Silver King Mine

The workings of the Silver King Mine are located near the southern limit of the township of Zeehan. The main shaft is situated about 150 yards west of the former Zeehan-Strahan railway and about 700 yards south of the Zeehan station.

Blissett (1962) has described the host rocks as "grey and green fossiliferous shale or slate, siltstone and pale grey sandstone forming the lower part of the Devonian Bell Shale, near the western limb of the Zeehan Syncline."

Waller (1904) reported the presence of several parallel lodes in the area, and described them as well-defined fissure lodes containing abundant siderite with galena, sphalerite, pyrite and chalcopyrite. The main lode was worked by means of a shaft, which was sunk to 250ft., with three levels, viz. No. 1 (106ft.), No. 2(176ft.) and No. 3 (246ft.). According to Waller, the silver content of the ore was consistently low, and ore from No. 3 Level assaying 70 to 75% lead carried only 25ozs. of silver per ton.

Blissett (1962) has reported that little mineralization was found in a series of boreholes drilled by Zeehan Explorations in 1947. According to Blissett the best intersection was over a width of 18 inches which assayed 47.5% lead, 5% zinc, 0.06% antimony and 17.6ozs. of silver per ton. This intersection was 10 to 20 feet below No. 3 (246ft.) Level and 150 feet south of the main shaft.

One specimen of high grade lead ore (P.232) was obtained

from the Department of Mines collection; other specimens were collected from the dumps near the workings.

The specimens consist essentially of galena with variable amounts of sphalerite in a gangue of siderite and quartz. Minor chalcopyrite, tetrahedrite, pyrite and bournonite were also observed in polished sections.

Galena is the major metallic constituent of most of the samples and occurs with siderite as irregular veins and patches in dark siltstone, shale and slate. Fractured fragments of these rocks are often present within the larger patches of the ore and gangue minerals. These fragments, generally less than 1sq.cm. in area, appear to have been extensively corroded by the vein minerals.

Tetrahedrite inclusions in the galena are common in most specimens and abundant in others (eg. P.39,232). These inclusions are generally of irregular shape, and range in size from 0.02mm. up to 0.08mm., but occasional larger areas, up to a maximum of 0.5mm x 0.3mm., are present in some specimens (eg. P.39, 40). These areas of tetrahedrite contain ovate inclusions of galena and also irregularly shaped inclusions of chalcopyrite. The chalcopyrite-tetrahedrite relationship is reversed in some specimens (P.37,40) where chalcopyrite is present as small areas containing inclusions of tetrahedrite. The relatively high tetrahedrite content of the galena in these samples is not in keeping with the comments by Waller (1904) on the low silver content of the ore, and it may be that these samples are not truly representative.

Bournonite was not observed in most specimens but is present in P.232 as abundant fine inclusions which range in shape and size from fine round bodies, 0.001mm in diameter, up to irregularly shaped bodies measuring 0. 1mm x 0.05mm. Some composite bournonite-tetrahedrite inclusions were also noted in the galena in this specimen.

Sphalerite is commonly associated with the galena as small areas and inclusions which appear to have undergone extensive replacement by the galena. The galena : sphalerite ratio varies considerably between specimens; galena is normally the more abundant of the two minerals, but sphalerite is the dominant component in P.144. Some sphalerite exhibits well-defined growth zoning (eg. P.37,144). A sphalerite-siderite vein in siltstone in Ts.36 consists of well-formed zoned crystals of sphalerite lining the edges of the vein with siderite present in the core. The width of the vein is 2mm., and individual sphalerite crystals are up to 0.5mm.

Chalcopyrite blebs are present in most of the sphalerite in these specimens (eg. P.37) and often show alignment along crystallographic planes.

Pyrite is not common in these ore specimens and is generally present as fine idiomorphic crystals (0.02mm. to 0. 1mm.) distributed through the galena and sphalerite.

Assemblages of ore minerals.

Common:	Galena - sphalerite
	Galena - tetrahedrite
	Chalcopyrite - sphalerite
	Chalcopyrite - tetrahedrite
	Chalcopyrite - galena
Infrequent:	Bournonite - galena
	Bournonite - galena - tetrahedrite
	Chalcopyrite - galena - sphalerite
	Chalcopyrite - galena - tetrahedrite
	Chalcopyrite - sphalerite - tetrahedrite
	Galena - pyrite
	Galena - pyrite - sphalerite
	Galena - sphalerite - tetrahedrite
	Pyrite - sphalerite

South King Workings

Workings to the south of the Silver King Mine were known as the South King workings. These are a short distance to the north of the Zeehan Bell Mine, and the orebody was originally worked from the No. 1 Level of that mine.

Waller (1904) described the ore shoot as "one of the most massive bunches of galena which has been mined in Zeehan". According to Waller the shoot reached a maximum width of 14 feet and contained about 50% galena. The ore carried about 45ozs. of silver per ton.

Further workings, known as Fahey's tribute, were located 400 feet north of the Zeehan Bell boundary. Fahey and party worked a large gossan formation which, according to Waller (1904) was 122 feet long and, at the depth of 30 feet, was 21 feet wide. The average silver content of the gossan was reported to be 90ozs. per ton, and 25 tons of copper ore (largely in the form of malachite) assaying 17% copper were sold. At a depth of 30 feet the gossan gave way to 4 feet of galena, assaying 100 ozs. of silver per ton, which continued to a depth of 90 feet.

The Tasmanian Museum collection contains one specimen of copper ore from the gossan formation. This specimen (X.5176/P.227) consists largely of malachite and azurite with fine covellite, chalcocite, limonite and clay material.

Zeehan Bell Mine

The workings of the Zeehan Bell Mine (also known as the Silver Bell Mine) are located south of the Silver King Mine. The main shaft is situated approximately ¾-mile east of the Silver King Mine, and approximately ½-mile east of the former Zeehan-Strahan railway.

The host rocks were described by Blissett (1962) as "grey and greenish-grey fossiliferous calcareous shale and siltstone with bands of pale-weathering sandstone forming part of the Devonian Bell Shale."

The main workings consist of a shaft and levels at 115ft. and 180ft. The ore-body is apparently a continuation of the lode worked in the South King workings.

Montgomery(1895) described the lode as consisting of "banded and brecciated siderite, quartz, blende, pyrite, galena, etc." The silver content was reported by Montgomery (1893) and Twelvetrees (1901a) as being rather low. Montgomery (1893) reported that 450 tons of ore sent to the Mount Zeehan Mill yielded 116tons of concentrate assaying 70% lead and only 30 ozs. of silver per ton. Tilley (1891, p.59) stated that 16 assays "of all classes of the ore" averaged 47% lead and 45ozs. of silver per ton. Twelvetrees (1901) noted that the zinc concentration of the lode was reported to increase going south.

Blissett (1962) has recorded that six boreholes drilled by Zeehan Explorations in 1947 intersected little mineralization. The highest assay was 13% lead, 12.9% zinc, and

4.3ozs. of silver per ton, over a drilled width of four feet.

The only samples which could be obtained for mineralogical examination were collected from dumps near the workings. The mineral constituents of these samples appear to be consistent with the brief descriptions referred to above, but the proportions differ. Galena is far less abundant than it apparently was in the ore mined, and the abundance of pyrite in the dump samples is probably misleading. The main constituents of the samples are pyrite and sphalerite in quartz and siderite gangue. Minor constituents are galena, chalcopyrite, arsenopyrite, tetrahedrite, stannite and cassiterite, with traces of bismuthinite and covellite.

Many of the dump specimens consist largely of either massive pyrite and quartz or massive siderite with sphalerite. The pyritic material consists of aggregates of idiomorphic and subidiomorphic pyrite crystals in a matrix of quartz. The pyrite crystals range from 0.05mm. to at least 3mm. in size. Arsenopyrite is often associated with the pyrite as idiomorphic crystals up to 0.5mm.

The pyrite, arsenopyrite and quartz can be seen, in polished section, to have undergone intensive fracturing, and many of the fractures are occupied by chalcopyrite, tetrahedrite and stannite.

Chalcopyrite is a prominent minor constituent of the pyritic samples, and in addition to occupying fractures,

chalcopyrite forms occasional irregularly shaped patches of up to 1cm. in overall width.

Tetrahedrite is often associated with the chalcopyrite, both in the veins within the fractured pyrite and in the larger areas of chalcopyrite. The tetrahedrite occurs as inclusions forming an intergrowth with the chalcopyrite, the size of most of the inclusions being less than 0.1mm. In some specimens (eg.P.230) the chalcopyrite contains extremely fine rod-like exsolution bodies of tetrahedrite with lengths of 0.001mm and less. Tetrahedrite also forms occasional larger areas, up to a maximum of 0.5mm. x 0.3mm., within the chalcopyrite. These areas contain inclusions of chalcopyrite, galena and (rarely) bismuthinite.

Stannite is a very minor constituent overall, but is conspicuous in occasional specimens (eg. P.26,230) as inclusions within the chalcopyrite and also within the pyrite. The inclusions of stannite within the chalcopyrite reach a maximum observed size of 0.3mm. x 0.2mm., but are generally no greater than 0.075mm. The larger inclusions contain fine veinlets and blebs of chalcopyrite. The stannite inclusions in the pyrite crystals range from 0.01mm. to 0.05mm., are irregular in outline, and have the appearance of having partially replaced the pyrite.

Sphalerite is present as occasional small areas, up to several millimetres in width, in the pyritic material but is more common in the samples of massive siderite. The sphalerite associated with the pyrite is moderately dark in

colour, whereas that in the siderite is considerably lighter and often shows well-defined growth zoning (eg. P.181/Ts.17). Some of the sphalerite in the pyritic specimens is associated with chalcopyrite, and occurs as irregularly shaped inclusions ranging from 0.005mm. up to 0.07mm. Very fine star- and cross-shaped exsolution bodies of sphalerite within the chalcopyrite were occasionally noted (P.31). Chalcopyrite blebs are common in the sphalerite associated with pyrite, but are more sporadically distributed in the sphalerite in siderite. Alignment of the blebs along crystallographic planes in the sphalerite is frequently observed. The sphalerite associated with the siderite gangue forms clusters of idiomorphic and subidiomorphic crystals (up to 0.5mm.) and broad patches and bands within the siderite. Galena is frequently associated with this sphalerite.

Galena, as stated above, is not common in these specimens and occurs mainly as small areas, no greater than a few millimetres in width. Although the proportion of galena in these samples is obviously not representative of the ore, there is sufficient present to indicate the textural relationships with the other constituents. Galena, like the sphalerite, is more common in the sideritic material than the pyritic material. It is noticeable that very little tetrahedrite is associated with the galena. As described above, tetrahedrite is more frequently associated with the chalcopyrite in these samples, and this feature would account for the low silver content obtained in the galena concentrates. This tendency for the tetrahedrite to be associated

with the chalcopyrite is unusual in the Zeehan ores. The inclusions of tetrahedrite that were observed within the galena are round and ovate in shape and range from 0.01mm up to 0.12mm.

Bismuthinite is present in some of the specimens (eg. P.31, 230) as rare clusters of needle-like bodies associated with tetrahedrite, chalcopyrite and galena.

A little cassiterite was noted in the pyritic material, occurring as fine crystals (0.03mm. to 0.075mm.) in the interstitial spaces within groups of pyrite crystals.

A trace amount of covellite is present in the chalcopyrite in P.26.

Assemblages of ore minerals.

Common:	Chalcopyrite - pyrite
	Chalcopyrite - sphalerite
	Galena - sphalerite
	Arsenopyrite - pyrite
	Pyrite - sphalerite
	Chalcopyrite - tetrahedrite
	Arsenopyrite - chalcopyrite - pyrite
	Galena - pyrite
Infrequent:	Arsenopyrite - chalcopyrite
	Arsenopyrite - chalcopyrite - tetrahedrite
	Cassiterite - pyrite
	Chalcopyrite - galena
	Chalcopyrite - galena - sphalerite - tetrahedrite
	Chalcopyrite - galena - tetrahedrite
	Chalcopyrite - pyrite - sphalerite
	Chalcopyrite - pyrite - tetrahedrite
	Chalcopyrite - stannite
	Galena - pyrite - sphalerite
	Galena - sphalerite - tetrahedrite
	Galena - tetrahedrite
	Pyrite - stannite
	Sphalerite - tetrahedrite
Rare:	Bismuthinite - chalcopyrite
	Bismuthinite - chalcopyrite - tetrahedrite
	Bismuthinite - galena - tetrahedrite
	Chalcopyrite - stannite - tetrahedrite
	Chalcopyrite - covellite

Sunrise Mine

The workings of the Sunrise Mine are located near the Little Henty River, approximately ¼-mile south-east of the Zeehan Bell Mine.

The mineralization is found within rocks of the Devonian Bell Shale, as at the Zeehan Bell Mine.

The workings were referred to briefly by Montgomery (1893) and were later described by Twelvetrees and Ward (1910). The ore-bodies were worked by means of two shafts. The first shaft was situated on the eastern side of the Little Henty River, in a sharp bend of the river. Montgomery (1893) reported that about thirty tons of ore, assaying from 69% to 73% lead and 80ozs. to 90ozs. of silver per ton, had been produced from these workings.

The other shaft was located on the western side of the river. The only reported production from these workings consisted of two parcels of ore totalling 8½tons. One parcel assayed 57.3% lead and 104 ozs. of silver per ton, the other 39% lead and 106.7ozs. of silver per ton. One vein, intersected in a crosscut at a depth of 107 feet, contained massive tetrahedrite with galena, and, according to Twelvetrees and Ward (1910), picked samples of this ore assayed 50.6% lead, 404ozs. of silver per ton, and 9.02% copper.

The only two specimens available from the Sunrise Mine were obtained from the collection of the Tasmanian Museum and the Queen Victoria Museum (Launceston). No material

of use was found in the dumps.

One of these specimens (P.224) consists entirely of coarse, well-crystallized galena. The individual cubic crystals have sides up to ½-inch in length, and no other minerals were observed either in hand specimen or polished section.

The other specimen (P.220, 221, 259) consists largely of massive siderite with included patches of grey siltstone, and one patch, several inches in width, of light brown sphalerite (P.220, 259) with a little associated galena. The sphalerite has apparently been replaced by the galena, which occurs throughout the sphalerite as irregularly shaped areas. Tetrahedrite inclusions are common in the galena as bodies of irregular shapes ranging in size from 0.02mm. to 0.1mm. Pyrite is disseminated through the sphalerite and galena as fine idiomorphic crystals, and also occurs in the sphalerite as narrow veinlets of very fine crystalline pyrite. This latter form of pyrite has been noted in sphalerite from some other mines in the district (eg. T. L. E., Stonehenge, and Despatch Mines). Blebs of chalcopyrite are present in the sphalerite, but are not common and occur only in occasional isolated groups in which the individual blebs range from 0.001mm. to 0.01mm. and show no particular orientation or alignment.

This specimen also contains several vughs which are lined by fine crystalline sphalerite, pyrite, quartz and siderite. Examination of a polished section (P.221) of

material from one of the vughs reveals that the pyrite is present as allotriomorphic granular material with a little chalcopyrite along intergranular boundaries. The sphalerite in the vughs is slightly darker than that of the coarser material, but the content of chalcopyrite blebs is again low.

Assemblages of ore minerals.

Common:	Galena - sphalerite
	Galena - tetrahedrite
	Pyrite - sphalerite
Infrequent:	Chalcopyrite - pyrite
	Chalcopyrite - sphalerite
	Galena - pyrite
	Galena - pyrite - sphalerite
	Galena - sphalerite - tetrahedrite

Austral Valley

The workings of several small mines are located in Austral Valley, which lies south of the Zeehan township and south-east of Manganese Hill. The mines in this area include the Maxim, Watt and McAuliffe's, North Austral, Austral, Montagu No. 1, and Central Balstrup mines. With the exception of the Central Balstrup Mine, the ore from these mines is essentially similar and the mineralogy can be covered by a single description.

The following description of the geology of the area is condensed from Blissett (1962).

The Balstrup Fault Zone, striking a little north of west, passes through the valley, bringing shattered sandstone and grit of the Crotty Quartzite in the north against decomposed greywacke and siltstone of the Crimson Creek Formation. To the south the Crimson Creek Formation overlies Oonah Quartzite and Slate.

The Montagu No. 1 Mine is located within the Crotty Quartzite. The workings of the Maxim, Watt and McAuliffe's, and North Austral Mines are all located within the Crimson Creek Formation.

North of the Montague No. 1 Mine, the Crotty Quartzite is faulted against the Devonian Florence Quartzite, and north of Watt and McAuliffe's Mine the Crimson Creek Formation is in faulted contact with the Florence Quartzite.

The Austral Mine, on the southern side of the valley is situated within disturbed and faulted grits and quartz

conglomerate of the Ordovician Caroline Creek Sandstone. This is overlain to the east by the Gordon Limestone, and to the north is in faulted contact with the Crimson Creek Formation.

Waller (1904) reported on some of these mines and it is apparent from Waller's descriptions that the numerous ore-bodies in the area were fissure lodes consisting essentially of variable amounts of galena in a siderite gangue. Little has been published on the silver content of the ore, but Waller reported that a small parcel of ore from Glock's West Lode (Maxim Mine) assayed 108ozs. of silver per ton. Petterd (1910) recorded that "fairly large quantities" of cerussite were mined from the Austral Mine.

Samples collected from the dumps of the mines in Austral Valley show no significant variation in mineralogy between the mines concerned. The samples consist largely of massive siderite with seams and patches of galena, and occasional small patches of sphalerite. Minor constituents observed in polished sections were chalcopyrite, pyrite, tetrahedrite and bournonite.

Galena is common in most of the siderite as fine veins and small irregularly shaped areas, but coarse crystalline galena is also present in some specimens (eg. P.42), with individual crystals up to ¼-inch. The galena has a high content of tetrahedrite which is present throughout the galena as inclusions ranging from 0.005mm. up to 0.5mm. The finer bodies are generally round or ovate, and the shape becomes less regular with increasing size. Sub-graphic

intergrowths of galena and tetrahedrite can occasionally be observed (eg. P.44).

Bournonite is present in much of the galena as very fine (0.0005mm. to 0.03mm.) inclusions. These bodies are generally round or ovate and are very common in some specimens (eg. P.42, 43). Rare composite bournonite-tetrahedrite inclusions are also present.

Sphalerite is a minor constituent of most samples and occurs as small areas which have apparently been extensively replaced by the galena, and as irregularly shaped clusters of crystals in the siderite. Many of these crystals show clearly defined growth-zoning (eg. Ts.42;Plate 9, No. 2). Some specimens (eg. P.45) contain areas of pale-brown sphalerite up to one inch in overall width. The sphalerite in all specimens contains sporadically distributed fine blebs of chalcopyrite. These blebs occur in clusters but individual blebs show no alignment.

Pyrite is present as fine idiomorphic and subidiomorphic crystals, ranging in size from 0.02mm. to 0.08mm., distributed through the galena, sphalerite and siderite. Pyrite is not a common constituent overall but in some specimens (P. 44, 259) is concentrated into clusters of subidiomorphic crystals in sphalerite.

Assemblages of ore minerals.

Common:	Galena - sphalerite
	Galena - tetrahedrite
	Bournonite - galena
Infrequent:	Chalcopyrite - galena
	Chalcopyrite - galena - pyrite
	Chalcopyrite - galena - tetrahedrite
	Chalcopyrite - sphalerite
	Chalcopyrite - tetrahedrite
	Galena - pyrite
	Galena - pyrite - tetrahedrite
	Galena - sphalerite - tetrahedrite
	Pyrite - sphalerite
Rare:	Bournonite - galena - tetrahedrite

Central Balstrup Mine

The Central Balstrup lease covered an area located in the western part of Austral Valley, and the workings of the Central Balstrup Mine are located approximately ½-mile south-east of Manganese Hill.

The ore bodies in this area occur within the Silurian Crotty Quartzite, which is faulted to the west and south against greywacke and shale of the Crimson Creek Formation (Blissett, 1962).

Several veins of siderite with galena were recorded by Twelvetrees and Ward (1910), who considered the veins to be part of the one lode system. Twelvetrees and Ward also reported that near the southern boundary of the lease a shaft 20 feet deep intersected ore containing "niccolite and ruby silver ores in addition to galena and some antimonial lead ore in a gangue of siderite". According to Twelvetrees and Ward, this ore assayed up to 30% nickel and 530ozs. of silver per ton. There is no record of the extent of the lode, but Blissett (1962) estimated that ore sold would not have exceeded 25 tons.

This nickel ore has been described by Williams (1958), who reported on the mineralogy of two specimens in the collection of the National Museum of Victoria. Williams made a detailed mineragraphic and X-ray diffraction study of the specimens and a summary of Williams' description is given below.

Williams found that the main constituent of each specimen

is niccolite, which occurs as mosaics of interlocking grains ranging from 0.1mm. to 0.3mm. in diameter. Maucherite is intergrown with the niccolite and occurs in areas up to 0.5mm. wide. Williams noted that some of these areas of maucherite consist of aggregates of smaller grains about 0.1mm. in diameter. Intergrown with both niccolite and maucherite is gersdorffite. This mineral is present as irregular veinlets up to 0.15mm. in width and as fine rounded and elongated blebs ranging from 0.01mm. down to a few microns in diameter. Williams considered the intergrowth of the blebs of gersdorffite in niccolite to be suggestive of a "pseudo-eutectic graphic texture."

Other sulphides associated with the nickel arsenides in these specimens are galena, pyrite, sphalerite and chalcopyrite. The pyrite was reported to occur as irregular grains, some of which are enclosed by niccolite. Sphalerite and chalcopyrite were described as minor constituents occurring as scattered irregular areas normally less than 0.2mm. in width and also, rarely, as minute veinlets in niccolite and gersdorffite. Sphalerite is also present as patches up to 5mm. in diameter and some of these patches contain exsolution bodies of chalcopyrite. Galena is more abundant than the sphalerite and chalcopyrite, and was reported by Williams to have replaced both of these minerals. A minor amount of marcasite was also reported as narrow veinlets in niccolite.

In addition to the nickel arsenides described above,

Williams identified minor amounts of the nickel-bearing sulphides hauchecornite (of Harcourt, 1942) and violarite. The hauchecornite was observed in one polished section as a small veinlet, 0.05mm in width and 0.3mm in length, within niccolite. In another specimen, the same mineral was reported by Williams to occur as small areas, up to 0.1mm in width, enclosed by galena. The violarite was reported as a narrow vein, up to 0.2mm in width, in one specimen only and Williams considered it to be pseudomorphous after pentlandite.

The secondary nickel arsenate, annabergite, was identified as a coating on both specimens.

An examination by the present author, of two further specimens, one each from the collections of the Tasmanian Museum and the Queen Victoria Museum, has provided some additional information on the mineralogy of the Central Balstrup ore.

The niccolite occurs as nodules ranging in diameter from 0.02mm up to 0.1mm. The smaller nodules often occur as clusters of nodules and nodular aggregates. Minor amounts of maucherite are present as fine intergrowths within the niccolite. In P.46 and 47(prepared from specimen X.314) the niccolite nodules are surrounded by, and apparently partially replaced by, a white mineral which is almost isotropic. A very weak anisotropism can be detected under oil immersion. A small amount of this material was drilled from the polished surface under the microscope to ensure a pure sample, and an X-ray powder diffraction photograph gave the pattern shown in Table 4. This pattern indicates that the material contains

two closely related phases, both of which are members of the gersdorffite-ullmannite series (NiAsS - NiSbS). With the exception of the higher d-values, the other lines occur in pairs. A comparison with the data of Berry and Thompson (1962) suggests that both phases approach the intermediate member "corynite" (arsenian ullmannite, Ni(As,Sb)S) in composition, but one phase appears to be between gersdorffite and "corynite" in composition, while the other phase is between "corynite" and ullmannite. Both phases can be indexed on a cubic lattice. A re-examination of the polished section using high magnification and oil immersion revealed very slight colour variations in a fine intergrowth pattern in the material which had been thought to be homogeneous. Etching with 1:1 nitric acid merely caused an iridescent stain on the surface and did not reveal any pattern of compositional variation. Attempts to drill samples for X-ray from the two different phases in the intergrowth were unsuccessful because of the extremely fine nature of the intergrowth.

Similar material is again present in P.217 and P.218 (prepared from specimen 1956:33:71) but shows growth zoning marked by very slight colour variations (Plate 10, No. 1). This zoning is accentuated by etching with 1:1 nitric acid (Plate 10, No. 2). Although the bands of different colour are, presumably, due to slight variations in composition, an X-ray powder diffraction photograph of a sample which

TABLE 4

Comparison of X-ray powder diffraction data of nickel minerals from Central Balstrup Mine, Zeehan, with data of Berry and Thompson (1962)

Gersdorffite* NiAsS Crean Hill, Sudbury, Ontario.		Ullmannite* NiSbS Salchendorf, Westphalia.		"Corynite" (Arsenian Ullmannite)* Ni(As,Sb)S Olsa, Carinthia			Central Balstrup Mine, Zeehan, (P.46)		Central Balstrup Mine, Zeehan, (P.217)	
d(meas,Å)	I	d(meas,Å)	I	d(meas,Å)	I	h,k,l	d(meas.,Å)	I	d(meas.,Å)	I
		4.17	3	4.10	3	011	4.09	M	**	
		3.40	1	3.34	1	111	3.34	tr.	**	
2.81	6	2.94	2	2.88	6	002	2.88(B)	M	2.85	W
2.51	9	2.64	10	2.59	10	012	2.59 2.56	S S	2.53	M
2.30	8	2.40	6	2.35	6	112	2.37 2.33	M M	2.32	M
1.994	3	2.08	2	2.04	3	022	2.05 2.02	tr. tr.	2.02	W
		1.863	1	1.821	1	013				
1.710	10	1.774	7	1.737	8	113	1.750 1.723	M M	1.713	M
1.629	2	1.701	1	1.661	2	222	1.681 1.653	tr. tr.		
1.566	6	1.631	4	1.598	4	023	1.613 1.589	W W	1.574	W
1.508	7	1.573	5	1.540	5	123	1.553 1.528	W W	1.519	M

* Data from Berry and Thompson (1962)

** X-ray diffraction photographs very dark in this region due to long exposure time required for small amount of material

Intensities for Central Balstrup patterns; S = strong, M = medium, W = weak, tr. = trace, B denotes broad line.

included material from several successive bands gave a pattern typical of only one mineral. The pattern is shown in Table 4, where it is compared with the sample from P.46 and data of Berry and Thompson (1962). A comparison of the data shows that this mineral is again intermediate in composition between gersdorffite and the "corynite" of Berry and Thompson, and is, therefore, similar to one of the phases in the material in P.46. Attempts to take X-ray photographs of material from the different colour bands were not successful, the bands being too narrow to provide sufficient amounts of pure material for satisfactory photographs.

Associated with the gersdorffite-ullmannite is a slightly whiter mineral showing moderately strong anisotropism, fine lamellar twinning and (rarely) growth zoning on a very fine scale. Etching with 1:1 nitric acid produces a strong effervescence and accentuates the growth-zoning, when present. This mineral is sometimes present as narrow borders (usually 0.01mm in width) separating the niccolite nodules from the gersdorffite-ullmannite material (Plate 11, No. 1), and appears to have partially replaced the niccolite. The same mineral also occurs as fine intergrowths with the gersdorffite-ullmannite, and the areas of gersdorffite-ullmannite in P.217 which show growth-zoning often have a central core of this mineral (Plate 10, Nos. 1 and 2). X-ray powder diffraction photographs of this mineral (see Table 5) have shown it to be rammelsbergite ($NiAs_2$).

Hauchecornite and violarite, noted by Williams (op.cit)

TABLE 5.

X-ray powder diffraction patterns for rammelsbergite.

Central Balstrup Mine, Zeehan.		Eisleben, Thuringia, Germany (Berry and Thompson, 1962)	
d(meas.,Å)	I	d(meas.,Å)	I
3.65	W	3.69	1
		3.02	½
2.85(B)	S	2.84	5
2.56	S	2.56	10
2.46	S	2.49	8
2.33	tr.	2.40	½
2.18	tr.	2.22	¾
2.02	tr.	2.04	¾
1.865	M	1.877	7
1.791	W	1.804	½
1.743	W	1.765	1½
1.692	W	1.698	3
1.626	tr.	1.639	¾
1.598	tr.	1.598	1½
1.518	tr.	1.540	¾
		1.510	¼
1.451	W	1.443	2

Intensities from Central Balstrup pattern:

S = strong, M= medium, W = weak, tr. = trace

B denotes broad line.

were not observed in either of these specimens. However, tetrahedrite was observed as small inclusions within galena and as small veins and irregularly shaped inclusions within the various nickel minerals and fine inclusions of proustite were observed within the niccolite and gersdorffite-ullmannite in P.217 and 218. This identification of proustite is based upon the optical properties. The colour is very similar to that of pyrargyrite observed in galena from some mines in the Zeehan field, but the bireflectance is more pronounced, giving a colour change from blue-grey to brownish-grey. Internal reflections are intense and typical fiery-red in colour. These proustite inclusions are up to 0.03mm. in size and are ovate to irregular in shape.

There is clearly scope for further mineralogical work on the nickel minerals in this ore, particularly on the gersdorffite-ullmannite material. Williams (op. cit.) has identified gersdorffite and the present author has demonstrated the presence of at least two intermediate members of the gersdorffite-ullmannite series, but the extent of the compositional variations is unknown. The finely intergrown nature of the minerals proved to be a serious hindrance in attempts to carry out precise identification. Material drilled from the polished sections was examined by X-ray powder diffraction photography, but to ensure pure samples only very small amounts of material could be obtained for any one sample. This necessitated long exposure times but, even so, the back reflection lines in the photographs were

not satisfactory for unit-cell edge measurements.

Future investigations should be directed towards determinations of the actual chemical composition of the phases of the gersdorffite-ullmannite series present in this ore.

Petterd (1910, p.32, 48) reported the presence of breithauptite and chloanthite at the Central Balstrup Mine, and quoted the following analysis, by W. F. Ward, for the breithauptite.

Ni	34%
As	23%
Sb	37%

This analysis does not compare favourably with the analyses listed by Palache et al. (1944), which show breithauptite to conform to the formula NiSb, with little or no arsenic.

Specimen X.314 of the Tasmanian Museum collection was labelled "Breithauptite and Chloanthite", and this is a specimen from the W. F. Petterd Collection. Polished sections P.46 and 47 were prepared from this specimen and, as described above, consist largely of niccolite and gersdorffite-ullmannite. The presence of either breithauptite or chloanthite in the Central Balstrup ore is, therefore, considered to be very doubtful.

Assemblages of ore minerals. *

(based on descriptions by Williams, 1958, and present author).

Common:	Gersdorffite - niccolite
	Gersdorffite - niccolite - rammelsbergite
	Gersdorffite - rammelsbergite
	Maucherite - niccolite
	Gersdorffite - maucherite - niccolite
	Galena - gersdorffite
Infrequent:	Chalcopyrite - galena
	Galena - niccolite - tetrahedrite
	Galena - sphalerite
	Galena - sphalerite - tetrahedrite
	Galena -tetrahedrite
	Galena - gersdorffite - maucherite - niccolite
	Gersdorffite - proustite
	Gersdorffite - tetrahedrite
	Niccolite - proustite
	Niccolite - pyrite
	Niccolite - tetrahedrite
Rare:	Chalcopyrite - gersdorffite
	Chalcopyrite - niccolite
	Chalcopyrite - sphalerite
	Galena - hauchecornite
	Gersdorffite - niccolite - violarite
	Gersdorffite - sphalerite
	Hauchecornite - niccolite
	Marcasite - niccolite
	Niccolite - sphalerite

* The name gersdorffite has been used for all members of the gersdorffite-ullmannite series.

Oceana Mine

The Oceana Mine is situated in the south-east of the Zeehan field, approximately 2 miles south of the township of Zeehan and near the former Zeehan-Strahan train line.

The ore-bodies of the Oceana Mine occur in the Gordon Limestone (Ordovician), and have been described by Jack (1960) as being located along two prominent shears which form part of a zone of intense shearing and local brecciation. According to Jack, this shear zone varies in width from a few inches to 60 feet, and while siderite is found over the whole width, galena mineralization occurs over only half this width and erratically along strike. Jack considers the shearing to be pre-ore and to have provided favourable access for the mineralization.

The ore consists predominantly of galena in a gangue of siderite and quartz, but ore minerals present as minor constituents are sphalerite, tetrahedrite, pyrite, bournonite, chalcopyrite and boulangerite.

The galena is sheared and shows a weak anomalous anisotropism. Present within the galena are abundant fine inclusions of tetrahedrite, bournonite and boulangerite. These inclusions range in size from 0.005mm. up to 0.06mm. and vary in shape from round and ovate to irregular (Plate 11, No. 2). Occasional composite inclusions of bournonite and boulangerite were also observed. There appears to be no tendency for the inclusions of these minerals to occur with any preferred orientation or distribution. Tetrahedrite is

also present as small areas up to 0.5cm., generally associated with chalcopyrite.

Sphalerite occurs as small areas up to 2mm. across within larger areas of massive galena and siderite. The sphalerite invariably shows signs of corrosion by the galena and small "remnants" of the sphalerite are common within the galena. Chalcopyrite is often present as minute exsolution blebs within the sphalerite; these bodies are generally no larger than 0.001mm., and are rarely greater than 0.005mm. Round and elongate blebs are represented, the latter showing a preferred orientation along crystallographic planes within the sphalerite host.

Chalcopyrite was also noted as occasional areas up to 1mm. across, within the galena, and appears to have been extensively replaced by the galena.

Pyrite is not abundant but was observed as small idiomorphic crystals within, and apparently extensively replaced by, galena. A little fine pyrite was also observed within sphalerite and tetrahedrite. The pyrite crystals are rarely greater than 0.02mm.

A single isolated inclusion of graphite was observed within siderite (P.156). This inclusion, measuring 0.2mm. x 0.05mm, contained several very fine inclusions of galena.

Assemblages of ore minerals.

Common:	Galena - tetrahedrite
	Bournonite - galena
	Boulangerite - galena
	Galena - sphalerite
Infrequent:	Boulangerite - bournonite - galena
	Chalcopyrite - galena
	Chalcopyrite - galena - sphalerite
	Chalcopyrite - sphalerite
	Galena - pyrite
	Pyrite - sphalerite
Rare:	Chalcopyrite - galena - tetrahedrite
	Chalcopyrite - sphalerite - tetrahedrite
	Chalcopyrite - tetrahedrite
	Galena - pyrite - sphalerite
	Galena - sphalerite - tetrahedrite
	Sphalerite - tetrahedrite

Tenth Legion Prospect

The Tenth Legion magnetite deposits are located in the Comstock area, approximately one mile north-west of the Silver Stream Mine.

The deposits have been reported on by Waller (1903), Blake (1940) and Hughes (1958). The magnetite was originally believed to have been derived from the Heemskirk Granite (Waller, 1903; Twelvetrees and Ward, 1910) and to be related to the sulphide ores of the Zeehan field. Twelvetrees and Ward (op. cit) placed the magnetite deposits in the "contact metamorphic zone" of the ores in their zonal classification. More recently, Hughes (op. cit) has shown that the magnetite was derived from the serpentinized Cambrian basic intrusion.

The following description of the geology of the area has been taken from Blissett (1962, p.253).

"The magnetite is associated with an intrusive mass of gabbro and amphibolite, probably of late Cambrian age, which has been partly serpentinized and dolomitized. The intrusion was injected into quartzite and slate considered to be of Upper Proterozoic or Lower Cambrian age, which further south are overlain by Lower (?) to Middle Cambrian greywacke, grit and siltstone or shale. After the Tabberabberan orogeny, the Heemskirk Granite was emplaced in Devonian times and the Tenth Legion deposit lies within its contact - metamorphosed aureole. A major fault trending north-west, believed to be Tertiary, downthrows the rock against highly sheared and cleaved Proterozoic quartzite, slate and schist to the north-east.

The basic igneous rocks and the surrounding sediments were contact - metamorphosed by the Devonian Granite. The chief effect was the development of calc-silicate hornfels, partly from the dolomitized serpentine, but also from the alteration of calcareous or dolomitic sediments within the sequence. Irregular patches of diopside occur within dense white calc-silicate hornfels shown by G. Everard (in Hughes, 1958) to consist of granular diopside and sericite. Other minerals include tremolite, actinolite, garnet, epidote, phlogopite, vesuvianite, chlorite and talc."

Hughes (1958) has calculated the ore reserves down to 200 feet as 3,000,000 tons.

The iron is almost entirely in the form of magnetite with minor hematite and limonite. Twelvetrees and Ward (op. cit.) reported traces of pyrite, sphalerite and galena in an exploratory tunnel, but bore logs by Hughes (op. cit.) of two diamond drill holes revealed only occasional traces of pyrite in the magnetite. Table 6, prepared by Blissett (op. cit.) from assays recorded by Blake (1940) and Waller (1903), demonstrates the variations in composition of the ore.

TABLE 6

Analyses of magnetite ore, Tenth Legion Prospect

	% range	Remarks
Fe	48.90-69.10	
SiO_2	0.20-15.04	
Al_2O_3	0.41-3.97	
CaO	Nil - 0.34	
MgO	0.10- 3.68	
MnO	0.19- 2.84	
P_2O_5	Tr.-0.14	
TiO_2	Nil - 0.17	
S	0.01 - 1.43	Only 2 samples over 0.2%
Acid insoluble	0.24-15.36	Only 3 samples over 10%

Waterhouse (1916) and Blake (1940) have reported the presence of several other magnetite bodies around the margins of the granite in the Comstock area. According to Blake, these bodies are short and narrow lenses, contained within serpentine and calc-silicate material.

SUMMARY OF MINERALOGY

In this section the distribution of the various minerals throughout the Zeehan field, and the textural relationships between the ore minerals, are summarized.

The summary involves a certain amount of repetition from the previous section, but the emphasis here is on the distribution of the various ore minerals and the interpretation of some of the textures.

Paragenesis.

Any discussion of textures in ore mineral assemblages must inevitably make reference to the paragenetic sequence of the ore minerals. This postulated sequence has been discussed at length by numerous authors including Newhouse (1928), Bastin(1950), and Edwards (1954), and several mechanisms have been suggested to account for the observed sequence. Edwards (op. cit.) demonstrated the consistency of the paragenetic sequence between mineral deposits, and Gilbert (1924), Newhouse (op. cit.), Bandy (1940), Edwards (op. cit.) and others have commented on the general correlation between the paragenetic sequence and the progressive change in such properties as hardness, melting points, solubility in water, free energies of formation, and cation: anion ratio of the minerals concerned.

Although the paragenesis of ore minerals has been widely accepted for many years, recent work on textures in ore mineral assemblages has cast serious doubts on the conventional interpretations of paragenetic sequences. The

sequence in a given deposit is interpreted from a study of the textures, and whereas it was once generally assumed that replacement of one ore mineral by another was indicative of changing composition in the ore-forming fluids, the recent work of McKinstry and Kennedy (1957) and McKinstry (1959, 1963) has shown that this conception is not necessarily correct. McKinstry and Kennedy have demonstrated that the replacement of one mineral by another can also be explained by changing equilibrium conditions which cause reactions and readjustments between existing minerals. It is, therefore, not necessary to explain all replacement textures by the introduction of new material.

The work of Brett (1964) and Stanton (1964) has cast further doubts on the conventional interpretations of textures.

Brett carried out controlled cooling experiments on solid solutions in the system Cu - Fe - S and produced a wide variety of exsolution textures. Brett's experimental work demonstrated clearly that many veining textures, mutual boundary textures, and textures suggesting replacement processes can be produced by exsolution. Most authorities on the interpretation of ore mineral textures had previously stressed the difficulties involved in the interpretation, and Edwards (op. cit.) realised that the mutual boundaries texture was ambiguous and could be formed by exsolution, simultaneous deposition or replacement. It is, however, clear that several of the exsolution textures produced

experimentally by Brett would previously have been described by most mineralogists as definite replacement textures had they been observed in natural mineral assemblages.

Stanton (op.cit.) has carried out a critical review and examination of textures of minerals in stratiform ores, and has presented convincing evidence that the "paragenetic sequence" observed in these ores is a crystalloblastic series comparable with that of silicate minerals in metamorphic rocks. By means of observations on natural mineral assemblages and synthetically annealed mineral assemblages, and by analogy with metals, Stanton has demonstrated that the textures observed in stratiform ores can be accounted for by growth "in the solid" during diagenesis and metamorphism. Stanton has suggested that interfacial free energies are important in the formation of textures during annealing, and that the resultant grain boundary configurations are due to a tendency towards minimum and equilibrium interfacial free energies. Although Stanton's work was concerned only with stratiform ores, the observation that textures normally accepted as "replacement" can be explained by the mutual interaction of grains growing in the solid from microcrystalline aggregates, suggests that the interpretation of textures in all ores is even more hazardous than previously realised.

The above remarks are not intended to imply that there is no such thing as a replacement texture, but should be regarded as a caution against the tendency to over-simplify the interpretation of ore mineral textures. Replacement textures undoubtedly do exist and Schouten (1934), for example, demonstrated that textures closely resembling exsolution textures could be produced by replacement of one sulphide by another.

The difficulties involved in the interpretation of the textures do not, however, invalidate the concept of a paragenetic sequence. In hydrothermal ores there must be a tendency for minerals to be deposited sequentially, whether this is due to changing composition of the ore-fluids or to changing equilibrium conditions. It is probable that both of these factors operate together in controlling the crystallization of ores from hydrothermal solutions.

Because of the uncertainties in the interpretation of textures, particularly those suggesting replacement, a detailed discussion of the apparent paragenetic sequence of the Zeehan ores is not justified. A conventional interpretation of the paragenesis, with each mineral arranged in order of formation, and with overlapping periods of formation designated, would clearly be quite meaningless on the basis of the present status of ore mineral textures.

A generalized paragenetic sequence is given below. This apparent sequence is regarded as being due to a combination of changing equilibrium conditions and changing composition, with time, in the ore-forming fluids. The sequence can be considered as consisting of three "stages", but the process of mineralization is regarded as having been continuous.

Early:	Pyrite, arsenopyrite, cassiterite, wolframite, quartz.
Intermediate:	Sphalerite, chalcopyrite, pyrrhotite, stannite, siderite.
Late:	Galena, tetrahedrite, boulangerite, bournonite,

bismuthinite, pyrargyrite, argentite.

The various minerals are summarized below. Ore minerals are treated first, followed by the non-metallic gangue minerals and, finally, the secondary minerals. The individual species within the ore and secondary minerals are discussed in alphabetical order.

Ore minerals of primary origin.

Antimony Sb

Petterd (1910, p.9) recorded native antimony as occurring in the Spray Mine in the form of "— thin radiating patches, about an inch in diameter, implanted on a siliceous matrix."

Native antimony has not been observed in this study. A specimen from the Tasmanian Museum collection (X.47/P.403), labelled "Native Antimony, Zeehan" has been found to be stibnite. This identification is based on optical properties and reaction to etching with potassium hydroxide.

Argentite Ag_2S

Argentite is a rare mineral in the Zeehan ores, and was noted in specimens from only two mines, viz. Spray Mine and Hanrahan's Adit (near the Junction Mine).

Petterd (1910, p.12) described this mineral as occurring at the Spray Mine as "flakes of practically pure argentite — on siderite and other veinstones". Specimen no. X.235 (P.52) from the Tasmanian Museum collection is in agreement with this description by Petterd. The thin films of argentite are present on siderite, and traces of galena, covellite and pyrite were noted in a polished section of the argentite.

Waller (1904, p.58) reported that the lode in Hanrahan's Adit contained pyrite with argentite and pyrargyrite. The only specimen of ore obtained from these workings contains a small amount of argentite as fine inclusions in galena (see p.128).

Arsenopyrite FeAsS

Arsenopyrite is a minor constituent of many of the ore-bodies in the Zeehan field, in particular in those rich in pyrite. Although most of the ores with a high proportion of pyrite contain some arsenopyrite, the ratio between the two minerals is not constant. Arsenopyrite was not observed in the material from the Silver Stream Mine, and the content is very low in the Comstock ore, but it is relatively common in ore from the Sylvester, Britannia and Spray Mines. The pyrite-stannite ore from the Oonah Mine also contains a relatively high proportion of arsenopyrite, although this is still a minor constituent.

As a generalization it is true to say that arsenopyrite is more common in the ores in the central to western part of the area than in the east, but it should be remembered that the lack of systematic sampling of the ore-bodies may result in an incorrect picture of the relative abundances of minor components of the ores.

The mode of occurrence of the arsenopyrite is as idiomorphic and subidiomorphic crystals, and clusters of crystals, closely associated with pyrite and quartz. The arsenopyrite is often moulded on the pyrite crystals, and vice versa, and individual arsenopyrite crystals are mostly within the size range 0.01mm. to 0.5mm., although occasional crystals up to 1mm. were noted in the Oonah pyrite-stannite ore.

Textures consistently indicate apparent replacement of the arsenopyrite crystals by galena and, to a lesser extent

by sphalerite. Examples of apparent replacement of arsenopyrite by boulangerite, bournonite and tetrahedrite were also observed (e.g. Spray Mine).

Bismuthinite Bi_2S_3

Bismuthinite is a minor constituent of the pyrite-stannite ore at the Oonah Mine and the nearby Clarke's Lode (Zeehan Queen). A trace amount of bismuthinite is also present in the Zeehan Bell ore.

The bismuthinite occurs in many different ore mineral assemblages (see p.123,124) in the the pyrite-stannite ore, but is most commonly associated with pyrite, arsenopyrite, stannite and chalcopyrite. The bismuthinite forms aggregates of bladed crystals, and in some specimens these aggregates measure up to 1.5cm. x 3mm. Some lamellar twinning is visible in polished sections, and fine bodies of tetrahedrite and stannite are occasionally located along cleavage planes in the bismuthinite.

Textural relationships suggest that the bismuthinite has partially replaced most of the minerals with which it is associated, but many of the textures are inconclusive and may be variously interpreted.

In ore from the Zeehan Bell Mine, bismuthinite was observed as rare small clusters of needle-like crystals within tetrahedrite, chalcopyrite and galena.

Boulangerite $Pb_5Sb_4S_{11}$

Boulangerite is a common mineral in the Zeehan area, particularly in the siderite-galena lodes in the central and eastern parts.

The abundance of boulangerite varies considerably, from rare or absent in some localities to abundant in others. The Spray Mine represents the most important occurrence of boulangerite, and it is also common in ores from the other mines in the central part, viz. Britannia, North Tasmanian, Tasmanian, Grubb's and Nubeena mines, and the various mines on Argent Flat and Queen Hill. Boulangerite is rare in the pyritic lodes at Comstock and in the pyrite-stannite ore of the Oonah Mine and Clarke's Lode. The siderite-galena lodes in many of the mines in the south-eastern part of the field appear to be very poor in boulangerite but it is moderately common in galena from the Oceana Mine. It is also quite common in most of the galena from mines around Moatana Hill.

As mentioned earlier, the boulangerite from Zeehan has been referred to as "jamesonite" in most previous reports (eg. Twelvetrees and Ward, 1910; Blissett, 1962). Stillwell (1947) tentatively identified the mineral as jamesonite on the basis of optical properties and etch test reactions, but stated that it could be boulangerite. Edwards and Carlos (1954) reported on the sulphur and selenium content of this mineral from the Spray Mine (see Table 16, p.279) and used the name boulangerite without further comment. The identity has now been confirmed by X-ray powder diffraction photographs

of samples from several mines. The diffraction pattern of boulangerite from the Spray Mine is shown in Table 7, and is compared with diffraction patterns of boulangerite from British Columbia (Berry and Thompson, 1962) and Rosebery (Williams, 1960).

The chemical analysis shown in Table 8 is reproduced from Twelvetrees (1901a). This analysis is incomplete (total = 87%), and a comparison with the analyses of boulangerite in Palache et al. (1944, p.421) indicates an error in the lead analysis.

The boulangerite in the Zeehan ores commonly occurs in galena as fine inclusions varying in shape from minute ovate "blebs" to fine rod-like and needle-like bodies (Plate 4, No. 2). The lengths of the inclusions are mostly within the limits 0.005mm. to 0.15mm. In much of the galena these boulangerite bodies are apparently distributed with random orientation but in some specimens (e.g. Grubb's, Tasmanian, Britannia mines) the "needles" are seen to exhibit alignment in crystallographic directions in the galena. These textural relationships suggest that the boulangerite bodies have precipitated as a result of unmixing of a solid solution of boulangerite in galena.

TABLE 7.

X-ray powder diffraction patterns for boulangerite.

Spray Mine, Zeehan		Babine bonanza, British Columbia (Berry and Thompson) 1962.		Rosebery, Tasmania (Williams, 1960)	
d(meas,Å)	I	d(meas,Å)	I	d(meas,Å)	I
3.92	W	3.93	2	3.91	0.5
3.70	S	3.72	10	3.74	3
3.46	tr.	3.44	1		
3.33	W	3.30	2	3.31	0.2
3.20	M	3.21	4	3.22	tr.
3.00	M	3.01	4	3.03	1
2.84(B)	S	2.81	9	2.83(B)	2
2.70	W	2.68	3	2.70	0.2
		2.59	½		
		2.51	½		
2.34	W	2.33	2	2.36(B)	tr.
2.24 }	W }	2.14	3	2.15(B)	tr.
2.14 }	M }				
2.02	W	2.05	1	2.02(B)	0.5
1.967	W	1.957	1		
1.918	tr.	1.910	3	1.930	0.2
1.859 }	M }	1.859	8	1.871	1
1.803 }	W }				
1.779	M	1.752	5	1.773(B)	0.2
		1.719	2		
		1.647	1		
1.534	tr.	1.583	1		
1.516	tr.	1.528	½		
		1.463	2		
		1.404	2		

Intensities: S= strong, M = medium, W = weak, tr. = trace

B denotes broad line.

TABLE 8

Boulangerite analyses

	(1)	(2)
Pb	40	50.57 - 59.01
Sb	29	22.69 - 29.49
S	18	18.08 - 19.91
Remainder		0 - 2.54
	87	

(1) "Jamesonite". Analysis by W. F. Ward in Twelvetrees (1901a,p.22)

(2) Range in composition of 14 analyses of boulangerite, in Palache et al. (1944, p.421)

In ores where the boulangerite is moderately abundant, it forms small areas, seams and veins in the galena. At the Spray Mine, where boulangerite is the dominant mineral, it forms massive patches and also occurs in the siderite gangue as finely disseminated crystals which occasionally merge into irregularly shaped areas (Plate 5, No. 1).

Tetrahedrite and bournonite are often associated with the boulangerite, and composite boulangerite-bournonite and boulangerite-tetrahedrite inclusions are occasionally observed in the galena.

One specimen (X.3456) from one of the Argent mines (see p.96) consists of a coating of felted masses of fine acicular boulangerite on quartz and siderite.

Textures observed in the ores (e.g. Spray Mine) suggest that pyrite, arsenopyrite and sphalerite have undergone replacement by boulangerite.

Bournonite $PbCuSbS_3$

Bournonite is a widespread minor constituent in the Zeehan ores, and, since it is closely associated with galena, the pattern of distribution in the area is generally similar to that of boulangerite.

The most abundant occurrences of bournonite are in the central and southern part of the field, at the Grubb's and Swansea mines, but bournonite is also conspicuous as a minor constituent of ores from most mines in the central, north-east, east, and south-east parts of the field. Bournonite was not observed in the pyrite-sphalerite ores from the western part of the area but is present in small amounts in the pyrite-stannite ore from the Oonah Mine.

The identity of the bournonite was checked with an X-ray powder diffraction photograph. The pattern is shown in Table 9 and is compared with bournonite from Neudorf, Germany (Berry and Thompson, 1962).

Petterd (1910) reported a chemical analysis of bournonite from one of the workings on Argent Flat. This analysis is shown in Table 10 and can be seen to compare reasonably well for most elements with analyses of bournonite listed in Palache et al. (1944, p.408).

TABLE 9

X-ray powder diffraction patterns for bournonite.

Zeehan-Western Mine, Zeehan.		Neudorf, Harz, Germany (Berry and Thompson, 1962)	
d(meas, Å)	I	d(meas, Å)	I
5.80 }	M }	5.79	3
5.68 }	M }		
4.72	tr.	4.75	½
4.34	M	4.37	4
4.06	M	4.08	3
3.89 }	S }	3.90	8
3.86 }	S }		
3.68	W	3.68	2
3.26	W	3.27	2
2.99	M	2.99	4
2.91	W	2.90	1
2.82	W	2.82	2
2.74	S	2.74	10
2.68	M	2.69	4
2.59	M	2.59	5
2.37	W	2.37	1
2.30	W	2.30	1
2.24	W	2.24	1
2.16	tr.	2.16	½
2.10	W	2.09	2
		2.02	½
1.982	M	1.985	3
1.951	M	1.945	3
1.848	M	1.848	4
1.767	M	1.765	6
1.725	tr.	1.728	½
1.665	W	1.664	2
1.630	W	1.631	2
1.587	tr.	1.585	½
1.556	W	1.556	2
1.481	W	1.480	1
1.424	W	1.427	2
1.390	W	1.389	1

Intensities: S = strong, M = medium, W = weak, tr. = trace.

TABLE 10

Bournonite analyses

	(1)	(2)
Pb	42.39	39.37. - 43.85
Fe	1.97	0 - 0.74
Ag		0 - 1.69
Zn		0 - 0.35
Cu	11.93	12.77 - 15.12
Sb	28.68	18.42 - 25.03
As		0 - 3.18
S	13.62	19.17 - 20.40
Remainder		0 - 1.67
	98.59	

(1) Petterd (1910, p.32)

(2) Range in composition of 9 analyses of bournonite in Palache et al. (1944, p.408)

Petterd (op. cit., p.31) reported that bournonite occurs at Zeehan "—— in the massive state and as well-formed crystals intermixed with quartz and galena". No crystalline material was observed in this study and the most common mode of occurence is as fine inclusions within galena (Plate 8, No. 2). These inclusions are commonly round and ovate in shape, but the shape becomes less regular with increasing size. The size limits are 0.005mm to 0.1mm., but the round or ovate bodies are mostly less than 0.05mm. In material where the bournonite is more common, it occurs in the galena

and siderite as massive patches ranging in size up to several centimetres. These areas of bournonite contain inclusions of galena, boulangerite and tetrahedrite. Composite boulangerite-bournonite and bournonite-tetrahedrite inclusions are also present in some galena specimens.

The bournonite bodies in the galena rarely show any tendency to occur in any particular orientation, but an exception is P.342 from the Colonel North area ("Tramway Formation") where fine bournonite bodies appear to be aligned in crystallographic planes in the galena. This is taken as evidence that the bournonite has exsolved from a bournonite-galena solid solution. In some other cases (e.g. Oonah Mine) bournonite-galena textures resemble the "mutual boundaries" texture, and graphic intergrowths of the two minerals were observed in ore from the Swansea Mine.

Lawrence (1962, pp. 32-33 and fig. 7) has reported exsolution lamellae of bournonite in galena in ores from the Phoenix Mine, Rivertree, N.S.W.. Lawrence described the lamellae as lying in the 100 planes of the galena and suggested that bournonite is able to enter into solid solution at elevated temperatures.

<u>Cassiterite</u> SnO_2

Cassiterite is not a common mineral in the Zeehan ores and has been found in ores from only four mines, three of which are situated in the Oonah - Queen Hill area. The cassiterite found in the pyrite-stannite ores from the Oonah Mine represents the main occurence of cassiterite in the Zeehan area. A similar association is present in Clarke's

Lode on Queen Hill, and small amounts of cassiterite occur in other ores on Queen Hill (Stormsdown and Zeehan Queen). A little cassiterite was also noted in ore from the Zeehan Bell Mine.

Two forms of cassiterite are present in the Oonah pyrite-stannite ore; one form is assumed to be primary cassiterite, whereas the other is thought to have resulted from a breakdown of the stannite. The primary cassiterite occurs (as described on p.119) as clusters of fine crystals within stannite, pyrite, arsenopyrite and quartz. Individual crystals range from 0.002mm to 0.075mm., and when present within stannite a thin border of chalcopyrite surrounds the cassiterite. This chalcopyrite is considered to have been precipitated from solid solution in stannite. The second form of cassiterite has been referred to as "needle tin" by Edwards(1951), and occurs only as cores (0.002mm to 0.015mm in width) within chalcopyrite veinlets in the stannite (Plate 6). In most specimens examined the needle tin was the more abundant of the two forms. The origin of the needle tin is discussed further under stannite (p.217).

Blissett (1960) reported that samples of the soft, heavily decomposed, pyritic ore from No. 1 Adit in the Stormsdown Mine assayed 4.13% tin. The hard pyrite ore from the open cut near No. 2 adit was found to assay 0.58% tin (Blissett,op.cit). Mineralogical examination has shown that fine cassiterite grains occur closely associated with pyrite and quartz in both types of ore. The cassiterite grains observed were within the size limits 0.001mm to 0.015mm.

One specimen of ore from the Zeehan Queen Mine contained rare fine grains of cassiterite with galena and sphalerite.

The only cassiterite observed in ores outside the Oonah-Queen Hill area was a minor amount in pyrite-rich samples from the Zeehan Bell Mine. The cassiterite in this material is present as groups of fine crystals, ranging from 0.03mm to 0.075mm., occurring mainly in interstitial areas within pyrite.

Chalcopyrite $CuFeS_2$

The Zeehan district is generally poor in copper mineralization. Chalcopyrite is not abundant in ore from any of the mines in the district, but is moderately common in three localities, viz. Silver Stream, Oonah and Zeehan Bell Mines. Abundant exsolution blebs of chalcopyrite may be observed in sphalerite from many other mines, but the actual chalcopyrite content of the ore is low.

The majority of the chalcopyrite occurs in exsolution assemblages with either sphalerite, stannite or tetrahedrite.

Chalcopyrite is common in the material examined from the Silver Stream Mine, where there is an intimate relationship between the chalcopyrite, sphalerite and pyrrhotite. The chalcopyrite and sphalerite are extensively intergrown, and sphalerite contains abundant exsolution bodies of chalcopyrite and pyrrhotite. The chalcopyrite areas also contain inclusions of exsolved pyrrhotite.

Chalcopyrite is closely associated with stannite in ore from the Oonah Mine and Clarke's Lode (Queen Hill). Most of the chalcopyrite occurs within the stannite as fine criss-

crossing and branching veinlets, as small areas of irregular outline, and as minute blebs. The veinlets appear to be segregation veins of exsolution origin and, as described elsewhere (p.202, 217), these veinlets often contain central cores of cassiterite ("needle tin"). Sphalerite is not common in the stannite ore but where present it also contains blebs of chalcopyrite.

Ore from the Zeehan Bell Mine contains chalcopyrite as a prominent minor constituent, particularly in the more pyritic samples. The chalcopyrite often occupies fractures and interstitial areas within the pyrite, and exhibits a close relationship with tetrahedrite. Fine rod-like exsolution bodies of tetrahedrite were observed within the chalcopyrite and small areas of tetrahedrite were found to contain inclusions of chalcopyrite. A little stannite is also present in the Zeehan Bell ore and this occurs within areas of chalcopyrite. The stannite inclusions contain very fine blebs and veinlets of chalcopyrite.

The chalcopyrite-tetrahedrite association is not common in the Zeehan ores, but other examples of the assemblage were also noted in specimens from the Silver King, Junction, Zeehan - Western and Montana S. L. Mines.

Exsolution blebs of chalcopyrite in sphalerite are very common in sphalerite in the western part of the area, particularly in the iron-rich sphalerite in the Comstock ores. In many of these specimens the chalcopyrite blebs occur in parallel lines along crystallographic planes in the sphaler-

ite, and occasional composite chalcopyrite-pyrrhotite bodies were observed (Plate 2). Although the abundance of the chalcopyrite-blebs shows a decrease in sphalerite in the eastern part of the area, most of the sphalerite contains some blebs. The size range of most of the blebs is 0.0005mm. to 0.005mm. In some specimens (e.g. Junction Mine) these blebs of chalcopyrite appear to define growth zoning in the sphalerite.

Small amounts of chalcopyrite in ore from the Tasmanian and Zeehan Bell mines were found to contain fine exsolution bodies of sphalerite, in the form of star-shaped inclusions with a maximum size of 0.006mm. (Plate 4, No. 1).

Bournonite and chalcopyrite are occasionally associated (e.g. Zeehan-Montana and Spray Mines) and the textural relationships suggest that this may be an exsolution assemblage.

Apparent replacement textures involving chalcopyrite suggest that pyrite has been replaced by chalcopyrite and that chalcopyrite has been replaced by galena.

<u>Franklinite</u> $ZnFe_2O_4$

Petterd (1910, p.73) recorded the presence of franklinite as "amorphous and crystalline bunches intermixed with galena" at the 200 ft. level of the Silver (Zeehan) Queen Mine.

This mineral has not been observed in the samples examined and it is, therefore, not possible to confirm Petterd's observation.

Galena PbS

Galena is the most abundant metallic mineral in the Zeehan ores. It occurs in close association with siderite gangue, and both minerals are more abundant in the eastern part of the field than in the west. The lodes in the east were mainly fissure lodes of siderite containing irregular veins and patches of galena. Galena is not abundant in the ore-bodies in the western part of the field and is a minor constituent only in the pyrite-stannite ore of the Oonah Mine and in the pyritic ore of the Stormsdown Mine on Queen Hill.

The silver content of the galena varies considerably throughout the field but was apparently higher in the central and eastern parts of the area than in the west. This is, however, a generalized pattern to which there are exceptions, e.g. ore from the Silver King Mine, assaying 70 to 75% lead, carried only 25ozs. of silver per ton, whereas galena in the nearby Fahey's Tribute assayed 100ozs. of silver per ton (Waller, 1904). The silver content of the galena from most mines is apparently due largely to inclusions of tetrahedrite (Plate 11, No. 2). Inclusions of pyrargyrite and/or argentite occasionally contribute to the silver content of the galena, but these minerals are not common in the specimens examined.

Boulangerite and bournonite are also very commonly associated with the galena, particularly in ore from the eastern part of the area (Plate 4, No.2, and Plate 8, No.2).

The majority of the galena samples observed were massive and non-crystalline, but occasional specimens exhibit well-formed crystals, e.g. samples from Sunrise and Comstock Mines. Some galena has undergone deformation due to shearing and consequently shows weak anomalous anisotropism in polished sections.

The textural relationships with other ore minerals consistently suggest that pyrite, arsenopyrite and sphalerite have been extensively replaced by the galena. The assemblages containing galena with boulangerite, bournonite and tetrahedrite have been interpreted as exsolution textures, for reasons discussed elsewhere (see pages 195, 201, 220).

Gersdorffite-Ullmannite NiAsS - NiSbS

Material from the gersdorffite-ullmannite system has been found in the nickel ore of the Central Balstrup Mine in Austral Valley.

Williams (1958) identified gersdorffite in association with niccolite and maucherite in two samples of Central Balstrup ore. Examination of further material from the Central Balstrup mine has demonstrated the presence of additional members of the gersdorffite-ullmannite system. X-ray diffraction data indicates that these are intermediate in composition between the two end-members. One member is apparently between gersdorffite and "corynite" (of Berry and Thompson, 1962), while the other is apparently between "corynite" and ullmannite, X-ray data and details of the mineralogy have been presented in the previous section (pp. 170-179).

Gold Au

Gold is very rare in the Zeehan ores; the only gold observed in this study occurred as rare particles in two specimens of ore from the Nubeena Mine. These particles are 0.01mm. in size, and occur within siliceous gangue material.

According to Petterd (1910, p.167), stannite from Clarke's Lode (Zeehan Queen) assayed 3dwt. of gold per ton in addition to 90ozs. of silver per ton.

Waller (1903, p.16) recorded that a small amount of alluvial gold was discovered in the vicinity of the Tenth Legion magnetite deposits.

Frank Long, the discoverer of the Zeehan field, is reported to have found traces of gold with galena in a small creek near the present site of the Zeehan Post Office (Tilley, 1891). There is, however, no record of any production of gold. Although gold was recovered at the Zeehan smelters most of this came from the lead-zinc ore brought from the Hercules Mine at Williamsford.

Hauchecornite $(Ni,Co)_7(S,Sb,Bi)_8(?)$

Williams (1958) identified very small amounts of hauchecornite (of Harcourt, 1942) in the nickel ore of the Central Balstrup Mine in Austral Valley.

Williams described the hauchecornite as occurring in small areas within galena and as a single narrow veinlet within niccolite.

No other occurrence of this mineral has been recorded in the Zeehan area.

Magnetite Fe_3O_4

With the exception of the Tenth Legion and other smaller magnetite deposits, all of which are regarded as being genetically related to Cambrian basic intrusive bodies, magnetite is of rare occurrence in the Zeehan mineral field.

The only magnetite observed in association with the sulphide ores in this investigation were occasional small round and ovate inclusions (up to 0.05mm. in diameter) within sphalerite in a specimen from the Silver Stream Mine (Plate, 1, No. 2).

Twelvetrees and Ward (1901) reported the presence of minor amounts of magnetite with sphalerite, galena, chalcopyrite and pyrite in the "copper" lode of the Silver Stream workings. Waller (1903) also reported magnetite in association with sphalerite on a section known as A.D. Sligo's lease, approximately one mile to the south of the Tenth Legion deposits. Attempts to locate Sligo's workings were unsuccessful because of the dense vegetation in the area.

Marcasite FeS_2

Marcasite occurs in small amounts in some of the ores in the Zeehan field but is not common. The main mode of occurrence is as fine intergrowths with pyrite, and for this reason it is slightly more common in the ores of the western part of the area. The mines in the Comstock area and some of those in the Queen Hill - Argent Flat area contain a little fine marcasite within the pyrite, but marcasite is rare elsewhere.

The relationship between the marcasite and pyrite is not clear, but textures suggest that the marcasite may have resulted from alteration of the pyrite.

Maucherite $Ni_{12-x}As_8$

Maucherite is present in small amounts in the nickel ore of the Central Balstrup Mine in Austral Valley.

The maucherite occurs as fine intergrowths with niccolite. The mineralogy of the ore has been described in the previous section (see pp.170-179).

No other occurrence of maucherite is recorded in the Zeehan area.

Niccolite NiAs

The only recorded occurrence of niccolite in the Zeehan field is at the Central Balstrup Mine in Austral Valley.

The niccolite is closely associated with maucherite, rammelsbergite and members of the gersdorffite-ullmannite system. The mineralogy of the ore has been described in the previous section (see pp.170-179) and, as this is the only such occurrence, repetition is not necessary.

Proustite Ag_3AsS_3

According to Petterd (1910, p.140), proustite has been found in mines in the Zeehan field. Although no proustite has been observed in any of the specimens of silver-lead ore examined by the present author, it is reasonable to regard the reports as authentic, since small amounts of the closely related mineral pyrargyrite have been noted in some specimens.

Petterd stated that the British-Zeehan (Spray) mine was the most notable occurrence of proustite in this area.

The only occurrence of proustite noted in this study is that in the nickel ore from the Central Balstrup Mine (Austral Valley). The proustite occurs as occasional fine inclusions (up to 0.03mm.) within niccolite and gersdorffite -ullmannite.

Pyrargyrite Ag_3SbS_3

Minor amounts of pyrargyrite have been observed in ore from several mines in the Zeehan area. The mines concerned are Grubb's, Nubeena, Argent No. 2, Hanrahan's Adit, and Zeehan-Western. In addition, Petterd (1910,p.141) stated that pyrargyrite was reported to have been found at the Oonah and British-Zeehan (Spray) mines, and Twelvetrees and Ward (1910,p.123) reported the presence of "ruby silver ores" in the nickel ore of the Central Balstrup Mine. Twelvetrees and Ward were presumably referring to pyrargyrite and proustite.

The mode of occurrence of the pyrargyrite observed in polished sections of the ores is as small inclusions within galena. These inclusions are generally round or ovate but irregular and crescent-like shapes were observed (Plate 8, No. 1). The majority of the pyrargyrite bodies are within the size limits 0.01mm to 0.1mm., but the narrow crescent-like bodies have a maximum length of 0.2mm.

The pyrargyrite bodies are considered to be exsolution bodies which have precipitated from a solid solution in the galena.

Pyrite FeS_2

Pyrite is an abundant mineral in the ores from the western part of the Zeehan field, but becomes less abundant in ores in the east, with the exception of the Conah-Queen Hill area.

The pyrite is invariably accompanied by quartz and, in the western part of the field, by sphalerite. Stannite and cassiterite accompany pyrite in the Conah and Queen Hill localities. Pyrite is also very common in samples from the dumps of the Zeehan Bell Mine, but a comparison with reports by Montgomery (1893, 1895) and Twelvetrees (1901a) indicates that these samples are not truly representative of the pyrite content of the ore-body. Early reports also indicate that pyrite became more abundant at depth in the Spray, Zeehan Queen and Zeehan-Western mines.

Arsenopyrite is commonly associated with the pyrite, but normally in only small quantities. A little pyrrhotite occurs as fine inclusions in pyrite from the Silver Stream, Comstock and Sylvester mines, and small amounts of marcasite occur as fine intergrowths in occasional specimens of pyrite.

Individual pyrite crystals are normally within the size limits 0.01mm. to 1mm., but occasional crystals were observed up to 0.5cm. (e.g. Comstock Mine). Some pyrite from the Boss Mine shows clearly defined growth zoning, with the zones marked by lines of minute inclusions (Plate 3, No. 1).

In addition to common idiomorphic and subidiomorphic

pyrite occurring throughout the ore and gangue, a second form, quite characteristic in appearance in polished sections, is present within the sphalerite from some mines, viz. T.L.E., Stonehenge, Despatch and Sunrise. This pyrite occurs as narrow veinlets (up to 0.05mm. in width) of very fine crystalline pyrite, and is entirely confined to the sphalerite (Plate 3, No.2).

Textural relationships with other minerals consistently suggest extensive replacement of pyrite by galena (Plate 5, No. 2) and to a lesser extent by sphalerite, chalcopyrite, stannite and tetrahedrite.

Pyrostilpnite Ag_3SbS_3

Pyrostilpnite was reported by Petterd (1910, p.147) to occur "closely associated with pyrite and cellular quartz" at the Donah Mine. It was not possible to confirm this reported occurrence.

Pyrrhotite $Fe_{1-x}S$

Pyrrhotite is a very minor constituent of the Zeehan ores, and occurs almost entirely as fine exsolution bodies within sphalerite. These exsolved pyrrhotite bodies are common in the iron-rich sphalerite of the western part of the Zeehan field, but are less frequent in the central region and are absent in the iron-poor sphalerite in the south-east and north-east.

The pyrrhotite bodies are mainly in the form of fine blebs, similar in shape and size to the chalcopyrite blebs, and sometimes showing alignment in crystallographic planes

in the sphalerite (Plate 1, No.1). Slightly larger bodies, up to 0.03mm., less regular in shape and showing no alignment, are also present in the sphalerite. Occasional composite chalcopyrite-pyrrhotite bodies may be observed in the sphalerite in the western part of the area (Plate 2).

Pyrrhotite is rare as inclusions in other minerals, but such inclusions were noted in pyrite and galena.

Rammelsbergite $NiAs_2$

Rammelsbergite has been identified in two specimens of ore from the Central Balstrup Mine in Austral Valley. The identification of this mineral, together with X-ray data, has been discussed in the previous section.

The rammelsbergite is closely associated with members of the gersdorffite-ullmannite system. The mineralogy of the ore has been described on pages 170-179, and since rammelsbergite does not occur elsewhere in the Zeehan area the detailed mineralogy will not be repeated here.

Rammelsbergite has not previously been recorded in Tasmania.

Sphalerite ZnS

Sphalerite is a common mineral in the Zeehan field, but is considerably more abundant in the western part than in the east. In the western part of the area, sphalerite and pyrite are the main constituents of the ores, but the abundance shows a general decrease to the east, where sphalerite is normally a minor constituent in the galena-siderite lodes.

Variations in composition of the sphalerite are discussed in detail in a subsequent section. The sphalerite shows a general decrease in iron content from west to east, and this can be correlated with a change in colour from very dark-brown sphalerite (marmatite) to pale-brown sphalerite. The sphalerite from the Swansea Mine in the southern part of the field is very low in iron-content and is very pale-brown in colour. Colour changes are, however, indicative of only gross changes in composition and have not been found reliable for small compositional changes.

Exsolution bodies of chalcopyrite and pyrrhotite are common in the sphalerite in the western part of the area but decrease in abundance to the east. Some specimens of sphalerite low in iron-content show well defined growth zoning, marked by changes in colour (Plate 9, No. 2). This zoning may be observed in transmitted light and has been found in specimens from Montana S.L., Junction, Silver King, Austral Valley, Zeehan Bell and Sunrise mines. The growth zoning has also been seen to be defined by exsolution blebs of chalcopyrite in sphalerite from the Junction Mine.

Textural relationships with the various other ore minerals indicate exsolution relationships with chalcopyrite and pyrrhotite, but suggest that sphalerite has partially replaced pyrite and arsenopyrite and that galena has extensively replaced sphalerite (Plate 5, No. 2).

Stannite Cu_2FeSn_4

Stannite is not a widespread mineral in the Zeehan

field, but is abundant in two lodes. These are the stannite lode at the Oonah Mine and Clarke's Lode on the Zeehan Queen property. Very small amounts of stannite were also observed in samples from Queen Hill (Dunn's Tunnel and Zeehan Queen Mine), Argent Flat, and the Zeehan Bell Mine. With the exception of the Zeehan Bell Mine, all other stannite occurrences are in the area between Argent Flat and Oonah Hill.

The stannite at the Oonah Mine is by far the most significant occurrence of this mineral in the Zeehan area. This occurrence of stannite has been described by Stillwell (1931) and discussed by Edwards (1951).

The Oonah and Clarke's Lode assemblages are identical, with complex mineralogy and textural relationships between the minerals. The stannite occurs as coarse patches and bands with a considerable range of associated minerals (as described in pages 116-124), in particular pyrite, chalcopyrite cassiterite, tetrahedrite, bournonite and bismuthinite. The list of ore mineral assemblages (p.123,124) illustrates the complex nature of the ore.

Several analyses of the stannite ore are shown in Tables 2 (p.109, Clarke's Lode) and 3 (p.117, Oonah Mine). With the exception of analysis (1) in Table 3, these refer to ore rather than stannite alone. Analysis (1) is reported to be of apparently pure stannite, but the intimate association of the stannite with other minerals is such that a pure sample would have been most unlikely.

Possibly the most interesting textural features of the

stannite are the presence of abundant exsolution blebs and segregation veinlets of chalcopyrite, and the occurrence of two forms of cassiterite. The segregation veinlets of chalcopyrite, show criss--crossing and branching forms in a pattern which strongly suggests that these veinlets occupy fractures in the stannite. The chalcopyrite appears to have precipitated from solid solution in the stannite and to have healed the fractures.

The two forms of cassiterite have been described on pages 119, 120. The first form, occurring as clusters of fine crystals may be observed in stannite, pyrite, arsenopyrite and quartz. In the stannite these crystals are invariably surrounded by a narrow border of chalcopyrite which is thought to have precipitated from the stannite. The second form has been described by Edwards (1951) as "needle tin", and occurs only within the stannite as central cores or seams in veinlets of chalcopyrite (Plate 6). These cores of cassiterite range from 0.002mm. to 0.015mm. in width and are often in direct proportion to the width of the enclosing veinlet of chalcopyrite. Some of the chalcopyrite - cassiterite veinlets also contain very fine crystalline pyrite, with individual crystals rarely greater than 0.002mm.

Edwards (op. cit) has discussed the possible origin of the needle tin in some detail, and has compared the Oonah occurrence with similar material from the Conrad Lode at Howell, N.S.W.. Frueh (1949) has stated that, at atmospheric pressure, stannite and chalcopyrite dissociate at temperatures

below 600°C..Edwards has suggested that the stannite has undergone fracturing above some critical temperature, thus causing partial dissociation of the stannite and resulting in the formation of cassiterite seams within chalcopyrite in the stannite. The fine associated pyrite would have been a further product of this dissociation.

An alternative interpretation of the needle tin representing primary cassiterite, surrounded by exsolved chalcopyrite, is not favoured because this form of cassiterite is restricted to the stannite.

Sphalerite is present in only isolated samples of the stannite ore, but the relationship is again suggestive of the stannite having been intensely fractured and sphalerite occupying the fractures (Plate 7, No. 1). There appears to have been some corrosion of stannite by sphalerite along the fractures.

Other textures observed suggest replacement of pyrite and arsenopyrite by stannite, and replacement of stannite by bismuthinite and galena. The textural relationships between stannite, tetrahedrite and bournonite could be interpreted variously. These textures could be taken as evidence of some partial replacement of stannite by tetrahedrite and bournonite, or could be interpreted as "mutual boundary" relationships with no replacement.

Stannite is also observed in small amounts as inclusions in pyrite in samples from Dunn's Tunnel (Queen Hill), Argent Flat and the Zeehan Bell Mine, and as fine inclusions in

galena in one specimen of ore from the Zeehan Queen Mine. Stillwell (1950) reported stannite associated with chalcopyrite and sphalerite in material from Argent Flat.

Stibnite Sb_2S_3

Stibnite has been observed in only one specimen from the Zeehan field. The specimen concerned is from the Tasmanian Museum collection (X.47/P.403) and is labelled "Native Antimony, Zeehan", but has been identified as stibnite (see p. 191).

The only locality recorded by Petterd (1910) for native antimony at Zeehan, was the Spray Mine. Since this specimen is from Petterd's collection, it is likely that it is from the Spray Mine.

Tetrahedrite $(Cu,Fe)_{12}Sb_4S_{13}$

Tetrahedrite is a minor but important constituent of the ores in the Zeehan field. Since the tetrahedrite is closely associated with the galena, it is more common in the central and eastern parts of the field than in the west.

The tetrahedrite content shows considerable variation between ores from the various mines, and even between different samples from same mine. The most abundant occurrences of tetrahedrite are at the Spray, Argent, Junction, Zeehan-Western and Oonah mines, but this mineral is also moderately common, as a minor constituent, in the ores from most mines in the north-eastern, south-eastern and southern parts of the field. Tetrahedrite is not common in the ores from the western localities.

Tetrahedrite appears to account for the major part of the silver content of most of the ores, and there is in general a good correlation between the observed abundances of tetrahedrite and the previously published silver contents of the ores from the various mines.

Petterd (1910) reported that well-formed crystals of tetrahedrite had been found in the deepest workings of the Zeehan-Western Mine, and some "fairly good crystal groups" had been discovered in the Oonah Mine. Twelvetrees and Ward (1910) reported an occurrence of massive tetrahedrite associated with galena in the Sunrise Mine, and quoted an assay of 404 ozs. of silver per ton.

In the samples examined, the main mode of occurrence of the tetrahedrite is as inclusions within galena (Plate 11, No. 2). The tetrahedrite inclusions are mainly within the size limits 0.001mm. to 0.5mm. The finer bodies are generally round or ovate but the shape becomes less regular with increasing size. Tetrahedrite is also associated with boulangerite and bournonite, as inclusions within these minerals or as composite inclusions with either in galena. At the Spray Mine, tetrahedrite occurs as inclusions in the boulangerite, and at Grubb's Mine the bournonite contains inclusions of tetrahedrite.

The textural relationship of the galena and tetrahedrite is interpreted as an exsolution relationship. Oriented lamellae of tetrahedrite in galena have not been observed but graphic and subgraphic intergrowths, considered to be

exsolution textures, have been observed in ores from the Montana S.L. and Austral Valley mines (Plate 9, No. 1). By analogy with other silver-lead ores (Edwards, 1954) it is reasonable to conclude that the tetrahedrite inclusions in galena have precipitated from a solid solution of the two minerals.

A small amount of the tetrahedrite is also associated with stannite, at the Oonah Mine, and chalcopyrite, at Zeehan-Western, Junction, Montana S.L., Silver King and Zeehan Bell mines.

As mentioned on page 218, the textural relationship between stannite and tetrahedrite is not clear. The chalcopyrite-tetrahedrite association is, however, quite clearly an exsolution relationship. Good examples of graphic textures were observed in samples from the Junction and Zeehan-Western mines (Plate 7, No. 2), and minute rod-like bodies of tetrahedrite in chalcopyrite from the Zeehan Bell Mine are considered to be exsolution bodies.

Ullmannite

See "Gersdorffite -- Ullmannite" (p.207)

Violarite Ni_2FeS_4

Williams (1958) reported the presence of a trace of violarite in one sample of ore from the Central Balstrup Mine, Austral Valley. The violarite was reported to occur as a single narrow vein, 0.2mm. in width, and was considered by Williams to be pseudomorphous after pentlandite.

Violarite was not observed in Central Balstrup ore

examined by the present author and has not been recorded elsewhere in the Zeehan field.

Wolframite $(Mn,Fe)WO_4$

The only reported occurrence of wolframite, within the recognized limits of the Zeehan field, is at the Oonah Mine. Small quantities have also been recorded in the quartz-cassiterite veins in the Heemskirk mineral field (Waterhouse, 1916).

Wolframite is a very minor constituent in the pyrite-stannite ore of the Oonah Mine, and has been noted in only two polished sections (P.13, 214) as subidiomorphic crystals, up to 1mm. across, within pyrite and quartz.

Gangue minerals.

The dominant non-metallic gangue minerals in the ore-bodies of the Zeehan field are quartz and siderite. Both minerals are present throughout the field but the proportions show considerable variation. Quartz is the main gangue constituent in the pyrite-sphalerite ores in the western part of the field, whereas siderite is particularly abundant in association with the galena ores in the east. Quartz is the dominant non-metallic mineral in the pyrite-stannite ore at the Oonah Mine, and is also abundant in the pyritic ore of the Stormsdown Mine.

Crystalline quartz is rare, except when it occurs in vughs. The quartz is more common as anhedral material forming the matrix between idiomorphic pyrite and arsenopyrite and in patches mixed with sphalerite. Petterd (1910, p.96) reported that the variety of opaline silica known as hyalite had been found as white to pale-green botryoidal masses in "the Argent Mine, Zeehan". Since there were several Argent mines located on Argent Flat, the specific locality of the hyalite is not known.

In the dumps of the Tramway Formation workings (see p. 81), samples of "hacked" or "chopped" quartz can be found. As mentioned on p. 81 , it is thought that the angular impressions have been caused by the preferential leaching of siderite or another carbonate mineral.

The siderite in the galena ores forms masses of anhedral and subhedral material. In polished sections the siderite

appears to have been extensively corroded by galena and to have undergone replacement along cleavages and grain boundaries. Much of the siderite now present in the samples collected from the surface dumps has undergone partial alteration to limonite.

Most of the siderite yields positive manganese reactions with sodium bismuthate. Since this is a qualitative test only, it is not known to what extent the manganese content of the siderite varies throughout the field. An investigation of variations in the composition of the siderite could yield some interesting geochemical information in a future study, but a major problem would be the availability of samples which have not suffered from the effects of weathering.

Calcite does not appear to be common but occurs in small amounts as narrow veins and patches associated with siderite in some mines(e.g. Oceana Mine).

Fluorite is a minor gangue constituent of the pyrite-stannite ore from the Donah Mine.

Barite has been reported from only three localities. Twelvetrees and Ward (1910,p.143) reported a "barytic quartz formation" in a crosscut on No.4 level of Grubb's Mine, and and a specimen of barite in the Tasmanian Museum collection (x.3048) confirms the occurrence of barite in this mine. Barite was also noted by Twelvetrees and Ward (op. cit.p.49) as occurring "in bunches in the lode-matter" in the Silver Stream workings, and Montgomery (1890) recorded barite in No. 2 Lode of the Mount Zeehan Mine.

Twelvetrees and Ward (op.cit., p.67) described the gangue in the South Comstock Mine as consisting of a "fibrous, radiating, greenish mineral, which is probable a pyroxene or an amphibole...".