide seams consist, in effect, of more or less massive boulangerite with inclusions of galena, in irregular patches of up to several millimetres across. Deposition of boulangerite thus overlapped both siderite and galena, and hence began much earlier than is commonly observed at Zeehan (the Spray mine again being the most notable exception).

The galena also contains small, rounded inclusions of sphalerite, intimately intergrown with boulangerite. By contrast with the more massive variety, these small inclusions do not contain exsolved chalcopyrite, and they appear to represent a second minor generation of sphalerite, deposited contemporaneously with the galena.

Some of the galena contains abundant irregular or ovoid patches up to 400μ wide, of tetrahedrite and minor chalcopyrite.

Fahey's Lode

Samples collected from the dumps in the vicinity of Fahey's lode consisted largely of massive sphalerite, brecciated and 'healed' with quartz and galena. Much of the sphalerite contains bleb- or rod-like inclusions of pyrrhotite and scattered, extensively corroded, grains of pyrite.

By contrast with the No. 1 lode ore, the galena contains only rare inclusions of tetrahedrite and boulangerite. Again no assays are available but atomic absorption analysis of the galena indicated 1,300 ppm Ag (50 oz/ton).

Nubeena Mine

The old workings lie in folded shale, slate and saccharoidal quartzite of the Oonah Quartzite and Slate.

Ore samples examined during the present study varied from massive pyritic ore to patchy veinlets and impregnations of galena in black slates. The massive pyrite has been extensively veined and partly replaced by intergrown siderite and sphalerite; these intergrowths have then been further intensely brecciated and healed by arsenopyrite, galena and minor tetrahedrite and chalcopyrite. The arsenopyrite appears to be slightly earlier than the galena, since it is also partly replaced by the latter; most of it occurs however, in sharply defined narrow (20-50μ wide) veinlets transecting the pyrite.

Sphalerite often is studded with very small blebs of chalcopyrite. Much of it occurs as irregular corroded residuals in galena; some, however, occurs as fine chalcopyrite-free inclusions intergrown with tetrahedrite patches up to 50μ wide in the galena. Tetrahedrite is only moderately abundant, but is often accompanied by smaller (up to 20μ) inclusions of boulangerite and bournonite. Some bournonite inclusions have partial narrow rims of boulangerite.

The galena also contains abundant corroded residuals of marcasite and pyrite, scattered subhedral crystals of quartz, and occasionally patches of micaceous gangue.

The enclosing shales are usually silicified, and contain disseminated subhedral grains of pyrite and marcasite.

Rare inclusions of pyrargyrite and gold were observed in ore and quartz-rich gangue from the Nubeena Mine.

Oceana Mine

The orebodies consisted of two sub-parallel lodes, striking north-west and dipping steeply to the north-east, following strongly developed shears in the Gordon Limestone. Generally most of the ore occurred as fissure fillings, in part brecciated, with concomitant development of cockade ore; associated with the major shears and with several small cross-faults were a series of ore-bearing tension fractures around which some replacement of the host rocks had occurred.

Jack (1961) considered the shearing to have been pre-ore and to have provided favourable access for the mineralisation. However the veins have frequently been displaced by subsequent movements and the galena specimen figured by Lyall (1966, fig. 4) is convincing evidence for post-crystallisation deformation. The caption for Lyall's figure states that the specimen is 'from the Zeehan fault zone', but the specimen was collected by one of the present authors (KLW) from West lode, Oceana mine.

On a microscopical scale, pyrite is observed to be a minor constituent of most sections, occurring usually as scattered, minute inclusions in galena and, less commonly, sphalerite and siderite. Most of these inclusions are extensively replaced, particularly by galena. One section contains several strongly zoned inclusions of pyrite in galena; these have unusual cores of radiating acicular of platy crystals surrounded by outer areas displaying more conventional zoning, parallel to crystal faces and accentuated by preferential replacement by galena.

Sphalerite occurs as irregular areas, up to several millimetres in diameter, usually enclosed within larger areas of galena or siderite. In some instances siderite and sphalerite alternate in a crustified sequence, but galena invariably corrodes the sphalerite or occurs in veins transecting it. The sphalerite varies in colour from light reddish to medium brown; it usually contains some exsolved blebs of chalcopyrite, but these are not abundant and they seldom exceed 10μ in diameter.

Coarser grained chalcopyrite occurs irregularly intergrown with galena; while some of the chalcopyrite appears to have been extensively replaced by the galena, other textures are of the 'mutual boundaries' type and are difficult to interpret paragenetically. Certainly however, both galena and chalcopyrite occur as cleavage fracture fillings in siderite, and both partly replace the siderite and are presumably younger. (The possibility that the penetration of the sulphides along the cleavages of the siderite arose from 'flowage' post-crystallisation deformation is rejected because of the marked corrosion and partial replacement of the siderite).

Veins of siderite, up to 1 cm wide, in limestone and dark shale often have cores of galena and minor chalcopyrite, again suggesting that the latter minerals are younger.

Large patches and seams of galena are relatively free from inclusions, apart from scattered residuals of pyrite and sphalerite. In the vicinity of substantial siderite masses, however, the galena is crowded with small rounded inclusions of tetrahedrite with minor bournonite and boulangerite;

all three sulphosalts were occasionally observed in composite inclusions. Much of the galena is noticeably sheared, and it is not unusual for the deformed galena to show a weak anomalous anisotropism.

Oonah Mine

The country rocks consist of slate, quartzite, siltstone and interbedded vesicular and amygdaloidal spilite, of the Success Creek phase. There is some evidence of graphitisation and, in places, pyritisation of the wallrocks adjacent to the lodes (Twelvetrees and Ward, 1910, p. 130, 132), although no outcrops or underground exposures were accessible for examination. This appears to be one of the rare instances of significant alteration and replacement of wallrocks in the Zeehan field.

Waller (1904) and Twelvetrees and Ward (1910) both state emphatically that the faulting was pre-mineralisation and that the fault 'has evidently deviated, not faulted, the lodes, and has itself become a definite lode-channel' (Twelvetrees and Ward, p. 130). This opinion appears to have been based largely on the occurrence of patches of ore, up to 60 cm wide, in the fault zone. While the findings of the geologists who were able to inspect the exposures cannot be discounted, it must be pointed out that the ores show textural evidence of post-crystallisation deformation (see below) and that, while the fault zone does contain some patches of ore, there was nevertheless an abrupt drop in grade as the veins entered the shear zone (*e.g.* Waller, p. 56, discussing the 24 m displacement of the Stannite lode: 'the slide [carried] ore for the whole of this distance [but] this ground is poor'). The present authors suggest that the faulting may have had a rotational component, about a hinge (in the sense of Gill, 1941) not far to the west of the Stannite lodes. If so, knowledge of the rotational component would assist in the search for the as yet unlocated continuation of the Galena lode north of the fault.

On the other hand, in a detailed discussion of the relative ages of the lodes and the major faulting, Twelvetrees and Ward (1910, p. 20-86), refer to a 'north carbonate lode' in the Oonah Mine, which was reported to cross the fault without apparent deviation. They also note that brecciation of lode material in the fault zone is rarely observed. Their evidence is not compelling, but it does suggest the need for a careful structural study should the workings again become accessible.

The various lodes on the Oonah section differ markedly from each other in their mineralogy. It is convenient to describe them separately.

Galena Lode

Samples from the Galena Lode proved difficult to obtain; those that were examined appear to be atypical in that they contain relatively little pyrite, which occurs principally as disseminated grains up to 100μ in diameter, enclosed in, and partly replaced by, galena and sphalerite. Some euhedral crystals of pyrite and arsenopyrite were observed within fragments of slaty host rocks enclosed within the ore. Rare inclusions of marcasite are intergrown with pyrite in seams of siderite replaced by galena.

Sphalerite occurs as patches and irregular veinlets, up to 1 cm wide, in a matrix of siderite, and as smaller, corroded inclusions in galena. It is usually mid-brown in colour and much of it is relatively free of inclusions. Elsewhere it contains a few disseminated blebs of chalcopyrite and pyrrhotite, up to 5μ wide.

Pyrrhotite is, unusually, somewhat more abundant as larger inclusions, up to 100μ wide, enclosed in galena and (more rarely) quartz. Much of this pyrrhotite is irregularly intergrown with chalcopyrite and, occasionally with small subhedral grains of pyrite.

The galena contains scattered rounded inclusions of tetrahedrite and bournonite (often intergrown) and rare boulangerite. These seldom exceed 50μ in diameter. The galena also contains corroded residuals of quartz gangue and penetrates sphalerite-gangue and chalcopyrite-gangue grain boundaries; in this case the quartz is evidently distinctly older than the galena.

Stannite Lode

Stannite occurs in coarsely crystalline areas, up to 10 cm or more in width, and as networks of narrow veinlets transecting pyrite-arsenopyrite-quartz aggregates. In some cases the stannite and pyrite show a crude banding, with individual bands being up to 1 cm wide; under the microscope each band is seen to contain considerable proportions of the other.

The stannite invariably shows fine lattice twinning, on which a relatively coarse lamellar or 'parquet' twinning is irregularly superimposed. The fine lattice twinning is described by Ramdohr (1960) as indicative of inversion from the high temperature cubic form to a low temperature tetragonal form.

Stannite, chalcopyrite, tetrahedrite and sphalerite are closely related in their distribution and paragenesis, each showing complex exsolution relationships with the others. Stannite and chalcopyrite are the most abundant, although locally sphalerite may predominate; generally stannite forms the host for abundant exsolved blebs and anastomosing segregation veinlets of chalcopyrite. The chalcopyrite in turn contains small exsolution blebs of stannite and both hosts contain additional exsolved tetrahedrite and sphalerite.

Also enclosed in the stannite, and to a lesser extent in sphalerite and chalcopyrite, are small (up to 30μ wide) ovoid, bladed or acicular inclusions of bismuthinite, in places intergrown with galena.

Edwards (1951) drew attention to the presence in the Stannite Lode ore of two types of cassiterite. The first, or primary cassiterite, consists of isolated, corroded crystals or clusters of crystals, enclosed in pyrite, arsenopyrite, quartz and stannite. When enclosed in the latter the cassiterite is often separated from it by an irregular, narrow sheath of chalcopyrite which appears to have unmixed from solid solution in the stannite.

The second form, or 'needle tin', consists of seams or veinlets of minute acicular prisms, and irregular grains, enclosed again by chalcopyrite sheaths transecting stannite. It is distinguished from the primary type partly by the habit of the crystals, and partly by a marked correlation between the grain size and abundance of the cassiterite on one hand and the width of the chalcopyrite seams on the other (except that many chalcopyrite seams contain no needle tin at all). The needle tin is restricted in occurrence to the stannite. The seams which contain needle tin appear to be fracture fillings rather than segregation veinlets. While some of the needle tin crystals are corroded, most are euhedral.

Ramdohr (1960) has described similar relationships in stannite ore from Hunan Province, China, and has suggested that the needle tin and chalcopyrite are produced by breakdown of stannite. This interpretation appears to be reasonable, but needs experimental verification; establishment of the limiting conditions of stannite stability could be useful in defining the mineralisation environment.

Galena in the Stannite lode is confined mainly to small areas, up to 250μ wide, enclosed in stannite, pyrite or chalcopyrite. Some of the galena contains small inclusions of tetrahedrite and bournonite. Rare acicular inclusions of boulangerite are present within bismuthinite and bournonite.

One of the specimens consists of intensely brecciated stannite, in a matrix of sphalerite. The stannite fragments contain abundant segregation veinlets of chalcopyrite, which are terminated abruptly at the fragment margins. The whole breccia is transected by continuous veinlets, 10 to 30μ wide of galena, and of chalcopyrite containing needle tin. The formation of the latter, therefore is demonstrably a relatively late stage process, and the associated chalcopyrite is younger than that in the segregation veinlets in the stannite.

Crystallisation of the galena was also evidently relatively late; however the galena and needle tin veinlets do not intersect within the section, and their paragenetic relationships could not be determined.

Wolframite has been recorded by Twelvetrees and Ward (1910), Edwards (1951) and was observed as rare subhedral crystals up to 1 mm wide, associated with pyrite and quartz.

The Stannite Lode is thus characterised by a remarkable mineralogy unlike any other in the Zeehan field, with the exception of Clarke's lode on the Silver Queen lease. It represents a major anomaly in the simple zonal scheme proposed by Waller and Twelvetrees and Ward.

Payne's Prospect

This name has been applied to a small pit in a lode cropping out on the eastern foot of Queen Hill (see fig. 2). The lodes are more or less vertical pyritic seams carrying some galena and sphalerite. The sulphides are crudely banded with alternating seams of pyrite and sphalerite, and the aggregates are porous and vuggy.

Pyrite occurs as massive aggregates, up to 1 cm wide, of subhedral grains, individually up to 1 mm in diameter. These areas contain abundant smaller inclusions of sphalerite, quartz and galena. Within the sphalerite bands, pyrite occurs both as residuals extensively replaced by sphalerite and galena, and also as fine-grained euhedral crystals in the sphalerite grain boundaries, and forming 'reaction rims' at galena-sphalerite interfaces. The 'reaction rims' almost invariably contain marcasite intergrown with the pyrite. In some sections they are absent or only weakly developed; in such cases the sphalerite usually contains bleb-like inclusions of pyrrhotite in a narrow zone adjacent to the contact.

Galena occurs in veinlets, up to several millimetres wide, transecting and replacing both sphalerite and pyrite. The galena from these veins is unusual, since it contains abundant inclusions of boulangerite and bournonite which elsewhere are commonly observed only in sideritic or sidero-pyritic ores. However, the vein exposures are poor and the possible occurrence of siderite cannot be eliminated.

The major non-sulphide gangue mineral is quartz.

The sphalerite is very dark in colour, much more so than might be expected from the FeS contents of 1.5 to 5.1 wt% determined by microprobe analysis.

Poverty Point Prospect

Immediately north of the junction of the Corinna and Trial Harbour roads, several lodes crop out at the foot of a south-trending spur of Montana Hill, locally called 'Poverty Point'. One of these has been exposed in a shallow pit: it is in a more or less vertical fissure vein, 30 cm wide, in mildly deformed grey-white to brown shale. It strikes almost due north.

The ore consists of dark sphalerite intergrown with granular aggregates of pyrite, which it replaces in part. Quartz in turn replaces the sphalerite along boundaries and adjacent to narrow transecting veinlets. Siderite is intergrown with sphalerite with no clear paragenetic relationships apparent.

Narrow veinlets of galena transect the earlier sulphides and carbonate, with some accompanying replacement. The galena is free of inclusions of sulphosalts.

The occurrence is a minor one, and is distinguished only by the fact that the highest iron content for Zeehan sphalerite was measured on a sample from this vein - one microprobe analysis point contained 20.9 wt% FeS (although determinations on other samples ranged as low as 8.8% FeS with a mean of 13.4%). The high value was measured on an opaque 'alteration zone', carrying finely disseminated pyrite and pyrrhotite, adjacent to a galena-sphalerite replacement boundary.

Queen (Zeehan Queen) Mine

The orebodies occurred within a tightly folded sequence of slate, siltstone and quartzite, with interbedded spilites, of the Success Creek phase.

Clarke's Lode

Published descriptions resemble those of ore from the Stannite lode in the Oonah mine. A single specimen (X 341) from the Tasmanian Museum collection was found to contain stannite and pyrite with minor chalcopyrite, galena, bismuthinite, arsenopyrite, tetrahedrite, cassiterite and quartz. The cassiterite occurred as 'needle tin' in chalcopyrite veins within stannite. Samples collected during the present investigation from outcrop on the north flank of Queen Hill, near the No. 4 Queen shaft, contained abundant stannite, and are thought to be from Clarke's lode.

No. 2 Lode

The sphalerite is dark brown and semi-opaque throughout, and the measured FeS contents are considerably lower than the colour suggests. Microprobe analyses of sphalerite in a specimen of crustified ore showed variations of 0.3 - 4.1 wt% FeS and 0.03 - 0.1 wt% MnS.

A siderite band in the crustified specimen contains scattered small (up to 80μ) euhedral crystals of arsenopyrite.

Atomic absorption analysis of a galena concentrate from the No. 4 Lode showed 2,250 ppm Ag, equivalent to 0.74 oz/unit Pb.

No. 3 Lode

Dump specimens consist mostly of massive intergrowths of siderite and sphalerite, veined and partly replaced by galena and quartz. Reaction rims of pyrite, up to 200μ across, occur at most siderite-sphalerite interfaces; in addition much of both siderite and sphalerite are honeycombed with narrow veinlets of late pyrite and marcasite. The sphalerite is also studded with exsolved inclusions of chalcopyrite and, less frequently, with cloudy zones of incipient exsolution of stannite (*cf.* Boundary mine, No. 1 Montana etc.). The chalcopyrite tends to have coalesced into larger patches, 50-100μ wide, along galena-sphalerite replacement contacts. Tetrahedrite is also noticeably concentrated along galena-sphalerite and galena-siderite contacts, tending to occur within the galena but apparently 'moulded' on the siderite or sphalerite. Subhedral arsenopyrite crystals also show a tendency, rather less definite, to be concentrated along galena-sphalerite boundaries.

No. 4 Lode

Dumps near the shaft and the old mill foundations are rich in sphalerite which is relatively dark in colour and shows a wide range of iron content (2.7 - 16.8 wt% FeS). Much of the sphalerite contains small blebs of pyrrhotite.

Galena is rare on the dumps (relative to sphalerite, which was discarded as waste); it occurs as small seams transecting both siderite and sphalerite, and containing minor amounts of tetrahedrite, boulangerite and bournonite. Some of the galena exhibits weak anomalous anisotropism as a consequence of mild deformation.

In some instances, siderite-sphalerite intergrowths have been shattered and healed with saccharoidal quartz.

Silver King Mine

The lodes occur in well-bedded sandstone, black shale and siltstone of the Bell Shale Formation. The host rocks strike north-west and dip steeply to the north-east.

The ore consists of granular aggregates of sphalerite and siderite, extensively veined, corroded and replaced by quartz, galena, chalcopyrite and tetrahedrite. Sphalerite-siderite age relationships are not clear: in places sphalerite is moulded on euhedral siderite crystals, but in general the two minerals appear to have crystallised more or less contemporaneously. Some euhedral quartz crystals are enclosed by both sphalerite and siderite.

Galena, chalcopyrite and tetrahedrite all have mutual boundary relationships and appear to have formed contemporaneously with each other but distinctly later than siderite and sphalerite. Tetrahedrite is unusually abundant, occurring as large inclusions, up to 1 mm wide, in sphalerite; despite its abundance, silver analyses of the galena gave relatively low values, in agreement with the reported assays. This suggests that silver values in the Zeehan veins are not always directly correlated with tetrahedrite abundances.

Where tetrahedrite replaces siderite, occasional rims of sphalerite are observed; many of the tetrahedrite inclusions in galena also have partial rims of sphalerite, which has presumably unmixed from solid solution.

In addition to the relatively large patches of chalcopyrite, up to 1 mm wide, in galena, the sphalerite also contains exsolved chalcopyrite, ranging from cloudy areas of incipient (sub-microscopic) exsolution to emulsoid globules up to 15μ in diameter. The sphalerite also contains similar small rods or blades of pyrrhotite; those are particularly well developed adjacent to galena replacement boundaries and are rare or absent elsewhere.

Sphalerite is pale beige to mid-brown in colour, with patchy zoning more common than the delicate growth zoning often observed in low iron sphalerites (*e.g.* Barton *et al.*, 1963). However a narrow veinlet (2 mm wide) in siltstone from the King mine, contains well formed growth zoned crystals of sphalerite lining the vein walls, and siderite filling the core.

Pyrite is very rare, occurring only as scattered, fine 'dusty' euhedral and subhedral crystals in sphalerite and galena.

Silver Stream (Kynance) Mine

The workings of the main Silver Stream lode occur in intensely folded schist, slate and sandstone of the Oonah Quartzite and Slate.

Ore samples consist of relatively coarse-grained intergrowths of pyrite, marcasite, magnetite and dark sphalerite, extensively penetrated and partly replaced by galena. The sphalerite appears to be distinctly younger than pyrite and magnetite, both of which it replaces, but the paragenetic relationships between pyrite and magnetite could not be established.

The magnetite occurs as irregular aggregates and rounded grains, up to 100μ wide, enclosed in sphalerite. Some pyrrhotite commonly occurs within sphalerite and 'moulded' around magnetite inclusions, which presumably provided nuclei for coalescence during its separation.

Large areas of sphalerite containing no replacing galena are almost free of inclusions of minerals other than pyrite and magnetite. As the extent of galena replacement increases, so do both the abundance and the grain size of bleb-like inclusions of chalcopyrite and pyrrhotite. The chalcopyrite inclusions are often strongly oriented and might be presumed to have resulted from exsolution; the pyrrhotite inclusions show no similar orientation but tend instead to be concentrated along grain or, less commonly, twin boundaries. The pyrrhotite cannot have been produced by simple exsolution (Barton and Toulmin, 1966), but presumably was produced by chemical adjustments during the crystallisation of the galena, as has been discussed by Williams (1968). In view of the close parallel between the distribution of pyrrhotite and chalcopyrite, it is possible that the chalcopyrite was also produced by changes in bulk chemistry rather than by simple unmixing of a solid solution.

Where replacement has advanced to the point where sphalerite occurs only as rounded residuals in a matrix of galena, the latter almost invariably contains abundant relatively coarse inclusions of pyrrhotite and chalcopyrite. Pyrrhotite in particular often forms partial rims on the unreplaced sphalerite. Evidently both pyrrhotite and chalcopyrite resisted replacement; as their original sphalerite matrix was removed, they coalesced into progressively larger grains. Composite pyrrhotite-chalcopyrite inclusions were observed in the larger areas of galena, but they are not abundant.

Some specimens evidently represent the culmination of the replacement process; they consist of massive, coarse-grained intergrowths of chalcopyrite, galena and pyrrhotite, which contain extensively corroded residuals of pyrite, sphalerite, and less commonly, magnetite. Some of the chalcopyrite occurs in narrow veinlets transecting sphalerite and the earlier sulphides.

In one section, a few small patches of siderite were observed invading sphalerite. These are distinguished by well developed reaction rims of pyrite at the sphalerite-siderite interfaces.

Some of the pyrite contains a small amount of finely intergrown marcasite.

The dark colour of the sphalerite is, in this case, a reflection of chemical composition. Fifteen electron microprobe analyses of Silver Stream sphalerites showed FeS contents ranging from 10.3 to 20.0 wt% with a mean of 15.6%. The manganese contents were particularly interesting; one analysis point which showed 19.0% FeS also contained 9.3 wt% MnS, which appears to be the highest manganese content yet reported for natural terrestrial sphalerites (Fleischer, 1955; Palache *et al.*, 1944). The remaining analyses showed Mn contents as low as 1.1% MnS, with a mean of 4.2%.

The only sulphosalt observed was boulangerite, which occurs as rare, minute inclusions within the galena.

Spray Mine

The host rocks are fractured and tightly folded Oonah Quartzite and Slate. Some descriptions of the mineralogy of the ore have previously been given by Petterd (1910) and Stillwell (1947). Specimens examined during the present study were somewhat variable in character, but generally consist of coarse grained intergrowths of pyrite and arsenopyrite in a matrix of quartz, these intergrowths are fractured and veined by siderite, sphalerite, boulangerite, galena and minor tetrahedrite and bournonite.

Both pyrite and arsenopyrite occur as euhedral crystals up to 0.5 mm in diameter, intimately intergrown in aggregates up to several centimetres across. The pyrite often has an unusual bladed habit suggesting that much of it may be pseudomorphous after marcasite or pyrrhotite. Etching of the arsenopyrite reveals excellent growth zoning.

In some sections pyrite is absent or of only limited abundance; arsenopyrite, however, is present in almost all sections. The relative abundance of arsenopyrite is another unusual feature of this ore.

Some samples contained fragments of silicified slate caught up in the sulphides; these often contain minute spherical inclusions of framboidal pyrite, which is probably of syngenetic or diagenetic origin.

Some of the sphalerite is free of small inclusions; more commonly, however, it contains abundant blebs of chalcopyrite, pyrrhotite and, rarely, irregular patches of tetrahedrite. As in many other instances, there is a strong tendency for chalcopyrite and pyrrhotite inclusions to be more abundant where the sphalerite has been veined and/or partly replaced by younger minerals. Under these circumstances the sphalerite also occasionally contains thin, discontinuous seams of fine-grained pyrite.

The most unusual feature of the mineralogy of the Spray ores is the relative abundance of boulangerite, which is present, in most of the sections examined, in much greater proportions than galena. The occurrence and mineralogy of boulangerite in the Spray ores are discussed by Both and Williams (1968, p. 233-234).

Galena is a relatively minor constituent of the samples examined; much of it occurs in the interstices of felted boulangerite aggregates, and larger areas up to several millimetres wide, are normally studded with fine inclusions of boulangerite. In addition seams of galena usually contain partly replaced residuals of pyrite, arsenopyrite and sphalerite, and minor small inclusions of tetrahedrite, chalcopyrite and bournonite.

Petterd (1910) reported the presence of argentite in siderite from the Spray mine; the identification has been confirmed by examination of a specimen from the W.F. Petterd Collection, now housed in the Tasmanian Museum (X 235). Petterd also recorded the presence of 'native antimony', but a specimen so labelled from the Petterd Collection (X 47) has been found to consist of stibnite. The specimen is labelled 'Native Antimony, Zeehan'. and it is not certain whether it came from the Spray lodes.

Stonehenge Mine

The lodes were well-defined fissure veins in faulted greywacke, grit and shale of the Crimson Creek Formation (Blissett, 1962).

The lodes of the Stonehenge and T.L.E. Mines show some differences in mineralogy in comparison with those of the Comstock and Boss mines to the north-west, notably the abundance of quartz gangue relative to siderite and pyrite. The ore of the Stonehenge mine was described by Twelvetrees and Ward (1910, p. 145) as containing 'a little copper and iron pyrites and a great deal of zinc blende, among which the galena appears in bands and blebs. What non-metallic gangue is present is chiefly silica, with siderite in occasional splashes. The metallic minerals fill almost the whole of the lode fissure, adhering tightly to the walls, but not passing beyond the fissure in such a way as to produce an impregnation of the country rock'. The galena and sphalerite were reported to be banded in the lower levels.

Samples collected during the present investigation were generally in accord with this description. Scattered dump material consists principally of pale to resinous brown sphalerite, showing considerable variation in colour and composition (1.4-14.4 wt% FeS and trace to 1.0 wt% MnS). The massive sphalerite contains veins and patches of galena and late quartz, with a noticeable but not invariable tendency for the darker sphalerite to be concentrated in narrow zones adjacent to the veins.

Under the microscope, the sphalerite is seen to contain scattered residual inclusions of extensively replaced pyrite; additional pyrite occurs occasionally as thin seams of fine-grained subhedral crystals transecting the sphalerite in the vicinity of galena veinlets. Narrow zones bordering galena or quartz patches and veinlets also commonly studded with inclusions of pyrrhotite, and are much darker in internal reflection. An electron microprobe profile across a dark zone adjacent to a quartz veinlet showed the iron content to increase as the vein is approached.

Irregular patches of chalcopyrite, up to 5 mm across, are intergrown with quartz and sphalerite. Within these intergrowths, sphalerite commonly contains abundant exsolved blebs of chalcopyrite; elsewhere it is substantially free of such inclusions. Both chalcopyrite and sphalerite contain isolated residual grains of magnetite and heavily corroded pyrite. Small inclusions of pyrrhotite are common in the chalcopyrite.

In some specimens, the quartz contains scattered aggregates, up to 100μ in diameter, of fine-grained lamellar marcasite.

Rare tetrahedrite and boulangerite are present in galena from this locality.

Stormsdown Mine

The workings known as the Stormsdown mine are located in the north-west slopes of Queen Hill, adjacent to the Trial Harbour road and north of the No. 4 Queen shaft. An adit driven approximately 60 m into the hill has intersected a small lode consisting of irregular masses of pyrite containing very fine-grained cassiterite withs sphalerite, galena and siderite. The ore occurs at the intersection of two small faults in tightly folded quartzite, siltstone, slate and spilite of the Success Creek phase; the faults have shattered and displaced a pyritic vein. Much of the ore consists of soft pug in the most intensely disturbed region at the intersection of the faults; as the faults are followed away from the intersection the ore becomes harder, and the grade decreases. The soft ore was reported to assay 4.13% tin, and the hard ore 0.58% (Blissett, 1961); due to the very fine grain size of the cassiterite ('flour tin') vanning test recoveries were less than 50%, but the ore has been treated successfully.

The ore has a complex mineralogy and the paragenetic sequence is difficult to unravel because of the severe deformation, which has produced a crude banding (the 'metamorphic banding' of Edwards, 1954) and has considerably disturbed the original intergranular relationships.

The samples examined consist essentially of pyrite and quartz, extensively replaced by sphalerite and siderite, and veined by late galena. Pyrite and quartz are the most severely deformed minerals, and both are paragenetically earlier than the sphalerite. Minor marcasite and arsenopyrite are associated with the pyrite, which also contains rare fine-grained inclusions of stannite, usually less than 50µ in diameter.

Many specimens are characterised by the presence of abundant small subhedral crystals of cassiterite, up to 30µ across; these are mostly enclosed in sphalerite, but a few occur in pyrite and siderite, and residual inclusions in galena where the latter mineral has replaced sphalerite are not uncommon. The textural relationships of the cassiterite provide no information concerning its age; its dominant occurrence in sphalerite suggests a genetic relationship between the two, but its exact significance is obscure.

The sphalerite usually contains abundant bleb-like inclusions of pyrrhotite and chalcopyrite; fine-grained pyrite, possibly of a second generation, often forms ill-defined rims at sphalerite-galena boundaries.

The Stormsdown galena contains a few scattered acicular inclusions of tetrahedrite. Most of the galena occurs as small patches in the interstices of the earlier sulphides or partly replacing them; rarely, seams of galena range up to several centimetres in width.

Sunrise Mine

Samples collected from the vicinity of the old workings consist of buff to resinous brown sphalerite intergrown with siderite, and veined and partly replaced by galena carrying traces of chalcopyrite. Sphalerite-siderite relationships are somewhat obscured by the tendency of late quartz veinlets to penetrate the grain boundaries and partly replace both minerals.

Large unreplaced areas of sphalerite are relatively free of inclusions, but thin seams of fine-grained pyrite are common in the vicinity of galena or quartz veins; much of this pyrite occurs in the grain boundaries of the sphalerite. Patches of chalcopyrite, up to 300µ wide, also tend to be clustered in the sphalerite along replacement boundaries.

Surprisingly, in view of the descriptions of Twelvetrees and Ward, the galena in most of the sections examined contained only sparsely disseminated ovoid inclusions of tetrahedrite, with some minor boulangerite. A specimen of sideritic ore from the Queen Victoria Museum (Launceston) collection contains abundant inclusions of tetrahedrite in patches of galena.

Sunshine Mine ('Tramway Formation')

The workings are located in tightly folded black slate of the Oonah Quartzite and Slate. The vein carries abundant sphalerite in a quartz-pyrite gangue, with occasional splashes of galena. The sphalerite, which is mostly rich resinous brown in colour, contains disseminated, subhedral and partly replaced crystals of pyrite, up to 0.5 mm in diameter; where the sphalerite has been replaced by galena, it also ocontains seams and patches of fine grained pyrite. Some pyrite occurs as small, extensively replaced residuals in the galena.

Large areas of massive sphalerite are studded with inclusions of quartz, up to 1 mm wide, penetrating grain boundaries or filling late fractures in the sphalerite.

The galena contains abundant small acicular inclusions of boulangerite. Individually these are up to 75μ long and 20μ wide, but frequently occur in radiating aggregates up to 0.3 mm wide. Interspersed with these inclusions, and sometimes intergrown with them, are less abundant rounded inclusions, up to 50μ wide, of tetrahedrite. Bournonite is a common but minor constituent of many samples and occurs as very fine round and rod-like inclusions within the galena.

No siderite was observed, either in the field or in the samples examined under the microscope. However, a noticeable feature of some samples is the presence of 'hacked' or 'chopped' quartz similar to that described by Petterd (1910, p. 149) from the north-east of Tasmania. Petterd attributed the sharp angular impressions in the quartz to the former presence of feldspar crystals, but the impressions in the Sunshine quartz are more probably due to the leaching of a crystalline carbonate, possibly siderite.

Quartz is abundant, both within the vein and as numerous milky veins, up to about 10 cm wide, in the adjacent slates. The quartz veins, many of which apparently fill tension gashes, resemble those observed at the Grubb's mine.

Swansea Mine

The country rocks consist of tightly folded and intensely shattered quartzites, red to brown shales, slates and minor conglomerate; large-scale structure in the vicinity of the Swansea mine is relatively complex due to the confluence of several major faults, and it is uncertain whether these rocks represent the upper part of the Oonah Quartzite and Slate or the lower part of the Crimson Creek Formation (Blissett, 1962).

Sulphides are particularly abundant on the dumps of this mine; they consist principally of sphalerite, galena, bournonite and siderite, with minor pyrite and quartz. Some samples are stained with blue and green copper carbonates, and some galena has iridescent blue surfaces due to incipient replacement by covellite.

The sphalerite occurs as massive aggregates, up to 25 cm in diameter, of pale beige to honey-coloured resinous and coarsely crystalline material. Although occasional pale brown seams are noted, in general the Swansea sphalerite is unusually light in colour; electron microprobe analyses of ten samples showed FeS contents ranging from 2.4 wt% down to less than 0.1% and MnS contents uniformly less than the limit of detection which, under the conditions of analysis, was about 0.03%. Atomic absorption analysis of two samples of Swansea sphalerite showed less than 25 ppm Mn in both cases.

Atomic absorption analysis for cadmium indicated 3,500 and 3,600 ppm for these two samples. There is a considerable discrepancy between these analyses and Reid's (1925) report of 2% cadmium, and it is concluded that the latter figure is not typical of the Swansea sphalerite (although production records indicate that 40 tons of cadmium were extracted from Swansea concentrates).

Iron content of the sphalerite is variable within the areas of single polished sections. Compositional changes are often gradational, but sometimes show abrupt discontinuities. These are seldom due to growth zoning of the type described, for example by Barton *et al.* (1963); instead they appear to have resulted from microfaulting of an originally inhomogeneous aggregate. The more marked cases invariably show evidence of fracturing along the discontinuity, and in some cases the fractures are partially penetrated by veinlets of galena and tetrahedrite. In many cases the fractures appear to be cleavage controlled, with adjacent areas of 'conjugate' cleavage fractures.

Inclusions within the larger areas of sphalerite are generally sparsely disseminated. They consist of isolated, small inclusions of pyrite and occasional blebs of chalcopyrite; both appear to be more abundant in samples of sphalerite extensively replaced by galena and bournonite.

Siderite is a common constituent, ranging from massive areas several centimetres in diameter down to small inclusions in the grain boundaries of sphalerite aggregates. The siderite is often intergrown with irregular patches of quartz, and it frequently contains scattered euhedral crystals of arsenopyrite and minor pyrite. Some pyrite and arsenopyrite also occur as euhedral inclusions in quartz.

Both siderite and sphalerite are extensively veined by galena, tetrahedrite and bournonite. Veins of galena transecting siderite in particular are often lined with tetrahedrite; in the larger areas of galena, tetrahedrite is also particularly common, as coarse patches up to 1 mm wide, adjacent to inclusions of, or enclosing, siderite.

A distinctive feature of the mineralogy of the Swansea ore is the presence of unusually abundant bournonite, occurring as seams up to several centimetres wide transecting sphalerite and siderite. The bournonite is closely associated with galena; there is a complete gradation from veins of galena with small inclusions of bournonite to veins of bournonite with small inclusions of galena. The bournonite does not show the same preferential association with areas of siderite as does tetrahedrite.

Much of the bournonite is coarse-grained and shows excellent cross-lamellar or 'parquet' twinning; extensive patches however, show incipient to complete recrystallisation to fine-grained equigranular, allotriomorphic aggregates in which individual grains are polysynthetically twinned. The recrystallisation is possibly a consequence of the post-mineralisation deformation which produced microfaulting in the sphalerite. Some of the galena shows well-developed kink bands.

The close associations between galena, tetrahedrite and bournonite suggest that all three minerals crystallised more or less contemporaneously. The concentration of tetrahedrite in the vicinity of siderite suggests either that the tetrahedrite began to crystallise slightly earlier than the galena or that the siderite exercised a chemical control favouring the precipitation of tetrahedrite. Galena and bournonite often are intergrown in sub-graphic or myrmekitic textures; while this may be indicative of contemporaneity, a number of experimental studies (Schouten, 1934; Brett, 1964) have suggested that such textures can be produced by several mechanisms and should be interpreted with caution.

Some chalcopyrite occurs as small, irregular inclusions in galena and bournonite.

Sylvester Mine

The Main lode workings are located in a series of interbedded greywacke, slate and 'melaphyre' of the Success Creek phase. Samples of pyritic lead-zinc ore matching Waller's (1904) description are reasonably common on the dumps of the Main lode workings. Many of these are crudely banded and contain appreciable proportions of siderite and chalcopyrite.

Pyrite occurs in massive granular aggregates, intergrown with euhedral crystals of arsenopyrite, and frequently enclosed in a matrix of quartz. Both pyrite and arsenopyrite are extensively replaced by sphalerite, siderite and galena.

The sphalerite is dark in colour, and contains abundant inclusions of chalcopyrite, pyrrhotite, and much less commonly, stannite. The sphalerite is partly replaced along grain boundaries by siderite, and the inclusions are noticeably more abundant adjacent to sphalerite-siderite boundaries which also frequently show pyrite reaction rims. Electron microprobe analyses of sphalerite areas containing inclusions and others which are inclusion free showed the former to be richer in iron (*e.g.* 16.9 compared with 13.3 wt% FeS), suggesting that the inclusions are not likely to have been produced by simple unmixing of a solid solution, but instead probably resulted from re-equilibration during crystallisation of the siderite.

These relationships are not ubiquitous. In some cases of coarse granular intergrowths of siderite and sphalerite, the sphalerite has a much lower iron content (down to less than 1% FeS) and rare inclusions of chalcopyrite are concentrated in narrow zones bordering transecting veinlets of quartz and galena, but show no preferential association with siderite. Apparently the deposition of siderite overlapped that of sphalerite; where the two minerals are contemporaneous, the sphalerite is more or less homogeneous and has a low iron content. Where the siderite is clearly younger, the sphalerite is markedly inhomogeneous and has a generally higher iron (and manganese) content. Younger galena and quartz evidently produced similar, but less pronounced, effects. Galena occurs as seams up to several millimetres wide, transecting and healing mildly shattered areas of sphalerite, and also invading the cleavages of siderite to form networks with distinctive rhombohedral patterns. The galena contains scattered irregular blebs of tetrahedrite, and rare acicular inclusions of boulangerite.

Several sections contain isolated, small inclusions of a hard, isotropic white mineral resembling pyrite but displaying slightly higher reflectivity. These are rounded in shape and seldom exceed 20µ in diameter; they were identified by electron microprobe analysis as ullmannite (NiSbS). By contrast with the 'ullmannite' observed at the Central Balstrup mine (actually of composition intermediate between gersdorffite and ullmannite), the Sylvester mine material appears to be remarkably pure in composition; although no reliable quantitative analysis could be performed due to the small size of the inclusions, qualitative wavelength scans showed no significant amounts of any elements other than Ni, Sb, S and traces of Fe.

T.L.E. Mine

The country rocks are shale, quartzite and grit of the Crimson Creek Formation, which are faulted against Oonah Quartzite and Slate a short distance to the north.

Most of the ore from T.L.E. mine was reported as being relatively rich in silver (Twelvetrees and Ward, 1910), but atomic absorption analyses of T.L.E. galena made during the present study, showed only 1,200 ppm silver, equivalent to 0.4 oz Ag/unit Pb. Furthermore, tetrahedrite, which invariably accompanies high silver grades elsewhere in the field, was not observed in T.L.E. samples by the present authors. It appears that the ore must have been highly variable in this respect, and that the samples examined by the present authors were, in this case, not representative of the ore as a whole.

Samples which were examined in the present study were all collected from the dumps, and consist principally of massive pale yellow to mid-brown sphalerite, with minor galena and quartz gangue. The sphalerite contains sparsely scattered, corroded residuals of pyrite, up to 100µ wide, and is partly replaced by galena; where the replacement is relatively extensive, the sphalerite is studded with small inclusions of pyrrhotite and chalcopyrite, accompanied by fine subhedral to euhedral crystals of pyrite occurring as impersistent reaction rims at sphalerite-galena boundaries or as narrow seams in sphalerite grain boundaries. A marked correlation was noted between the intensity of replacement and the abundance of these inclusions.

Much of the quartz occurs as narrow veinlets, up to 30µ wide, transecting the sphalerite and often studded with minute euhedral crystals of arsenopyrite.

Minor marcasite is intergrown with aggregates, up to 2.5 mm wide, of euhedral and subhedral crystals of pyrite.

The T.L.E. and Stonehenge ores differ from most of the other Zeehan deposits in that they contain relatively little siderite or pyrite; quartz is by far the most abundant gangue mineral.

Tasmanian and North Tasmanian Mines

Tasmanian Mine

The ore was worked from a northerly trending adit and a shallow shaft. The southern portion of the workings is in chert, shale and siltstone of the Crimson Creek Formation; at 36 m in the adit 'broken country' was encountered (Montgomery, 1890), and to the north the host rocks are sheared and shattered Proterozoic quartzite, siltstone and shale (Blissett, 1962).

Samples collected from the dumps contain abundant pyrite, sphalerite and galena, with siderite and some chalcopyrite. The sphalerite varies somewhat in colour, and is darker than that from the Swansea mine to the south and the North Tasmanian mine to the north.

Pyrite occurs as crudely banded aggregates up to 5 mm wide, consisting of euhedral to subhedral grains enclosed in a quartz matrix. The 'banding' arises from alternation of such aggregates with bands of sphalerite, siderite, and/or galena.

Much of the pyrite is corroded and partly replaced by sphalerite, siderite and galena. In many cases the replacement has clearly been controlled by pyrite grain boundaries; elsewhere the pyrite has been brecciated and replacement has proceeded outwards from the fractures.

The sphalerite in turn is replaced by siderite and galena. Where replacement has been most intense, the sphalerite contains abundant inclusions of chalcopyrite and pyrrhotite, and sphalerite-galena boundaries are often lined with discontinuous 'reaction rims' of pyrite and minor marcasite.

Siderite also contains similar pyrite and marcasite adjacent to galena boundaries. The two types of pyrite show distinctive differences in habit; the early fracture-replaced aggregates are composed of anhedral grains corroded around the margins, while the second type commonly displays 'atoll' textures which probably are of crystalloblastic rather than replacement origin.

Some of the sphalerite contains scattered rounded residuals of magnetite; occasional larger patches of magnetite, up to 500μ wide, are extensively replaced by siderite.

Seams of galena contain rare, minute inclusions of tetrahedrite and sporadic inclusions of boulangerite. Several small inclusions, up to 15μ wide, of a hard, white, strongly anisotropic mineral were observed within the galena or adjacent to galena-sphalerite boundaries; this mineral could not be identified with certainty, but resembles rammelsbergite or pararammelsbergite. Several inclusions of a bright orange-pink, strongly anisotropic mineral, tentatively identified as breithauptite, were also observed within galena or, in one instance intergrown with pyrrhotite enclosed in sphalerite.

Patches of chalcopyrite, up to 5 mm wide, are irregularly intergrown with galena and occasionally contain 'stars' of exsolved sphalerite.

The mineralogy of these samples is apparently in reasonable agreement with the descriptions of Montgomery and Waller. Atomic absorption analysis of a sample of galena showed 1,200 ppm silver, equivalent to 0.4 oz Ag/unit Pb and corresponding approximately with the assay quoted above. Electron microprobe analyses of the sphalerite showed iron contents ranging from 6.1-12.3 wt% FeS (mean 10.2%) and 0.1-1.3 wt% MnS (mean 0.37%).

The markedly pyritic nature of the ore and the chemical data both contrast sharply with ore from the Swansea mine (*q.v.*), a short distance to the south-east (atomic absorption analysis of Swansea galena indicated 2,600 ppm silver). It is believed the Tasmanian samples were derived from the northern portion of the workings and the anomalous contrasts stem from the effects of post-mineralisation faulting, which has brought into vertical juxtaposition two lodes which originally occupied different positions in the zonal sequence.

One problem with this interpretation is the improbably fortuitous coincidence, within the Tasmanian workings, of lodes north and south of a fault on which it is believed post-mineralisation movement took place. The workings are at present inaccessible, and existing descriptions are not sufficiently detailed to allow comparison of the ores on either side of the fault. This problem remains unresolved; however, if there has been no post-mineralisation displacement, the Tasmanian ores then present one of the few unexplained anomalies in the zonal pattern of the Zeehan field.

North Tasmanian Mine

The host rocks appear to have been grey shale, siltstone and quartzite of the Oonah Quartzite and Slate. They are faulted against Cambrian greywacke, grit and shale (Blissett, 1962).

Samples collected from the dumps consist largely of intergrown siderite and sphalerite, both extensively replaced by galena. Arsenopyrite is abundant, occurring largely as stringers along siderite-sphalerite boundaries and as residuals in galena. The stringers consist of aggregates of tiny euhedral crystals.

The galena contains scattered inclusions of tetrahedrite, bournonite and minor boulangerite, together with rare, minute grains of a hard, highly reflecting, strongly anisotropic mineral tentatively identified as rammelsbergite or pararammelsbergite. Several of these inclusions are intergrown with arsenopyrite.

Fragments of black slate enclosed in the ore are studded with spherical inclusions of framboidal pyrite, up to 10μ wide; this habit contrasts sharply with that of a few residual grains in sphalerite.

The galena commonly shows deformed cleavages and a weak anomalous anisotropism, indicative of post-crystallisation deformation; this is probably a consequence of movement on the major fault south of the shaft.

Despite extensive replacement by galena, the sphalerite contains only rare blebs of chalcopyrite and no observed pyrrhotite or secondary pyrite (cf. Tasmanian Mine). The FeS content (0.2 to 5.3 wt%, mean 2.7%) and MnS content (<0.03 to 0.28 wt%, mean 0.05%) proved to be unexpectedly low.

Western (Zeehan Western) Mine

The host rocks are folded and partly brecciated grey, green and black shale, slate and siltstone of the Success Creek phase. They contain interbedded flows(?) of amygdaloidal spilite (the 'melaphyre' of Waller, 1902, 1904 and Twelvetrees and Ward, 1910).

A small collection of samples from dumps near the shaft and adjacent to the old mill (across the Corinna road, to the south-west) consisted mostly of weathered siderite, with small quantities of sphalerite and galena. Most of the sphalerite occurs as ragged, possibly partly replaced, inclusions in siderite; these often contain abundant blebs, up to 5μ wide, of chalcopyrite.

Galena veins and partly replaces both sphalerite and siderite. Associated with the galena are patches of quartz, which occasionally form impersistent rims against sphalerite. The galena also commonly contains large (up to 400μ wide) irregular patches of tetrahedrite, which in turn are often intergrown with chalcopyrite. Some of the tetrahedrite inclusions have a partial rim of sphalerite.

Bournonite, boulangerite and pyrargyrite occur as inclusions within the galena, but vary considerably in abundance between specimens. Bournonite also occurs as rare patches up to several centimetres across; these areas contain inclusions of galena and boulangerite.

The siderite commonly contains small, disseminated subhedral crystals of arsenopyrite, which also occur as residuals in galena which has replaced siderite. Rare lamellar inclusions of marcasite in siderite were also observed.

Pyrite is a rare constituent of these samples, occurring only as minute corroded residuals in siderite and, rarely, as 'fringes' or reaction rims where galena veins sphalerite and partly replaces it. One specimen consists almost entirely of pyrite, with small amounts of galena, chalcopyrite, tetrahedrite and sphalerite occupying fractures and intergranular spaces; this specimen may correspond to the pyritic ore reported by Waller (1902) from the lower levels.

Zeehan (Mount Zeehan or New Mount Zeehan) Mine

The lodes were more or less vertical, trending NNE or NNW within the Crimson Creek Formation. To the south and east, the Cambrian rocks are faulted against the Crotty Quartzite, and to the north-east the Despatch Fault separates them from the Gordon Limestone.

Samples collected by excavating the dumps near the main shaft contained galena and resinous sphalerite in a siderite gangue, agreeing with the early descriptions. Some specimens are pyritic and contain abundant fine-grained arsenopyrite.

The siderite is intimately intergrown with quartz, and contains patchy, ragged inclusions of sphalerite. The sphalerite contains abundant, bleb-like bodies of chalcopyrite and, less commonly, pyrrhotite. These are concentrated adjacent to grain boundaries and particularly adjacent to siderite contacts; some minor fine-grained pyrite also occurs at siderite-sphalerite interfaces.

Patches of galena replace both siderite and sphalerite. Inclusions of bournonite and some tetrahedrite are abundant within the galena, which also contains small, irregular patches of chalcopyrite. The latter patches are particularly common as rims along galena-sphalerite contacts, where the smaller blebs in the sphalerite have apparently coalesced into larger areas as the sphalerite was progressively replaced.

Euhedral crystals of arsenopyrite, up to 50μ wide, are scattered through both sphalerite and siderite.

Zeehan Bell Mine

The mine was also known as Bell, and in the period 1889-1895, as Silver Bell.

The host rocks are buff, grey and greenish grey shale, siltstone and sandstone comprising part of the Bell Shale Formation. Montgomery (1895) described the veins as containing 'banded and brecciated siderite, quartz, blende, pyrite, galena etc.'

Smelters treating stannite ore from the Oonah mine were located in the vicinity of the Zeehan Bell mine, and as a result, it is difficult to be certain of the origin of much of the adjacent dump material.

Samples studied during the present investigation included two specimens obtained by trenching by Rio Tinto Exploration Ltd about 1957. These both consisted of granular brecciated intergrowths of sphalerite, siderite and quartz, with minor inclusions of chalcopyrite and galena. The quartz occurs as late transecting veinlets which also include much of the galena. The latter contains scattered inclusions of tetrahedrite, and some minor tetrahedrite also occurs intergrown with larger areas of chalcopyrite. Pyrite is rare, and is largely confined to small grains at galena-sphalerite boundaries.

REFERENCES

BARTON, P.B.; BETHKE, P.M.; TOULMIN, P. 1963. Equilibria in ore deposits. *Spec.Pap.Miner.Soc.Am.* 1:171-185.

BARTON, P.B.; TOULMIN, P. 1966. Phase relations involving sphalerite in the Fe-Zn-S system. *Econ.Geol.* 61:815-849.

BATEMAN, A.M. 1956. *Economic mineral deposits*. 2 ed. Wiley : New York.

BLISSETT, A.H. 1961. Stormsdown mine, Zeehan (R. Fieldhouse and D. Dunkley). *Tech.Rep.Dep.Mines Tasm.* 5:26-29.

BLISSETT, A.H. 1962. One mile geological map series. K/55-5-50. Zeehan. *Explan.Rep.geol.Surv.Tasm.*

BOTH, R.A. 1966. *The zoned ore deposits of the Zeehan mineral field*. M.Sc. Thesis. University of Tasmania : Hobart.

BOTH, R.A.; WILLIAMS, K.L. 1968. Mineralogical zoning in the lead-zinc ores of the Zeehan field, Tasmania. Part I. Introduction and review; Part II. Paragenetic and zonal relationships. *J.geol.Soc.Aust.* 15:121-137; 217-244.

BRETT, R. 1964. Experimental data from the system Cu-Fe-S and their bearing on exsolution textures in ores. *Econ.Geol.* 59:1241-1269.

EDWARDS, A.B. 1951. Some occurrences of stannite in Australia. *Proc.australas. Inst.Min.Metall.* 160-161:5-59.

EDWARDS, A.B. 1954. *Textures of the ore minerals and their significance*. 2 ed. Australasian Institute of Mining and Metallurgy : Melbourne.

FLEISCHER, M. 1955. Minor elements in some sulfide minerals. *Econ.Geol.*, 50th Anniv. Vol:970-1024.

GILL, J.E. 1941. Fault nomenclature. *Trans.R.Soc.Can.*, Sect. IV (3) 35:71-85.

JACK, R. 1961. Report on the Oceana mine, Zeehan. *Tech.Rep.Dep.Mines Tasm.* 5:77-88.

KING, D. 1961. *A statistical and geological review of the Zeehan silver-lead mines, West Tasmania*. Rio Tinto Australia Exploration Pty Ltd. (Unpubl.)

LYALL, K.D. 1966. The origin of mechanical twinning in galena. *Am.miner.* 51: 243-247.

MONTGOMERY, A. 1890. Report on the state of the mining industry on the West Coast. *Rep.Secr.Mines Tasm.* 1889-90:3-18.

MONTGOMERY, A. 1895. Report on the progress of the mineral fields in the neighbourhood of Zeehan. *Rep.Secr.Mines Tasm.* 1894-95:vii-li.

PALACHE, C.; BERMAN, H.; FRONDEL, C. 1944. *Dana's system of mineralogy*. 7 ed. Vol. 1. Wiley : New York.

PARK, C.F. 1955. The zonal theory of ore deposits. *Econ.Geol.*, 50th Anniv. Vol:226-248.

PETTERD, W.F. 1910. *Catalogue of the minerals of Tasmania*. Department of Mines, Tasmania.

RAMDOHR, P. 1960. *Die Erzmineralien und ihre Verwachsungen*. 3 Aufl. Akademie-Verlag : Berlin.

REID, A.M. 1925. Report of the Swansea Mine, Zeehan. *Unpubl.Rep.Dep.Mines Tasm.* 1925:22-25.

SCHOUTEN, C. 1934. Structures and textures of synthetic replacements in "open space". *Econ.Geol.* 29:611-658.

SOLOMON, M. 1965. Geology and mineralization in Tasmania. *Publ.8th commonw. Min.Metall.Congr.* 1:464-477.

STANTON, R.L. 1964. Mineral interfaces in stratiform ores. *Trans.Instn Min. Metall.* 74:45-79.

STILLWELL, F.L. 1947. Lead ore specimens from the Spray mine, Zeehan, Tasmania. *Mineragr.Invest.C.S.I.R.O.* 365.

STILLWELL, F.L. 1950. Test products from lead ore, Zeehan. *Mineragr.Invest. C.S.I.R.O.* 459.

TWELVETREES, W.H.; WARD, L.K.; 1910. The ore bodies of the Zeehan field. *Bull.geol.Surv.Tasm.* 8.

WALLER, G.A. 1902. *Report on the Western silver mine, Zeehan.* Mines Department, Tasmania.

WALLER, G.A. 1903. *Report on the iron and zinc-lead ore deposits of the Comstock district.* Mines Department, Tasmania.

WALLER, G.A. 1904. *Report on the Zeehan silver-lead mining field.* Mines Department, Tasmania.

WILLIAMS, K.L. 1958. Nickel mineralization in western Tasmania, *in: F.L. Stillwell Anniversary Volume:* 263-302. Australasian Institute of Mining and Metallurgy : Melbourne.

WILLIAMS, K.L. 1959. *The mineralogy of some Tasmanian nickel deposits.* M.Sc. thesis. University of New England : Armidale.

WILLIAMS, K.L. 1968. *Hydrothermal zoning: a study of the lead-zinc ores of Zeehan, Tasmania.* Ph.D. thesis. Australian National University : Canberra.

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OTHER PUBLICATIONS

A one inch to one mile Geological Map (50¢) and Explanatory Report ($1.00) of the Zeehan area were published in 1962.

A complete list of publications may be obtained from:

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