

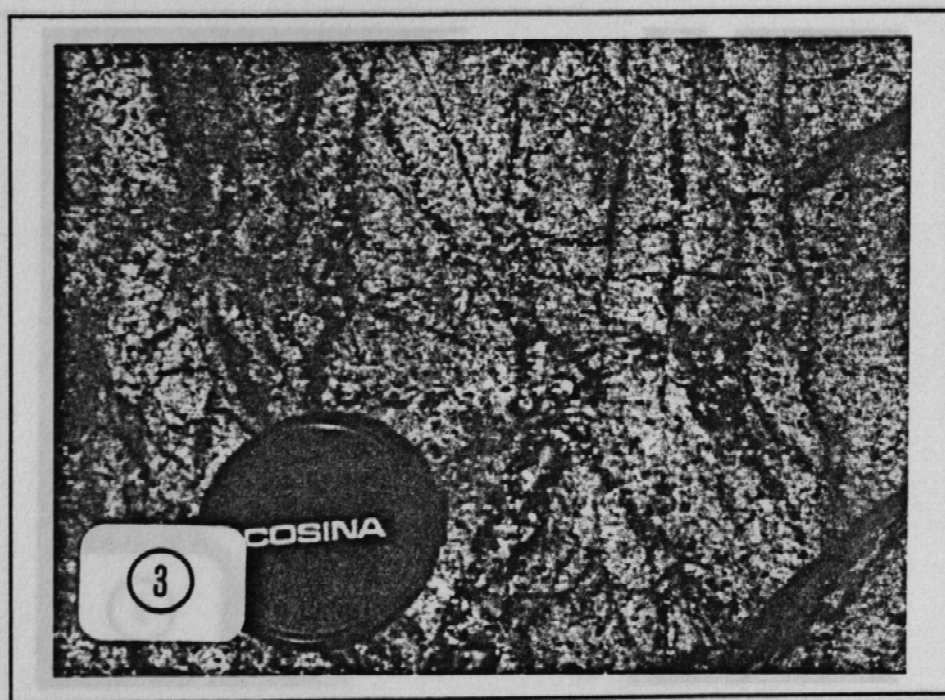


Figure Plate 2.3. Quartz vein stockwork in the Malati Store intrusion.

The sulphide mineralogy in the albitized intrusions is dominated by disseminated pyrite, with minor amounts of arsenopyrite and accessory amounts of stibnite and chalcopyrite (See Chapter 3.1). Ilmenite and rutile are common accessory minerals and occur as disseminated grains and nests up to ± 3 mm in diameter. Rutile content is occasionally sufficiently abundant to give the rock a dark grey appearance. Sulphide mineralization is confined to the albite-rich material, with only minor sulphides occurring in the quartz stockwork. Carbonate is pervasive and occurs as disseminated crystals and occasional veinlets which commonly occupy up to 10 % of the rock. Quartz $\pm$ tourmaline $\pm$ sulphide $\pm$ rutile/ilmenite veins, usually with a no apparent orientation, occur throughout the body (Plate 2.4) and are observed to radiate out into the country schist. Alteration adjacent to the vein (Plate 2.5) in the country rock is manifested as silicification and sulphidation, with minor tourmaline and rutile development which eradicates the fabric of the country rock. This alteration zone commonly comprises an outer sericite alteration assemblage (Figure 2.4). Milky-quartz with irregular fine grained beryl and minor amounts of scheelite, occurs within the body as irregular blows which are often in excess of two meters wide (Plate 2.6). Borehole MMD1 intersected a 2m wide quartz-beryl body, at 59.7m within the country rocks, indicating that these bodies penetrate into the country schists. A visible alteration halo, up ± 5 m wide, encompasses the granodiorite intrusion.

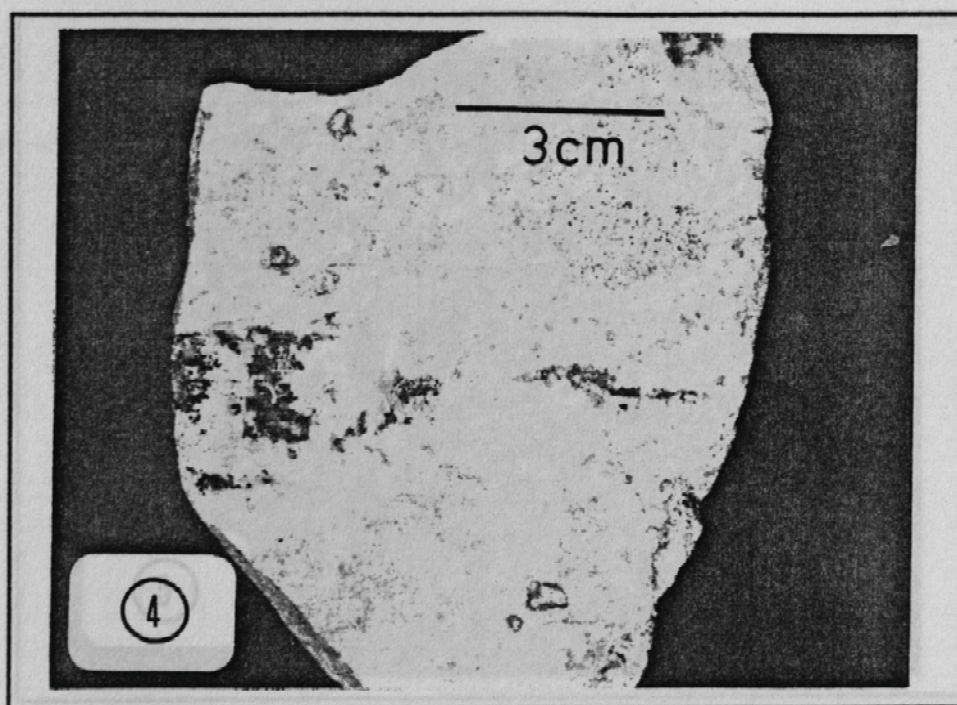


Figure 2.4. Quartz-tourmaline $\pm$ sulphide $\pm$ rutile vein within albitized granodiorite. Malati Store intrusion.

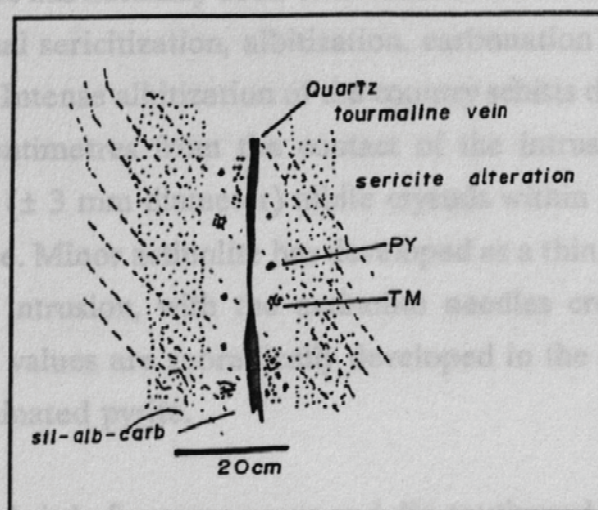


Figure 2.4. Sketch of quartz-tourmaline-rutile vein in country schist. Note eradication of fabric and inner zone of silicification, albitization and carbonation and outer selvage of sericite alteration. Minor pyrite (PY) and tourmaline (TM) occur in the inner zone.

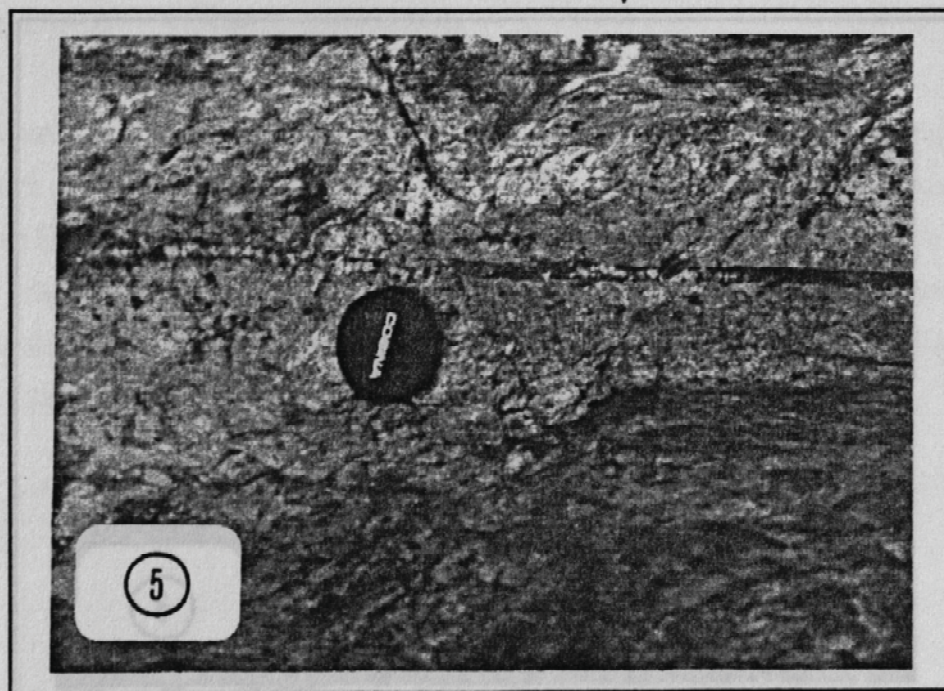


Plate 2.5. Quartz-tourmaline-pyrite $\pm$ rutile vein in country schist. Note bleaching and sulphidation of the schist. Malati Store mine.

The country rock fabric has normally been eradicated to 0.5 -1 m. The alteration includes silicification, occasional sericitization, albitization, carbonation and sulphidation of the quartz-chlorite schist. Intense albitization of the country schists does not normally extend more than several centimetres from the contact of the intrusion. This results in the development of large ($\pm$ 3 mm diameter) albite crystals within the altered schist giving it a spotted appearance. Minor actinolite has developed as a thin alteration selvage along the contact with the intrusion, with the actinolite needles cross-cutting the regional schistose fabric. Gold values are sporadically developed in the alteration zone and are related to fine disseminated pyrite.

Late, shallow dipping, brittle fractures occur and dip southward at 10 - 15° (Figure 4.2). The sense of movement is difficult to determine, but is likely be south over north. These fracture zones are filled with fault gouge and breccia, in places up to 50cm in width. Diamond drilling suggests that the brittle fractures have displaced the body by a maximum of 5m at depth.

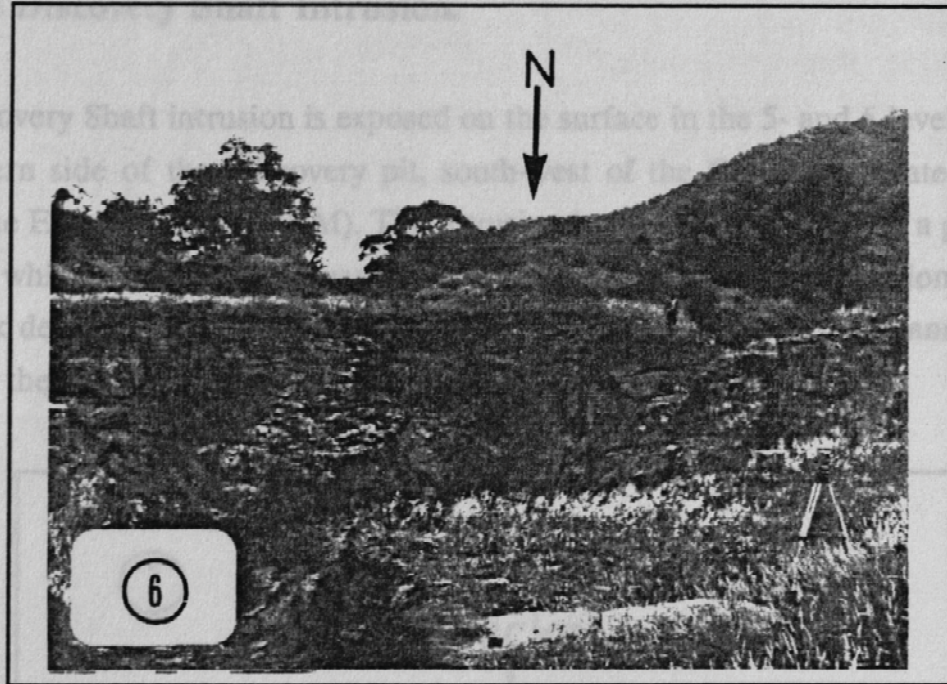


Plate 2.6. View of eastern section of the Malati Store quarry looking north towards Castle Koppies. Note quartz-beryl blow in quarry wall.

A steep easterly dipping north south dolerite dyke dissects the intrusion (Figure 2.3), resulting in weak, upright fabric development parallel to the contact. Small pyrite veins are present in the dyke, suggesting that pyrite may have been mobilized from within the intrusion. The dyke cross-cuts the low angle brittle shears.

Plate 2.7. View of Discovery Shaft gold mine looking north towards the Blue Jacket mine. Cobra pit is to the right.

The intrusion is also exposed in an inclined shaft and an open-pit system which was developed to exploit the apatite-rich zone which occurs in close proximity to the intrusion (Figure 2.3). The intrusion is more than 100 m thick in three of the Malati Store intrusion, although the central part is less massive, with remnant magmatic textures and rim fabrics characteristic of the intrusion. Zones of intense alteration consist of albite (50 - 70%), quartz (20 - 30%), and 10 - 20% of variable amounts of chlorite, carbonate and rutile. Small (3 - 6 mm) of alkali feldspar are present and are largely replaced by quartz. This textural feature suggests that the porphyritic Willie pluton and the Discovery Shaft intrusion are co-genetic (See Figure 2.3).

2.2. The Discovery Shaft Intrusion.

The Discovery Shaft intrusion is exposed on the surface in the 5- and 6-level benches of the western side of the Discovery pit, south-west of the Cobra pit (Plate 2.7) in the Gravelotte Emerald Mine (GEM). The intrusion is also interpreted to be a granodiorite intrusion which has undergone varying degrees of albitization, sulphidation and quartz stockwork development (Plate 2.8). The body is intrusive into the mafic and ultramafic schists of the Mulati Formation.

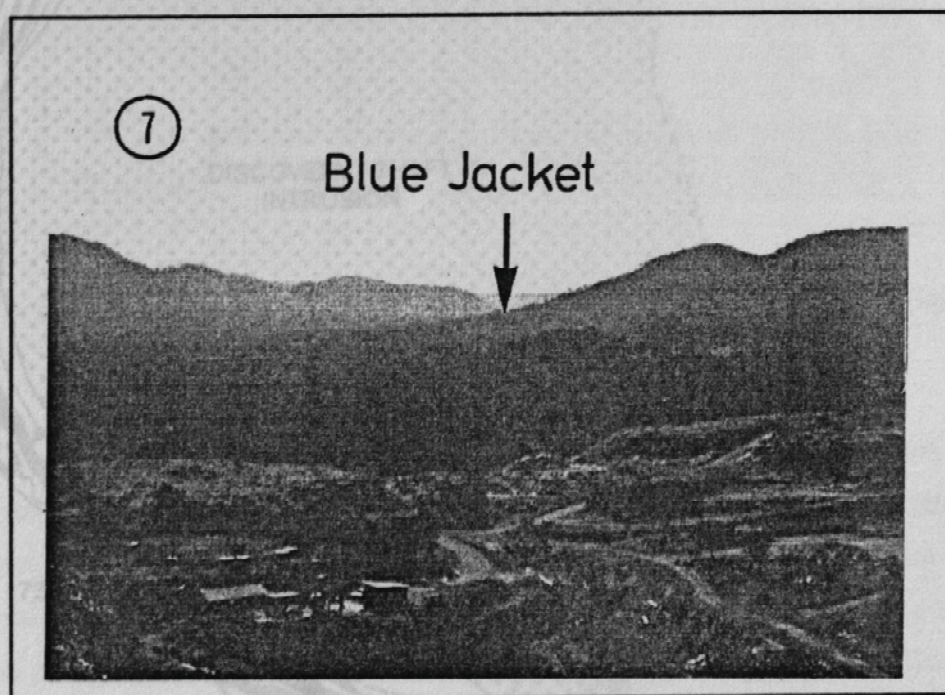


Plate 2.7. View of Discovery Shaft gold mine looking north towards the Blue Jacket mine. Cobra pit is to the right.

The intrusion is also exposed in an inclined shaft and underground development system which was developed to exploit the spatially related pyritic schist which occurs in close proximity to the intrusion (Figure 2.5). The intrusion has many features similar to those of the Malati Store intrusion, although the alteration (albitization) is less intense, with remnant magmatic textures and rim fabrics occasionally observed. Zones of intense alteration consist of albite (50 - 70%), quartz (20 - 30%), orthoclase (10 - 20%) and variable amounts of chlorite, carbonate and rutile. Occasionally, phenocrysts (3 - 6 mm) of alkali feldspar are present and are largely replaced by albite and sericite. This textural feature suggests that the porphyritic Willie pluton and the Discovery Shaft intrusion are co-genetic (See Figure 1.2.).

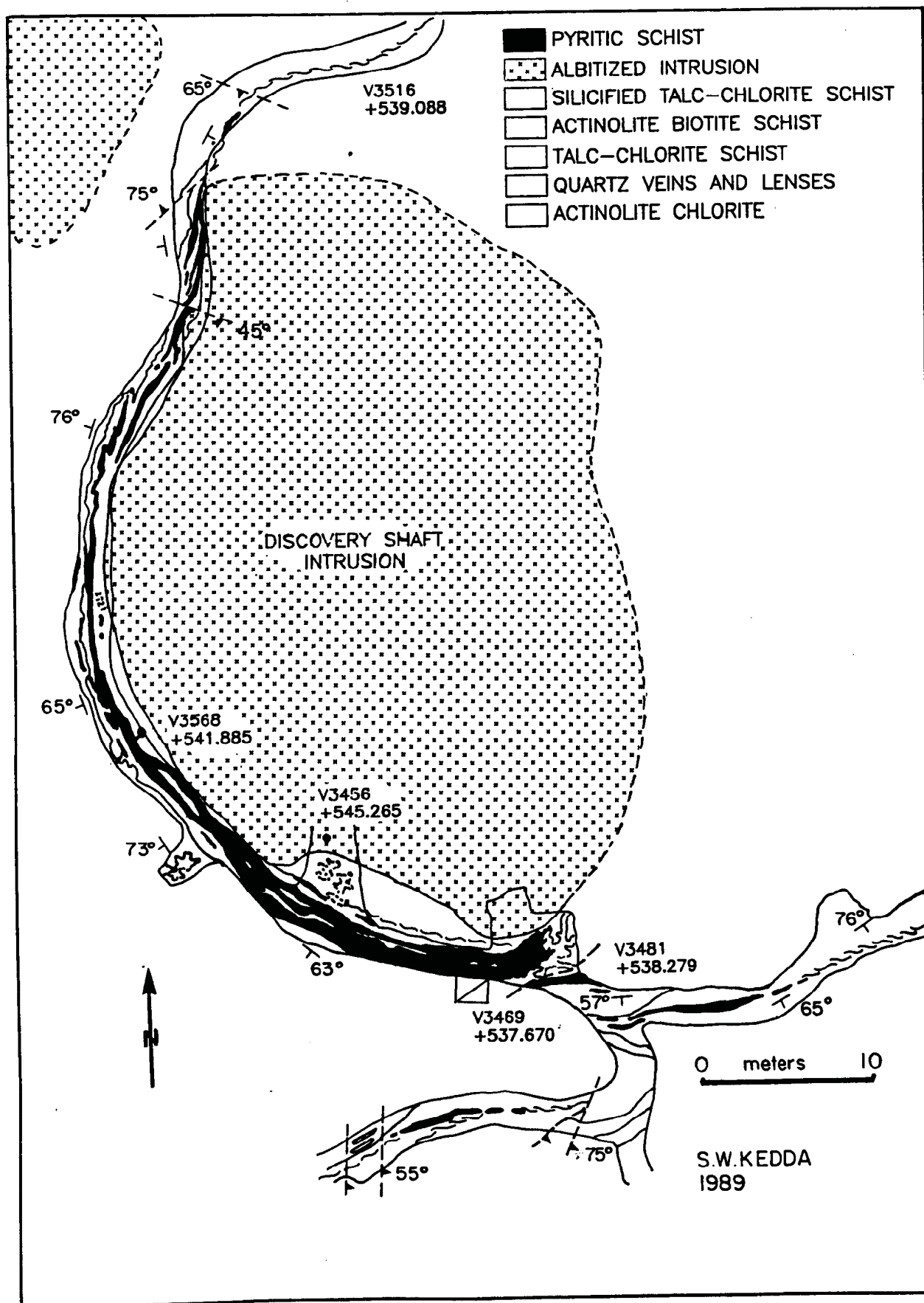


Figure 2.5. A geological map of the Discovery Shaft mine 5-level.
Note the relationship of the intrusion to the ore zone.

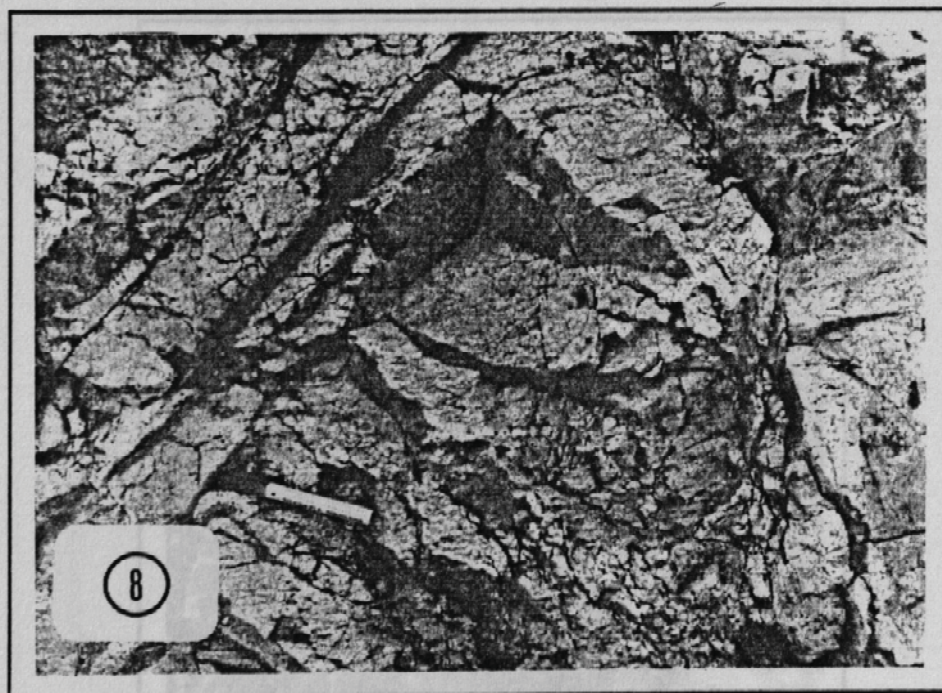


Plate 2.8. Surface exposure of the Discovery Shaft intrusion in 6-level Discovery pit. Note quartz stockwork.

The intrusion contains occasional xenoliths of altered schistose material which are usually actinolite-rich and are occasionally well mineralized with auriferous pyrite. Near the sheared contact, the intrusion comprises zones of actinolite and chlorite as well as occasional biotite rich zones. Along the exposed southern contact of the intrusion a pronounced, steep, ductile shear fabric is developed within the host rock schists, parallel to the contact of the intrusion (Plate 2.9). A ductile fabric is occasionally developed along the contact within the intrusion, especially near the surface where the intrusion is in contact with the sheared ore zone. However, the major part of the intrusion generally exhibits only minor internal development of regional fabric. The rim fabric is largely eradicated by the later albitization but is occasionally visible.

The intrusion contains disseminated euhedral, auriferous pyrite and occasional rosettes of molybdenite. Chlorite, ilmenite and rutile are also common accessory minerals within the intrusion. Gold mineralization within the intrusion is highly erratic, ranging from trace quantities to samples in excess of 10 g/t. Except for the ore zone only sporadic, gold values, are developed along the intrusive contact. Quartz-tourmaline $\pm$ sulphide $\pm$ ilmenite/rutile veins are common throughout the body.



Plate 2.9. Intrusive contact between granodiorite and talc-chlorite schist, showing well developed shear fabric.
11-level Discovery Shaft

They commonly radiate from the intrusion into the country schists, where they are dragged into the shear zone and become sheared out. Occasionally quartz-beryl $\pm$ scheelite $\pm$ carbonate bodies occur as irregular veins within the intrusion. Quartz-beryl-albite $\pm$ carbonate veins / blows are also common within the Discovery pit, where they are associated with emerald mineralization. As in the Malati Store intrusion, the Discovery Shaft intrusion contains quartz stockworks. The stockwork consists of clear quartz and occurs as highly irregular veins which are barren of mineralization (Plate 2.10). The majority of sulphide mineralization occurs within the felsic material with very little occurring within the quartz breccia. Underground development and diamond drilling indicate that the intrusion occurs as a plug-like body of some 50 - 60 m in diameter that may increase in size with depth. From 5-level development a similar albitized granitoid quartz stockwork development occurs to the north-east of the main intrusion (Figure 2.5.) which also appears to increase in size with depth.

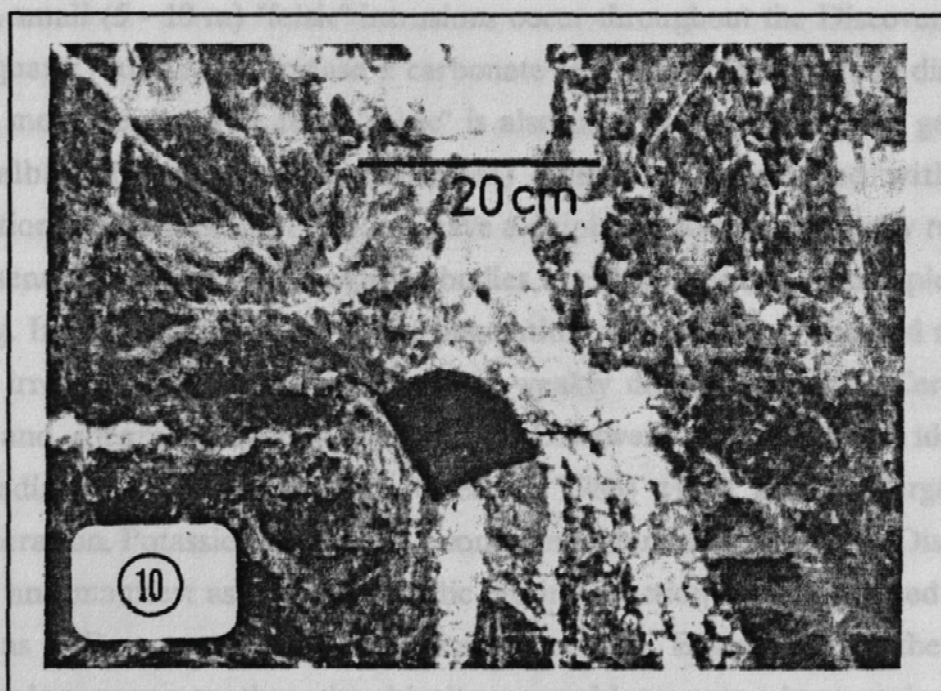


Plate 2.10. Highly irregular quartz stockwork in granodiorite.
11-level Discovery Shaft

The mafic and ultramafic schists in the Discovery pit generally strike east-west and dip steeply to the south-west. However, major local changes in orientation occur as a result of the presence of the large number of felsic intrusions found throughout the area. The schists have a variable composition, but are composed predominantly of chlorite and talc. Layers of actinolite and often biotite occur within these units. Carbonate is a ubiquitous mineral, occasionally becoming the dominant mineral, occurring as small ($\pm 3 - 5$ mm) irregular lenses. The majority of the carbonate occurring within the country rocks is unrelated to that associated with the gold mineralization and may represent early sea water alteration carbonate (See Chapter 5). Minor quantities of quartz-muscovite schist occur and are considered to represent more felsic horizons. Numerous, unstriated, cubic pyrite crystals occur within the mafic and ultra-mafic schists, which commonly have well developed quartz pressure shadows and are unrelated to mineralization, being of possible diagenetic origin. Meta-doleritic and meta-gabbroic material is also common within the Cobra and Discovery pits. A fine-grained mafic dyke is truncated by the Discovery Shaft intrusion on 7-level.

The unaltered Willie pluton (Plate 2.11) occurs approximately 2 km to the east of GEM. The lack of continuous surface exposure prevents determination of the relationship between the Willie pluton, the felsic intrusives and associated pegmatite phases at GEM.

Numerous, small (5 - 10 m) "felsic" intrusions occur throughout the Discovery pit. They consist of quartz - albite - orthoclase $\pm$ carbonate and occasionally contain disseminated pyrite and molybdenite. The term "felsic" is also used by the local mine geologists to describe albite-rich pegmatites (albitites) which are associated with emerald mineralization. These felsites commonly have a daupiric, and are apparently rootless and may represent structural boudins. Other bodies are shown to exhibit complex shearing and folding. In the Cobra Pit, the albite pegmatites are commonly sheared and folded, are highly irregular and occasionally have a weakly developed fabric. Certain highly deformed and sheared "felsic" bodies in the Discovery pit have been identified as siliceous sediments (Golden Dumps Research, 1986) which have undergone severe potassic alteration. Potassic alteration is a common feature throughout the Discovery and Cobra pits and manifest as mono-mineralic biotitic reaction rims associated with felsic intrusives, as well as zones of quartz-sericite alteration. Evidence from the Discovery Shaft intrusion suggests that the biotite assemblage may, in certain cases, be paragenetically late and that potassium-rich fluids may have migrated along the contact of the felsic intrusion producing monomineralic zones along the contact. Biotite-sericite zones are not always related to felsic intrusions and may in fact, be related to shear zones. These zones have acted as conduits to potassium-rich mineralizing fluids originating at depth. Small amounts of beryl/emerald, fluorite, pyrite, albite and molybdenite may be associated with these alteration zones. Zones of sodium metasomatism also occur where the original mafic schists are replaced by fine grained albite and minor sericite, indicating that the fluids responsible for albitization within the intrusions have also migrated into the country schists.

An actinolite reaction rim is commonly superimposed onto the pre-existing greenschist facies metamorphic assemblage along the contacts of the felsic intrusions. This reaction zone consists predominantly of actinolite-chlorite-talc and carbonate. In certain cases, the actinolite occurs as an essentially mono-mineralic assemblage. The actinolite schist may be up to several centimetres in width, with the actinolite needles up to 2cm long and several millimetres wide. Smaller needles often occur as radial forms. The actinolite generally occurs as an overgrowth to other minerals and may be replaced by later biotite and sericite.

The unaltered Willie pluton (Plate 2.11) occurs approximately 2 km to the east of GEM. The lack of continuous surface exposure prevents determination of the relationship between the Willie pluton, the felsic intrusives and associated pegmatite phases at GEM.

The Willie pluton is, however, a porphyritic granodiorite which shows only minor internal fabric development parallel to the contacts. This fabric is probably due to the forceful intrusive nature of the intrusion. Minor east-north-east trending shear zones parallel to the regional fabric are however present. This study indicates that the Discovery Shaft intrusion and pegmatites within GEM are related either to the Willie pluton or to a granitoid of similar chemical composition.

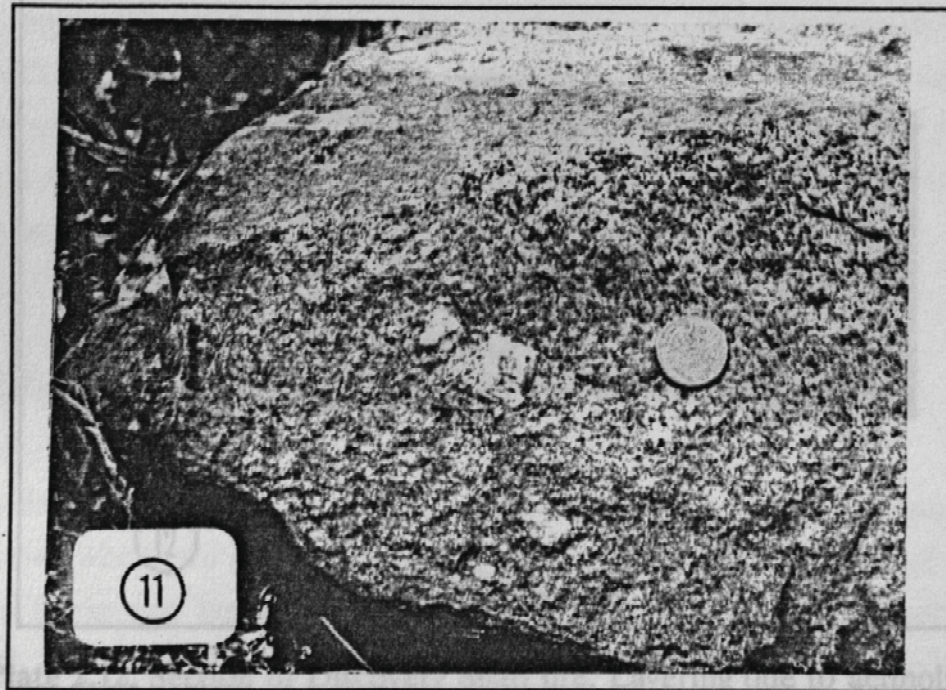


Plate 2.11. Outcrop of the Willie pluton at GEM. Note large quartz and feldspar phenocrysts.

2.3. The Discovery Shaft Ore Body

The ore body at the Discovery Shaft mine consists of a sheared, banded pyritic unit of variable thickness (0.5 - 1.5 m) (Plate 2.12). The mineralized zone outcrops on the Discovery pit 5-level bench and appears to be folded around the Discovery Shaft intrusion (Figure 2.5). The auriferous zone consists of a plunging, anticlinal structure with a steep (70 - 80°) southern limb and a less steep (60 - 70°) eastern limb. The Discovery Shaft intrusion appears to have induced the steeping of the dip at higher levels where the pyritic zone abuts against the intrusion. At 150m below the surface, the ore zone is 6 - 7 m from the intrusion and has a markedly shallower dip. At upper levels, the intrusion contact is

sheared but becomes progressively less sheared with depth as the distance between the shear zone and intrusion increases. There is an inverse relationship between the grade of the ore zone and its proximity to the Discovery Shaft intrusion. The ore zone exhibits a decrease in grade with depth and along strike of the shear zone away from the intrusion contact.

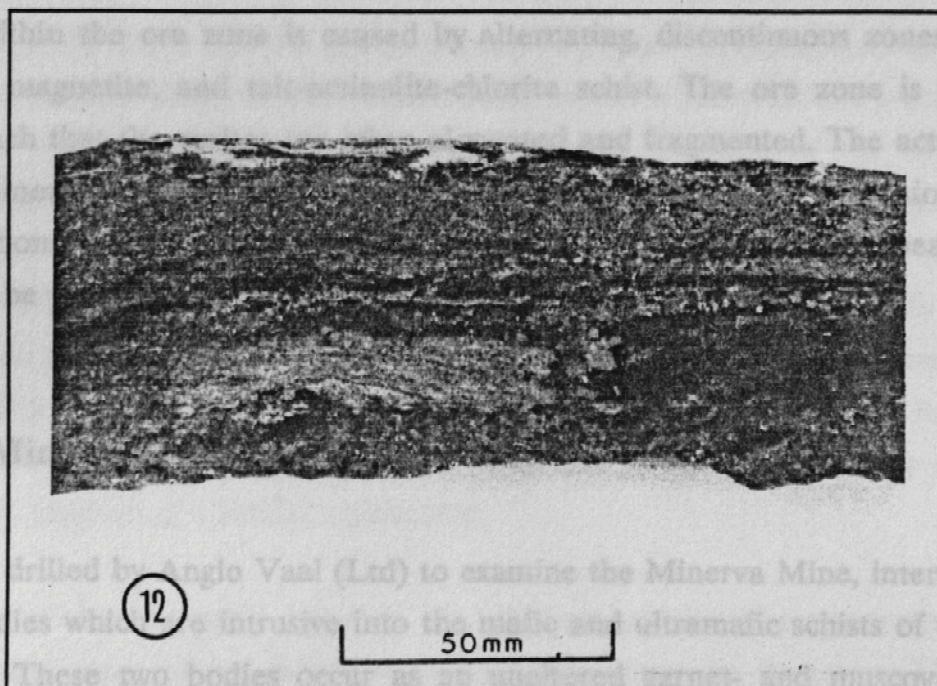


Plate 2.12. Section of Discovery Shaft ore. Layering due to actinolite and pyrite rich zones. 11-level

The sheared, iron-rich horizon continues along strike for ± 100 m to the east and 60 m to the north, but only contains rare sporadic auriferous pyritic zones. Where it is not mineralized, the ferruginous horizon is composed of sheared, magnetite, iron carbonate, quartz and fine cubic pyrite. The zone is interpreted to represent a banded iron stone formation occurring within the mafic and ultra-mafic schists that has undergone intense shearing and deformation. The sheared, iron-rich horizon continues along strike for ± 100 m to the east and 60 m to the north, but only contains rare sporadic auriferous pyritic zones. Where it is not mineralized, the ferruginous horizon is composed of sheared, magnetite, iron carbonate, quartz and fine cubic pyrite. The zone is interpreted to represent a banded iron stone formation occurring within the mafic and ultra-mafic schists that has undergone intense shearing and deformation. It is suggested that the Discovery Shaft intrusion intruded into a shear zone, which developed along and within an iron rich, banded iron stone horizon. Auriferous fluids from within the intrusion,

reacting with the iron-rich lithology, resulted in pyrite and gold precipitation. A lack of any major continuous mineralization developed along the entire contact of the intrusion indicates that a pre-requisite for the precipitation of auriferous pyrite is the presence of an Fe-rich host rock with which the auriferous fluids would react. Other minor auriferous, Fe-rich horizons occur within the Discovery pit, but they are of limited strike.

Banding within the ore zone is caused by alternating, discontinuous zones of pyrite, pyrrhotite, magnetite, and talc-actinolite-chlorite schist. The ore zone is extensively sheared, such that the pyrites are often elongated and fragmented. The actinolite and chlorite minerals have a preferred orientation parallel to the intrusion contact. Quartz-carbonate veins within the shear zone show complex folding and shearing which appears to be predominately sinistral in character.

2.4. The Minerva Mine Intrusion.

Bore holes drilled by Anglo Vaal (Ltd) to examine the Minerva Mine, intersected two granitic bodies which are intrusive into the mafic and ultramafic schists of the Mulati Formation. These two bodies occur as an unaltered garnet- and muscovite-bearing granodiorite and a variably albitized granodiorite containing disseminated auriferous pyrite, minor stibnite, chalcopyrite, arsenopyrite and small amounts of beryl.

The albitized granodiorite shows intense hydraulic brecciation and is similar to those observed within the Discovery Shaft and Malati Store intrusions. The body is intrusive into a talc-chlorite actinolite assemblage that shows limited alteration along the contact. Fine actinolite is developed along the contact. The intrusion consists predominantly of albite, with small amounts of relic orthoclase, hornblende, quartz and ilmenite/rutile.

The ore zone at Minerva is hosted within an amphibolite horizon and occurs as an auriferous pyritic zone. Minor amounts of pyrrhotite, chalcopyrite molybdenite and scheelite occur. Later shearing has resulted in redistribution of gold into quartz-gold stringers.

2.5 Conclusions

The albite-rich rocks examined in this study all have features which suggest that they represent the sodium metasomatised cupola zones of a series of granodiorite intrusions. There are distinct petrographic and textural similarities which exist between the three intrusions examined, suggesting a link between the processes responsible for alteration and gold $\pm$ molybdenite $\pm$ stibnite mineralization. It is apparent that potentially economic grades of gold mineralization can be developed within these albitized portions of the granodiorite intrusions, as seen by the successful exploitation of the Malati Store intrusion. The spatial relationships between albitized granodiorite intrusions and the gold-antimony mineralization of the Antimony Line suggests that a genetic relationship might exist between the types of mineralization. The Discovery Shaft ore body is believed to have been formed from the interaction between auriferous fluids generated from within the Discovery Shaft granodiorite intrusion and the sheared iron-rich horizon into which it intruded. The Minerva mine ore zone is also closely related to a albitized granodiorite, suggesting a similar mechanism.

The close spatial relationship between the albitized cupolas of granodiorite (sodium alteration) and zones of potassic alteration present along the Antimony Line and at GEM, suggest a genetic link between the two alteration styles. This idea is discussed in more detail later. The presence of beryl within the albitized granodiorites is suggestive of a relationship between the beryl/emerald mineralization associated with the albite pegmatites and the granodiorites.

CHAPTER 3.

Mineralogy and Petrography

3.1 Sulphide Mineralogy

Samples of albitized granitoid from the Malati Store, Discovery Shaft and Minerva Mine, as well as the pyritic schist from Discovery Shaft, were cut and polished to examine the opaque mineral assemblage and its relationship to the associated silicate minerals.

3.1.1 Albitized Intrusions

The sulphide mineralogy of the albitized intrusions is relatively simple and is dominated by euhedral pyrite, with only minor amounts of associated sulphides. The majority of pyrite includes and overgrows a variety of silicate minerals, indicating that sulphide precipitation occurred late in the hydrothermal alteration sequence. Sulphide mineralization occurs principally within albite-rich zones, with only minor amounts occurring within the clear quartz stockwork.

3.1.2. Malati Store Intrusion

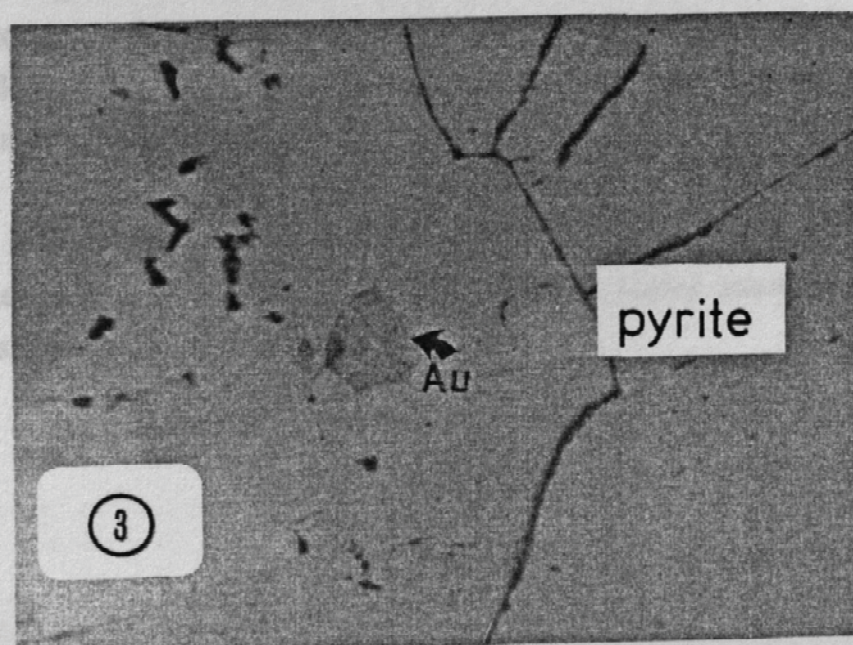
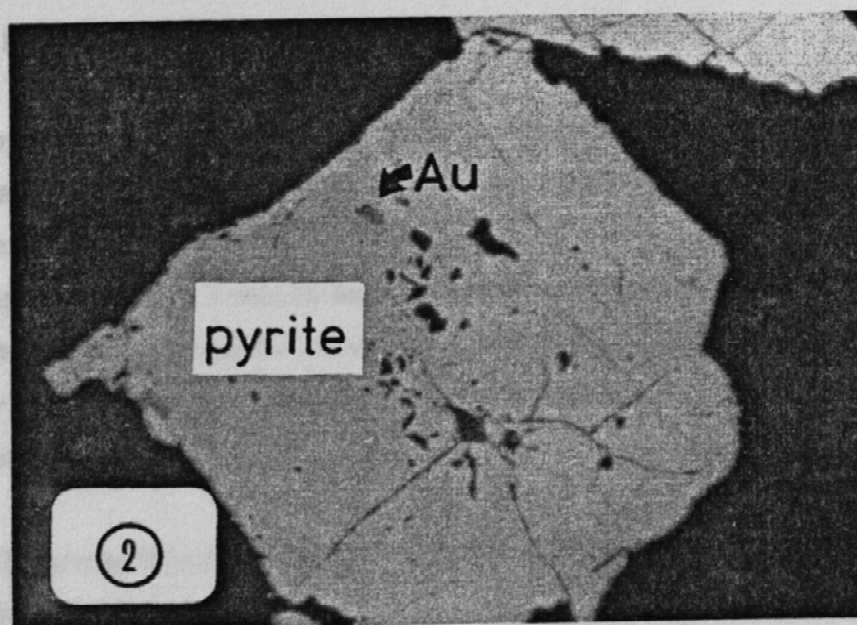
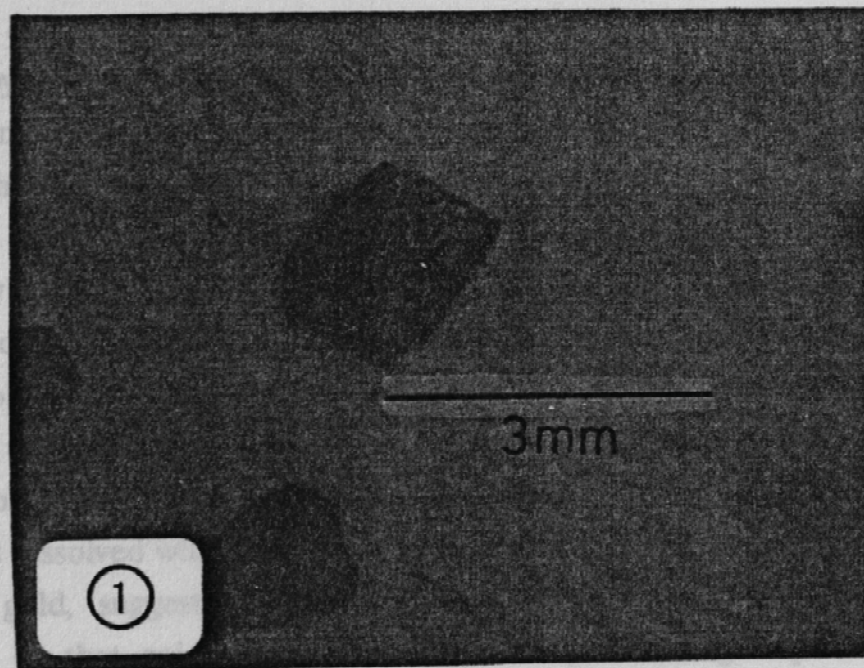
The sulphides of the Malati Store intrusion comprise predominantly euhedral pyrite (80 - 90%), arsenopyrite (5 - 10%) and minor pyrrhotite, stibnite, molybdenite, chalcopyrite as well as traces of aurostibnite, cinnabar, tetrahedrite and possible tellurides. Late fluid ingress along fractures has resulted in the development of a limited suite of secondary minerals, including covellite.

The sulphides comprise $\pm 5\%$ of the host rock and occur as irregular disseminations distributed throughout the intrusion, ranging from small (< 1 mm) disseminations to large irregular (± 10 mm) aggregates of pyrite. The sulphides are paragenetically late, and enclose and overgrow early replacement albite. Sulphides liberated by hydrofluoric acid treatment indicate that the pyrite exists predominantly as well formed pyritohedrons, with limited striations developed along crystal faces (Plate 3.1). Using the pyrite morphology and saturation-temperature relationships of Murowchick and Barnes (1987), it is suggested that these sulphides were formed from solutions of moderate to high sulphur saturation and at a temperature of $\pm 250^\circ\text{C}$.

Plate 3.1. Well-formed pyrite pyritohedra from the Malati Store intrusion.

Plate 3.2. Inclusion-rich core of euhedral pyrite containing native gold.
Malati Store intrusion. (X200. Oil)

Plate 3.3. Gold inclusions and irregular berthierite (FeSb_2S_4) in pyrite.
Malati Store intrusion. (X500. Oil)



Etching of the pyrite grains with acidified KMnO_4 revealed an apparent lack of internal structure and zonation to the pyrites, indicating constant fluid conditions. However, some pyrite crystals showed evidence of a more arsenic-rich core.

Native gold only occurs within the euhedral pyrite, usually within the inclusion-rich core, as small ellipsoidal or irregular droplets (5 - 30 μm in diameter) (Plates 3.2 and 3.3). No free gold was observed in any of the sections examined. Neutron activation analysis (NAA) suggests that gold probably also occurs as microscopic inclusions within the pyrite or possibly dissolved within the pyrite lattice (see Chapter 4.3). The NAA also suggests that gold occurs dissolved within the arsenopyrite lattice. There is no evidence for late, fracture-filling gold, suggesting that the gold and pyrite were either deposited simultaneously, or that gold was precipitated onto pre-existing sulphide grains by electrochemical means. The presence of arsenic rich pyrite would make electrochemical precipitation of gold from solution onto pyrite grains highly likely.

Arsenopyrite appears to be the earliest formed sulphide mineral, occurring as well formed, euhedral, inclusion free crystals which are often enclosed by later pyrite or pyrrhotite phases (Plates 3.4 and 3.5). The arsenopyrite crystals are of variable size, ranging from single crystals of 3 mm in diameter to fine irregular needle-like grains. The arsenopyrite content of the sulphide assemblage is variable, ranging from less than 1% to zones with >10%. Later hydrothermal ilmenite occasionally replaces arsenopyrite along grain boundaries.

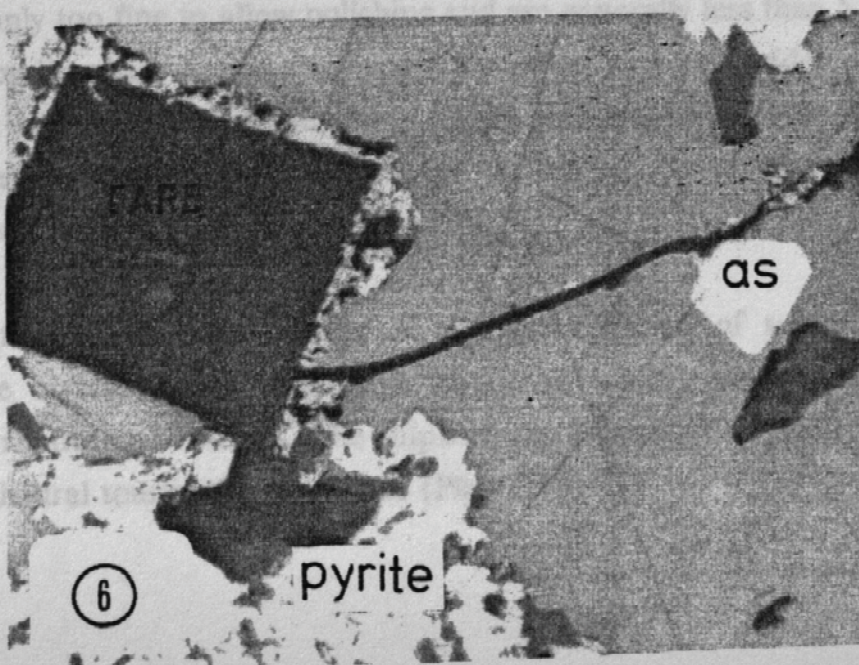
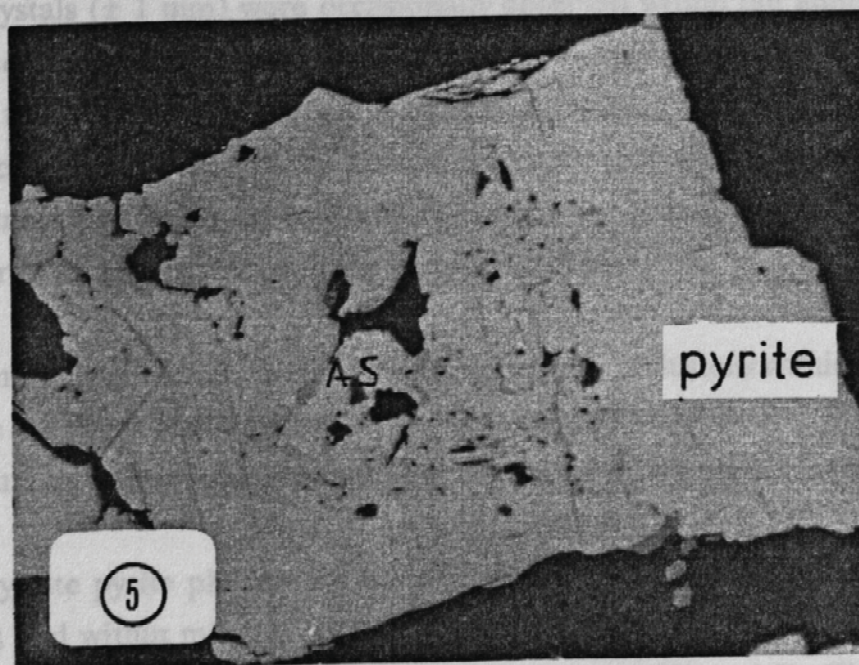
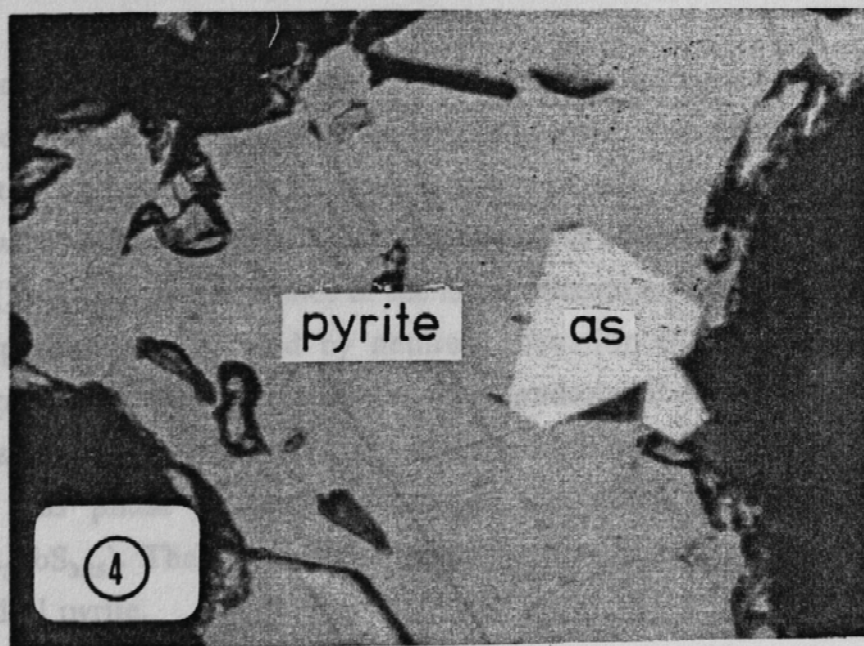
Pyrrhotite is fairly rare as it has been largely completely replaced by pyrite. Small crystals are enclosed within pseudomorphic pyrite as irregular to rounded grains, commonly within the core regions of the pyrite. The replacement of pyrrhotite take place preferentially along cracks and grain boundaries. The pyrrhotite crystals themselves occasionally enclose euhedral arsenopyrite crystals, with no apparent reaction evident between the minerals (Plate 3.6).

Pyrite occurs as isolated disseminated euhedral grains of variable size, up to 3 mm in diameter, commonly with an inclusion-rich core. However minor amounts of irregular, anhedral, porous aggregates are present.

Plate 3.4. Euhedral arsenopyrite within pyrite.
Malati Store intrusion. (X200).

Plate 3.5. Euhedral pyrite within inclusion-rich core containing
arsenopyrite, berthierite and pyrrhotite.
Malati Store intrusion. (X200).

Plate 3.6. Replacement of pyrrhotite by pyrite.
Note euhedral arsenopyrite crystal. Dark cubic mineral is
ferroan-dolomite. Malati Store intrusion. (X500. Oil)



The inclusions consist mainly of silicates, as well as minor amounts of euhedral rutile, pyrrhotite, chalcopyrite, carbonates and, occasionally, gold. The silicate inclusions are commonly orientated perpendicular to pyrite cleavage planes. The early euhedral pyrite phase is overgrown by anhedral pyrite which often contains zones of irregular intergrowth with berthierite (FeSb_2S_4). The presence of the latter mineral explains the high antimony content of the pyrites, as indicated by neutron activation (See Chapter 4.3). Fine irregular arsenopyrite intergrowths occur and form gradational contacts with the pyrite. The pyrite is usually anisotropic as a result of a high arsenic content. Commonly associated with this phase are minor amounts of stibnite, cinnabar (HgS) and tetrahedrite ($\text{Cu}_3\text{SbS}_{3.25}$). The tetrahedrite occurs as fine granular materials included within the anhedral pyrite.

Large angular crystals (± 1 mm) were occasionally observed within the anhedral pyrite phase. The reflection properties and morphology, as well as the presence of stibnite nearby, suggests that this mineral may be aurostibnite (AuSb_2). Other highly reflective minerals were occasionally seen within the inclusion-rich core of the euhedral pyrites. Their minute dimensions ($<2 \mu\text{m}$) make identification by optical means difficult, but they are considered to also be aurostibnite or, possibly tellurides.

Chalcopyrite commonly occurs as small ($<50 \mu\text{m}$), irregular inclusions within pyrite. The irregular nature of the chalcopyrite does not suggest exsolution. Occasionally, chalcopyrite occurs as irregular disseminated grains along albite grain boundaries.

A paragenetically late pyrite phase, with minor chalcopyrite and stibnite, occurs along grain boundaries and within mineral cracks as fine irregular films. It occurs commonly within late, stress deformed and shattered feldspar material (Plate 3.7). The sulphide films are commonly too fine to allow polishing and are generally less than 5 microns in thickness. This pyrite phase appears to represent redistributed sulphides precipitated during hydraulic brecciation of the intrusion. Small amounts of sulphide occasionally occur in the quartz-veins along grain boundaries and cracks. The extremely fine nature of these films gives the quartz an iridescent colour.

Large, cross-cutting pyrite veins consist of an agglomeration of small, commonly subhedral, pyrite crystals which also show an inclusion-rich core containing gold, chalcopyrite, pyrrhotite and silicates. The sulphide grain boundaries are irregular and often contain euhedral tourmaline inclusions (Plate 3.8).

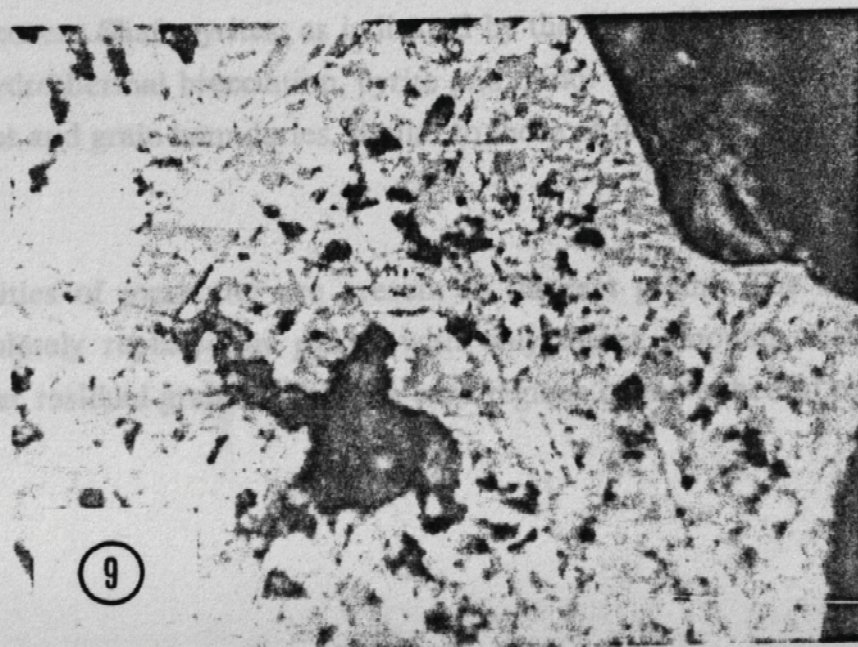
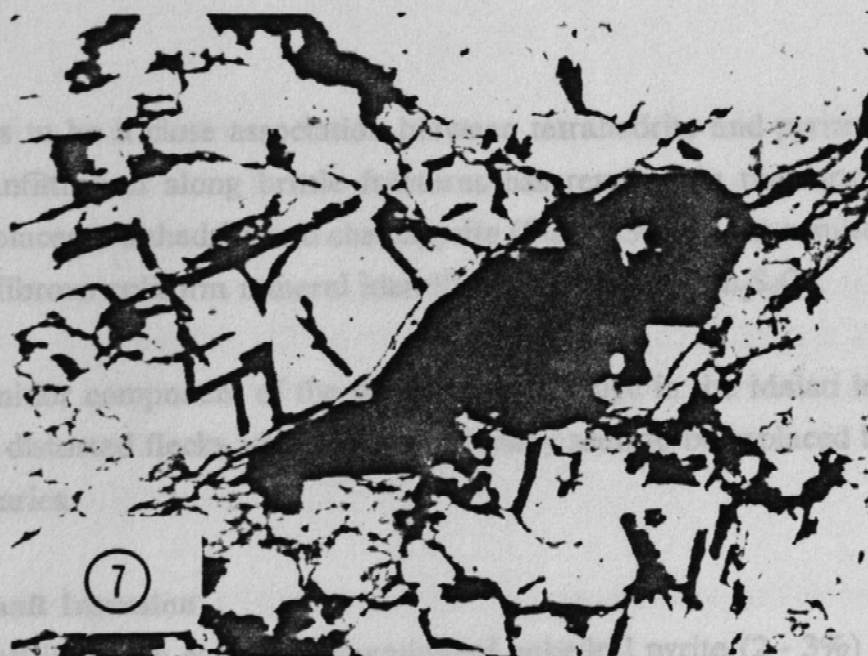
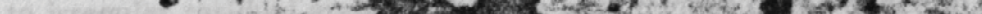
Plate 3.7. Late films of pyrite along micro fractures in plagioclase and quartz.
Green mineral is late chlorite. Discovery Shaft intrusion. (X200),

Plate 3.8. Late sulphide-tourmaline vein.
Malati Store intrusion. (X200),

Plate 3.9. Covellite replacing tetrahedrite.
Malati Store intrusion. (X500, Oil).



The pyrite in the Disco intrusion is distinct from that in the Malati Store intrusion, indicating a low arsenic content. This confirms the low arsenic content of the Disco intrusion (see Table 5.3). In zones of intense hydrothermal alteration, thin films of arsenic-bearing minerals are visible along fractures and grain boundaries (see Plate 3.7).



There also appears to be a close association between tetrahedrite and pyrite in these veins. Late fluid infiltration along brittle fractures has resulted in the formation of covellite, which replaces tetrahedrite and chalcopyrite (Plate 3.9) and has resulted in the precipitation of a fibrous coliform mineral identified as kermisite ($\text{Sb}_2\text{S}_2\text{O}$).

Molybdenite is a minor component of the sulphide assemblage in the Malati intrusion, occurring as small distorted flecks which are occasionally seen to be replaced by pyrite along grain boundaries.

3.1.3. Discovery Shaft Intrusion

The Discovery Shaft intrusion contains disseminated euhedral pyrite (2 - 3%) which is erratically distributed throughout the intrusion. The morphology of the pyrite is similar to that of the Malati Store pyrite where the pyrite occurs predominantly as euhedral pyrite pyritohedrons which commonly contain inclusion-rich cores. The inclusions consist of pyrrhotite, chalcopyrite, rutile and, occasionally, gold. All the gold observed in this deposit occurred within euhedral pyrite as small (5 - 10 μm) irregular, ellipsoid inclusions (Plate 3.10). There is no evidence for late fracture filling of gold. An anhedral pyrite phase is seen to overgrow the earlier euhedral phase. The major difference in the sulphide assemblage between the Malati Store and Discovery Shaft intrusions is the decreased quantity of arsenopyrite and antimony minerals within the Discovery Shaft intrusion and increased quantity of molybdenite. Only minor quantities of arsenopyrite occur as small (<20 μm) euhedral inclusions within pyrite. Stibnite and tetrahedrite were only rarely observed.

The pyrite in the Discovery intrusions is distinctly isotropic by comparison with the Malati Store intrusion, indicating a low arsenic content. This confirms the low arsenic content of the Discovery Shaft pyrites, as indicated by the NAA (See Chapter 5.3). In zones of intense hydrothermal brecciation, pyrite and minor chalcopyrite occur as fine films along fractures and grain boundaries, similar to those of the Malati Store intrusion (See Plate 3.7).

Only minor quantities of pyrrhotite are present as discrete grains. The majority of pyrrhotite is completely replaced by pyrite, with only minor amounts occurring as rounded to irregular residual grains within the core regions of the euhedral pyrite.

Molybdenite occurs as small distorted flakes and rosettes (3 - 10 mm in diameter). This mineral appears to be paragenetically early, with small amounts being replaced by pyrite. Quartz $\pm$ tourmaline $\pm$ ilmenite/rutile $\pm$ pyrite veins of variable thickness, similar to those in the Malati Store intrusion, are common. The granular pyrite veins contain native gold as fine inclusions commonly within an inclusion rich core. There is a greater quantity of chalcopyrite present within the Discovery Shaft intrusion, both as inclusions within pyrite and as irregular grains which post-date silicate crystallization. Occasionally zones may contain $\pm$ 3% disseminated chalcopyrite.

The sulphides, especially near the intrusion contact, are replaced by late chlorite along grain boundaries and cracks.

3.1.4. Minerva Mine Intrusion

The albitized intrusion at Minerva mine has a sulphide assemblage identical to that at Discovery Shaft. This comprises an early pyrrhotite phase which has been largely replaced by pyrite and a euhedral pyrite phase which has an inclusion-rich core, as well as a late inclusion-free anhedral phase. The majority of the pyrite occurs as the euhedral form. Similarly, there were only minor quantities of arsenopyrite and stibnite present. Gold is present as fine inclusions within the inclusion-rich core of pyrite grains. There are also minor quantities of late disseminated chalcopyrite of quantity similar to that of the Discovery Shaft intrusion. Pyrite and minor chalcopyrite occur as fine, irregular films along late stress fractures and grain boundaries, particularly in the plagioclase minerals. The sulphides are commonly replaced by a late chlorite along grain boundaries.

3.2 Oxides and Associated Minerals

Magnetite and haematite are not present within the albitized intrusions, nor is there any evidence for replaced magnetite grains. Magnetite is, however, a common accessory oxide phase in the unaltered intrusions, suggesting that possible sulphidation of pre-existing Fe-oxide phases might have occurred or that magnetite was an unstable oxide phase during the prevailing hydrothermal alteration. The oxide phases in the albitized intrusions are dominated by hydrothermally precipitated ilmenite and rutile.

3.2.1. Malati Store Intrusion

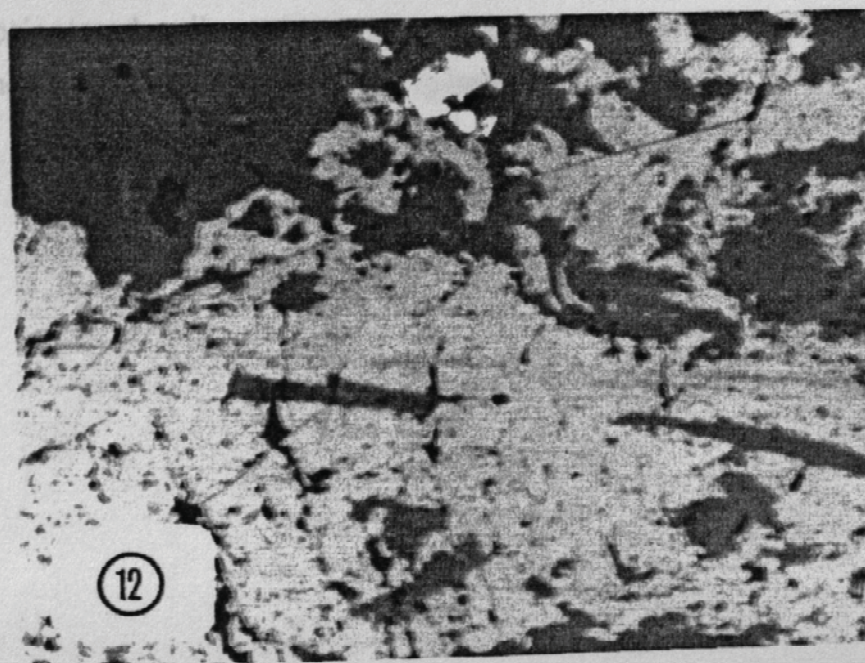
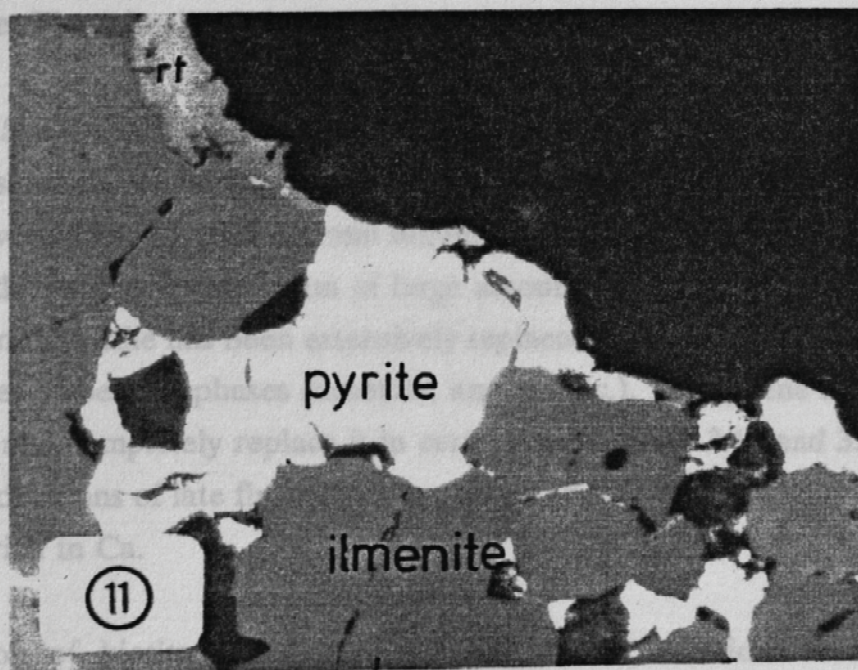
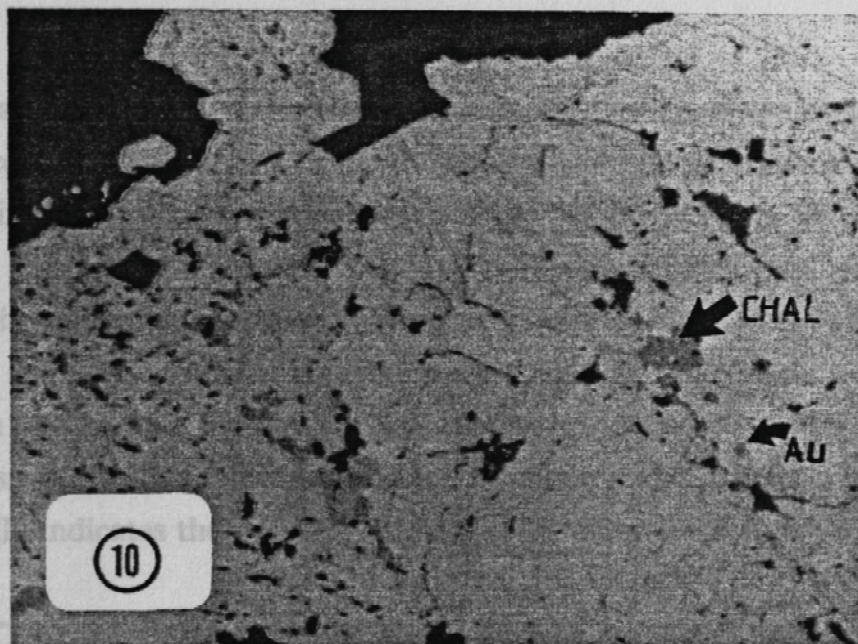
The earliest oxide phase is hydrothermally precipitated ilmenite, consisting of large ($\pm$ 1 mm) granular ilmenite masses. The ilmenite is replaced by rutile along grain boundaries and cracks and as irregular masses within the granular ilmenite mass. Certain ilmenite crystals appear to be more susceptible to replacement by rutile than others (Plate 3.11.). The replacement of ilmenite by rutile generally precedes pyrite mineralization, which cross-cuts the replacement rutile and occasionally includes the rutile. Ilmenite is commonly encapsulated by pyrite and, in such cases has not been affected by rutile replacement. Replacement rutile consists of fine-grained, irregular intergrowths, with occasional porous aggregates and poor crystal form (Plate 3.12). No haematite or other Fe-minerals are associated with the replacement of ilmenite by rutile. This suggests that the iron liberated by the replacement process was incorporated into the rutile lattice, or was mobile in the solutions and was incorporated into phyllosilicate or sulphide phases. One example has indicated that the replacement of ilmenite by rutile results in the development of a fine rutile - pyrite intergrowth, indicating that the iron liberated during the alteration was incorporated into the sulphide phases. In thin section, the replacement rutile is dark brown/red, suggesting a higher Fe content than the later hydrothermally precipitated rutile.

Throughout the Malati Store intrusion there is an abundance of hydrothermally introduced rutile. This rutile has a tendency to develop idiomorphically, occurring either as euhedral needles or as nests of rutile, up to 3 mm in diameter (Plate 3.13). The latter may comprise 1 - 3% of the albitized granodiorite. Rutile commonly occurs as euhedral inclusions within inclusion-rich cores of the pyrite.

Plate 3.10. Euhedral pyrite containing inclusions of chalcopyrite, gold, silicates and minor pyrrhotite.
Discovery Shaft intrusion. (X500. Oil).

Plate 3.11. Replacement of granular ilmenite by rutile (rt) and pyrite (py).
Malati Store intrusion. (X500. Oil)

Plate 3.12. Irregular replacement rutile. Malati Store intrusion. (X200)



The hydrothermal rutile is light red-brown to transparent in thin section, suggesting low iron content. Occasionally the rutile is replaced along grain boundaries by sphene and possibly other Ti mineral phases, but not to the same degree as in the Discovery Shaft intrusion. Fine grained, orientated rutile aggregates occasionally occur within a fine-grained, albite-quartz-chlorite matrix. Examples from the less altered Minerva and Discovery Shaft intrusions indicate that early alteration of hornblende and possibly biotite, results in fine-grained irregular rutile being exsolved along the cleavage planes. Due to the intense albitization which has occurred within the Malati Store intrusion only the exsolved rutile indicates the pre-existence of mafic minerals (See Plate 3.16).

Scheelite (CaWO_4) occurs as occasional, coarse-grained, irregular masses within the milky quartz blows and is commonly associated with fine grained euhedral beryl and black tourmaline. The scheelite has a light brown to sandy colour.

3.2.2. Discovery Shaft and Minerva Mine Intrusions

These two intrusions display similar oxide mineral assemblages to those of the Malati Store intrusion, with an early hydrothermal ilmenite phase replaced by rutile. There has also been an hydrothermal introduction of large amounts of euhedral rutile. However, in these intrusion the rutile has been extensively replaced by sphene ($\text{CaTi}[\text{SiO}_4](\text{H},\text{F})$) and possibly other Ti-bearing phases (brookite, anatase etc.). The sphene is seen to rim the rutile grains and completely replace it in certain cases (Plate 3.14 and 3.15). There are therefore, indications of late fluid migration within these intrusions where the fluids may have been rich in Ca.

The chloritization of biotite and hornblende within the intrusions results in the precipitation of fine-grained rutile along the silicate cleavage planes. In areas of intense albitization the orientated rutile grains may be observed within replacement albite. This rutile phase is, however, usually replaced by sphene.

Plate 3.13. Hydrothermal rutile in albite.
Malati Store intrusion. (X500. Oil)

Plate 3.14. Hydrothermal rutile being replaced by late sphene.
Discovery Shaft intrusion. (X500. Oil. Reflected light)

Plate 3.15. Replacement of rutile by late sphene, viewed under
transmitted light, showing remnant core of brown/red rutile
and rim of transparent sphene.
Discovery Shaft intrusion. (X500. Oil)