CHAPTER 5: MINERALOGY AND ALTERATION

5.1 INTRODUCTION ...

This chapter is divided into three sections, and documents the alteration and vein mineralogy's associated with the Devonian Pine Hill Granite in the Renison-Dundas district. The chapter presents an overview of:

(i) regional alteration,
(ii) mineralisation in the Renison-Dundas district, and
(iii) mineral paragenesis and metal distribution on major faults at Renison.

Detailed descriptions of the district scale alteration and mineralisation are beyond the scope of this study, but a brief review and interpretation is presented to place into context the broader relationships associated with the granitic intrusion. At Renison a detailed mineral paragenesis for the Federal-Bassett Fault has been established, based on extensive drill-core logging, underground mapping, and petrographic studies. Spatial and temporal vein assemblages, and related deformation events at Renison are outlined in an attempt to understand the major features responsible for the deposition of a world class carbonate replacement tin deposit.

5.2 ALTERATION IN THE RENISON DISTRICT ...

5.2.1 Thermal Metamorphism ...

A distinct thermal metamorphic aureole and associated mineral assemblage is developed within the Crimson Creek Formation and Success Creek Group above the Pine Hill intrusion (Patterson, 1979; Patterson et al., 1981; Ward, 1981; Manly, 1982; Holyland, 1987; and Morrison, 1993). A summary of the mineral associations within the various host-rocks is presented in Figure 5.1 (drafted in conjunction with Morrison, 1993). The thermal metamorphic aureole is recognised by extensive recrystallisation of sediments up to 800 metres radially away from the northwest plunging contact of the Pine Hill Granite. Contact metamorphism associated with emplacement of the main granite phase has changed the mineralogy and the texture of the host sequences, but not the bulk chemistry (Davies, 1985; Holyland 1987; Morrison, 1993). The contact metamorphic aureole, within 100 m of the granite contact, is identified by the development of 1-2 mm cordierite spots within pelitic and arenaceous units of the Success Creek Formation (Fig. 5.1). At increased distances (200 m...
to 400 m) from the granite contact, biotite hornfels define the metamorphic aureole in the non-carbonate units. This pattern is, however, strongly influenced by faulting.

Figure 5.1 Schematic representation of the thermal metamorphic aureole characteristics of the host sediments relative to their contact with the main Pine Hill Granite. (Data sourced from Patterson, 1979; Davies, 1985; Holyland, 1987; Manly, 1982).

During contact metamorphism, the siliceous clastic rocks of the Success Creek Group developed fine grained micaceous intergrowths with sutured and sub-polygonal quartz. Patterson (1979) described the development of albite-epidote hornfels to hornblende hornfels facies assemblages proximal to the granite. Quartz-muscovite ovoid spots, between 1-2 mm, in tourmalinised shales and siltstones are thought to have replaced cordierite of thermal metamorphic origins. Within sericitised andesitic greywackes of the Crimson Creek Formation, extensive retrograde chlorite after biotite is commonly intergrown with poikiloblastic muscovite. Patterson (1979) notes that actinolite and biotite increase toward the granite contact in greywackes and shales. Davies (1985) has suggested that some of the disseminated dravite found in impure carbonate laminae and clastic wallrocks at Renison resulted from thermal metamorphism of illite-rich clays which contain up to 500 ppm boron (Walker & Price, 1963), but he considers the dominant source of boron responsible for tourmalinites in the mine sequence, and associated with carbonate replacement mineralisation, originated from granite derived magmatic hydrothermal fluids.

Carbonate units develop a distinct thermal metamorphic mineral assemblage compared to non carbonate units. The impure limestones associated with the Crimson Creek Formation
form distinctive banded calc-silicate hornfels in close proximity to the intruded Pine Hill Granite, while more dolomitic units of the mine sequence are recrystallised to marble. The impure limestones of the Crimson Creek Formation develop flakes of chlorite, talc and tremolite on the outer edge of the contact aureole, which give way to calcite veinlets and calcite + talc + clinochrysotile. Sporadic calcite + tremolite (after diopside) ± grossular rocks occur close to the granite contact (Patterson, 1979).

Recrystallisation in the thermal metamorphic aureole extends from 800 metres to 1000 metres in close proximity to the Federal-Bassett Fault structure, which defines the eastern margin of the uplifted Renison mine horst. Holyland (1987) noted that in the immediate mine area the aureole extended to 2100 R.L. on the Federal-Bassett Fault but did not extend to the Up-dip orebodies to the west. Consequently diagenetic pyrite, graphite or carbonaceous material is preserved outside of the aureole, but more reduced conditions associated with pyrrhotite mineralisation prevailed within the aureole.

5.2.2 Metasomatism ...

Extensive metasomatic replacement fronts have formed during emplacement of the Devonian Pine Hill Granite into Eo-Cambrian sediments. The reaction fronts advance away from granite-sediment contacts and major fault structures, and were responsible for producing Renison's characteristic distal skarn assemblage (Kwak, 1987). Intimately associated with the metasomatic replacement mineralisation are a series of overprinting, vein-hosted, mineral assemblages which are spatially and temporally zoned around the Pine Hill Intrusion. Metasomatic mineral associations and systematics are dependent on the sedimentary host-rocks, as detailed in Figure 5.2 (drawn in conjunction with Morrison, 1993; silicates are listed on the top line of each lithological unit in this figure). In Figure 5.2 metasomatism is related to fluid expulsion from granite cupolas or apophyses, and not from the main granite body. These fluids formed veins and replacement bodies with different mineralogy and bulk chemistries to the host sequences.

In the Renison district six metasomatic zones are recognised (together with a greisen zone within the Pine Hill Granite), associated with the host sediments and overprinting the contact metamorphic hornfels (Fig. 5.2). These zones are:

(i) Greisen Zone  (iv) Biotite Zone
(ii) Skarn Zone   (v) Talc/Chlorite Zone
(iii) Amphibole Zone (vi) Carbonate Zone

Each zone is named for the major mineral present. A brief discussion of each zone is presented below. The complex alteration patterns represent a snapshot in time, with the zones reflecting declining temperature gradients away from a volatile rich granite apophysis. As the metasomatic fluids supplied from the granite apophysis waned with time, the outer probably
Figure 5.2. Schematic outline of the metasomatic assemblages around apophyses in the Pine Hill Granite, Renison, Tasmania. Abbreviations: Act - actinolite; Ank - ankerite; Asp - arsenopyrite; Ax - axinite; Cass - cassiterite; Chl - chlorite; Chond - chondrodite; Cpy - chalcopyrite; Cpx - clinopyroxene; Diop - diopside; Fl - fluorite; Gnt - garnet; Gn - galena; Hum - humite; Mt - magnetite; Phlog - phlogopite; Po - pyrrhotite; Py - pyrite; Qz - quartz; Rhod - rhodochrosite; Sid - siderite; Ser - sericite; Sph - sphalerite; Tm - tourmaline; Tpz - topaz; Trem - tremolite; Wolf - wolframite.
cooler zones collapsed inward, causing the inner hotter zones to become overprinted by lower temperature mineral assemblages. In this classification, the outermost occurrence of higher temperature mineral assemblages are used to define the boundary of the zones.

In the field, metasomatic mineral assemblages are mappable units and in themselves define broader alteration envelopes around potential orebodies (Meinert, 1992). Because most mesothermal granitic intrusions have a zonal alteration assemblage associated with their emplacement, the recognition of these alteration features can be critical to early exploration for significant economic mineralisation. The recognition of metasomatic alteration assemblages and zonal relationships in the Renison district will assist, therefore, future exploration geologists to target potential sites of economic tin mineralisation, provided these alteration features are interpreted correctly, i.e., in terms of lithological variations, structural complexity and proximity to granite apophyses.

5.2.2.1 Greisen Zone ...

At Pine Hill, an extensive quartz-tourmaline greisen developed within an apophysis of the granite (Fig. 5.3). The greisen can be divided into four main zones, based on the work of Groves (1968), Patterson (1979), Ward (1981), Manly (1982) and Holyland (1987):

(i) Tourmalinised zone
(ii) Fluorite-tourmaline zone
(iii) Sericitised granite zone
(iv) Albitised granite zone

The upper tourmalinised zone is 25m thick at the apex of Pine Hill and thins to less than 2 m on the limbs. This zone consists of a massive greisen in which the texture of the granite is totally destroyed and metasomatism has replaced all minerals except quartz. Greisenization involved the precipitation of tourmaline and quartz, together with topaz, muscovite, and minor molybdenite, cassiterite and fluorite. Below the tourmalinised cap, the fluorite-tourmaline zone is less than 10m thick and contains tourmaline, fluorite, sericite, siderite, topaz and cassiterite. The sericitised zone varies in thickness (Fig. 5.3) and is characterised by intense sericitisation of plagioclase cores with the formation of discrete muscovite and fluorite crystals. The texture of phenocrysts is preserved but the fine grained groundmass has been extensively recrystallised. Biotite has been altered to muscovite and chlorite and fine grained brown phyllosilicates pseudomorph orthoclase. All of the least altered granite phases at Pine Hill exhibit some form of albitisation of the plagioclase feldspars.

Bajwah et al. (in press) have identified a tourmaline rich alteration zone beneath the Renison Mine at the foot of the Federal-Bassett Fault that is analogous to the Pine Hill greisen. This
Figure 5.3 Plan and longitudinal section of the Pine Hill skarn mineralisation. G - garnet-diopside skarn, V - vesuvianite skarn, W - wrigglite skarn, A - amphibole skarn, M - mica skarn, T - tourmaline skarn, 1 - tourmaline cap, 2 - tourmaline-quartz-fluorite zone, 3 - sericitised zone, 4 - albitised zone. (After Manly, 1982; Holyland, 1987)
zone is also surrounded by a sericitic zone leading outward to an albitised margin (Fig. 4.6). Further drilling is required to better define these inferred alteration patterns within the Pine Hill Granite.

5.2.2.2 Skarn Zone...

Concentrically zoned about the Pine Hill greisen within limestone units of the Crimson Creek Formation are several skarn assemblages, 550 m stratigraphically above the Renison mine sequence (Fig. 5.3; Manly, 1982). Similar limestone units occur in the hanging-wall of the Federal-Bassett Fault and also host mineralisation in the Dalcoath Open-cut. The limestone units of the Crimson Creek Formation represent upper shallow water members in a repetitive sedimentary cycle (Morrison, 1993). The steep south to south-east dipping skarns within the limestone units at Pine Hill extend along strike over 900m, in a northeast-southwest direction and vary in thickness from 2 to 30 m. Although not shown in Figure 5.2, six divisions have been identified by Manly (1982) in the skarn zone. These divisions are defined by their dominant mineralogy away from the apex of Pine Hill (Fig. 5.3):

(i) Tourmaline zone  (iv) Vesuvianite zone
(ii) Mica zone  (v) Garnet & pyroxene zone
(iii) Amphibole zone  (vi) Epidote zone

The following description of these zones is based dominantly on the work of Manly (1982) and Holyland (1987). The alteration assemblages are described in order from distal to proximal, relative to the Pine Hill Granite apex.

Distal to the Pine Hill skarn assemblages, the carbonate horizons are partially recrystallised to marble. Holyland (1987) recognised calc-silicate alteration containing coarse poikiloblastic patches of wollastonite associated with subordinate disseminated sphene and grossular garnet developed on the outer fringe of the garnet-diopside skarn. Manly (1982) recognised a retrogressive epidote-chlorite assemblage partially altering the garnet-pyroxene skarn at a distance greater than 700 m from the greisen contact. Axinite rather than tourmaline was identified as the dominant boron metasomatic mineral phase associated with epidote alteration in this distal region.

The garnet-diopside skarn of Manly (1982) is considered to be the primary skarn associated with the Pine Hill intrusion, and contains 50 modal percent garnet plus pyroxene in bands 1 cm - 2.5 m thick. This skarn consists of andradite, diopside - hedenbergite, ± magnetite ± sphene ± cassiterite, and relic textures of this assemblage are recorded in all the skarn zones.

A stage II vesuvianite skarn overprints the primary garnet-diopside skarn with alternating bands, up to 1 m thick, of 20 modal percent vesuvianite and magnetite. This zone is itself overprinted by amphibole and epidote, altering the vesuvianite to vermiculite. The
vesuvianite skarn contains approximately 5 modal percent amphibole and 15 modal percent garnet and diopside.

A poorly defined wriggilitic skarn has been described between the vesuvianite and amphibole skarns (Manly, 1982; Holyland, 1987). The typical wriggilitic textures (Askins, 1975; Kwak and Askins, 1981a & 1981b; Dobson, 1982; Wright, 1986; Halley, 1987; Kwak, 1987) contain thin (0.04 - 0.5 mm), wavy, crenulated, alternating layers of magnetite + green amphibole and colourless fluorite.

Amphibole-rich assemblages are the dominant stage III skarn, overprinting both stage I and stage II assemblages with 35 modal percent ferrohastingsite in bands up to 2 m thick with less than 10 modal percent biotite (or phlogopite). Axinite, tourmaline, arsenopyrite and magnetite occur as accessory phases in this stage together with overprinting veins and patches of pyrrhotite, cassiterite, fluorite, calcite and muscovite.

Stage IV skarn consists of a mica-rich zone composed of brown biotite/phlogopite after ferrohastingsite/tremolite from the earlier amphibole zone together with green and purple fluorite, chlorite and vermiculite. This assemblage constitutes greater than 35 modal percent of the rock. Alteration is associated with veins of pyrrhotite plus cassiterite and sphene.

Proximal to the granite is the tourmaline zone which is composed of a tourmaline dominated matrix extensively cut by veins containing tourmaline, fluorite, quartz, pyrrhotite, pyrite and calcite. Unveined remnants comprise up to 30 modal percent of the rock, and consist of tremolite or chlorite after biotite (Holyland, 1987).

Summary Of Skarn Mineralogy:

Holyland (1987) summarised the features of the Pine Hill skarns. He noted that the skarn mineralogy at Pine Hill is unusual because vesuvianite is dominant as an early phase, whereas diopside is scarce, and phlogopitic biotite is abundant while wollastonite and epidote are rare.

The increase in $X_{Mg}$ and $X_{Al}$ and near-constant $X_{Fe}$ in garnet solid solutions recorded by Holyland (1987) during evolution of the skarn system are atypical, as most skarns contain garnets with increasing mole fractions of iron toward the intrusive (Einaudi et al., 1981). Holyland (op. cit.) accounted for these inconsistencies by suggesting that the hydrothermal fluids were derived from granitic sources, rather than granodioritic sources (Dobson, 1982), and consequently produced lower total Fe and Fe/Al ratios, and higher Al in their alteration assemblages. Such granitic fluids are usually associated with tungsten skarns (Guy, 1980; Kwak & Tan, 1981; Kwak, 1987). Typically, however, low Fe/Al ratios and reduced sulphur
are a function of low total chlorine contents related to tin-bearing granites (Burnham & Ohmoto, 1980).

A high fluorine activity is suggested by the presence of fluorite, and by fluorine in the stable, widespread hydrous mineral phase vesuvianite. High $X_{CO2}$ was interpreted by Holyland (1987) because of the rarity of wollastonite, but he also noted that vesuvianite is typically considered to indicate low $X_{CO2}$. Low oxygen fugacities are indicated by the paucity of epidote and other Fe$^{3+}$-bearing minerals in the proximal skarn environment, and sulphur fugacities below the pyrrhotite-pyrite buffer are suggested by the presence of pyrrhotite ± arsenopyrite assemblages.

5.2.2.3 Distal Alteration Features ...

Alteration facies away from the proximal skarn zone are complex and highly dependant on a number of factors, including: the composition of the host sediments, structural preparation of sediments for the ingress of hydrothermal fluids, changes in fluid/rock ratios, and fluid chemistry evolution. Previous investigations have interpreted alteration facies in the clastic sediments and carbonate horizons around the Renison mine area (Patterson, 1979; Patterson et al., 1981; Morrison, 1982; Davies, 1985; Holyland 1987) but no attempt was made to integrate these studies to produce a district interpretation of alteration features prior to Morrison (1993). The recognition of distinct alteration patterns is difficult, and only a cursory attempt is presented in Figure 5.2. This diagram should only be used as an initial guide to alteration patterns both spatially and temporally associated with the apophyses on the Pine Hill Granite.

In conjunction with this study, Morrison (1993) recognised that the metasomatic zones overprint the contact metamorphic hornfels and that the outer limit of biotite hornfels coincided with the change from amphibole to chlorite metasomatism. Not all of the zones identified are necessarily present in a particular area but the pattern in drill holes is for higher temperature zones to be better developed closer to Pine Hill and deeper within any particular drill hole. These zones are also recognised to be attenuated in the mine area along the Federal-Bassett Fault away from a dilational jog in the fault, and above an apophysis in the Pine Hill Granite.

Within the Crimson Creek Formation, segments of the skarn zone (tourmaline-quartz-clinopyroxene) extend away from the apex of Pine Hill for 2.5 km in a northeast direction to the Ring River, and 3 km west to Serpentine Hill (Figs. 2.2 & 5.2; Morrison, 1993). The amphibole zone (actinolite-tremolite-diopside) extends 4 km northeast but less than 3 km west from the apex of Pine Hill (Figs. 2.2 & 5.2). Actinolite and tremolite in this zone typically occur as radiating aggregates or matted fibres with a carbonate overprint, and are associated
with disseminated sphene, bladed axinite and hydrothermal apatite. In the mine area, the chlorite/talc zone is best developed in and around the carbonate replacement orebodies. When present in the dolomite units of the North-Bassett Fault, the chlorite/talc zone grades into the amphibole zone at depth (Rendeep Orebodies), and gives way to a carbonate zone (siderite, ankerite and/or calcite) near surface, distal to the Federal-Bassett Fault (Fig. 5.2). The carbonate zone can be recognised up to 5 km northwest of Pine Hill at the Owen Meredith workings. In the Envelopes region of the mine, the talc/chlorite zone overprints the skarn zone at depth and the amphibole zone at higher levels (Fig. 5.2).

5.2.3 Vein Assemblages ...

Intimately associated with the metasomatic replacement fronts, and more systematic in nature, are several generations of veins spatially related to apophyses in the Pine Hill Granite. Three distinct stages of telescoped vein mineralisation have been recognised within the mineral paragenesis of the Renison-Dundas district (Fig. 5.2):

(i) Oxide-Silicate Stage
(ii) Main Sulphide Stage
(iii) Carbonate-Base Metal Stage

These mineralised vein stages have been recognised throughout the Renison district and are well developed in the Federal-Bassett Fault at Renison. A detailed paragenetic sequence has been determined for each assemblage, together with a history of related deformation and reactivation (Section 5.4.2; Fig. 5.15). In the Renison-Dundas district the early hydrothermal Oxide-silicate Stage is characterised by tourmaline + quartz + arsenopyrite ± cassiterite ± wolframite ± pyrrhotite. This stage occurs within the skarn and amphibole zones and overlaps with the biotite metasomatic assemblages (Fig. 5.2).

The Sulphide Stage is the dominant carbonate replacement stage in the “distal skarn” assemblage (Kwak, 1987) at Renison, but can be recognised in the vein paragenesis throughout the mines and prospects of the Renison-Dundas district. The mineralogy is dominated by pyrrhotite + pyrite + quartz ± cassiterite ± arsenopyrite ± chalcopyrite. This sulphide stage overprints the earlier oxide-silicate vein assemblages and is associated with the metasomatic biotite and talc/chlorite zones.

The final vein stage is a Carbonate-Base Metal Stage, characterised by siderite and base metals, and a late vug-fill carbonate assemblage. These stages, unlike the first two vein stages are uneconomic at Renison but have been mined in the Renison-Dundas district for Ag-Pb-Zn.

The following sections present an overview of mineralisation patterns in the Renison-Dundas district before discussing in detail the Renison vein assemblages.
5.3 MINERALISATION IN THE RENISON-DUNDAS DISTRICT...

Mineralisation in the Renison-Dundas district exhibits the following overlapping deposit types:

(i) tin-rich deposits;
(ii) copper-antimony-silver deposits;
(iii) lead-zinc-silver deposits; and
(iv) copper-nickel deposits.

Table 5.1 summarises the range of mineralisation styles historically mined in the district (after Crossing, 1991). Far in away the most important commodity is tin, which has been mined from a range of deposit styles; the largest ore bodies are represented by the Renison style of stratabound carbonate replacement, together with related fault and fracture mineralisation. At the turn of the century, argentiferous antimonial-copper-lead lodes called 'fahl-ore' and argentiferous lead-zinc ores were also mined successfully in the district from a number of NNW/NNE trending fissure lodes. The copper-nickel deposits at Cuni (Fig. 5.4, No's 56-60) are Cambrian in age and related to magmatic segregations within mafic dykes (Blissett, 1962). All other styles of mineralisation in the district are associated with the Devonian Pine Hill intrusion. The Cambrian copper-nickel styles of mineralisation will not be discussed further.

5.3.1 Overview Of Renison-Dundas Mineral Field...

Previous investigators noted the existence of a weak metal zonation in the Renison-Dundas district, with a central tin zone surrounded by a discontinuous peripheral zone of minor copper-silver and lead-zinc deposits, but details of the exact nature of this mineral field have not been forthcoming (Blissett, 1962; Groves, 1968; Patterson, 1979; Herman & White, 1989). Kitto (1993b) was the first to recognise and discuss the intimate association between metal zonation and the shape of the underlying Pine Hill Granite intrusion.

The Renison-Dundas mineral field covers an area of 200 km², south of Lake Pieman to a line east of the Murchison Highway from Misery Hill to Mt Dundas, and includes the abandoned mining townships of Renison Bell and Dundas (Fig. 5.4). The Pine Hill Granite outcrops in the central-northern region of the mineral field. Mining operations have occurred discontinuously since the discovery of the field in the late 1880's and early 1890's. The largest period of mining activity occurred prior to World War I when the Dundas township was one of the largest in Tasmania. Since that time, sporadic mining operations have occurred but the Renison Tin Mine is the only fully operational mine in the district today. A number of small-scale, one man, operations still extract secondary minerals such as crocoite (PbCrO₄) and cerrusite (PbCO₃) for sale to gem collectors (Fig. 5.4, No. 46 - Adelaide Mine, No. 47 -
<table>
<thead>
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<th>TYPE</th>
<th>DESCRIPTION</th>
<th>COMMODITY</th>
<th>MINERALOGY</th>
<th>EXAMPLE</th>
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</thead>
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<td>FAULT</td>
<td>• Multi-phase sulphide mineralogy</td>
<td>Sn, Cu</td>
<td>Qz, Po, Asp, Tour, Cass, Cpy</td>
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<td></td>
<td>• Pyrrhotite replacement of carbonate-magnetite mineralisation</td>
<td>Sn</td>
<td>Po, Carb, Mt, Cass</td>
<td>Renison (Polaris)</td>
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<td>FISSURE</td>
<td>• Stanniferous lodes occupying NNW trending fractures</td>
<td>Sn, Cu</td>
<td>Qz, Po, Py, Asp, Cpy, Cass</td>
<td>Frazers, Exe River</td>
</tr>
<tr>
<td>LODES</td>
<td>• Antimonial-copper-lead lodes occupying NNW/NNE fractures and veins</td>
<td>Cu, Pb, Ag</td>
<td>Qz, Sid, Py, Gal, Sph, Tetra, Jam</td>
<td>Curtain Davis lodes</td>
</tr>
<tr>
<td></td>
<td>• Lead-zinc lodes occupying NNW trending fractures</td>
<td>Pb, Zn, Ag</td>
<td>Sph, Py, Gal, Sph, Jam, Croc</td>
<td>South Comet, Maestries</td>
</tr>
<tr>
<td>VEINS</td>
<td>• Quartz-tourmaline veins adjacent to granites</td>
<td>Sn</td>
<td>Qz, Tour, Cass</td>
<td>Penzance</td>
</tr>
<tr>
<td>FRACTURE</td>
<td>• Silicified, tourmalinised and fractured siltstones</td>
<td>Sn</td>
<td>Qz, Tour, Po, Asp, Cass</td>
<td>Renison (Melba)</td>
</tr>
<tr>
<td>STRATABOUND</td>
<td>• Massive sulphide replacement of faulted dolomites</td>
<td>Sn</td>
<td>Po, Qz, Talc, Sid, Asp, Tour, Cass</td>
<td>Renison (stratabound)</td>
</tr>
<tr>
<td>&quot;RAZORBACK&quot;</td>
<td>• Massive sulphide replacement of faulted, dolomitised ultramafics</td>
<td>Sn</td>
<td>Po, Py, Qz, Talc, Sid, Asp, Cass</td>
<td>Razorback, Grand Prize</td>
</tr>
<tr>
<td>SILL</td>
<td>• Massive sulphide accumulated at base of gabbroic sill</td>
<td>Cu, Ni</td>
<td>Penti, Mill, Po, Py, Cpy</td>
<td>Cuni Deposits</td>
</tr>
</tbody>
</table>

**TABLE 5.1** Types of mineralisation mined in the Renison-Dundas district. Abbreviations: Asp - arsenopyrite; Carb - carbonate; Cass - cassiterite; Cpy - chalcopyrite; Croc - crocoite; Gal - galena; Jam - jamesonite; Mil - millerite; Mt - magnetite; Po - pyrrhotite; Py - pyrite; Qz - quartz; Sid - siderite; Sph - sphalerite; Tetra - tetrahedrite; Tour - tourmaline.
Figure 5.4   Mines and prospects in the Renison-Dundas district.

Red Lead Mine). Specimen quality, purple bladed axinite \([(Ca, Mn, \text{Fe}^{2+})_3Al_2BO_3(Si_4O_{12})OH]\) is also collected from an opencut at Colebrook Hill (Fig. 5.4, No. 19).

Mineralogical and structural details on each of the sixty identified mines and prospects located in the Renison-Dundas district (see Fig. 5.4) have been summarised in Table 5.2 and Table 5.3. Much of the information tabulated has been obtained from past geological records (e.g., Montgomery, 1896; Twelvetrees, 1900 & 1906; Waller, 1902; Reid, 1925; Elliston, 1950; Blissett, 1962; Forsythe, 1969; Herman & White 1989) and from visits to the majority of these mines and prospects.

Table 5.2 separates the mines and prospects into their major commodities (i.e., Sn deposits, Cu deposits, Pb-Zn deposits & Cu-Ni deposits) and presents a summary of the styles of mineralisation observed in each. These styles range from greisens, carbonate replacement, altered ultramafics, base metal quartz veins and stringers, to wallrock breccias and carbonate infill mineralisation. Also tabulated are the major structural trends for each deposit together with a compilation of the major, intermediate and minor commodities present. Table 5.3, like the previous table separates the mines and prospects into their major commodities but presents a tabulation of their mineral assemblages.

5.3.2 Structural Controls To Mineralisation ...

All of the deposits in the Renison-Dundas district are associated with or occur as fracture filled fissure veins, or as mineralised breccia zones. Two major structural trends hosting mineralisation are immediately obvious from Table 5.2. These structural trends consist of sets of major NW and NNE trending faults that act as hosts to mineralisation (Reid, 1925; Blissett, 1962). These fault sets are interpreted as extensional conjugate faults, developed above the flattened roof zone of the Pine Hill Granite batholith during emplacement of that body. Figure 5.5 illustrates the structure contours for the granite-sediment contact in the area and highlights the flat topped nature of the batholith and the distribution of deposits along the margins of the granite; also see Fig. 4.5.

The northwest trending set of faults appear to dominate as the preferential sites to mineralisation, and represent a zone near normal to the minimum compressive stress (\(\sigma_3\)) during granite emplacement, which dilated due to high fluid pressures associated with the mineralising hydrothermal fluids. Figure 5.6 illustrates the relationships between conjugate vein sets, stress directions, and preferred sites of mineralisation in the Renison-Dundas district. Similar mechanisms for preferred directional dilation of conjugate faults are discussed in Hodgson (1990).
Table 5.2 Prospects and mines in the Renison-Dundas mineral field, and a list of their styles of mineralisation (1-8), together with their structural trends. Filled circles, crosses and open circles represent major, intermediate and minor commodities at each prospect. A list of references used to assist the compilation of this table are given in the text.
Table 5.3 Prospects and mines in the Renison-Dundas mineral field and a list of their mineralogies. A list of references used to assist the compilation of this table are given in the text.
Figure 5.5 Structure contours for the Devonian Pine Hill Granite in the Renison-Dundas district. Granite contour interpretation from residual gravity survey by Leaman (1990).
Figure 5.6 Diagrammatic representation of the NW and NE trending conjugate vein sets in the Renison-Dundas district, and formation of preferential NW trending sites to mineralisation (dilation zones) by bulk inhomogeneous flattening (after Hodgson, 1990).
Major mineralised faults observed at the South Comet Mine (Fig. 5.4, No. 54; Table 5.2 & 5.3) and at the Curtin Davis Mines (Fig. 5.4, Nos. 21-26; Table 5.2 & 5.3) have kinematic indicators which suggest initial dip-slip movement was followed by dextral reactivation. This scenario is similar to Renison where initial dip slip movement associated with granite emplacement is overprinted by a dextral reactivation of the Federal-Bassett Fault as the granite related stress field decayed and the regional Devonian Tabberabberan stress field began to dominate. At Renison this strike slip reactivation produced a dilational jog in the Federal-Bassett Fault which contains the major Federal orebody. The orientation of $O_3$ in the Renison-Dundas mineral field, associated with dilation of the northwest trending faults, is consistent with the conclusions drawn from the Renison deposit (Chapter 3). It can be concluded, therefore, that district scale mineralisation occurred under similar conditions to those recorded at Renison, and is genetically associated with the Pine Hill Granite.

Mineralised veins in the district occur in brittle shear zones, and in the case of the Curtin Davis deposits (Fig. 5.4, Nos. 21-26; Table 5.2 & 5.3) along bedding-controlled dilation zones in the hinges and limbs of tightly folded sediments. Vein textures and kinematic indicators, similar to Renison, indicate that mineralisation and deformation within the shear zones developed synchronously at low mean stress due to high fluid pressures.

The large majority of vein deposits in the district typically contain steeply plunging ore shoots located at the intersection of two sub parallel fault planes (e.g., South Comet Mine; Bartlett, 1993). Because of the undulate nature of the fault surfaces the steeply plunging ore shoots pinch and swell and are therefore discontinuous along strike and do not extend more than a few hundred metres down dip. This style of deposit has made mining on a large scale difficult and uneconomic.

5.3.3 Tin Deposits ...

Mineralisation in the Renison-Dundas district exhibits a broad telescoped zonation pattern centred upon the Pine Hill Granite (Fig. 5.7). Leaman and Richardson (1989) consider the Pine Hill Granite to be, "...probably the most important granite in western Tasmania. This granite has introduced an array of mineralisation styles, as well as remobilisation of older volcanic material. Its transverse relationship to the Dundas Trough is probably the critical element. It is almost fully roofed. The roof is irregular and...mineralisation can be directly correlated to roof form and body distribution." They also note that, "...zonation studies are likely to be fruitful, as the crest of the intrusion is irregular with key focal points. Renison is presumably one of these."

The central tin zone, closest to Pine Hill, has a diameter of approximately 6 km and extends northward and includes the Renison and Exe River deposits (Fig. 5.4, No. 1 & 8) together
Figure 5.7  Telescoped metal zonation in the Renison-Dundas district, centred around the underlying Devonian Pine Hill Granite intrusion (compare with Fig. 5.5).
with the Olympic and Athena deposits (Fig. 5.4, No. 10 & 11) to the east. The southern extension of the tin zone occurs south of Pine Hill at the Fraser Mine and Green's Prospect (Fig. 5.4, No. 4 & 5). A separate tin zone approximately 2.5 km in diameter is recognised around both the Grand Prize and Mines Razorback (Fig. 5.4, No. 6 & 7) in the south-eastern region of the mineral district. A comparison of the tin zones (Fig. 5.7) with the granite contours (Fig. 5.5) clearly demonstrates an association between proximity to the Pine Hill Granite and apophyses within the roof of the intrusion. Two cross-sections through the Renison-Dundas district (Fig. 5.8a & 5.8b) illustrate the telescoped nature of mineralisation, defined by the mines and prospects in the district, and the close association between mineralisation and distance from the intrusion. Figure 5.8 (a) is a NNW-SSE cross-section of the Renison-Dundas district through the Renison-Pine Hill-Curtin Davis areas and clearly shows the steep sided nature of the Pine Hill body and the undulate top to the granite-sediment contact. Associated with the intrusion is a telescoped metal zonation that passes from a tin-rich centre, to copper mineralisation, and out distally to a lead-zinc halo. Figure 5.8 (b) is a north-south cross-section through the Pine Hill and Razorback regions, at 370 000 E, and illustrates the close association between tin mineralisation and apophyses in the granite.

It can be inferred from the regional cross-sections (Fig. 5.8) that tin mineralisation in the Renison-Dundas district only occurs within a 1.5 km radius of the Pine Hill Granite-sediment interface. Because uneconomic skarn styles of tin mineralisation occur within the first 500m of the Pine Hill Granite, initial exploration should be undertaken within 500 - 1500m of the granite contact.

The mineralogy of the deposits within the tin zones have been presented in Tables 5.2 & 5.3 and consist of an Oxide-Silicate Stage of mineralisation referred to previously in Figure 5.2. Tables 5.2 and 5.3 illustrate that the major commodity mined in the tin zone were carbonate replacement styles of mineralisation. Cassiterite deposits with an average grade between 1 - 2 wt. % Sn were the principal targets, although at the Fraser workings arsenopyrite was mined.

At the Curtin Davis deposits, which occur on the steep northern face of Godkin Ridge, the Oxide-Silicate Stage has been recognised in the lower-most workings, but this has been overprinted by later sulphide and carbonate stages (Herman & White, 1989) resulting in a telescoped metal zonation.

A number of the tin deposits (e.g., Razorback, Grand Prize, Karlson-Riley, Greens Prospect) represent replacement mineralisation along margins of dolomitised Cambrian ultramafic bodies (Table 5.2). This suggests that the ultramafic bodies and related Cambrian thrusts acted as zones of structural weakness and provided a locus for Devonian hydrothermal fluids (Crossing, 1991). The ductile nature of most of the ultramafics, however, has prevented an
Figure 5.8a NW - SE cross-section of the Renison-Dundas district through Pine Hill, illustrating the telescoped metal zonation centred on the Devonian Pine Hill Granite. Granite morphology is based on residual gravity interpretations by Leaman (1990).

Figure 5.8b N - S cross-section of the Renison-Dundas district through Pine Hill and Mt. Razorback at 370 000E, illustrating the telescoped metal zonation centred on the Devonian Pine Hill Granite. The smaller Sn zone associated with the Razorback and Grand Prize deposits is shown centred upon a second apophysis in the granite. Granite morphology is based on residual gravity interpretations by Leaman (1990).
excessive ingress of hydrothermal fluids along such mineralising structures, and consequently ultramafic replacement deposits in the district are small and uneconomic.

5.3.4 Copper Deposits ...

Overlapping the central tin zone in the Renison-Dundas district are a number of copper-rich deposits that define a 2 km wide annulus of copper mineralisation (Fig. 5.7). These deposits include the Curtin Davis workings, Bonnie Dundee, Fahl, Rich P. A., Svengali and Colebrook Hill deposits (Fig. 5.4, No. 12 - 26; Table 5.2 & 5.3). The majority of the copper-rich deposits occur along the south-eastern margin of the Pine Hill Granite adjacent to the two tin-rich zones. The exact significance of this fact is uncertain except to say that it forms an intermediate zone of mineralisation between the central tin zones and the peripheral lead-zinc styles of mineralisation around the Pine Hill Granite. The telescoped nature of the copper mineralisation is shown in Figures 5.8 (a) & (b), which demonstrate that copper-rich mineralisation occurs in a zone 0.5 - 2.5 km away from the Pine Hill Granite-sediment interface.

The overlapping telescopic nature of mineralisation at the Curtin Davis mines has been briefly described by Herman and White (1989). They recognised that the earliest stage of quartz + arsenopyrite ± pyrite ± pyrrhotite ± cassiterite mineralisation (equivalent to the Oxide-Silicate Stage, Fig. 5.2), in the lowest levels of the mine workings progress vertically upward into a siderite dominated mineral assemblage containing quartz + pyrite + chalcopyrite + tetrahedrite ± arsenopyrite ± pyrrhotite ± galena ± sphalerite. The sulphides exhibit a variable mode of occurrence from coeval, fine to coarse disseminated inclusions and intergranular fillings in a sideritic gangue, to later cross-cutting and stringer style veins. Herman and White (1989) interpreted the field associations as representing the vertical upward migration and evolution of a granite derived hydrothermal fluid along dilational open spaced fissures.

Tables 5.2 and 5.3 shows that the major commodity in the copper zone is a 'fahl-ore' consisting of tetrahedrite and chalcopyrite. The ore was worked primarily for the silver content of the tetrahedrite which averaged 600 g/t silver (Blissett, 1962). The final mineralising event recognised in the copper zone are a series of late stage stringer veins of jamesonite which overprint all previous sulphide stages.

5.3.5 Lead - Zinc Deposits ...

Peripheral to, but overlapping the copper-rich zone is a ~2 km wide outer halo of argentiferous lead-zinc deposits (Fig. 5.7). The majority of these deposits, like the copper deposits, are concentrated along the southeastern margin of the Pine Hill Granite
A number of deposits also occur along the western margin of the granite and overprint the Cuni deposits (Fig. 5.4, Nos. 33, 34, 56 - 60), and still others occur in the northwestern and northern region of the mineral field (Fig. 5.4). East of the district Devonian mineralisation overlaps and overprints Cambrian volcanogenic hosted massive sulphide deposits at Rosebery and Hercules. The complex nature of this relationship has been discussed by Khin Zaw (1991).

The telescoped nature of the lead-zinc mineralisation in the Renison-Dundas mineral field can be seen more clearly in Figures 5.8 (a) & (b). Pb - Zn mineralisation occurs 2 - 4 km radially away from the Pine Hill Granite-sediment interface. The major producers of silver, and more recently lead and zinc, occur in the southeastern region of the mineral field. The South Comet Mine (Fig. 5.4, No. 54), for example, began operations in 1911 miningargentiferous galena. It was re-opened on a small scale in early 1990 to extract sphalerite, employing up to eight men. Secondary minerals such as crocoite and cerrusite are also mined from this area for sale to local and overseas collectors.

Tables 5.2 & 5.3 indicate that the majority of the argentiferous lead-zinc deposits occur as fissure infills or as partial replacements of altered ultramafics bodies. Mineralisation consists of a siderite gangue overprinted by lead-zinc mineralisation. The typical vein assemblage consists of siderite + pyrrite + galena + sphalerite ± chalcopyrite ± quartz. Jamesonite overprints all previous stages of mineralisation as either fine stringers, occasional coarse veins, or large shoots.

5.4 MINERALISATION AT RENISON ...

The previous sections of this chapter have presented details on the alteration and mineral zonation patterns in the Renison-Dundas district associated with the Devonian Pine Hill Granite. The remainder of this chapter will deal, in detail, with the mineralisation at the Renison Tin Mine, concentrating mainly on the paragenetic vein assemblages associated with the Federal-Bassett Fault.

5.4.1 Major Styles Of Mineralisation ...

Four main styles of mineralisation are recognised and mined at Renison, as shown in the generalised cross-section of the mine (Fig. 5.9). These styles are:

(i) Stratabound carbonate-replacement ore;
(ii) Fault ore;
(iii) Stratafault ore [a combination of types (i) and (ii)]; or
(iv) Fracture ore.
Figure 5.9  Generalised cross-section of the Renison Tin Mine illustrating approximate locations for the various ore types.
Stratabound carbonate replacement mineralisation was greatest in the No. 3 Dolomite horizon and decreased to a minimum in the No. 1 Dolomite horizon. A better perspective of the irregular nature of stratabound carbonate replacement by cassiterite-rich pyrrhotite orebodies can be seen in Figures 5.11, 5.12 and Figure 3.15. Each diagram presents the No. 1, No. 2 and No. 3 Dolomite horizon, respectively, as footwall projections showing the position of known stratabound pyrrhotite replacements orebodies. The dissection and large separations observed within respective dolomite horizons are an artefact of fault displacements; the directions of which can be seen in Figure 3.11, Figure 5.10 and Appendix 1. Collectively, the footwall projections illustrate the complex and irregular nature of carbonate replacement mineralisation which has been spatially controlled by the proximity
Figure 5.10  Schematic diagram illustrating locations for the stratabound carbonate replacement orebodies relative to the No. 1, No. 2, and No. 3 Dolomite horizons, and the bounding Federal-Bassett Fault, Blow Fault and Transverse Faults. The North Bassett, Federal and Envelope regions of the Federal-Bassett Fault are also indicated.
Figure 5.11  Footwall projection of the No. 1 Dolomite horizon at Renison, indicating the relative positions of massive stratabound carbonate replacement orebodies.
SULPHIDE REPLACEMENT OF NO.2 DOLOMITE
(FOOTWALL PROJECTION)

Figure 5.12  Footwall projection of the No. 2 Dolomite horizon at Renison, including the relative positions of massive stratabound carbonate replacement orebodies.
interpreted of the mineralised feeder faults to the carbonate horizons. The importance of first, second, and third order fault structures to fluid ingress has been discussed in Chapter 3. The partial absence of No. 1 and No. 2 Dolomites from the northwest regions of the footwall projections in Figure 5.11 and 5.12, respectively, are the result of erosion. The footwall projections illustrate that ore distribution is heterogeneous within the dolomite horizons and typically forms elongate lobes bounded by the Transverse Faults. Stratabound carbonate replacement orebodies developed on both downthrown and upthrown blocks. The largest of the orebodies typically occur adjacent to the Federal-Bassett Fault associated with the major Transverse Faults ('Shear P' and 'Shear L'), particularly in the No. 2 Dolomite horizon. Davies (1985) discussed the vertical variations in ore replacement within a single dolomite horizon. These range from complete dolomite replacement, footwall and hangingwall controlled replacement, central replacement, to selective interbedded replacement of numerous dolomitic lamellae.

Distinct zonation patterns in the stratabound replacement ore from unaltered host dolomite through to massive sulphide zones have been recognised (Davies, 1985; Holyland, 1987). The progressive sequence of carbonate replacement is:

Host Dolomite → Hydrothermal Carbonate → Disseminated Sulphide → Talc-Sulphide → Massive Sulphide.

Boundaries between the hydrothermal carbonate zone and the host dolomites are invariably sharp, as are the boundaries between the massive sulphide zone and the outer mineralised zones. The talc-sulphide zone is generally absent to poorly developed and has sharp boundaries with the adjacent mineralisation, when present. The disseminated sulphide zone unlike the others, has diffuse boundaries and can vary greatly in width up to several metres. The hydrothermal carbonate zone can be absent resulting in the massive sulphide zone coming in direct contact with the host dolomite. In such instances, the outer portion of the massive sulphide zone is defined by a narrow talc-sulphide region, or hydrothermal siderite reaction front (Plate 5.1a).

Pyrrhotite is the major constituent of the stratabound carbonate replacement orebodies. Holyland (1987) noted an increase in the percentage of pyrite in stratabound mineralisation in the Up-dip areas (Fig. 5.10; eg., Rings, Sligo, Godkin), away from the pyrrhotite dominated contact aureole of the northerly plunging Pine Hill Granite. Minor gangue minerals within the ore include chalcopyrite, pyrite, arsenopyrite, quartz, tourmaline, tremolite, talc, phlogopite, siderite and fluorite. Galena and sphalerite commonly occur on the massive pyrrhotite margins as a late vein-hosted mineral assemblage. Tin occurs predominantly as cassiterite with grains typically minus 150 µm in diameter.
PLATE 5.1

A: Stratabound carbonate replacement front. Reaction front showing stratabound carbonate replacement of the No. 2 Dolomite horizon by massive pyrrhotite, giving way to hydrothermal carbonate (siderite), and finally unaltered dolomite. Minor talc occurs at the contact between massive pyrrhotite and siderite. Note the contact with the overlying siliciclastic sediments is extremely sharp and devoid of mineralisation. Location - Dreadnought 2125 stope.

B: Fracture ore. Mineralised dolomitic sediments of the Renison Bell Member associated with the Melba orebody illustrating an oxide-silicate stage vein assemblage consisting of quartz + arsenopyrite + pyrrhotite + pyrite. The dolomitic sedimentary layers show partial replacement by pyrrhotite, and the more siliciclastic layers have been extensively tourmalinised. Location - Melba 1985 stope.
Total sulphur contents of the stratabound carbonate replacement orebodies systematically increase with distance from the Federal-Bassett Fault, as shown in Figure 5.13. A near linear relationship exists between total sulphur and MgO contents for the replacement orebodies, based on current production figures. These trends reflect both increased pyrrhotite precipitation due to increased $\Sigma S$ concentration, and dilution of quartz and talc assemblages due to decreases in silica activities with distance from the Federal-Bassett Fault. Patterson (1979) described mineralogical and elemental zoning patterns in the stratabound carbonate replacement orebodies in which Sn, As, Cu and S declined concentrically away from a given point on the boundary fault. The poorly defined zonation was attributed to an overlap of multiple fluid foci.

5.4.1.2 Fault Mineralisation ...

(i) Fault Ore

Fault mineralisation is developed in sections of the Federal-Bassett Fault and the Transverse Faults, averaging 4m true thickness (Fig. 5.9). In the Federal area fault mineralisation reaches 40m true thickness and contains an average 0.9% Sn. Fault ore is also mined from Polaris, a fault bounded orebody at the intersection of 'Shear P' and 'Shear L' in the Up-dip regions of the mine, beneath the Argent orebody (Chapter 3; Kitto, 1992a). Mineralisation in Polaris is up to 6m thick with average grades of 1.7% Sn (Cannard, 1991).

In the Federal region, fault mineralisation typically occurs as massive to semi-massive pyrrhotite with a gangue of quartz, arsenopyrite, tourmaline, phlogopite and minor pyrite, chalcopyrite, stannite, bismuth, ilmenite, fluorite and apatite. The dominant tin mineral is cassiterite, which varies in size from 100 $\mu$m to 1 mm.

In the Polaris orebody, early fault controlled carbonate-magnetite mineralisation has been overprinted by a cassiterite-rich pyrrhotite assemblage. Gangue minerals include talc, chlorite, quartz, arsenopyrite, galena, stannite, chalcopyrite, and boulangite (Barber, 1990). Intergranular cassiterite in pyrrhotite ranges from 20 - 400 $\mu$m (Simonsen, 1988). Carbonate-magnetite mineralisation has also been identified in various fault controlled locations within both the Federal-Bassett and Transverse Faults as a precursor to sulphide mineralisation.

(ii) Stratafault Ore

Stratafault ore is transitional between stratabound and fault ores and occurs, "...in areas of complex faulting where two sub-parallel faults are sufficiently close to allow the intermediate mine sequence material, both dolomitic and non dolomitic, to be mineralised" (Fig. 5.9;
Figure 5.13: Total sulphur versus MgO (wt. %) in the stratabound carbonate replacement orebodies. A systematic increase in sulphur contents of the orebodies is evident with distance from the Federal-Bassett Fault (Fig. 5.10).
Strata fault ore is recognised in the Envelopes region, south of the intersection of 'Shear L'/Federal contact, and also in the North Bassett region, north of the 'Shear P'/Federal contact (Fig. 5.10). Tin grades average 1.4% in the Envelopes and 1.0% in the North Bassett. The recently discovered strata fault/fault Rendeep orebodies in the North Bassett Fault between 1600m R.L. and 1400m R.L. contain a probable reserve of 3.3 mt at 1.96% Sn, and an additional resource of 3 mt at 1.5% Sn (Fig. 5.14). Figure 5.14 is a longitudinal projection of the Federal-Bassett Fault, looking northeast from the footwall to the hangingwall over a strike length of almost 2 km. It illustrates the location of Strata fault, Fault and Stratabound orebodies that are bounded by the fault couple, and also indicates the location of the northerly plunging Devonian Pine Hill Granite that underlies the mine workings and supplied hydrothermal fluids responsible for mineralisation.

5.4.1.3 Fracture Ore ...

Fracture ore is restricted to the Melba orebody and consists of a zone of mineralised anastomosing sheeted vein complexes in quartzites and shales of the Lower Renison Bell Formation (Fig. 5.9; Section 3.5.3.2). The Melba orebody is anticlinal in cross-section and located between 'Shear L' and 'Shear P' from 65780N to 65980N (Appendix I). It is developed above a convex west flexure in the Federal-Bassett Fault between 1800m R.L. and 1900m R.L. and is bounded to the north by the footwall of 'Shear P' (Fig. 3.10).

Typical fracture ore consists of 30-50 mm wide oxide-silicate veins with sub-parallel to straight margins and sharp to semi-diffuse wallrock contacts. Vein assemblages are quartz dominated with minor proportions of cassiterite ± arsenopyrite ± pyrrhotite ± pyrite mineralisation. The wallrocks have been extensively tourmalinised, and pyrrhotite occurs as bedding-parallel replacements of the carbonate-rich laminated sediments (Plate 5.1b). Cassiterite ranges in size from 50-200 μm and is typically pale in colour. Melba fracture ore has an average grade of 1.1% Sn (Cannard, 1991).

5.4.2 Vein Paragenesis And Deformation Of The Renison Ores ...

This section presents a vein paragenesis for the Renison Tin Mine based on the proposed deformation history outlined in Chapter 3. Interpretations are based on geometric relationships and kinematic indicators from underground exposures (Section 3.2) together with detailed handspecimen and petrographic evidence obtained from 117 diamond drill-hole intersections of the Federal-Bassett and 83 diamond drill-hole intersections of the Transverse Faults.
Figure 5.14 Longitudinal projection of the Federal-Bassett Fault showing the location of strata fault and Rendeep orebodies (dotted outlines). The extent of underground workings on the Federal-Bassett Fault and the proposed new shaft development for the Rendeep area are also indicated.
5.4.2.1 Previous Investigations ...

Patterson (1979) and Patterson et al., (1981) provided the first detailed study of the vein paragenesis at Renison. They outlined six paragenetic stages based on mineralogical variations. Stages 1 and 2 represented carbonate replacement mineralisation while stages 3 to 6 were vein assemblages. A brief summary of each stage is listed below.

Stage 1: cassiterite + silicates;
Stage 2: cassiterite + pyrrhotite + arsenopyrite + silicates + minor sulphides & iron oxides;
Stage 3: cassiterite + pyrrhotite + arsenopyrite + silicates + minor sulphides;
Stage 4: sphalerite + galena + silicates + carbonates ± fluorite;
Stage 5: calcite + quartz ± chlorite;
Stage 6: carbonate, quartz, fluorite, and sulphides.

Davies (1985) described the nature of stratabound carbonate replacement mineralisation, concentrating on the dilatant textures in the host dolomite horizons (Section 5.4.1.1), and more recently Holyland (1987) has proposed 13 paragenetic stages, based on a Markov chain analysis, for the Pine Hill contact skarns (Early Stages 1 - 6) and the Renison deposit (Late Stages 1 - 7). Holyland's mineral paragenesis for Renison is listed below.

Late Stage 1: quartz + tourmaline;
Late Stage 2: pyrrhotite;
Late Stage 3: arsenopyrite quartz;
Late Stage 4: base metals + rhodochrosite;
Late Stage 5: quartz + calcite;
Late Stage 6: multi-species vug-fills;
Late Stage 7: Ca-montmorillonite.

An obvious omission from each of the previous mineralogical investigations has been a detailed interpretation of the relationships between deformation and related mineralisation within the Renison deposit. Structural investigations (Chapter 3) have already emphasised the importance of major faults in focussing mineralising fluids into structurally prepared dolomitic hostrocks. It has also been demonstrated that a number of brittle reactivations of the major faults occurred during mineralisation at Renison which has opened dilational jogs and allowed continual fluid infiltration. The following section aims to present a detailed assessment of the associations linking deformation and mineralisation at Renison.

5.4.2.2 Links Between Deformation And Vein Paragenesis ...

Figure 5.15 presents a model that links, for the first time, deformation events at Renison with the vein paragenesis. Five mineralogical stages are recognised, and each is separated by distinct deformation events, with the exception of the final stage. The mineralogical stages represent temporal variations in the mineralogy of the deposit with declining temperatures.
Figure 5.15  Mineralogy, vein paragenesis and deformation relationships for the Renison Tin Mine, western Tasmania. Abbreviations: Anat - anatase; Arg - argentite; Asp - arsenopyrite; Bis - bismuth; Calc - calcite; Carb - carbonate; Cass - cassiterite; Chl - chlorite; Cpy - chalcopyrite; Dol - dolomite; Flu - fluorite; Gal - galena; Goeth - goethite; Graph - graphite; Haem - haematite; Ilm - ilmenite; Leuc - leucoxene; Marc - marcasite; Melnik - melnikovite; Mt - magnetite; Musc - muscovite; Pent - pentlandite; Phlog - phlogopite; Po - pyrohellite; Py - pyrite; Qz - quartz; Rut - rutile; Scheel - scheelite; Sid - siderite; Sph - sphalerite; Stan - stannite; Trav - travestine; Wolf - wolframite.
Spatial variations exist on a district scale (Section 5.2 & 5.3) but are not as obvious on a mine scale. The mineralogical stages are:

(i) Oxide-silicate Stage
(ii) Sulphide Stage
(iii) Late Base Metal Stage
(iv) Vug-fill Carbonate Stage
(v) Supergene Stage

The simplification of the vein paragenesis to five stages, based on deformation events, provides a more traditional Sn-W vein style of nomenclature for the mineralisation at Renison (eg., Kelly & Turneaure, 1970; Kelly and Rye, 1979).

The following discussion presents a brief account of the mineral paragenesis and deformation event associated with each paragenetic stage. A more detailed account of each mineral phase is given in Section 5.4.3. It should be stressed that because of repetitive precipitation and self-sealing episodes, together with spatial and temporal variations within the major fault structures any paragenesis will be an over-simplification of the facts, and therefore some caution should be applied when using such a scheme.

5.4.2.3 Oxide-Silicate Stage ...

Studies of brittle deformation and reactivation textures at the Renison Mine have identified four generations of fault striations based on the style and relative age of kinematic indicators (Section 3.4). The initial normal-dextral fault movement, with up to 700m of dipslip displacement in the immediate mine area, is considered contemporaneous with the earliest stages of mineralisation. No striations predate the mineralising fluids, and first generation fibres occur parallel to the steeply plunging undulate fault surfaces, with mineralogy's consistent with the host vein assemblage (Kitto & Berry, 1991; Kitto 1992a; Plate 5.2a).

The earliest recognised mineral assemblage in the Federal-Bassett Fault is the Oxide-silicate Stage assemblage (Figure 5.15). This stage can be divided into three sub-groups based on the dominant mineralogical associations. The earliest Oxide-silicate Stage assemblage consists of relict hydrothermal carbonate + magnetite ± tourmaline ± graphite ± talc ± chlorite. This assemblage can be found as minor residual vestiges within quartz + arsenopyrite + cassiterite assemblages or later sulphide assemblages along the Federal-Bassett and Transverse Faults (eg., 111126, 111338, & 111339). The Polaris orebody contains the largest known example of this style of mineralisation at Renison (Section 3.5.3.2 & Section 5.4.1.2; Simonsen, 1988; Barber, 1990; Plate 5.2b; Sample No. 111378). Detailed descriptions of individual minerals associated with this stage in the mineral paragenesis are provided in Section 5.4.3.
PLATE 5.2

A: Hanging wall of the Federal-Bassett Fault, showing corrugations and undulations in the fault surface associated with normal-dextral fault movement (Chapter 3). Location - Federal 2190 Sill.

B: Massive pyrrhotite with a relict clast of carbonate magnetite mineralisation from the early oxide-silicate stage in the Polaris orebody. Sample No. 111378; DDH U2016 (iii) 22.8 m. Abbreviations: Carb - dolomite, Mag - magnetite, Po - pyrrhotite.

C: Wolframite + quartz + arsenopyrite mineralisation from the oxide-silicate stage, overprinted by pyrrhotite + pyrite + chalcopyrite + bismuth from the main sulphide stage. Federal-Bassett Fault sample No. 111249; DDH U1377 (iii) 77.5 m. Abbreviations: Asp - arsenopyrite, Bis - bismuth, Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Wolf - wolframite.

D: Arsenopyrite + quartz + wolframite mineralisation from the oxide-silicate stage, overprinted by pyrrhotite + pyrite + chalcopyrite + bismuth from the main sulphide stage. Federal-Bassett Fault sample No. 111311; DDH U1985 (iv) 67.7 m. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Qz - quartz, Wolf - wolframite.

E: Quartz (euhedral) + arsenopyrite vein margin, from the oxide-silicate stage, with a central infill of pyrrhotite + quartz. Federal-Bassett Fault sample No. 11132; DDH U2194 (ii) 114.3 m. Abbreviations: Asp - arsenopyrite, Po - pyrrhotite, Qz - quartz.

F: Dolomitic-siltstone breccia containing a quartz fragment exhibiting a dextral off-set, and selective pyrrhotite replacement of more dolomitic clasts. Federal-Bassett Fault sample No. 111288; DDH U1853 (i) 42.0 m. Abbreviations: Po - pyrrhotite, Qz - quartz.

G: Quartz + arsenopyrite from the oxide-silicate stage, sheared and overprinted by a massive pyrrhotite assemblage from the main sulphide stage. Federal-Bassett Fault sample No. 111047; DDH S939 (iii) 842.5 m. Abbreviations: Asp - arsenopyrite, Po - pyrrhotite, Qz - quartz.

H: Photomicrograph of an arsenopyrite + cassiterite + pyrite assemblage from the oxide-silicate stage, sheared and overprinted by pyrrhotite. A dextral shear, from left to right in this specimen, has produced a foliation of arsenopyrite and cassiterite fragments away from the original euhedral arsenopyrite crystal, and formation of a weak pressure shadow on the lower left-hand corner of the crystal. Federal-Bassett Fault sample No. 111113; DDH U803 (iii) 93.0 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Po - pyrrhotite, Py - pyrite.
The second Oxide-silicate Stage assemblage is dominated by quartz with variable amounts of tourmaline + arsenopyrite + cassiterite ± wolframite ± ilmenite ± rutile ± pyrrhotite ± pyrite ± chalcopyrite (Figure 5.15; Plates 5.1b & 5.2c, d & e; Sample Nos. 111249, 111311, 111332). This assemblage is ubiquitous with fault mineralisation, and best represented by the Melba fracture ore (Section 3.5.3.2 & Section 5.4.1.3). Wallrocks show pervasive silicification and tourmalinisation but may have extensive pyrrhotite replacement of selected carbonate-rich lamellae. Arsenopyrite deposition during the second Oxide-silicate Stage is intimately associated with cassiterite deposition.

The third Oxide-silicate Stage assemblage is sulphide dominated and represents the initial onset of the Main Sulphide Stage of mineralisation before dextral reactivation of the Federal-Bassett Fault (Figure 5.15; Section 3.4.5). It overprints earlier assemblages and is associated with minor replacement of dolomitic sequences. Pyrrhotite dominates the assemblage, with variable amounts of quartz + cassiterite + arsenopyrite ± fluorite ± talc ± tremolite ± topaz. This assemblage is identified in handspecimen by the ductile-like deformation of pyrrhotite relative to the more brittle behaviour of arsenopyrite, quartz, cassiterite and pyrite (Plate 5.21, g, & h; Sample Nos. 111288, 111047, 111026).

### 5.4.2.4 Main Sulphide Stage ...

Dextral wrench reactivation on the Federal-Bassett Fault produced the dilational jog that hosts the Federal Orebody; a consequence of differential displacements on the Transverse Faults resulting in formation of a weak dextral kink fold across the mine horst (Section 3.5.4). The stresses associated with the dextral wrench played a significant role in the formation of the largest carbonate replacement styles of mineralisation at Renison, within low pressure dilational zones adjacent to sigmoidal convex flexures along the Transverse Faults (Fig. 5.12 & Fig. 3.14). This event had the effect of dilating fault structures and re-focussing the sulphide-rich hydrothermal fluids responsible for cassiterite-rich stratabound carbonate replacement mineralisation.

The Main Sulphide Stage of mineralisation (Fig. 5.15) resulted in the classic pyrrhotite dominated distal skarn assemblages associated with stratabound carbonate replacement at Renison (Patterson, 1979; Davies, 1985; Holyland, 1987; Plate 5.3c, d, e ,f, g & h; Sample Nos. 111065, 111272, 111264, 111242, 111006). The mineral assemblage is a continuation of the late Oxide-Silicate Stage (Figure 5.15). It is dominated by massive pyrrhotite ± cassiterite ± arsenopyrite ± quartz ± fluorite, which overprints the earlier assemblages, but also contains minor base metals such as chalcopyrite ± sphalerite ± galena ± stannite ± bismuth ± argentite ± chlorite (Plate 5.3a & b; Sample Nos. 111006, 111310). The minor base metal phases are typically interstitial to the late oxide-silicate assemblage.
PLATE 5.3

A: Massive sulphide replacement of dolomite - stratafault ore. Massive pyrrhotite containing euhedral pyrite and minor quartz from the main sulphide stage, cross-cut by a late microfracture containing melnikovite. Federal-Bassett Fault sample No. 111006; DDH S371 (i) 310.2 m. Abbreviations: Melnik - melnikovite, Po - pyrrhotite, Py - pyrite.


C: Classic stratabound carbonate replacement reaction front. Massive pyrrhotite replacement of dolomite with minor talc, giving way to a hydrothermal siderite front, and finally unreplaced dolomite. Note the micro-fracture development associated with carbonate replacement. Location - Dreadnought 2125 stope. Courtesy of Renison Ltd.

D: Stratabound carbonate replacement reaction front from Rendeep. Massive green talc with minor disseminated pyrrhotite replacing dolomite. Note the micro-fracture development associated with carbonate replacement. Federal-Bassett Fault sample No. 111065; DDH S1450 (ii) 1027.5 m. Abbreviations: Dol - dolomite.

E: Stratabound carbonate replacement contact with black shales. Massive pyrrhotite + quartz replacement of dolomite, in contact with disseminated pyrrhotite in a former dolomitic siltstone. Federal-Bassett Fault sample No. 111272; DDH U1614 (iii) 57.0 m. Abbreviations: Po - pyrrhotite, Qz - quartz.

F: Classic carbonate replacement texture. Massive pyrrhotite + talc ± arsenopyrite (not visible at this scale) intergrowth, exhibiting fine grained and delicate carbonate replacement textures. Pyrrhotite veinlets throughout this specimen emphasise the importance of fracture development in this replacement process. Federal-Bassett Fault sample No. 111264; DDH U1563 (iii) 119.7 m. Abbreviations: Po - pyrrhotite.

G: Edge of carbonate replacement mineralisation. Massive talc + tremolite intergrowth after dolomite, overprinted by a later pyrrhotite ± arsenopyrite assemblage. Note the intricate fracture control on the carbonate replacement process. Federal-Bassett Fault sample No. 111242; DDH U1305 (ii) 123.5 m. Abbreviations: Asp - arsenopyrite, Po - pyrrhotite, Trem - tremolite.

H: High grade ore associated with the margin of carbonate replacement mineralisation. Massive talc overprinted by a pyrrhotite + cassiterite + arsenopyrite assemblage and minor chalcopyrite veinlets. Federal-Bassett Fault sample No. 111006; DDH S381 (iv) 400.5 m. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Po - pyrrhotite.
Detailed descriptions of the individual minerals associated with this stage in the mineral paragenesis are provided in Section 5.4.3.

5.4.2.5 Late Base Metal Stage ...

Minor brittle reactivation of fault structures after the Main Sulphide Stage allowed infiltration of a hydrothermal fluid responsible for Late Base Metal Stage mineralisation (Fig. 5.15). The association of this stage with either the reverse-sinistral or normal-sinistral reactivations (Section 3.4.6 & Section 3.4.7) is tenuous, but cannot be dismissed (Figure 5.15). Petrographic studies identified a number of related textural features which include carbonate filled syntaxial crack-seal veins in quartz and siliciclastics (Ramsay, 1980; Cox, 1987), sinistral microfolds in weakly mineralised sediments, and minor replacement of pyrrhotite along microveinlets by either pyrite or marcasite ± siderite ± galena ± sphalerite ± chalcopyrite ± stannite (Plate 5.4a, b, c, d & e; Sample Nos. 111149, 111121, 111106, 111149, 111144).

Late Base Metal Stage mineralisation in the upper levels of the mine show characteristic crustiform rhodochrosite lined veins infilled by combinations of the following minerals: sphalerite ± galena ± quartz ± chlorite ± bismuth ± green fluorite ± calcite ± pyrrhotite ± pyrite (Plate 5.4f, g & h; Sample No. 111328). At deeper levels in the Federal-Bassett Fault, arsenopyrite fills the Late Base Metal Stage rhodochrosite veins and may represent a precursor to the higher level assemblages. Cassiterite is not associated with the late base metal arsenopyrite, unlike the preceding paragenetic stages where arsenopyrite is intimately associated with high tin grades. Detailed descriptions of the individual minerals associated with this stage in the mineral paragenesis are provided in Section 5.4.3.

5.4.2.6 Vug-fill Carbonate Stage ...

The Vug-fill Carbonate Stage is characterised by brecciation of sediments and earlier stages of mineralisation, and filling of Late Base Metal Stage vugs, or fault cavities with a carbonate dominated mineral assemblage (Figure 5.15; Plate 5.5a, b, c, d, e, f, g, h; Sample Nos. 111051, 111013, 111032, 111497, 111498, 111440, 111499, 111500). The complete Vug-fill Carbonate Stage mineral paragenesis is never completely developed at any one location, and was described in detail by Patterson (1979):

Earliest:  
(a) cream to buff rhombohedral dolomite;  
(b) colourless (rare purple) fluorite as scattered cubes and octahedra;  
(c) clear quartz that may be coeval with or slightly later than (b);  
(d) rare euhedral chalcopyrite crystals, 0.5 - 1.0 mm diameter, growing on (b) and (c), or on (a) where fluorite and quartz are absent;  
(e) colourless calcite, usually in isolated crystals or aggregates;
PLATE 5.4

A: Photomicrograph showing quartz + pyrite + chalcopyrite ± pyrrhotite intergrowth (oxide-silicate stage), with late base metal stage related crackseal development in quartz containing syntactical siderite infill. Federal-Bassett Fault sample No. 111149; DDH U938 (ii) 66.2 m. Plane polarised light. Abbreviations: Py - dominantly pyrite, Qz - quartz.

B: Photomicrograph showing brecciated arsenopyrite (oxide-silicate stage) containing siderite crackseal veinlets related to the late base metal stage fault reactivations. Federal-Bassett Fault sample No. 111121; DDH U825 (ii) 64.1 m. Plane polarised light. Abbreviations: Asp - arsenopyrite, Sid - siderite.

C: Photomicrograph showing a siderite crackseal vein cross-cutting earlier carbonate replacement mineralisation. Replacement mineralisation consists of tremolite replacement of dolomite, overprinted by quartz + pyrrhotite mineralisation. The reaction front associated with carbonate replacement illustrates the increasing saturation of the mineralising fluid with silica during carbonate replacement; reflected by changes in the mineral assemblage from tremolite to quartz dominated. Federal-Bassett Fault sample No. 111106; DDH U790 (iii) 57.2 m. X-nicols. Abbreviations: Po - pyrrhotite, Sid - siderite, Trem - tremolite.

D: Photomicrograph showing a sinistral shear in tourmalinised sediment hosting quartz and arsenopyrite in a pyrrhotite ground mass. Federal-Bassett Fault sample No. 111149; DDH U938 (ii) 66.2 m. Plane polarised light. Abbreviations: Po - pyrrhotite, Qz - quartz, Tour - tourmaline.

E: Photomicrograph showing base metal stage mineralisation consisting of spongy pyrite + marcasite + chalcopyrite + galena + stannite replacement of main sulphide stage pyrrhotite containing quartz. Federal-Bassett Fault sample No. 111144; DDH U836 (ii) 20.4 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Gn - galena, Marc - marcasite, Qz - quartz, Sid - siderite, Stan - stannite.

F: Crustiform rhodochrosite vein with sphalerite + galena + quartz and minor pyrite + chalcopyrite vein infill. Note that the base metal mineralisation has not replaced or altered the dolomitic hostrock to the vein. Location - Federal 2000 stope on the Federal-Bassett Fault. Abbreviations: Gn - galena, Py - pyrite, Qz - quartz, Rhod - rhodochrosite, Sph - sphalerite.

G: Near vertical base metal stage rhodochrosite vein with minor sphalerite + galena + pyrite + quartz infill (approximately 50 cm wide), cross-cutting horizontal laminated Dalcoath Member siltstones. Location - Polaris orebody.

H: Late base metal stage vein with crustiform rhodochrosite margins and a quartz + green fluorite + chlorite infill. Federal-Bassett Fault sample No. 111328; DDH U2127 (vii) 111.5 m. Abbreviations: Chl - chlorite, Flu - fluorite, Qz - quartz, Rhod - rhodochrosite.
PLATE 5.5

A: Vug-fill carbonate stage vein containing clear fluorite, white quartz and calcite in a dolomitic breccia. Federal-Bassett Fault Sample No. 111051; DDH S952A (iii) 780.7 m. Abbreviations: Calc - calcite, Flu - fluorite, Qz - quartz.

B: Vug-fill carbonate stage vein of white quartz and dolomite cross-cutting a base metal stage vein of quartz + fluorite + chlorite + bismuth. Federal-Bassett Fault Sample No. 111013; DDH S0391 (iii) 942.3 m. Abbreviations: Carb - dolomite, Chl - chlorite, Flu - fluorite, Qz - quartz.

C: Brecciated cherty siltstone with a vug-fill carbonate stage infill of quartz and dolomite between clasts. Federal-Bassett Fault Sample No. 111032; DDH S0876 (i) 863.0 m. Abbreviations: Carb - dolomite, Qz - quartz.

D: Brecciated massive pyrrhotite from the main sulphide stage, with open space base metal stage sphalerite ± galena overprint; and a vug-fill carbonate stage infill of dolomite + quartz + calcite rosettes + pyrite cubes (not visible). Location - Dreadnought 2125; Sample No. 111497. Abbreviations: Calc - calcite, Dol - dolomite, Po - pyrrhotite, Qz - quartz, Sph - sphalerite.

E: An open void in the hangingwall of the Federal-Bassett Fault with a vug-fill carbonate stage mineralogy. Early milky quartz is overgrown with buff rhombohedral dolomite covered in clear euhedral singularly terminated quartz crystals (5 mm) + clear cubes of fluorite (4 mm) + rare pyrite pyritohedral crystals (1 mm). Encrusting the whole assemblage are buff-brown coloured rosettes of calcite (0.5 - 1 mm). Location - Federal 2000 stope; Sample No. 111498. Abbreviations: Cal - calcite, Dol - dolomite, Flu - fluorite, Py - pyrite, Qz - quartz.

F: An open void containing a late vug-fill carbonate stage assemblage of buff dolomite with clear euhedral quartz crystals covered in clear calcite rosettes and a light dusting of pyrite. 'Shear P' Sample No. 111440; DDH S1183 (i) 50.0 m. Abbreviations: Cal - calcite, Dol - dolomite, Py - pyrite, Qz - quartz.

G: Late vug-fill carbonate stage mineral assemblage, containing white rhombohedral calcite overgrown with clear euhedral quartz crystals (broken) and bladed calcite with a fine dusting of pyrite. Location - North Stebbins 1840 stope; Sample No. 111499. Abbreviations: Cal(B) - bladed calcite, Cal(R) - rhombohedral calcite, Py - pyrite, Qz - quartz.

H: Brecciated siltstone with an overgrowth of late vug-fill carbonate stage minerals. Milky quartz overgrown with clear euhedral quartz and cubic shaped pyrite crystals. A fine dusting of dolomite covers all earlier mineral phases. Location - Envelope 2000 stope; Sample No. 111500. Abbreviations: Dol - dolomite, Py - pyrite, Qz - quartz.
(f) pyrite in scattered 0.5 - 1.0 mm diameter incomplete pyritohedral crystals, typically with an iridescent tarnish, encrusting earlier bands; and

Latest:  
(g) calcite in 0.5 - 2.0 mm rosettes of clear to milky white rhombohedra.

Detailed descriptions of the individual minerals associated with this stage in the mineral paragenesis are provided in Section 5.4.3.

5.4.2.7 Supergene Stage ...

A weak phase of supergene alteration in massive pyrrhotite occurs along minor fractures and joints. Alteration consists of either greigite or marcasite-pyrite intergrowths adjacent to central calcite micro-veinlets (Figure 5.15; Plate 5.6 a, b; Sample Nos. 111260, 111364). Minor amounts of limonitic haematite and goethite are rare. Detailed descriptions of the individual minerals associated with this stage in the mineral paragenesis are provided in Section 5.4.3.

Mineral deposition from hydrothermal fluids at Renison still occurs today. CaCO₃ is currently precipitating from hot groundwater sourced from a broken stem pipe in the floor of the drive which caps the underground diamond drill hole U1042; a drill-hole that intersects the Pine Hill Granite. The travertine is being deposited in the H54 Hangingwall Cross-cut as a ~30 cm thick scale along the floor of the drive. Chemical analysis of the hydrothermal fluids indicates high levels of Li, B, Ti, Mn, Br, Rb, Cs, W, Fe, Sr, and Ba (Morrison, 1992) reflecting groundwater interaction with the underlying Pine Hill Granite.

5.4.3 Renison Ore Microscopy ...

Following on from the vein paragenesis and related deformation events presented in Section 5.5.2, this section sequentially describes the mineralogy and microparagenetic relationships of each mineral listed in Figure 5.15.

(i) Graphite represents a rare, early paragenetic phase in the oxide-silicate assemblage and occurs as sub-euhedral isotropic fragments with low reflectivity in sheared, silicified and tourmalinised sediments. In Plate 5.6c (Sample No. 111104) corroded flakes of graphite, up to 25μm in diameter, are cut by fractures infilled with pyrrhotite, tourmaline, quartz and arsenopyrite. Patterson (1979) identified a second form of graphite, up to 50μm in length, with a strong bireflectance and anisotropism within a talc-rich assemblage. This variety of graphite has not been identified in this study.

(ii) Carbonate occurs in a variety of forms throughout the mineral paragenesis at Renison. The earliest hydrothermal carbonate is intimately associated with magnetite as relict clasts within the Oxide-Silicate and Main Sulphide Stages (Plate 5.2b, Plate 5.6d, Plate 5.7a & b;
PLATE 5.6

A: Classical pyrrhotite + talc replacement texture of dolomite, cut by later fracture controlled supergene pyrite + marcasite after pyrrhotite. Federal-Bassett Fault Sample No. 111260; DDH U1522(i) 88.0 m. Abbreviations: Po - pyrrhotite, Py - pyrite.

B: Massive carbonate replacement mineralisation consisting of pyrrhotite + euhedral pyrite and minor arsenopyrite ± tourmaline ± cassiterite; cut by later fracture controlled melnikovite after pyrrhotite with a central fracture infill of calcite. Polaris Sample No. 111364; DDH U11439(iii) 43.1 m. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Melnik - greigite, Po - pyrrhotite, Py - pyrite, Tour - tourmaline.

C: Photomicrograph showing rarely observed, early oxide-silicate stage sub-euhedral graphite flakes, cut by fractures which are infilled by later oxide-silicate stage pyrrhotite, tourmaline, quartz and arsenopyrite. Federal-Bassett Fault Sample No. 111104; DDH U0790(i) 55.2 m. Reflected light. Abbreviations: Asp - arsenopyrite, Graph - graphite, Po - pyrrhotite, Qz - quartz, Tour - tourmaline.

D: Photomicrograph showing relict early oxide-silicate stage carbonate + magnetite mineralisation, adjacent to a shear zone with brecciated arsenopyrite associated with minor chalcopyrite, in weakly colloform melnikovite + laminar marcasite after pyrrhotite. Federal-Bassett Fault Sample No. 11144; DDH U0336(ii) 20.4 m. Reflected light. Abbreviations: Asp - arsenopyrite, Carb - carbonate, Mag - magnetite, Marc - marcasite, Melnik - greigite.

E: Carbonate replacement reaction front with talc replacement of a dolomite host containing a number of small stylolites. Associated with the carbonate replacement process are a number of calcite veinlets, that are thought to result from CO₂ effervescence (Davies, 1985) during dolomite replacement by acidic hydrothermal fluids. Federal-Bassett Fault Sample No. 111064; DDH S1450(i) 1020.0 m. Abbreviations: Calc - calcite, Dolm - dolomite.

F: Late base metal stage finely banded crustiform rhodochrosite with minor sphalerite + quartz + pyrite, infilling brecciated massive pyrrhotite mineralisation from the main sulphide stage. Federal-Bassett Fault Sample No. 111328; DDH U2127(vi) 110.2 m. Abbreviations: Carb - rhodochrosite, Po - pyrrhotite, Py - pyrite, Sph - sphalerite.

G: Photomicrograph showing a late base metal stage, finely banded crustiform rhodochrosite vein, with thin interband overgrowths of sphalerite. Minor crack-seal veins occur in the siliclastic host parallel to the margin of the rhodochrosite vein. Federal-Bassett Fault Sample No. 111109; DDH U0797(iii) 116.7 m. X-nicols. Abbreviations: Rhod - rhodochrosite, Sph - sphalerite.

H: Photomicrograph showing lower magnification of Plate 5.6 (g). The centre of the late base metal stage rhodochrosite vein contains bands of pyrite and coarse calcite crystals. Federal-Bassett Fault Sample No. 111109; DDH U0797(iii) 116.7 m. X-nicols. Abbreviations: Calc - calcite, Py - pyrite, Rhod - rhodochrosite.
PLATE 5.7

A: Photomicrograph showing the earliest oxide-silicate stage carbonate (dolomite), intergrown with magnetite in the Polaris orebody. Federal-Bassett Fault Sample No. 111338; DDH S0425 (i) 83.1 m. Plane polarised light. Abbreviations: Dol - dolomite, Mag - magnetite.

B: Photomicrograph showing the earliest oxide-silicate stage carbonate + magnetite mineralisation overprinted by minor pyrrhotite from the main sulphide stage in the Polaris orebody. Federal-Bassett Fault Sample No. 111338; DDH S0425 (i) 83.1 m. Reflected light. Abbreviations: Dol - dolomite, Mag - magnetite, Po - pyrrhotite.

C: Photomicrograph showing an oxide-silicate stage, zoned euhedral quartz crystal in sulphides, and containing a central core with acicular needles of tourmaline. Federal-Bassett Fault Sample No. 111093; DDH U0741 (iii) 77.3 m. Plane polarised light. Abbreviations: Qz - quartz, Tour - tourmaline.

D: Photomicrograph showing an oxide-silicate stage arsenopyrite crystal zoned by fine tourmaline crystals, in a tourmalinisied sediment containing quartz and minor pyrrhotite + chalcopyrite. Federal-Bassett Fault Sample No. 111089; DDH U0685 (i) 113.5 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Tour - tourmaline.

E: Photomicrograph showing weakly folded pale brown tourmalinised sediment containing quartz clasts, and sulphide replacement of more dolomitic zones. Federal-Bassett Fault Sample No. 111093; DDH U0685 (i) 113.5 m. Plane polarised light. Abbreviations: Po - pyrrhotite, Qz - quartz, Tour - tourmaline.

F: Photomicrograph showing a tourmalinised clast with dextral off-set, and infilled by pyrrhotite. Federal-Bassett Fault Sample No. 111150; DDH U0938 (iii) 68.2 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Po - pyrrhotite, Tour - tourmaline.

G: Photomicrograph showing long acicular needles of early rutile (2mm) within oxide-silicate stage arsenopyrite + quartz, overprinted by a main sulphide stage assemblage of pyrrhotite + chalcopyrite. Federal-Bassett Fault Sample No. 111094; DDH U0741 (iv) 77.5 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Rut - rutile.

H: Photomicrograph showing sub-euhedral grains of ilmenite pseudomorphing an acicular needle of rutile (?) in a groundmass of quartz + chalcopyrite + arsenopyrite. Federal-Bassett Fault Sample No. 111095; DDH U0741 (v) 60.6 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Ilm - ilmenite, Qz - quartz.
Sample Nos. 111378, 111144, 111339). The carbonate generally forms large interlocking sub-euhedral crystals. Microprobe analyses of this hydrothermal carbonate in the Polaris orebody (Barber, 1990) indicate the carbonate is Ca and Mg rich (i.e., dolomite) with minor Fe and Mn.

Siderites and hydrothermal carbonates associated with the margins of the stratabound carbonate replacement orebodies were described in detail by Davies (1985; Plates 5.3c & d; Sample No. 111055). He identified a number of subdivisions within the hydrothermal carbonate zone from dolomite through to massive sulphide ore. On the outer limit of the dolostone-hydrothermal carbonate, a zone of sporadic-intense, multidirectional calcite veins occur which are thought to result from CO₂ effervescence (Davies, 1985; Plate 5.6e; Sample No. 111064). The central carbonate zone contains brown, coarsely crystallineankerite, with high levels of iron and manganese, in association with magnesian siderilites. The innermost hydrothermal carbonate zone contains recrystallised magnesian siderilites in association with talc and tremolite (Plates 5.1a & 5.3c).

**Rhodochrosite** (2 - 30 mm) is an early gangue mineral in Late Base Metal Stage assemblages, occurring as banded, spherulitic or rhombohedral crystals (Plates 5.4g, h & Plates 5.6f, g, h; Sample Nos. 111328, 111328, 111109). Photomicrographs 5.6g and h demonstrate the finely banded crustiform nature of intergrowths between rhodochrosite and sphalerite. These photomicrographs also illustrate a weakly developed crack-seal texture within the siliciclastic wallrocks that is typically associated with Late Base Metal Stage mineralisation (see Section 5.4.2.5).

(iii) Hydrothermal sub-euhedral magnetite grains (10-500 μm) are coeval with, or replace cleavage and/or fracture planes of carbonates from the early Oxide-Silicate Stage. Plates 5.7a and 5.7b (Sample No. 111338) show photomicrographs of a relict carbonate-magnetite clast in pyrrhotite from the Main Sulphide Stage. Total replacement by pyrrhotite of both phases occurs over millimetres, leaving no trace of the early assemblage (also see Plate 5.2b), explaining why carbonate-magnetite mineralisation is rarely observed.

(iv) **Tourmaline** is ubiquitous with the Oxide-Silicate Stage and together with quartz dominates the alteration assemblage in siliciclastic wallrocks adjacent to major carbonate replacement orebodies. The acicular to tabular crystals are typically fine grained, pale brown in colour, zoned and intergrown with or forming inclusions in other Oxide-Silicate minerals (e.g., quartz, arsenopyrite, cassiterite, talc, tremolite, pyrrhotite, fluorite; Plates 5.7 c & d; Sample Nos. 111093, 111089). Tourmalinised sediments have resisted later alteration overprints and record deformation textures both in the wallrocks and within massive pyrrhotite (Plates 5.7 e & f; Sample Nos. 111089, 111150). Davies (1985) recognised that the strongest development of tourmalinite bands occur in muddy lamellae and beds within
two metres of the massive sulphide zones adjacent to stratabound carbonate replacement orebodies. He further recognised that scheelite was restricted to intensely altered siliciclastic wallrocks, whereas dravite characterised calcareous sediments.

(v) Rutile typically occurs as long acicular crystals, up to 2.0 mm long in the Oxide-silicate Stage, on the margins between massive sulphide mineralisation and siliciclastic sediments (Plates 5.7 g; Sample No. 111094). Sub-euhedral grains of ilmenite are a common accessory phase, and may occur as small intergrowths with rutile (Plates 5.7 h; Sample No. 111095). Ultrafine leucoxene and anatase aggregates (after rutile/ilmenite?) have been identified by a number of researchers in laminated metasomatized and tourmalinised siliciclastics. W. H. Fander (1987) has recorded the presence of minor inclusions of ilmenite and rutile within cassiterite.

(vi) Phlogopite laths (50 - 200 μm) occur as a minor phase in stratabound carbonate replacement ore associated with Oxide-silicate Stage, where it is typically red-brown in thin section and intergrown with tremolite, quartz and minor sulphides. X-ray diffraction analyses closely resemble those of fluorophlogopite (Patterson, 1979). Pale green chlorite alteration of phlogopite is widespread (Plate 5.8 a; Sample No. 111110).

(vii) Scheelite grains (<2 mm) are associated with the early Oxide-Silicate assemblages within the lower Federal-Bassett Fault. Scheelite is typically stressed and fractured, and occurs as a minor phase adjacent to, or within fractures of, wolframite grains (Sample Nos. 110990, 111015, 111049, 111091). Plate 5.8b (Sample No. 111193) illustrates a 0.2 mm cleaved anhedral grain of scheelite in quartz adjacent to a 15 mm euhedral lath of wolframite. Scheelite in this example is showing partial replacement along cleavage planes by brown wolframite.

(viii) Wolframite laths (<15 mm) are a minor component of the Oxide-Silicate assemblage, and occur as coeval intergrowths with arsenopyrite, quartz and cassiterite (Plate 5.8c; Sample No. 111193). Pyrrhotite typically infills fractures in wolframite laths but may occur as an outer zoned equilibrium intergrowth in large wolframite grains. Patterson (1979) identified rare inclusions of wolframite in cassiterite.

(ix) Arsenopyrite rhombs (1 - 4 mm) and corroded pyrite euhedra are the first sulphide phases to precipitate in the Oxide-Silicate/Main Sulphide Stage, and may on rare occasions constitute up to 25 % of cassiterite-rich ore (Plate 5.8d). Arsenopyrite may contain small inclusions of cassiterite ± quartz ± tourmaline ± pyrite (Plate 5.7d, & Plates 5.8e & f; Sample Nos. 111089, 111112, 111124), but pyrrhotite typically forms replacive complex embayments and fracture infills of the arsenopyrite rhombohedra (Plate 5.8 d, g; Sample No. 111104). Following brecciation of arsenopyrite during dextral wrench reactivation,
PLATE 5A

A: Photomicrograph showing a carbonate replacement front consisting of chloritised pale-brown phlogopite, together with quartz + pyrite, partly pseudomorphing and replacing earlier tremolite. The change in silicate assemblages from tremolite to phlogopite and quartz indicate increased silica saturation associated with the mineralising fluid as the replacement front progressively moved through the assemblage. Federal-Bassett Fault Sample No. 111110; DDH U0797 (iv) 119.2 m. Plane polarised light. Abbreviations: Cass - cassiterite, Chl - chlorite, Phlog - phlogopite, Py - pyrite, Qz - quartz, Trem - tremolite.

B: Photomicrograph showing an oxide-silicate stage assemblage of scheelite + wolframite + quartz. Wolframite has preferentially replaced scheelite along cleavage planes and fractures. Federal-Bassett Fault Sample No. 111193; DDH U1112 (i) 21.0 m. Plane polarised light. Abbreviations: Sch - scheelite, Wolf - wolframite.

C: Photomicrograph showing an oxide-silicate stage assemblage consisting of a large sub-euhedral wolframite lath with a quartz inclusion and associated with a euhedral arsenopyrite crystal. Wolframite is overprinted by pyrrhotite resulting in a cusp and cavities type intergrowth along one side of the lath. Minor chalcopyrite occurs along grain boundaries of the earlier mineral assemblage and is associated with pyrrhotite mineralisation. Federal-Bassett Fault Sample No. 111193; DDH U1112 (i) 21.0 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Wolf - wolframite.

D: Massive cassiterite intergrown with arsenopyrite, and minor pyrrhotite + pyrite. The intimate association between cassiterite and arsenopyrite deposition is a common mineral association, particularly in high grade ore assemblages. Location - North Stebbins 2180. Courtesy of Renison Ltd. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Po - pyrrhotite, Py - pyrite.

E: Photomicrograph showing an oxide-silicate stage mineral assemblage of euhedral arsenopyrite with cassiterite inclusions, within an equant quartz crystal also containing cassiterite inclusions, and surrounded by pyrrhotite with minor pyrite. Fracture infills of the arsenopyrite by quartz and pyrrhotite indicate that cassiterite and arsenopyrite were paragenetically earlier than the quartz and later pyrrhotite. Note the cusp and cavities replacement of the arsenopyrite by pyrrhotite. Federal-Bassett Fault Sample No. 111112; DDH U0803 (ii) 92.6 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Po - pyrrhotite, Py - pyrite, Qz - quartz.

F: Photomicrograph showing an oxide-silicate stage mineral assemblage containing an intergrowth of sub- to euhedral zoned cassiterite and quartz crystals, together with interstitial arsenopyrite. Federal-Bassett Fault Sample No. 111124; DDH U0825 (iv) 77.5 m. Plane polarised light. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Qz - quartz.

G: Photomicrograph showing euhedral arsenopyrite rhombohedra with partial replacement by pyrrhotite, resulting in a cavities/atoll type texture. The groundmass consists of quartz with minor finely disseminated tourmaline. Federal-Bassett Fault Sample No. 111104; DDH U0790 (i) 55.2 m. Reflected light. Abbreviations: Asp - arsenopyrite, Po - pyrrhotite, Qz - quartz.

H: Photomicrograph showing etched rhombohedral arsenopyrite crystals (saturated chromic acid) revealing complex twinning and weak concentric zoning. Federal-Bassett Fault Sample No. 111083; DDH U0638 (ii) 87.0 m. Reflected light. Abbreviations: Asp - arsenopyrite.
PLATE 5.8

HIGH GRADE ORE
(cass + asp + py + po)

A. Trem, Chl, Cass, Qz, Phlog

B. Wolf, Qz

C. Cpy, Asp, Po, Qz, Wolf

D. Cass, Asp, Po, Py

E. Cass, Asp, Po, Qz

F. Cass, Asp, Qz

G. Po, Asp, Qz

H. Asp
chalcopyrite, stannite, sphalerite and galena have filled fractures and veinlets. Etching of arsenopyrite with saturated chromic acid reveals complex twinning and a weak concentric zoning in many grains (Plate 5.8 h; Sample No. 111083), but no significant variation in As/S ratios have been detected using electron microprobe techniques.

A second phase of arsenopyrite deposition, devoid of cassiterite, occurs in association with Late Base Metal Stage rhodochrosite in the lower levels of the Federal-Bassett Fault.

(x) **Cassiterite** is the only economic mineral extracted from Fenison ore and occurs as zoned, equant, euhedral crystals with either sector extinction or twinning (Plate 5.9a, b, c; Sample Nos. 111122, 111092, ) in the Oxide-silicate/Main Sulphide Stages of mineralisation. Typical cassiterite grains are between 20 and 150 μm, ranging up to 1 mm in rare cases. Patterson (1979) recognised that cassiterite colour varies from clear to brown, to deep red-brown in mineralisation from the Melba fracture ore, stratabound ore, and the Pine Hill greisens, respectively. Cassiterite precipitation was synchronous with arsenopyrite and quartz in fault ore (Plate 5.8d, e, f; Sample Nos. 111112, 111124). In the stratabound carbonate replacement assemblages, cassiterite was deposited with quartz, talc, tremolite, pyrrhotite, arsenopyrite ± pyrite ± tourmaline ± chlorite ± fluorite (Plate 5.9b, d, e, f; Sample Nos. 111092, 111103, 111092, 111089). Corrosion of cassiterite by pyrrhotite and chlorite is a common feature of the Main Sulphide Stage, as is replacement cassiterite by chalcopyrite to stannite. Co-precipitation of cassiterite and arsenopyrite is characteristic of the Oxide-Silicate Stage at Renison and is explained by Heinrich and Eadington (1986) as a wallrock independent redox buffer (discussed further in Chapter 9).

(xi) **Quartz** has been recognised throughout the paragenetic sequence at Renison. It dominates alteration in the siliciclastic rocks, occurring as anhedral to euhedral intergrowths. Quartz crystals from the Oxide-Silicate/Main Sulphide Stage of the paragenesis are typically 1 - 30 mm long, doubly terminated and may contain inclusions of tourmaline, cassiterite, arsenopyrite and occasional pyrrhotite (Plate 5.7c, Plates 5.8e, f, g & Plate 5.9g; Sample Nos. 111093, 111112, 111124, 111104, 111109). Quartz grains associated with silica replacement fronts at the edges of stratabound carbonate replacement orebodies are anhedral and have a characteristic texture due to the alignment of remnant inclusions after replacement of original talc and tremolite minerals (Plate 5.9 e; Sample No. 111092). Rare pale green vermiculite inclusions may occur in quartz veins associated with carbonate replacement (Plate 5.9 h; Sample No. 111058). In the Late Base Metal and Vug-fill Carbonate Stages, quartz is typically euhedral (<5 mm), zoned and inclusion free.

(xii) **Talc** is typically colourless in thin section, and is widely distributed as massive finely disseminated laths in altered carbonate-rich rocks. Talc is found most commonly associated with the Main Sulphide Stage stratabound carbonate replacement orebodies, and also with
A: Photomicrograph showing an intergrowth of massive sub-euhedral zoned cassiterite crystals from the oxide-silicate stage of mineralisation; the central crystal shows sector extinction. Federal-Bassett Fault Sample No. 111122; DDH U0825 (ii) 64.1 m. X-nicols. Abbreviations: Cass - cassiterite.

B: Photomicrograph showing a large euhedral cassiterite crystal with sector extinction enclosed within a euhedral quartz crystal. The quartz crystal occurs as an inclusion in massive main sulphide stage pyrrhotite. Federal-Bassett Fault Sample No. 111092; DDH U0741 (ii) 57.0 m. X-nicols. Abbreviations: Cass - cassiterite, Po - pyrrhotite, Qz - quartz.

C: Photomicrograph showing an intergrowth of massive sub-euhedral zoned cassiterite crystals; the central crystal exhibits multiple twinning. Federal-Bassett Fault Sample No. 111122; DDH U0825 (ii) 64.1 m. X-nicols. Abbreviations: Cass - cassiterite, Qz - quartz.

D: Photomicrograph showing the intimate association between oxide-silicate stage cassiterite and arsenopyrite deposition. Both the arsenopyrite and cassiterite have cusp and cavies textures against pyrrhotite which is replacing the crystals, resulting in subhedral crystal outlines. Pyrrhotite and stannite infill fractures in arsenopyrite. Federal-Bassett Fault Sample No. 111103; DDH U0777 (vi) 106.0 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Po - pyrrhotite, Stan - stannite.

E: Photomicrograph showing subhedral cassiterite grains in a carbonate replacement mineral assemblage. Early euhedral cassiterite and tremolite crystals have been overprinted and partly replaced by a quartz + pyrrhotite + phlogopite (?) assemblage. Pale-green chlorite after phlogopite is common (see Plate 5.8a). Relict pseudomorphs of tremolite crystals in quartz are a characteristic feature of the carbonate replacement process. Federal-Bassett Fault Sample No. 111092; DDH U0741 (ii) 57.0 m. Plane polarised light. Abbreviations: Cass - cassiterite, Chi - chlorite, Po - pyrrhotite, Qz - quartz, Trem - tremolite.

F: Photomicrograph showing tourmalinised siliciclastic sediments containing a main sulphide stage cassiterite-rich vein, exhibiting disseminated and fracture infills of pyrrhotite + chalcopyrite. Federal-Bassett Fault Sample No. 111089; DDH U0685 (i) 113.5 m. Reflected light. Abbreviations: Cass - cassiterite, Cpy - chalcopyrite, Po - pyrrhotite, Tour - tourmaline.

G: Photomicrograph showing a euhedral hexagonal quartz crystal with small inclusions of euhedral cassiterite. Quartz occurs as an inclusion in main sulphide stage pyrrhotite. Federal-Bassett Fault Sample No. 111109; DDH U0797 (iii) 116.7 m. Plane polarised light. Abbreviations: Cass - cassiterite, Po - pyrrhotite, Qz - quartz.

H: Photomicrograph showing "wormy" vermiculite intergrowths in a quartz + pyrrhotite + pyrite vein cross-cutting dolomitic sediments. Such textures are rarely observed. Federal-Bassett Fault Sample No. 111058; DDH S1400 (ii) 1174.0 m. X-nicols. Abbreviations: Doi - dolomite, Po - pyrrhotite, Qz - quartz, Verm - vermiculite.
stratafault ores in the Federal-Bassett Fault. Talc is particularly well developed in the Rendeep area, where sulphide levels are low. Talc deposition occurs at the reaction front between massive sulphide and hydrothermal carbonate, and represents a decrease in silica activity associated with carbonate replacement reactions during the Oxide-Silicate/Main Sulphide Stages (Section 5.4.1.1). Talc exhibits a range of textural features that comprise intergrowths, inclusions and/or replacement by disseminated pyrrhotite, phlogopite, quartz and cassiterite. Chloritic alteration of talc is generally widespread.

(xiii) *Tremolite*, like talc, is associated with Main Sulphide Stage stratabound carbonate replacement and stratafault ores. Tremolite occurs as large colourless to pale green laths, fibrous bundles or as acicular needles with interstitial talc and carbonate, which is overprinted and replaced by variable amounts of disseminated pyrrhotite, phlogopite, quartz, chlorite and cassiterite (Plates 5.10a, b, c, d; Sample Nos. 111106, 111110, 111121).

(xiv) *Pyrrhotite* is the dominant sulphide mineral in the Oxide-Silicate/Main Sulphide stages at Renison and typically contains inclusions of the earlier paragenetic phases (Fig. 5.15). Pyrrhotite occurs as anhedral interlocking grains up to 2 mm in diameter in which twinning and deformation lamellae may be present (Plate 5.10e; Sample No. 111114). A minor period of pyrrhotite deposition, together with siderite, occurred during Late Base Metal Stage mineralisation (Plate 5.10f; Sample No. 111123). Etching of pyrrhotite with a saturated chromic acid solution highlights the hexagonal and monoclinic intergrowths within pyrrhotite (Plate 5.10g; Sample No. 111123). Typically the ore is dominated by hexagonal pyrrhotite with monoclinic lamellae developed around veinlets and grain boundaries of mineral inclusions. The inference is that monoclinic lamellae develop in high strain zones of hexagonal pyrrhotite due to deformation processes.

Exhaustive studies of pyrrhotite compositions at Renison have been undertaken by Stillwell & Edwards (1943), Hills & Haynes (1969), Haynes and Hills (1970), Groves (1968), Collins (1972) and Patterson (1979). They found that hexagonal pyrrhotites have a 2A, 5C superstructure type and that the low trace element compositions (Co, Ni, Mn) are comparable with cassiterite-sulphide deposits in the rest of western Tasmania. The iron compositions of hexagonal (?) pyrrhotite were determined by Haynes and Hills (1970) and found to range between 47.5 and 48.0 atomic weight percent iron. In contrast, Groves (1968) obtained a range of values between 47.03 and 47.45 (av. 47.20; n=3) atomic weight percent iron for purely hexagonal pyrrhotites. Experimental extrapolations of Lusk *et al.* (1993) on the low-temperature hexagonal pyrrhotite data of Groves (*op. cit.*) estimates a pressure and temperature for mineralisation at Renison of 1.5 kbars at 200-280°C. For high temperature hexagonal pyrrhotite in equilibrium with pyrite, the estimated pressure and temperature are >0 kbars at 360°C.
PLATE 5.10

A: Photomicrograph showing a tremolite intergrowth with minor talc, replacing recrystallised dolomite, and overprinted by disseminated pyrrhotite. Federal-Bassett Fault Sample No. 111106; DDH U0796 (iii) 57.2 m. X-nicols. Abbreviations: Dol - dolomite, Po - pyrrhotite, Qz - quartz, Trem - tremolite.

B: Photomicrograph showing advanced carbonate replacement, with a silica front of quartz and pyrrhotite, overprinting earlier tremolite after dolomite. Federal-Bassett Fault Sample No. 111106; DDH U0790 (iii) 57.2 m. X-nicols. Abbreviations: Po - pyrrhotite, Qz - quartz, Trem - tremolite.

C: Photomicrograph showing a carbonate replacement assemblage of tremolite + quartz + phlogopite + cassiterite + pyrrhotite after dolomite, with chlorite alteration of the silicate assemblage. Federal-Bassett Fault Sample No. 111110; DDH U0797 (iv) 119.2 m. Plane polarised light. Abbreviations: Cass - cassiterite, Chi - chlorite, Po - pyrrhotite, Qz - quartz, Trem - tremolite.

D: Photomicrograph showing tremolite laths associated with carbonate replacement mineralisation overprinted by pyrrhotite + pyrite, with minor chalcopyrite. Federal-Bassett Fault Sample No. 111121; DDH U0825 (i) 64.1 m. Reflected light. Abbreviations: Po - pyrrhotite, Py - pyrite, Trem - tremolite.

E: Photomicrograph showing deformation lamellae in coarse grained pyrrhotite from the main sulphide stage. Some recrystallisation of pyrrhotite has taken place as evidenced by the smaller polygonal grains along the margin of the larger pyrrhotite grains. Federal-Bassett Fault Sample No. 111114; DDH U0809 (ii) 98.0 m. Reflected light, polar partly crossed. Abbreviations: Po - pyrrhotite.

F: Photomicrograph showing main sulphide stage pyrrhotite with partial brecciation and replacement by base metal stage siderite + chalcopyrite + pyrrhotite along basal cleavage planes of the main sulphide stage pyrrhotite. Marcasite replacement after pyrrhotite has been controlled by the basal cleavage. Minute amounts of base metal stage galena are deposited within the basal cleavage planes of the main sulphide stage pyrrhotite and highlight the cleavage. Federal-Bassett Fault Sample No. 111123; DDH U0825 (iii) 72.5 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Gn - galena, Marc - marcasite, Po - pyrrhotite, Sid - siderite.

G: Photomicrograph showing main sulphide stage pyrrhotite etched by a saturated solution of chromic acid. The base metal stage fractures in the hexagonal pyrrhotite (pale brown) have resulted in lamellae of monoclinic pyrrhotite (dark brown) along margins, and galena deposition (iridescent blues and greens) within basal cleavage partings. The diagonal striations across the photomicrograph are a result of the polishing process. Federal-Bassett Fault Sample No. 111123; DDH U0825 (iii) 72.5 m. Reflected light. Abbreviations: Asp - arsenopyrite, Gn - galena, Po (hex) - hexagonal pyrrhotite, Po (mon) - monoclinic pyrrhotite.

H: Photomicrograph showing corroded oxide-silicate stage anhedral pyrite that may represent the first sulphide phase precipitated. Pyrite deposition is pre- to syn-oxide-silicate stage cassiterite and arsenopyrite. Fracture infills in pyrite include main sulphide stage chalcopyrite + stannite + pyrrhotite. Federal-Bassett Fault Sample No. 111103; DDH U0777 (vi) 106.0 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cass - cassiterite, Cpy - chalcopyrite, Po - pyrrhotite, Py - pyrite, Stan - stannite.
Several generations of pyrite have been identified in the Renison deposit, none of which represent significant proportions of the ore. Earliest pyrite occurs as corroded subhedral inclusions up to 2 mm in pyrrhotite or arsenopyrite and may represent the earliest stages of sulphide deposition associated with Oxide-Silicate Stages of mineralisation (Plate 5.10h & Plate 5.11a; Sample No. 111103). The second generation of pyrite occurs as a replacement of pyrrhotite during Late Base Metal veining and occurs as either pyrite euhedra, spongy pyrite or as minute euhedral grains intergrown with laminated marcasite (Plates 5.11b, c; Sample No. 111097, 111144). Other stages of pyrite occur as incomplete pyritohedral crystals encrusting carbonates in the Vug-fill Carbonate Stage, or associated with micro-botryoidal Supergene Stage alteration around fractures in earlier pyrite (Plate 5.11d; Sample No. 111161). This later stage of micro-botryoidal alteration has been described as greigite in handspecimen and typically has calcite associated within the central fracture around which alteration has occurred.

Pentlandite has been tentatively identified as pinkish exsolutions (25 μm) in an undeformed pyrrhotite of the Oxide-Silicate Stage (111095). Pentlandite has not been described at Renison previously, and the presence of this phase has not been confirmed by the electron microprobe.

Chloanthite - (Ni, Co)As₂₋ₓ - has been identified by Renison geologists and occurs as a single vein 3 cm wide in the Federal 2170 stope. Paragenetic relationships of this vein with the main stages of mineralisation could not be determined with certainty, but is thought to overprint the cassiterite-bearing stages of mineralisation in the mine. In handspecimen, chloanthite is steely-grey, massive and is cut by randomly oriented pyrrhotite veinlets. In thin section, chloanthite tarnishes almost immediately to a dull silver-grey colour. It occurs as massive and weakly brecciated grains with quartz and pyrrhotite veinlets.

The occurrence of pentlandite and chloanthite raises questions as to the possible source for nickel, given that the nearest ultramafic complex occurs at Pine Hill, 3 km southeast of the mine, and copper-nickel deposits occur in the Cuni area west of the Murchison Highway near Dundas (Fig. 5.4). Obviously the mineralising fluids were carrying minute amounts of Ni but the source for this element remains questionable.

Fluorite appears as a minor gangue phase in several paragenetic stages. In the Oxide-Silicate/Main Sulphide Stage clear fluorite (<20 mm) occurs as anhedral intergrowths with pyrrhotite and quartz with characteristic replacement of pyrrhotite by chalcopyrite along the margins of fluorite grains (Plate 5.11e; Sample No. 111088). Fluorite may contain inclusions of quartz, chalcopyrite, cassiterite, stannite, and pyrrhotite. Base Metal Stage breccias contain anhedral green fluorite (<50 mm) associated with siderite ± chlorite, and Vug-fill Carbonate Stages contain clear, or rarely, purple euhedral cubes of fluorite (<10 mm).
PLATE 5.11

A: Photomicrograph showing early oxide-silicate stage pyrite euhedra within arsenopyrite. Partial replacement of the pyrite by main sulphide stage chalcopyrite is apparent and may account for the euhedral outline to chalcopyrite at the contact between arsenopyrite and pyrrhotite. Federal-Bassett Fault Sample No. 111103; DDH U0777 (vi) 106.0 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Py - pyrite, Qz - quartz.

B: Photomicrograph showing main sulphide stage pyrrhotite cut by a late base metal stage vein consisting of carbonate + sphalerite + stannite + chalcopyrite + pyrite. Examples of both spongy and euhedral pyrite are associated with the base metal stage of mineralisation. Federal-Bassett Fault Sample No. 111097; DDH U0748 (ii) 30.9 m. Reflected light. Abbreviations: Asp - arsenopyrite, Carb - carbonate, Cpy - chalcopyrite, Po - pyrrhotite, Py - pyrite, Stan - stannite.

C: Photomicrograph showing three forms of pyrite replacement of main sulphide stage pyrrhotite by base metal stage mineralisation. Pyrite occurs as large subhedral grains, spongy pyrite, and intergrown with marcasite with minor chalcopyrite + stannite. Non sulphide minerals associated with pyrrhotite are topaz with muscovite alteration. Federal-Bassett Fault Sample No. 111144; DDH U0936 (ii) 20.4 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Marc - marcasite, Po - pyrrhotite, Py - pyrite, Stan - stannite, Tpz - topaz.

D: Photomicrograph showing fracture controlled supergene replacement of pyrite by colloform melnikovite. Minor calcite and marcasite typically infill the fractures which control melnikovite replacement of pyrite, or pyrrhotite. In drill-core melnikovite readily breaks down to a fine white powder. Federal-Bassett Fault Sample No. 111161; DDH U0978 (ii) 99.1 m. Reflected light. Abbreviations: Asp - arsenopyrite, Cpy - chalcopyrite, Melnk - greigite, Py - pyrite, Qz - quartz.

E: Photomicrograph showing an intergrowth of fluorite, pyrrhotite and chalcopyrite from the main sulphide stage. Chalcopyrite typically replaces pyrrhotite along grain boundaries between fluorite and pyrrhotite. Federal-Bassett Fault Sample No. 111088; DDH U0638 (vii) 97.9 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Flu - fluorite, Po - pyrrhotite.

F: Late base metal stage vein of colloform rhodochrosite + sphalerite + galena with a central infill of brecciated colloform vein material, and chlorite + bladed pyrite + minor clear quartz crystals. Location - Howard 2000 stope, Fault B. Courtesy of Renison Ltd. Abbreviations: Chi - chlorite, Py - pyrite, Qz - quartz, Rhod - rhodochrosite, Sph + Gn - sphalerite and galena intergrowths.

G: Photomicrograph showing a rare occurrence of topaz in association with arsenopyrite and pyrite from the late oxide-silicate stage. Fracture controlled muscovite replacement of granular topaz intergrowths are ubiquitous with topaz occurrences. Federal-Bassett Fault Sample No. 111144; DDH U0936 (ii) 20.4 m. X-nicols. Abbreviations: Asp - arsenopyrite, Chi - chlorite, Musc - muscovite, Py - pyrite, Tpz - topaz.

(xviii) Chlorite is well developed along the outer margins of Main Sulphide Stage stratabound and stratafault mineralisation as a late paragenetic replacement of quartz ± phlogopite ± tremolite ± talc (Plates 5.8 a; 5.9e, h; 5.10c; Sample Nos. 111110; 111092; 111058). The chlorite is typically pale green Fe-rich ripidolite in altered siliciclastic lithology's, and Mg-rich sheridanite in the calcareous host rocks (Patterson, 1979; Davies, 1985). Davies (op. sit.) noted that ferroan clinohlore develops on the fringes of alteration in impure carbonate beds. A second phase of chlorite precipitation, in association with bladed pyrite, forms a central vein assemblages in colloform Late Base Metal veins (Plate 5.11f).

(xix) Topaz (1.0 mm) rarely occurs and is a minor phase found associated with the late Oxide-Silicate Stage at the extremities of carbonate replacement mineralisation (Plate 5.11g; Sample No. 111144). Topaz is readily recognised by its high relief, and occurs as granular intergrowths with arsenopyrite and pyrite (after pyrrhotite) in talc and carbonate. Texturally the topaz is clear with multiple fractures and partial replacement by muscovite (?) or talc.

(xx) Muscovite and sericite constitute a minor phase in the Oxide-silicate/Main Sulphide Stages, and occur as fine grained disseminations in siliciclastic sediments in the Melba fracture ore zone and similar areas, associated with quartz, tourmaline, cassiterite, pyrrhotite and pyrite mineralisation. Muscovite also occurs as an alteration selvage along cleavage planes, grain boundaries, and fractures in topaz. X-ray diffraction patterns for muscovite correspond to 2M muscovite (Patterson, 1979).

(xx) Chalcopyrite is ubiquitous to most paragenetic stages at Renison and reaches up to one percent in the lower mine workings of the Federal area. In the Oxide-Silicate Stage, anhedral chalcopyrite is intimately associated with pyrite + arsenopyrite + cassiterite + quartz + pyrrhotite, replacing the sulphides along grain boundaries and fractures (Plate 5.11a, h; Sample No. 111103). In the Main Sulphide Stage chalcopyrite also displays replacement textures in pyrrhotite + fluorite + quartz + cassiterite mineral assemblages, but is in equilibrium with sphalerite, galena and bismuth when present. The Late Base Metal Stage contains anhedral to euhedral chalcopyrite intergrowths, with minerals ranging from rhodochrosite ± quartz ± pyrite ± pyrrhotite ± sphalerite ± galena ± stannite ± bismuth ± argentite (Plate 5.12a; Sample No. 111082). In the Vug-fill Carbonate Stage, rare euhedral chalcopyrite crystals up to 1 mm have encrusted dolomite ± fluorite ± quartz. In each of the first three paragenetic stages at Renison, chalcopyrite corrodes cassiterite, resulting in variable amounts of associated stannite.

(xxii) Stannite, a minor mineral in the Renison ores, typically occurs with chalcopyrite as a replacement of cassiterite in Oxide-Silicate/Main Sulphide Stages along grain boundaries and within fractures. Stannite rims cassiterite in the absence of chalcopyrite, but chalcopyrite
typically occurs somewhere within the immediate mineral assemblage (Plate 5.12b, Sample No. 111117). Stannite also occur as exsolutions along crystallographic axes in chalcopyrite from the Oxide-Silicate/Main Sulphide Stages and the Late Base Metal Stage (Plate 5.12c, d; Sample No. 111102, 111174). Minor stannite exsolutions rarely occur in both sphalerite and galena from the Late Base Metal Stage.

(xxiii) Galena occurs as a minor phase in mineralisation associated with both the Main Sulphide and Late Base Metal Stages at Renison. In deformed ores, galena occurs along grain boundaries, at triple points and within the basal cleavage of massive pyrrhotite (Plate 5.12e; Sample No. 111123). Galena associated with the Late Base Metal Stage has a well developed cleavage, is typically coeval with chalcopyrite, sphalerite, and carbonate, and has exsolution lamellae, or intergrowths with bismuth ± stannite ± boulangerite (Plate 5.12f; Sample No. 111144).

(xxiv) Sphalerite is a minor phase at Renison which appears to have coeval precipitation with chalcopyrite; particularly during the Base Metal Stage where it is precipitated with chalcopyrite ± carbonate ± galena ± stannite ± bismuth ± quartz ± pyrrhotite. Sphalerite occurs as zoned, sub-euhedral equant grains (<20 mm) with abundant inclusions of chalcopyrite and lesser amounts of pyrrhotite and stannite, along cleavage planes and within healed fractures (Plate 5.12g, h; Sample Nos. 111084; 111094).

(xxv) Anhedral bismuth grains (<50 μm) are commonly found associated with galena from the Main Sulphide (Plate 5.13a, b; Sample No. 111103) and Base Metal Stages. One example of grains up to 5 mm (111039) occurs in a quartz + arsenopyrite + cassiterite assemblage from the Oxide-Silicate Stage. W. H. Fander (1987) notes that native bismuth typically occurs with traces of bismuthinite and emplectite, but these minerals have not been identified in this study.

(xxvi) A single occurrence of an anhedral grain of argentite intergrown with a vein assemblage of chalcopyrite, quartz, carbonate, galena and bismuth in massive pyrrhotite was identified in sample 111103 (Plate 5.13b). As argentite has not been recorded previously, and microprobe analyses of this mineral phase have not been undertaken, this identification should be viewed with caution.

(xxvii) Marcasite after pyrrhotite has two different associations. The first example of marcasite development occurs in the Late Base Metal Stage assemblages where lamellae-like intergrowths of marcasite and small euhedral pyrite ± calcite ± chalcopyrite ± galena ± stannite, together with spongy pyrite replace pyrrhotite (Plate 5.13c; Sample No. 111144). Supergene replacement of pyrrhotite, by fracture-controlled marcasite, spongy pyrite and
A: Photomicrograph showing late base metal stage vein in massive pyrrhotite from the main sulphide stage. Late base metal stage subhedral chalcopyrite intergrown with sphalerite, in a rhodochrosite pyrrhotite assemblage. Minor galena occurs within fractures of the vein assemblage and along the basal cleavage of the massive pyrrhotite. Federal-Bassett Fault Sample No. 111082; DDH U0638 (i) 85.0 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Po - pyrrhotite, Rhod - rhodochrosite, Sph - sphalerite.

B: Photomicrograph showing stannite replacement of cassiterite along grain boundaries and within fractures. Stannite development is typically associated with the presence of chalcopyrite. Federal-Bassett Fault Sample No. 111117; DDH U0817 (i) 99.8 m. Reflected light. Abbreviations: Cass - cassiterite, Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Stan - stannite.

C: Photomicrograph showing stannite exsolution along crystallographic preferred directions in chalcopyrite, associated with an arsenopyrite + quartz assemblage. Federal-Bassett Fault Sample No. 111102; DDH U0777 (v) 105.0 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Qz - quartz, Stan - stannite.

D: Photomicrograph showing an equilibrium assemblage between chalcopyrite and stannite, with crystallographic preferred intergrowths of the two phases. This mineral assemblage is associated with a late base metal stage vein in massive pyrrhotite from the main sulphide stage. Federal-Bassett Fault Sample No. 111174; DDH U1023 (ii) 40.8 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Po - pyrrhotite, Qz - quartz, Stan - stannite.

E: Photomicrograph showing late base metal stage galena deposition along the basal cleavage of pyrrhotite grains meeting at a triple junction. Deformation lamellae within the massive pyrrhotite from the main sulphide stage is apparent in the lower grain. Federal-Bassett Fault Sample No. 111123; DDH U0825 (iii) 72.5 m. Reflected light, polars partly crossed. Abbreviations: Gn - galena, Po - pyrrhotite.

F: Photomicrograph showing a late base metal stage assemblage of galena + chalcopyrite + quartz + carbonate. Galena exhibits well developed cleavage pits developed during slide preparation. Visible within the galena are minor intergrowths of bismuth and stannite. Federal-Bassett Fault Sample No. 111144; DDH U0936 (ii) 20.4 m. Reflected light. Abbreviations: Bis - bismuth, Carb - carbonate, Cpy - chalcopyrite, Gn - galena, Qz - quartz, Stan - stannite.

G: Photomicrograph showing euohedral sphalerite, from the late base metal stage, intergrown with chalcopyrite and pyrrhotite. Exsolution of both chalcopyrite and pyrrhotite are seen to be aligned along cleavage planes in the sphalerite. Where large inclusions of chalcopyrite occur in sphalerite, zones of chalcopyrite depletion are evident. Federal-Bassett Fault Sample No. 111084; DDH U0638 (iii) 89.0 m. Reflected light. Abbreviations: Cpy - chalcopyrite, Po - pyrrhotite, Sph - sphalerite.

H: Photomicrograph showing base metal stage sphalerite + chalcopyrite replacement of pyrrhotite and arsenopyrite. Fractures in euohedral sphalerite have been infilled by chalcopyrite containing minor anhedral galena and bismuth grains. Exsolution of chalcopyrite is also evident in the sphalerite. Federal-Bassett Fault Sample No. 111094; DDH U0741 (iv) 77.5 m. Reflected light. Abbreviations: Asp - arsenopyrite, Bis - bismuth, Cpy - chalcopyrite, Gn - galena, Po - pyrrhotite, Qz - quartz, Sph - sphalerite.
PLATE 5.13

A: Photomicrograph showing an intimate intergrowth of base metal stage galena and bismuth associated with a vein in a main sulphide stage assemblage of pyrrhotite + pyrite. The black zones in the photomicrograph are holes in the slide. Federal-Bassett Fault Sample No. 111103; DDH U0777 (vi) 106 m. Reflected light. Abbreviations: Bis - bismuth, Gn - galena, Po - pyrrhotite, Py - pyrite.

B: Photomicrograph showing base metal stage chalcopyrite + argentite + bismuth + galena overprinting and replacing main sulphide stage pyrrhotite. Federal-Bassett Fault Sample No. 111103; DDH U0777 (vi) 106 m. Reflected light. Abbreviations: Arg - argentite, Bis - bismuth, Cpy - chalcopyrite, Gn - galena, Po - pyrrhotite.

C: Photomicrograph showing late base metal stage marcasite lamellae after pyrrhotite, intergrown with galena, calcite, chalcopyrite and subhedral pyrite. Spongy pyrite replacement of pyrrhotite is also visible. Federal-Bassett Fault Sample No. 111144; DDH U0936 (ii) 20.4 m. Reflected light. Abbreviations: Calc - calcite, Cpy - chalcopyrite, Gn - galena, Marc - marcasite, Po - pyrrhotite, Py - pyrite.

D: Photomicrograph showing fracture controlled supergene marcasite and spongy pyrite replacement of massive main sulphide stage pyrrhotite. The fractures associated with supergene replacement typically contain calcite and pyrite infill. Federal-Bassett Fault Sample No. 111148; DDH U0938 (i) 51.5 m. Reflected light, polars partly crossed. Abbreviations: Calc - calcite, Marc - marcasite, Po - pyrrhotite, Py - pyrite.
siderite assemblages (Plate 5.13d; Sample No. 111148) represent the second stage of occurrence. Greigite may also occur with this mineral association.

(xxviii) Previous investigators have recorded either single occurrences, or minor traces of bismuthinite, pyargyrite, lillianite, canfieldite, franckeite and jamesonite, in galena from Renison ores (Stillwell & Edwards, 1943; Groves, 1968; Patterson, 1979) but these minerals have not been recognised in this study.

5.4.4 Metal Distribution On Faults At Renison ...

Metal distribution patterns (metres thickness x percent grade) on the major faults at Renison were investigated to establish spatial and temporal zonation patterns, and to compare fault geometry with ore grades. Each of the metal distribution diagrams were constructed by gridding the assay data using an inverse distance cubed method. The technique applied had a maximum scan distance of 150 m, requiring twelve drill-holes to satisfy the search. Grid mesh sizes were 10 m and a linear colour search for red was specified.

5.4.4.1 Metal Distribution On The Federal-Bassett Fault ...

The geometry of the Federal-Bassett Fault over a 2 km strike length was constrained by 20 m spaced cross-sections. These sections have previously been discussed in Chapter 3 and presented in Appendix I. Figure 5.16 is a longitudinal projection of the Federal-Bassett Fault, and illustrates the major structural irregularities evident in the footwall. Indicated are the fault contacts between the Federal-Bassett Fault and the Envelope Fault, 'Shear L', 'Shear P', Fault 'A', and Fault 'Z'. Also shown are the approximate location of flexures within the Federal-Bassett structure, and three schematic cross-sectional diagrams of the Federal-Bassett Fault.

The Envelope Fault and Fault 'A' contacts, against the Federal-Bassett Fault, represent boundaries to footwall faults within dilational concave flexures of the Federal-Bassett Fault (Fig. 5.16 a, b, d; see Appendix I: Sections 65280N to 65560N and Sections 66200N to 66700N). The 'Shear L' - Federal-Bassett Fault contact traverses a relatively simple near-vertical course across the longitudinal projection, and terminates on the Lower Envelope Flexure. The 'Shear P' - Federal-Bassett Fault contact, however, traces an irregular path due to its intersection with the Melba Flexure (Fig. 5.16 a, c; see Appendix I: Sections 65780N to 65980N). The Fault 'Z' - Federal-Bassett Fault contact is near vertical, with Fault 'Z' being a near-vertical sub-parallel footwall bounding structure in the North-Bassett region of the Federal-Bassett Fault.
Figure 5.16  Major structural irregularities controlling mineralisation along the Federal-Bassett Fault. (a) Longitudinal projection of the Federal-Bassett Fault illustrating the main ore zones (Upper & Lower Federal, Envelopes, Rendeep), fault contacts (Envelope Fault, 'Shear L', 'Shear P', Fault A, Fault Z) and fault flexures (Envelope, Melba, Federal, Fault 'A'). (b) Schematic cross-section through the Envelope ore zone on the Federal-Bassett Fault. (c) Schematic cross-section through the Federal ore zone on the Federal-Bassett Fault showing the relationship between the Melba Fracture ore zone, 'Shear P', and fault flexures. (d) Schematic cross-section through the North Bassett region of the Federal-Bassett Fault.
The position of major flexures in the Federal-Bassett Fault are indicated by cross hatching (Fig. 5.16a). In the Envelope region, a major concave flexure occurs between 1800 R.L. and 2000 R.L. and is delineated by the traces of the Upper and Lower Envelope Flexures (Fig. 5.16 a & b). A second flexure, the Melba Flexure, traverses diagonally across the Federal-Bassett Fault and was instrumental in forming the Melba fracture ore at the intersection between the Melba Flexure - 'Shear P' - Federal-Bassett Fault (Fig. 5.16 a & c). Several minor horizontal flexures occur in the North Bassett region, of which the Fault 'A' Flexure is the most persistent (Fig. 5.16 a & d).

Figure 5.17 illustrates a tin accumulation pattern for the Federal-Bassett Fault, together with an overlay showing the structural irregularities. Two major zones of tin enrichment (Sn > 10m x %) are highlighted: the Federal - Envelopes region between 65400N and 65900N, and the Rendeep area between 66300N and 66700N. A third zone of minor tin accumulation occurs above Rendeep between 1800 R.L. and 2000 R.L., over a strike length of 800m from 66200N to 67000N.

A comparison of tin accumulation and structural irregularities in the Federal-Bassett Fault illustrate a strong correlation between mineralisation and fault dilation caused by flexures and/or fault intersections (Fig. 5.17). The location of the dolomite horizons adjacent to, and within, the Federal-Bassett Fault couple also affect tin accumulation patterns.

Sn mineralisation in the Federal area was controlled primarily by the intersections of 'Shear L' and 'Shear P' with the Federal-Bassett Fault. 'Shear L', in particular, was responsible for dilation of the Federal area below 1900 R.L., where it intersected and permitted mineralisation of the No. 2 Dolomite Horizon. Above 1800 R.L., 'Shear P' is associated with the Federal Flexure which allowed extensive dilation and mineralisation in the Upper Federal area (Fig. 5.17). In the Envelope region, the Envelope Flexures restricted major Sn mineralisation to a stratatfault zone between 1800 R.L. and 2000 R.L. However, in the Federal region, the divergence of the Envelope Flexures and their intersection with the Transverse Shears assisted the development of major tin accumulations. The intersection of the Lower Envelope Flexure with 'Shear L' has created a constriction in the Federal-Bassett Fault with limited mineralisation. However, the overlap zone between the Lower Envelope and Melba Flexures created a dilational region that linked the Upper and Lower Federal areas and permitted access to mineralising fluids. The Melba Flexure - 'Shear P' intersection represents a cut off zone below which tin accumulation is low. Above this zone, however, mineralising fluids have deposited Sn.

In the North Bassett area, the Upper and Lower Fault 'A' contacts have restricted the mineralisation to a stratatfault zone approximately 800m long and 200m high. This zone of mineralisation is disrupted by the Fault 'Z' - Federal-Bassett Fault contact. The highest Sn
RENISON TIN MINE
FEDERAL BASSETT FAULT

Sn Accumulation
NW-SE Longitudinal Projection
Scale 1:10,000

Linear colour stretch - Red = Sn > 10 metres x %
IDW² gridding, mesh size 10m, scan distance 150m

Figure 5.17
accumulation occurred in the zone of closest approach between the Upper and Lower Fault 'A' contacts near 66600N. An area between Fault 'A' and the Fault 'A' Flexure represents a constriction on the Federal-Bassett Fault in which Sn accumulation has been minimal.

Interpretations of structural controls on mineralisation in the Rendeep area has not been attempted due to the lack of drill-hole information at the time of this investigation. The Rendeep area is currently the subject of an intensive investigation by Renison geologists to prove up ore reserves and increase the profitability and life of the mine. The irregularity in the Sn accumulation patterns at depth along the Federal-Bassett Fault is in part an artefact of the paucity of drilling at depth along the fault, combined with the inability of the contouring program to deal with the small data set for this region.

Accumulation diagrams for a suite of elements assayed at Renison (Sn, W, As, Bi, S, Cu, Ag, Pb, Zn, Fe) were produced to assess spatial and temporal distributions of these elements (Appendix III - see plots of metal accumulation diagrams, data location and fault thickness). As discussed in Section 5.4.2, Sn is associated with the Oxide-Silicate/Main Sulphide Stage of mineralisation. Sn accumulation on the Federal-Bassett Fault therefore reflects mineralisation related to these events. Other elements which show a similar distribution to Sn are S, As, Bi, W, and Cu. These metals are also associated with minerals related to the Oxide-Silicate/Main Sulphide Stage. Of these metals, W and Bi are concentrated towards the base of the Federal region (Fig. 5.18: W > 0.5 m x %), As and Cu are concentrated in the central Federal region, and S is concentrated in the upper Federal region.

The elements Ag, Pb, and Zn are diagnostic of the Late Base Metal Stage in the vein paragenesis at Renison. Metal accumulation diagrams for these elements show that the Federal region was important to their distribution, but the distribution is peripheral to the earlier metals. Metal accumulation plots for the Late Base Metal Stage show that Ag (Fig. 5.19: Ag > 200 m x ppm) is less dispersed than Pb, which is in turn less dispersed than Zn.

In conclusion, metal accumulation plots highlight the strong influence that structural irregularities and dolomite had on ore distribution along the Federal-Bassett Fault. Spatial and temporal investigations of metal distribution, in conjunction with the vein paragenesis, for the Federal-Bassett Fault show that a telescoped metal zonation exists. The observed sequence of metal distribution (including S) along the Federal-Bassett Fault away from the Pine Hill Granite underlying the Renison Mine is:

\[
W, Bi > Sn, As > Cu > S > Ag > Pb > Zn \\
(Proximal) \\
( Distal)
\]
Figure 5.18
RENISON TIN MINE
FEDERAL BASSETT FAULT

Ag Accumulation
NW-SE Longitudinal Projection
Scale 1:10,000

Linear colour stretch - Red = Ag > 200 metres x ppm
iDW^2 gridding, mesh size 10m, scan distance 150m

Figure 5.19
5.4.4.2 Metal Distribution On 'Shear P' ...

The 3-D shape of the Transverse Fault, 'Shear P', was presented in Figure 3.15. In this diagram it was evident that a number of irregularities occur along the surface of 'Shear P' from the beginnings of the fault adjacent to the Federal-Bassett Fault/Melba Fracture Orebody to the Up-dip extremities adjacent to the Blow Fault. Sn accumulation (Sn > 5 m x %) plotted upon this 3-D diagram (Fig. 5.20) highlights the association between fault irregularities and mineralisation (Appendix IV - see plots of metal accumulation, data locations and fault thickness). These depressions in the fault surface correspond with intersections of dolomite horizons. The lack of mineralisation within the Melba region is due to the assay data from this area being included in the Federal-Bassett Fault data-set.

The largest area of Sn mineralisation, evident in Figure 5.20, is located near the surface in the central area of 'Shear P'. This region corresponds to the intersection of the fault with the No. 2 Dolomite (Dreadnought Orebody; Fig. 5.12). The intersection of the Blow Fault with 'Shear P' also allowed mineralisation of the No. 2 Dolomite (Black Face Open-cut; Fig. 5.12). Adjacent to this area at depth, the Polaris orebody represents a large zone of Sn accumulation in a dilational zone at the intersection between both 'Shear P' and 'Shear L'. The Polaris Orebody is an early Oxide-Silicate Stage carbonate-magnetite style of mineralisation overprinted by a later Oxide-Silicate/Main Sulphide Stage of Sn-rich mineralisation. In Figure 5.20, the smaller unlabelled zones of mineralisation correspond to weakly mineralised intersections of either No. 1, No. 2, or No. 3 Dolomites.

Based on metal accumulation plots for 'Shear P', the spatial and temporal distribution of the elements assayed at Renison are almost identical to the results for the Federal-Bassett Fault. The observed sequence of weak telescoped metal zonation (including S) along 'Shear P' away from the Federal-Bassett Fault intersection is:

\[
\text{Bl} > \text{Sn, As} > \text{Cu} > \text{S} > \text{Ag} > \text{Pb}, \ (W) > \text{Zn} \\
\text{(Proximal)} \\
\text{(Distal)}
\]

Some questions arise as to the location of tungsten (W) in this telescoped zonation. The anomalous tungsten data may reflect the early Oxide-Silicate Stage mineralisation associated with carbonate-magnetite in the Polaris orebody.

5.4.4.3 Metal Distribution On 'Shear L' ...

Figure 5.21 presents a 3-D image of 'Shear L' with accompanying Sn accumulations (Sn > 5 m x %). As for 'Shear P', Sn mineralisation along 'Shear L' is associated with fault irregularities and the intersection of dolomite horizons (Appendix V - see plots of metal accumulation, data locations and fault thickness).
RENISON TIN MINE
SHEAR P

Sn Accumulation
Isometric Projection

Linear colour stretch - Red = Sn > 5 metres x %
IDW^2 gridding, mesh size 10m, scan distance 150m

Figure 5.20
RENISON TIN MINE
SHEAR P

Sn Accumulation
Isometric Projection

Linear colour stretch - Red = Sn > 5 metres x %
IDW-2 gridding, mesh size 10m, scan distance 150m
RENISON TIN MINE
SHEAR L

Sn Accumulation
Isometric Projection

Linear colour stretch - Red = Sn > 5 metres x %
IDW^2 gridding, mesh size 10m, scan distance 150m

Figure 5.21
The lower most Sn accumulation in 'Shear L', adjacent to the intersection with the Federal-Bassett Fault, corresponds to stratafault mineralisation. Toward the top of the 'Shear L' - Federal-Bassett Fault contact, high Sn values reflect the intersection of the No. 2 and No. 3 Dolomite Horizons and correspond to the location of the South Stebbins and Howard Orebodies, respectively (Fig. 3.14 & Fig. 5.12). Adjacent to this area but away from the Federal-Bassett Fault contact, two Sn-rich accumulations represent mineralised dolomites associated with the North Stebbins and Colebrook Orebodies (Fig. 3.14 & Fig. 5.12). Halfway along 'Shear L', the small Sn accumulation zone indicates the location of the Sligo Orebody (No. 3 Dolomite) and just before the contact with the Blow Fault is a Sn accumulation representing the fault intersection with the Argent Orebody (No. 3 Dolomite; Fig. 3.14). The final example of Sn accumulation in the Up-dip extremity of 'Shear L' is the Polaris Orebody which is located in the dilatational intersection of both 'Shear L' and 'Shear P'.

The spatial and temporal distribution of elements in 'Shear L' are compatible with both the Federal-Bassett Fault and 'Shear P'. The telescoped metal zonation (including S) along 'Shear L' away from the Federal-Bassett Fault intersection is:

\[ \text{Bi > Sn, As, W > Cu > S > Ag > Pb > Zn} \]

(Proximal) (Distal)

5.5 SUMMARY ...

Within the Renison-Dundas district the intrusion of the Devonian Pine Hill Granite thermally metamorphosed, metasomatised and structurally prepared the overlying sedimentary rocks for mineralisation. Thermal metamorphism baked and altered the sediments which assisted brittle deformation of the overlying sediments and the formation of a set of conjugate faults above the flat topped roof zone of the intrusion. This event allowed the over-pressured hydrothermal fluids released from apophyses in the granite to be focussed into preferred dilational sites, normal to the minimum compressive stress direction (\(\sigma_3\)) resulting in northwest oriented fissure deposits throughout the region. Complex metasomatic alteration patterns around apophyses associated with the Pine Hill intrusion resulted in six recognised alteration zones, which are further complicated by host rock lithology's (greisen zone, skarn zone, amphibole zone, biotite zone, talc/chlorite zone, carbonate zone). Intimately associated with the metasomatic replacement mineralisation is a series of less complicated and more systematic vein hosted mineral assemblages which are spatially and temporally zoned about apophyses in the granite (Oxide-silicate Stage, Sulphide Stage, Carbonate Stage). Economic mineralisation hosted by fracture filled fissure veins in the district define a telescoped zonation pattern from a central tin zone within two kilometres of the granite - sediment contact; out through an approximately 2 km wide copper annulus that occurs up to
2.5 km from the intrusion, which is further surrounded by a 2 km wide halo of lead-zinc mineralisation recognised up to 4 km from the underlying Pine Hill Granite.

At the Renison Tin Mine, detailed investigations of the mineral paragenesis along the Federal-Bassett Fault has identified the same spatial and temporal vein assemblages observed in the Renison-Dundas district. This study has recognised for the first time the close association between deformation events and associated mineralisation in the Renison deposit. The mineralogical stages represent temporal variations in the hydrothermal fluid associated with declining temperatures. The more traditional Sn-W deposit type classification, consisting of a five stage vein paragenesis, has been proposed for Renison and related to fault reactivations. The stages comprise: Oxide-silicate Stage, Main Sulphide Stage, Late Base Metal Stage, Vug-fill Carbonate Stage, and Supergene Stage. Cassiterite deposition occurred within the first two stages (Oxide-silicate Stage and Main-Sulphide Stage), and is intimately associated with arsenopyrite deposition in vein assemblages from the Oxide-silicate Stage. Stratabound carbonate replacement mineralisation, however, was restricted to the late Oxide-silicate/Main Sulphide Stage when a dextral wrench across the mine horst refocussed the mineralising fluids into dilational zones adjacent to the No. 1, No. 2 and No. 3 Dolomite horizons. Metal accumulation along the Federal-Bassett Fault has been controlled by structural irregularities which include: flexures, fault intersections and contacts with adjacent dolomite horizons. A telescoped metal zonation has been recognised along the Federal-Bassett Fault at Renison, away from the underlying Pine Hill Granite, and is based on paragenetic studies of spatial and temporal vein assemblages, together with metal accumulation plots. The metal zonation away from the Pine Hill Granite is:

\[
W, Bi \gg Sn, As \gg Cu \gg S \gg Ag \gg Pb \gg Zn
\]

(Proximal) \hspace{1cm} (Distal)

5.6 FUTURE AREAS FOR RESEARCH ...

The Renison-Dundas area is perhaps one of the best available examples of a zoned mineral district. Residual gravity interpretations of the underlying Pine Hill Granite (Leaman, 1990) has allowed a spatial interpretation to be made of the ore deposits within the mineral field which surrounds this intrusion. General features associated with thermal metamorphism and alteration, together with spatial and temporal vein assemblages related to the Pine Hill Granite in the Renison-Dundas district have been recognised and documented in this study. However, except for the Renison deposit, specific details still need to be documented throughout this zoned mineral field.

Potential areas for future research in the Renison-Dundas district include:

(i) Documenting the specific details of thermal metamorphic affects in the host rocks intruded by the Pine Hill Granite. No documentation of thermal metamorphic effects
in the Dundas area currently exists. All studies have been confined to the Renison area, north of and including Pine Hill.

(ii) Documenting specific details of the metasomatic alteration zones associated with apophyses in the Pine Hill Granite. A number of apophyses obviously exist in the roof zone of the intrusion (e.g., Pine Hill, Renison, Razorback). This study has briefly identified the alteration assemblages in Renison area, north of and including Pine Hill, but considerable research is required to accurately detail the specific mineral assemblages. This type of study will greatly assist future exploration programs in the region by identifying alteration associated with underlying granite apophyses and helping to locate major fault structures linked to potential sites of economic mineralisation.

(iii) Detailed investigations of structural controls on mineralisation, and documentation of the mineral paragenesis within the numerous abandoned mines and prospects across the Renison-Dundas mineral field is virtually non-existent. Any research in both these areas would greatly extend the geological knowledge in this region. Isotopic and fluid inclusions studies within this region also provide a fertile field for future research.