5 LOCAL GEOLOGY

5.1 LITHOLOGY

5.1.1 Hanging Wall

The hanging wall mostly consists of biotitegneiss, which comprises massive, unlayered rocks made up of patches of coarse-grained quartz and feldspar (plagioclase and microcline) separated by patches of granular fine-grained quartz, plagioclase and microcline. Also present are major to minor amounts of brown biotite, magnetite, and traces of green hornblende and zircon. The majority of opaque minerals consist of interstitial magnetite and pyrrhotite in close association with one another, together with small amounts of pyrite and ilmenite. Ilmenite may occur both as discrete granules, and as coarse lamellae exsolved from a titaniferous magnetite (Richards, 1999).

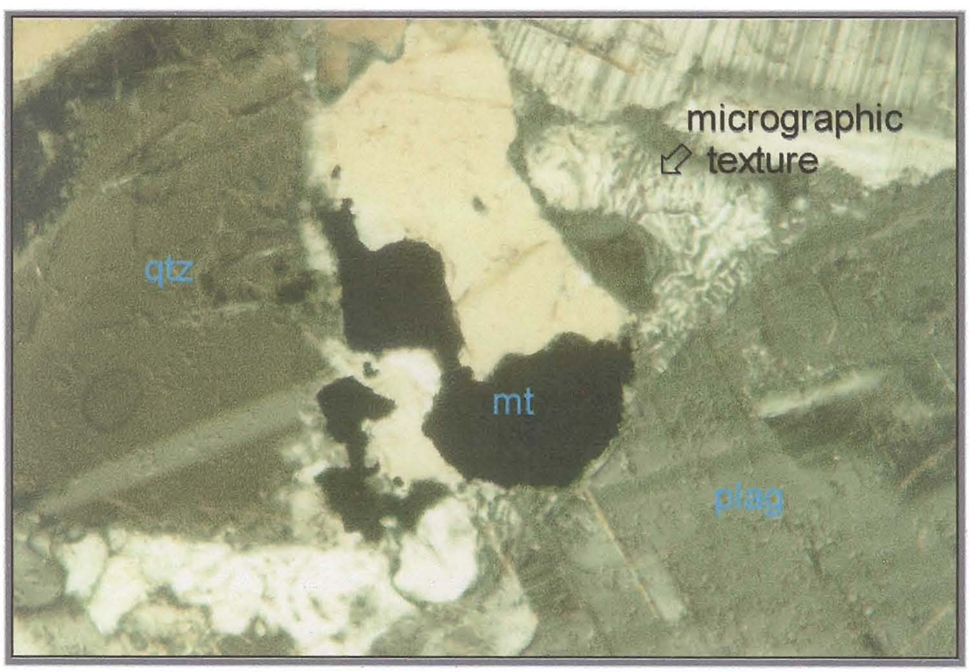

Figure 7. Hanging wall mineralogy. Micrographic texture occurs typically between areas of coarser-grained quartz (qtz) and feldspar and finer-grained intervening areas. (Polarised light, X 100) (Richards,1999). (mt – magnetite and plag – plagioclase).

The composition and textures present in the rock suggest that this was originally a magmatic igneous rock. The presence of interstitial magnetite and ilmenite, green hornblende and zircon, is consistent with a deep-seated magmatic proto-rock of possible granitic composition. The micrographic textures may own to a later hydrothermal event after the initial upper amphibolite metamorphism. The metamorphism appears to have affected the proto-rock with the formation of biotite, the mobilisation and recrystallisation of small amounts of magnetite, and the recrystallisation of some of the finer-grained quartz in particular into elongated subparallel crystals. The rock can probably be best classified as an orthogneiss (Richards, 1999).

5.1.2 Footwall

The footwall consists mainly of biotite hornblende gneiss (Figure 8) and amphibolite, with the amphibolite being possible later intrusive sills. On a microscopic scale, this rock is very poorly foliated. It consists principally of quartz with minor amounts of plagioclase, together with ragged flakes of biotite, which imparts a penetrative foliation to the rocks.

Most biotite, however, is located along grain boundaries. In addition, minor to trace amounts of pyroxene and hornblende are present as irregularly shaped bodies, interstitial to quartz. Zircon is present in trace amounts as inclusions in biotite, hornblende and quartz. In addition, there are traces of garnet in the rock. Opaque mineralisation is present in major to minor amounts and consists predominantly of magnetite, with lesser amounts of pyrite, pyrrhotite and very small amounts of chalcopyrite. The minerals in this gneiss are, in decreasing order: plagioclase, quartz, hornblende, biotiete, orthoclase, sphene, magnetite / ilmenite, apatite and zircon.

The texture of the rock is granular, with a moderately large degree of variation in grain size, being made up of clusters and layers of moderately coarse-grained, interlocking quartz with intervening areas, layers and lenses of fine-grained, interlocking quartz and occasional feldspar. Quartz tends to be greatly elongated in the direction of foliation in coarse-grained layers, and associated finer-grained feldspar commonly contains worm-like inclusions of quartz in a micrographic texture.

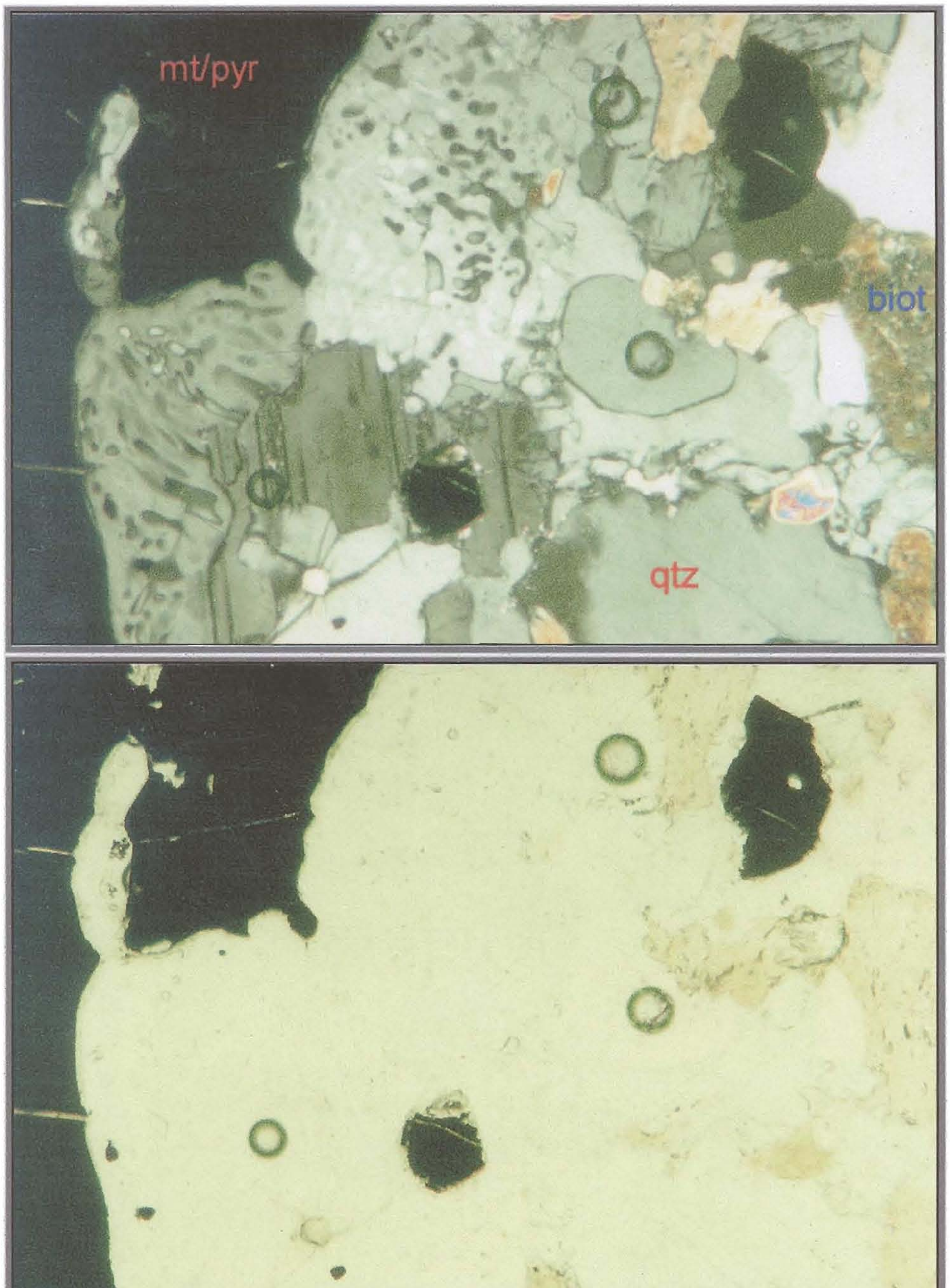

Figure 8. Footwall mineralogy. Micrographic textures between alkali feldspar and quartz (qtz) commonly occur in finer-grained areas that also contain biotite (biot), plagioclase and opaque mineralisation, between coarser-grained quartz and feldspar. (pyr – pyrite and mt – magnetite). (Top: polarised light; bottom: plane light; X 100).

Minor orthopyroxene, with green-pink pleochroism (i.e. hypersthene), are also present. It is generally intergrown with quartz and feldspar as ragged anhedral grains, and appears to be confined to the predominantly fine-grained regions of the rock grains (Richards, 1999). This is indicative of upper amphibolite to granulite facies that existed during the metamorphism.

Compositionally and texturally, the rock is poorly foliated biotite hornblende gneiss that appears to have resulted from the metamorphism of an igneous intrusive rock, possibly granite. The variation in grain size, the presence of micrographic textures, the occurrence of trace amounts of zircon and of relatively large amounts of magnetite suggest that it could have been a granite in which the quartz has subsequently undergone substantial modification to form elongated crystals, as well as foliation. The finer-grained parts of the rock appear to have been affected and modified to a much lesser degree. Also of note is the apparent second orientation direction displayed by magnetite mineralisation, which is presumably stress-induced grains (Richards, 1999).

A massive amphibolite occurs randomly throughout the Jannelsepan Formation, but it is not considered to be part of the original layered sequence, the same as with the massive amphibolite in the Copperton Formation (Theart, 1985). This hornblende-plagioclase amphibolite is believed to have a intrusive basaltic rock as precursors, owing to the rather featureless and uniform texture and grain size which are characteristic of sills and dykes. The conclusion was the same as in the case with the Copperton Formation, that the massive amphibolite layers probably intruded the sequence as dykes or sills after the ore formation, but prior to the regional deformation and metamorphism.

5.1.3 Sulphide Zone

Samples were taken from a less sulphide-rich part of the core, but with visible chalcopyrite in the hand specimen, as well as from an area of massive sulphide mineralisation. The main sulphide minerals present are pyrrhotite and sphalerite, with lesser amounts of chalcopyrite and pyrite. Galena is present in trace amounts only (Richards, 1998).

Sulphide mineralisation may occur as either patches of massive mineralisation or disseminated in the intervening gangue minerals of the host rock. In areas of massive mineralisation, pyrrhotite and sphalerite appear to be particularly well associated with each another. Chalcopyrite is usually present in only trace amounts and seems to occur as relatively isolated 'patches' throughout the host rock mineralisation. Massive pyrrhotite/sphalerite appears to replace the protolith almost completely, but a relatively large number of remnants, generally subrounded particles of host rock, occur within the pyrrhotite and sphalerite as inclusions. These clasts are interpreted as the product of "durchbewegung" (Theart, 1995).

There is no evidence of grain boundaries in either massive pyrrhotite or massive sphalerite, but both minerals have been extensively fractured in places, particularly pyrrhotite, and the microfractures were infilled probably with chlorite. The fracturing can be a product of later effects. Pyrrhotite and sphalerite are generally coarsely intergrown with one another and small amounts of chalcopyrite may also be incorporated into the texture. Chalcopyrite, when present, generally occurs along, or adjacent to, the common boundary between pyrrhotite and sphalerite as an exolution feature (Richards, 1998).

Small inclusions of sphalerite may be present in pyrrhotite, but are rare; size is usually <100 μm. and commonly 20 – 30 μm. Small subrounded inclusions of pyrrhotite may be found in sphalerite and are more common than sphalerite inclusions in pyrrhotite. The pyrrhotite grain size is generally <20 – 30 μm with occasional larger inclusions up to 50 μm in diameter. Inclusions of chalcopyrite in sphalerite also occur and are common in areas where chalcopyrite is associated with the common boundary between sphalerite and pyrrhotite, but are less common elsewhere. The chalcopyrite grain size is generally <20 μm. Very fine-grained, almost submicroscopic, linear bodies of exsolved chalcopyrite are found in sphalerite, but are generally widely dispersed and relatively rare (Richards, 1998). This exsolved chalcopyrite is also common at Prieska Cu Zn mine.

Coarser-grained chalcopyrite is usually found closely associated with the common boundary between pyrrhotite and sphalerite, and is generally of irregular shape and of variable grain size. Width of these grains can vary from <10 μm to >200 μm. Chalcopyrite may contain a small number of inclusions of sphalerite and pyrrhotite of mostly less than 35 μm in size, while the shape of inclusions is largely irregular, to subrounded (Richards, 1998).

Pyrite occurs as small to large, irregularly-shaped bodies which apparently replace larger masses of sphalerite pyrrhotite and chalcopyrite. The pyrite can contain small inclusions of other sulphide minerals, and sometimes also gangue. The size of the inclusions is generally <100 μm. The size of the pyrite grains can be greater than 2.5 to 3 mm in diameter.

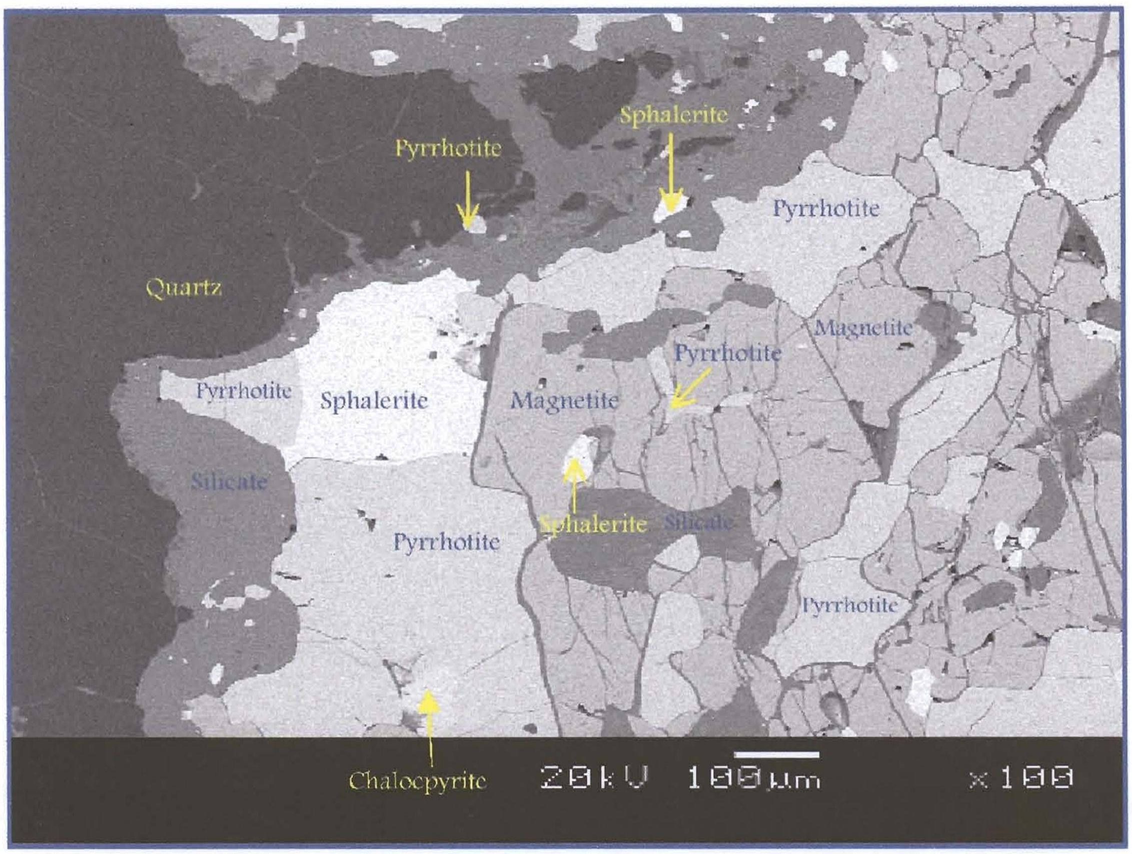

Figure 9. Sulphide mineralogy. Silicate replacing magnetite intergranular, as well as occurring along fractures and margins. Magnetite is also being replaced by pyrrhotite and sphalerite.

Intergranular sphalerite generally appears to contain large numbers of inclusions of chalcopyrite, either as small irregularly-shaped grains of <10p.m in size, or as exsolved lamellae of <2 – 3 µm in width. Chalcopyrite inclusions are far more numerous in this finer-grained sphalerite than in the coarser-grained, more massive sphalerite (Richards, 1998).

Very fine-grained sulphides, consisting predominantly of pyrrhotite and, to a much lesser extent, chalcopyrite and galena, can occur as disseminated particles throughout the host rock, mainly in association with chlorite. Grain shape is irregular (i.e. subangular to subrounded) and size is generally 25 – 75 µm with some particles of up to ±150 µm in size. Quartz in the host rock is generally free of sulphide mineralisation. Only trace amounts of sphalerite are found as fine-grained disseminated particles in the host rock (Richards, 1998).

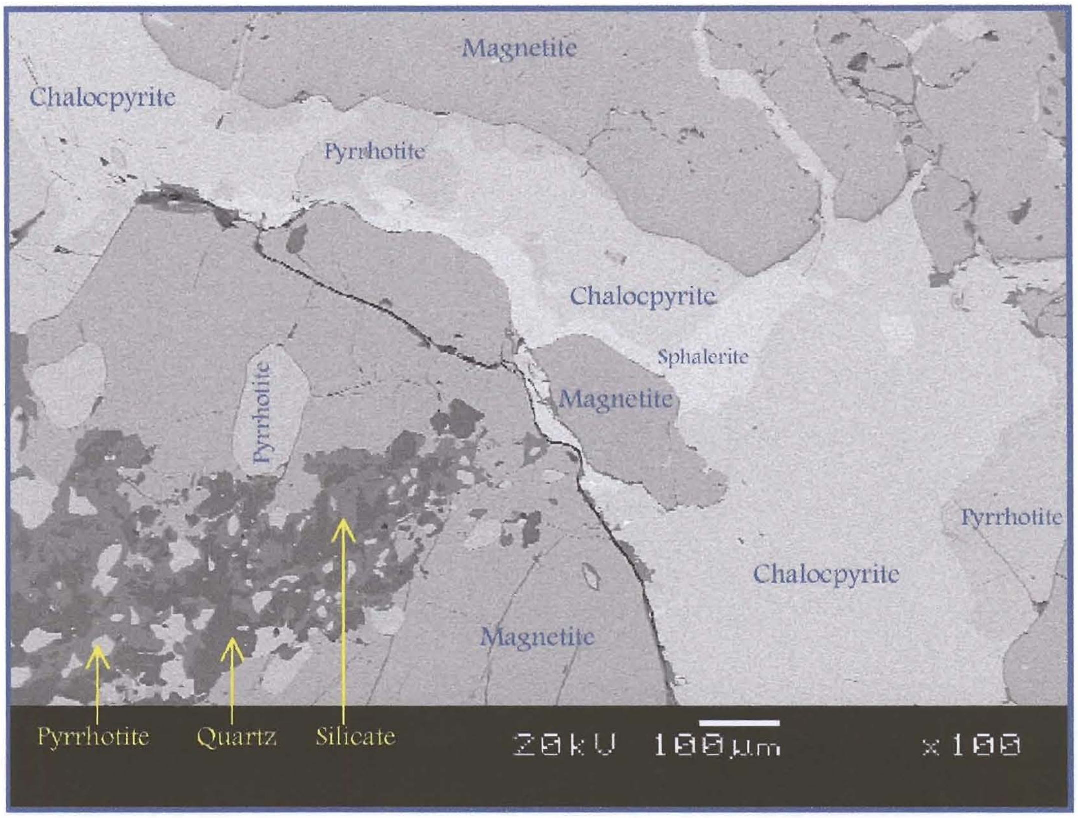

Figure 10: Sulphide mineralogy. Magnetite being invaded by sulphides, that in turn exhibit multiple and consecutive replacements among themselves.

5.2 MICRO-ANALYSES

The compositions of the specific minerals were determined with energy dispersive X-ray (EDS) analysis. The main substitute for Zn in sphalerite is iron (Fe), while manganese (Mn) and cadmium (Cd) are also common, so that sphalerite may be expressed as (Zn, Fe, Mn, Cd) S. Sphalerite in the sample under investigation has an average Fe content of 8.47% (Figure 11), while other sulphide minerals are essentially free of contaminants. Gangue minerals appear to be mainly quartz and silicates, varying in composition between CaFeMg-silicates and CaFe-silicate, like hornblende, anthophyllite and cummingtonite-grunerite (Reyneke, 2002).

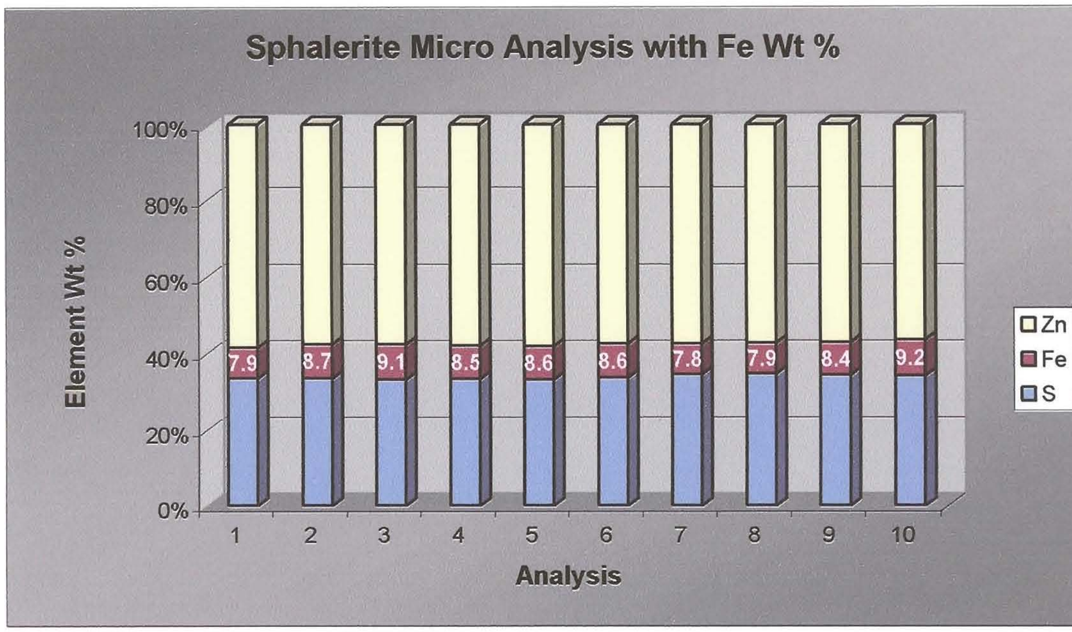

Figure 11: Sphalerite micro-analyses (Reyneke, 2002).

Other samples were also analysed by using electron microprobe analysis with a semi-quantitative program. The results can be seen in Table 5.

Table 5. Electron microprobe analysis in percentage weight of core samples.

Mineral	Fe	Cu	Mn	Zn	S
Sphalerite	7.06	0	0.36	59.16	33.42
	6.89	0	0.32	59.22	33.57
	7.29	0	0.30	58.67	33.73
	7.04	0.02	0.27	59.43	33.24
Pyrrhotite	59.80	0	0.11	0.08	40.01

Note that there is a consistent ±7% (wt) Fe contained within the sphalerite. Fe is the main substitute for zinc in sphalerite, and according to Deer *et al.* (1992), up to 26% (wt) Fe has been reported in sphalerite. For beneficiation purposes, high Fe-bearing sphalerite does not apparently respond as well to the normal flotation process as sphalerite with a low Fe content. The high iron content sphalerite will decrease the plant yield, which means less Zn concentrate and a lower revenue. Detail studies should be conducted, in the pre-feasibility and feasibility stage, to quantify the effect of the high iron content sphalerite in the plant and to determine if new plant designs can't address the possible problem.

5.3 DISCUSSION

The principal sulphide present in the sample is pyrrhotite with a lesser amount of sphalerite. Small amounts of chalcopyrite, pyrite and traces of galena also occur, but are not uniformly distributed throughout the mineralised zone. The host rock minerals appear to consist of quartz with lesser amounts of chlorite. These statements means that drill holes has not intersected any feeders, if it have not been eroded due to the steep dipping of the deposit.

Pyrrhotite and sphalerite occur in massive form, becoming interstitial to host rock gangue minerals in less mineralised areas. Fine-grained sulphides (mainly pyrrhotite with only traces of sphalerite) occur throughout the less well-mineralised parts of the host rock, where they seem to be associated principally with chlorite.

Chalcopyrite occurs in isolated patches throughout the zone of mineralisation and, when present, appears to concentrate along common boundaries between pyrrhotite and sphalerite. Pyrite can replace both pyrrhotite and sphalerite, but is not widely distributed through the mineralised zone.

Massive and coarse-grained sphalerite contains a number of inclusions of both pyrrhotite and chalcopyrite; these are generally $<20 - 30$ μm in size. A small amount of chalcopyrite occurs as extremely fine-grained exsolved blebs and laminae in the sphalerite.

The relatively large grain size and massive to interstitial habit of much of the ore indicates that it should be possible to produce a high grade concentrate with high recovery rates, using routine beneficiation procedures for a sulphidic ore of this type. It should, however, be borne in mind that large amounts of pyrrhotite are present which will have to be separated from sphalerite and chalcopyrite. Removal of pyrite will probably be quite easily achieved because of its relatively large grain size, smooth grain boundaries and comparatively isolated granular habit. Pyrrhotite on the other hand can be separated magnetically and can be dispose of more easily that the pyrite.

It should be noted that a sphalerite concentrate would contain a certain amount of chalcopyrite as a result of the presence of exsolved chalcopyrite in the sphalerite ore. In addition, the presence of chlorite in the ore suggests that large amounts of slimes may be generated in the beneficiation process and may have to be suppressed.

Electron-microprobe analyses of sphalerite indicate that approximately 7% (wt) Fe may be expected to occur in all the sphalerite. The high Fe percentage may be enough to affect the floatation of sphalerite adversely and should be investigated further (Richards, 1998). It is proposed that pilot floatation test work be done at Rosh Pinah with a bulk sample of the high Fe-sphalerite.