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Carole

PETROGRAPHY OF UVX DRILL HOLE M3

by

Peter McLean

April, 1987

4-30-87

Carole —
I have negatives in for duplicate prints now. Thus I can get you a copy of this with real photos eventually.

Don

U.V.X. Petrography of Drill Hole M3

M3 143'

Ore minerals		Gangue Minerals
Hematite	4%	Quartz - 90%
Goethite/lepidocrocite	6%	
Rutile	tr	

Textures

Quartz - Quartz grains occur as clasts and matrix and total 90 % of the sample (Plate a). Clasts are up to .4mm, rounded, display serated grain boundaries and are altering to fine-grained quartz at these grain boundaries. Some grains have undulose extinction. The matrix quartz is fine-grained, up to .02 mm, and commonly elongate. Veinlets of quartz/hematite are present but minor. Coarse quartz grains are commonly rimmed and overgrown by hematite.

Hematite/Goethite - Hematite and goethite mineralization occurs as two forms. Hematite occurs as disseminated euhedral grains up to .25 mm . These euhedral grains are commonly hexagonal and may be pseudomorphs of magnetite or pyrite (Plate b). The euhedral hematite is commonly brecciated with secondary goethite filling fractures and in some cases extensively replacing the hematite. Goethite rims on hematite are also common. Fine (up to .02mm), anhedral hematite grains are disseminated through the fine-grained quartz matrix. Goethite is common as anhedral amorphous masses associated with the fine-grained quartz matrix (Plate c). Hematite/goethite veinlets cut coarse quartz grains but also bifurcate around grains.

Rutile - Rutile occurs as fine (up to .1 mm), anhedral grains that commonly appear brecciated in - situ . Rutile is most commonly associated with hematite.

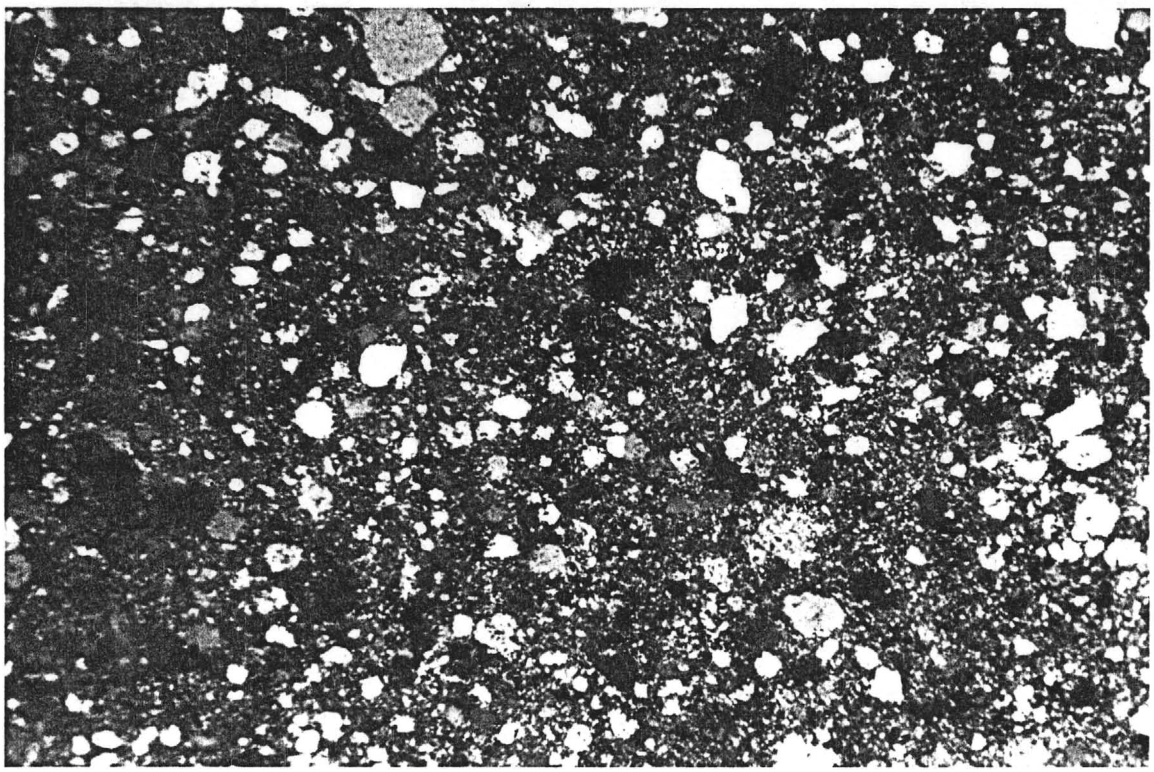


Plate a). 143 ' Matrix and clast quartz with hexagonal hematite (black). Transmitted light (crossed nicols) . 25 X

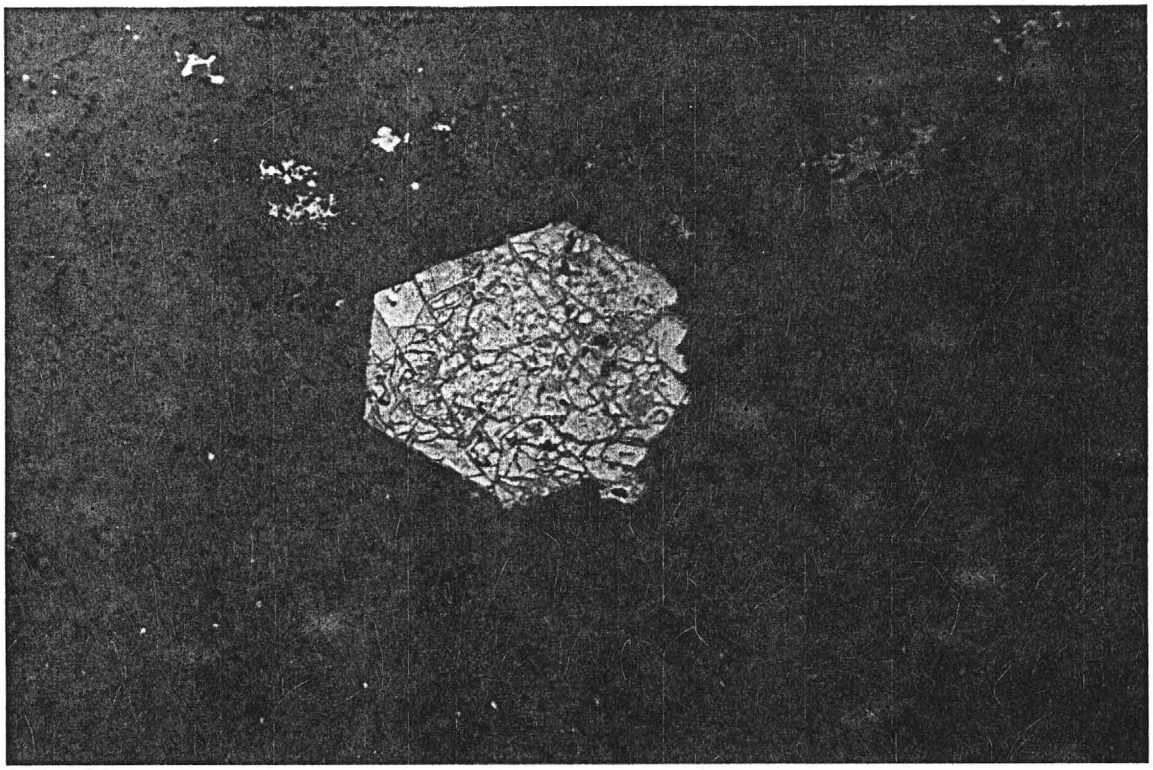


Plate b). 143 ' Hexagonal, brecciated hematite with goethite filling fractures. Amorphous goethite is present. Reflected light. 160 X

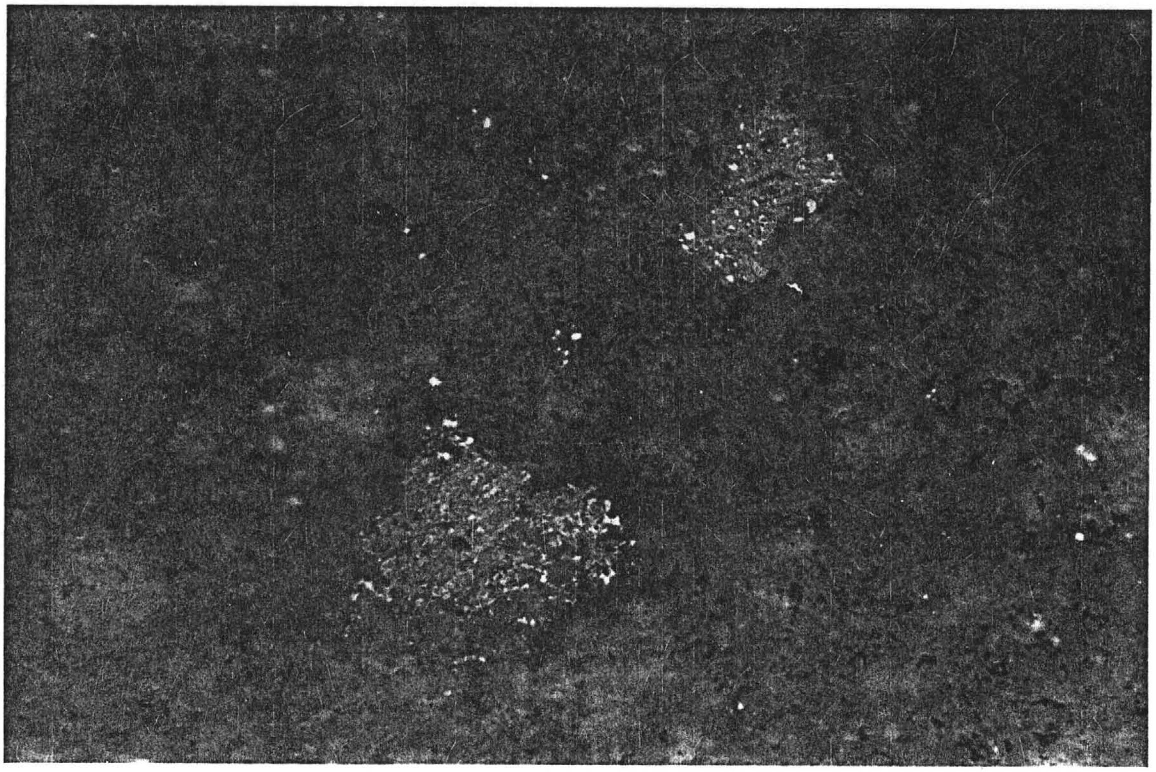


Plate c). 143 ' Amorphous masses of goethite rimming and overgrowing quartz. Reflected light. 160X.

M3 157'

Ore Minerals		Gangue Minerals	
Hematite	1%	Quartz	75%
Goethite	25%		
Rutile	tr		
Gold	tr		
Electrum ?	tr		

Textures

Quartz - Fine-grained (.02mm) quartz is ubiquitous. These grains are anhedral but generally elongate, with sutured grain boundaries. Coarser-grained quartz (up to .25 mm) occurs in pods or lenses (Plate d). This quartz has sutured grain boundaries and rare undulose extinction. These pods of quartz are not common and appear associated with vugs.

Hematite - Hematite is disseminated, extremely fine-grained (< .02 mm), anhedral and commonly associated with goethite. Hematite inclusions are present in goethite.

Goethite - Goethite occurs as pervasive amorphous masses throughout the slide (Plates e,f). Fine-grained masses are also common. Some goethite masses have a vague hexagonal form suggesting total replacement of hematite (Plate e).

Rutile - Rutile occurs as fine (.02 mm), anhedral grains associated with hematite and goethite.

Electrum - Electrum (?) occurs as fine-grained (.01mm) laths within goethite masses and as anhedral grains in the fine-grained quartz matrix (Plates g,h).

Gold - Two forms of gold mineralization are present. Fine (.01mm) gold occurs in and rimming the hexagonal goethite (Plates e,f). Free gold is present in the fine-grained quartz matrix as anhedral grains approximately .01 mm but up to .03 mm (Plates i,j). Some gold is whitish suggesting silver is present.

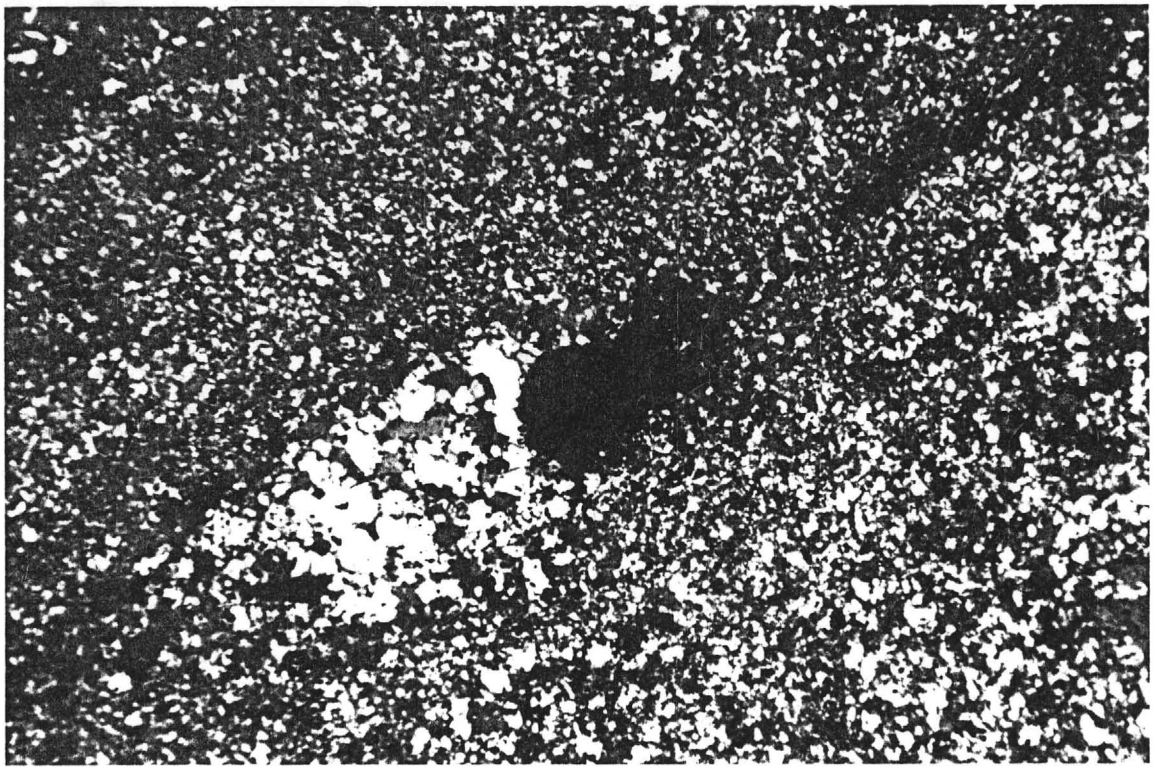


Plate d) 157 ' Pod of coarse quartz in a fine-grained quartz matrix. Hematite/goethite overgrowths. Transmitted light (crossed nicols). 25X

Plate e) 157 ' Pseudo-hexagonal goethite with inclusions of hematite, gold and rutile. Reflected light. 400X

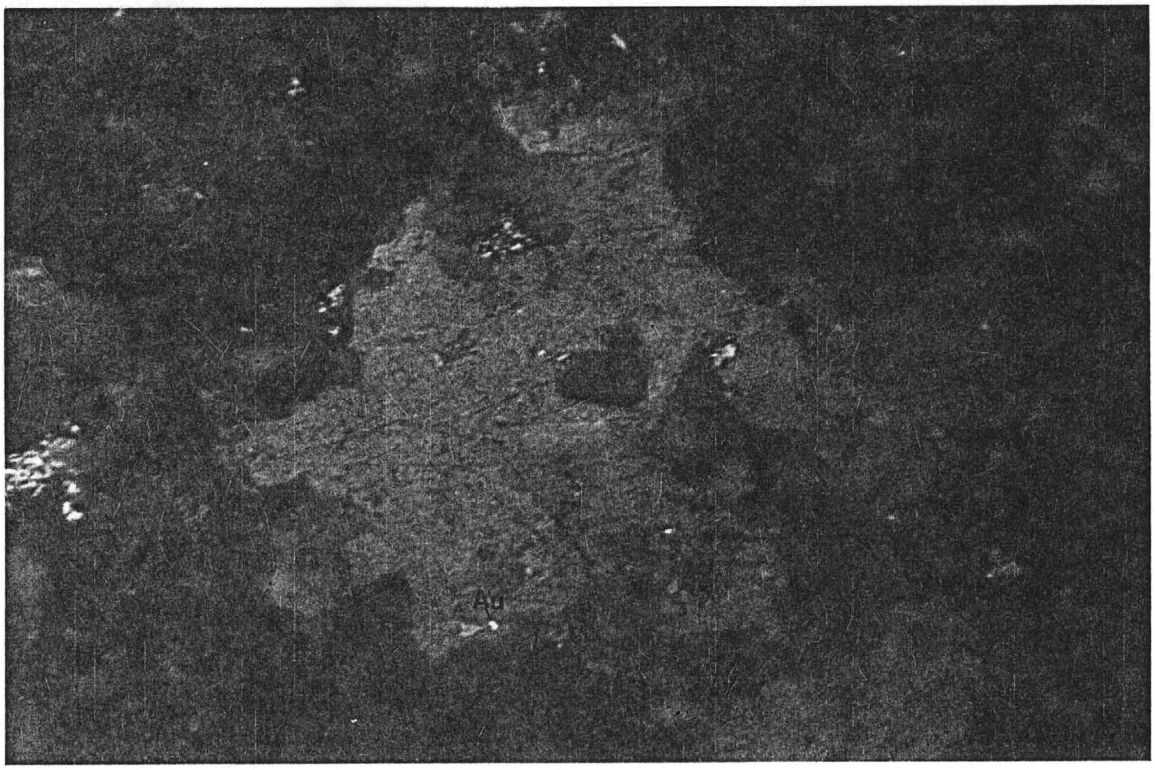


Plate f) 157 ' Amorphous mass of goethite in quartz. Note gold grain. Reflected light . 400X

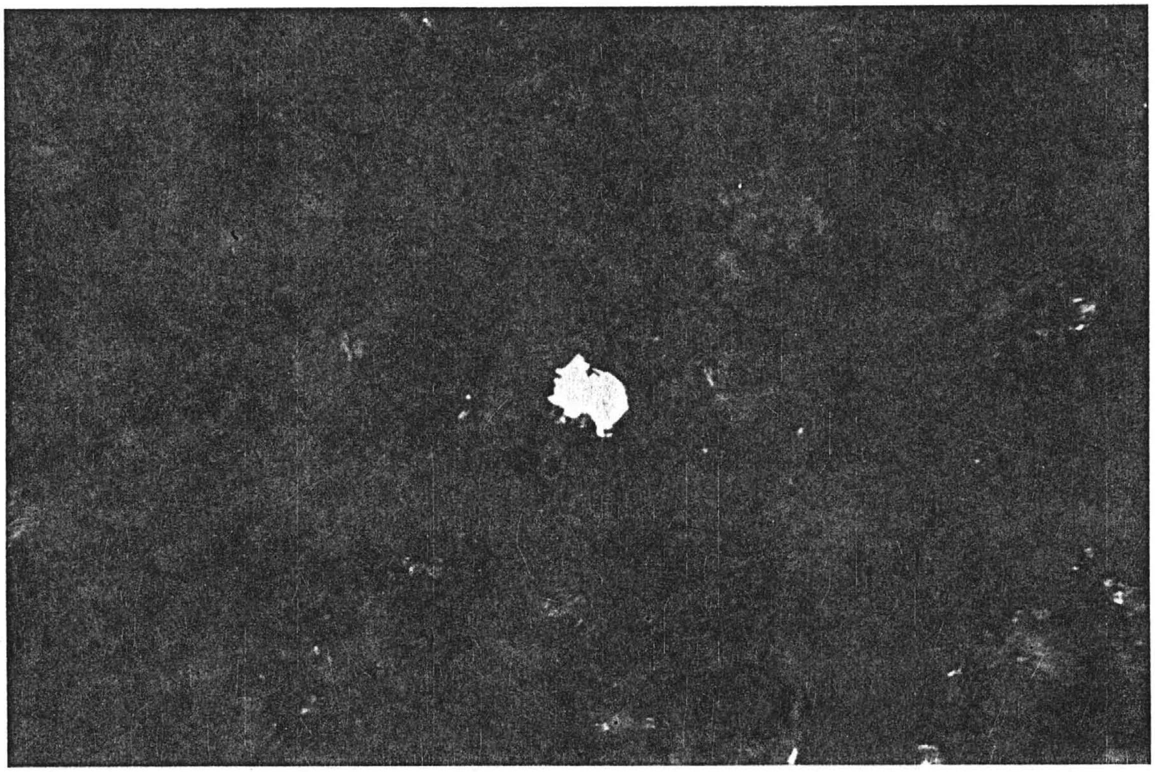


Plate g) 157 ' Fine, anhedral grain of electrum in the quartz matrix. Reflected light. 400X

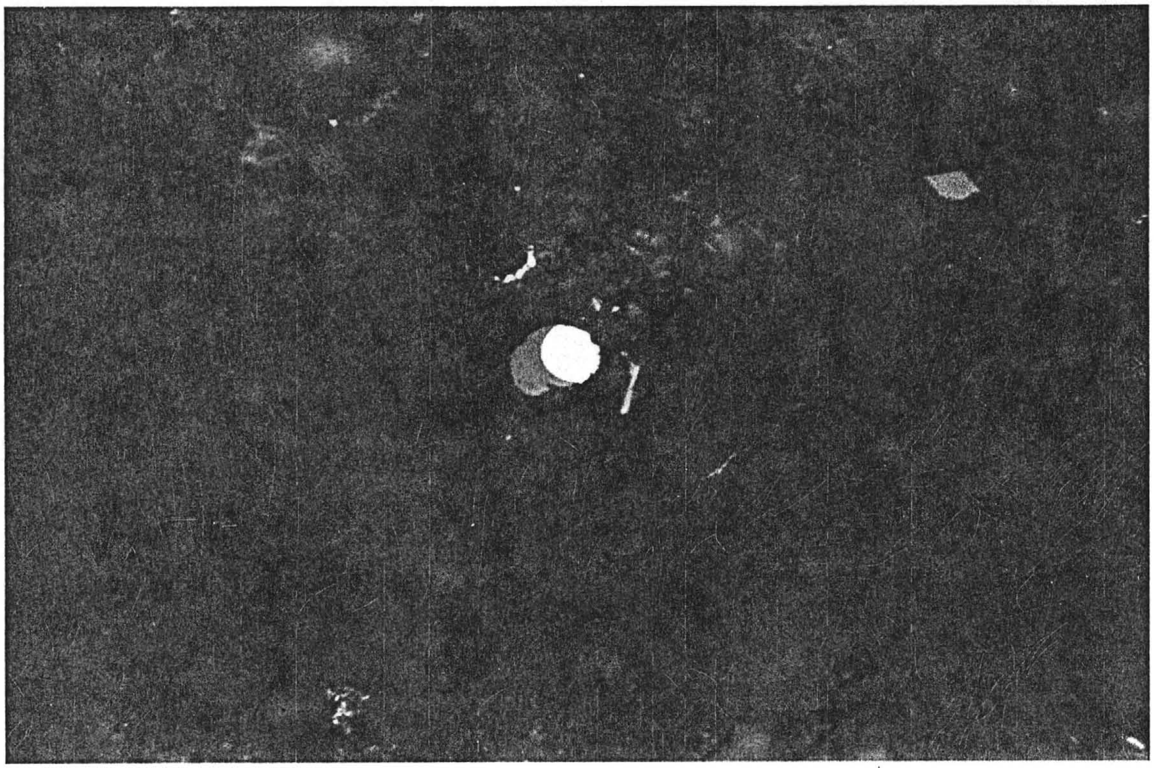


Plate h) 157 ' Round grain of electrum in fine-grained quartz associated with a vug. Reflected light. 400X

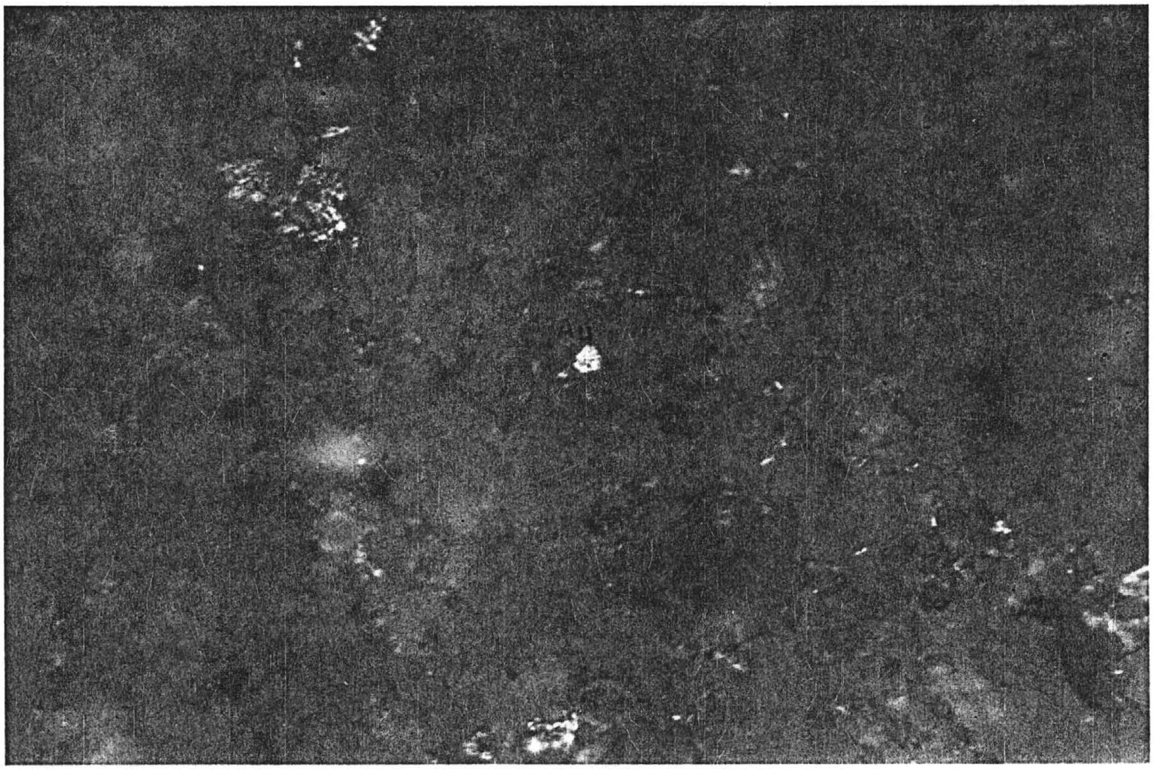


Plate i) 157 ' Fine-grained gold in the quartz-goethite matrix. Reflected light. 400X

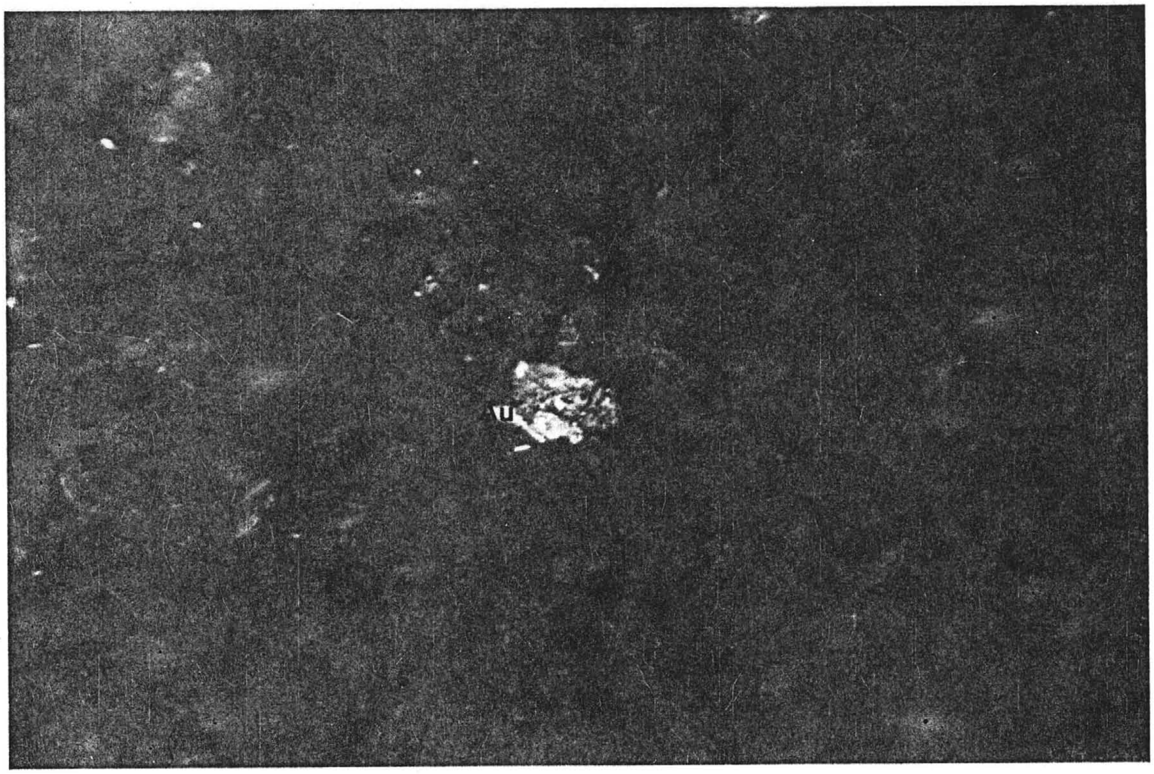


Plate j) Gold grain with goethite and quartz in the matrix. Reflected light. 400X

M3 164'

Ore Minerals		Gangue Minerals
Goethite	40%	Quartz - 60%
Hematite/Rutile	1%	
Electrum	tr	
Gold	tr	

Textures

Quartz - Matrix quartz and clasts of quartz are present. Matrix quartz is fine-grained (.02mm) and elongate with sutured grain boundaries (Plate k). Pods of matrix quartz preserve the outline of coarser grains. Coarse-grained (up to 3mm) quartz occurs in clasts of coarse grains and as veinlets (Plate k). Quartz in clasts is anhedral with sutured grain boundaries, undulose extinction and commonly brecciated by hematite/goethite stringers. Vein quartz is relatively unaltered with good comb textures present and porosity preserved at the vein centre (Plate l). One quartz grain in the matrix has distinct growth zoning outlined by fine-grained inclusions.

Goethite - Amorphous masses of goethite overgrow the entire slide except the quartz vein (Plate m). Subhedral masses which may have replaced hematite are present.

Hematite/Rutile - Hematite and rutile commonly occur as fine (.04mm) anhedral grains. They commonly occur together in clusters of brecciated fragments. Goethite rims are common on hematite.

Electrum - Fine (.02mm) grains of electrum are not common but when present are associated with hematite and pods of coarse-grained quartz.

Gold - Fine (.01mm) gold occurs as rounded blebs (Plates m,n,o). Gold is commonly associated with the quartz matrix and goethite.

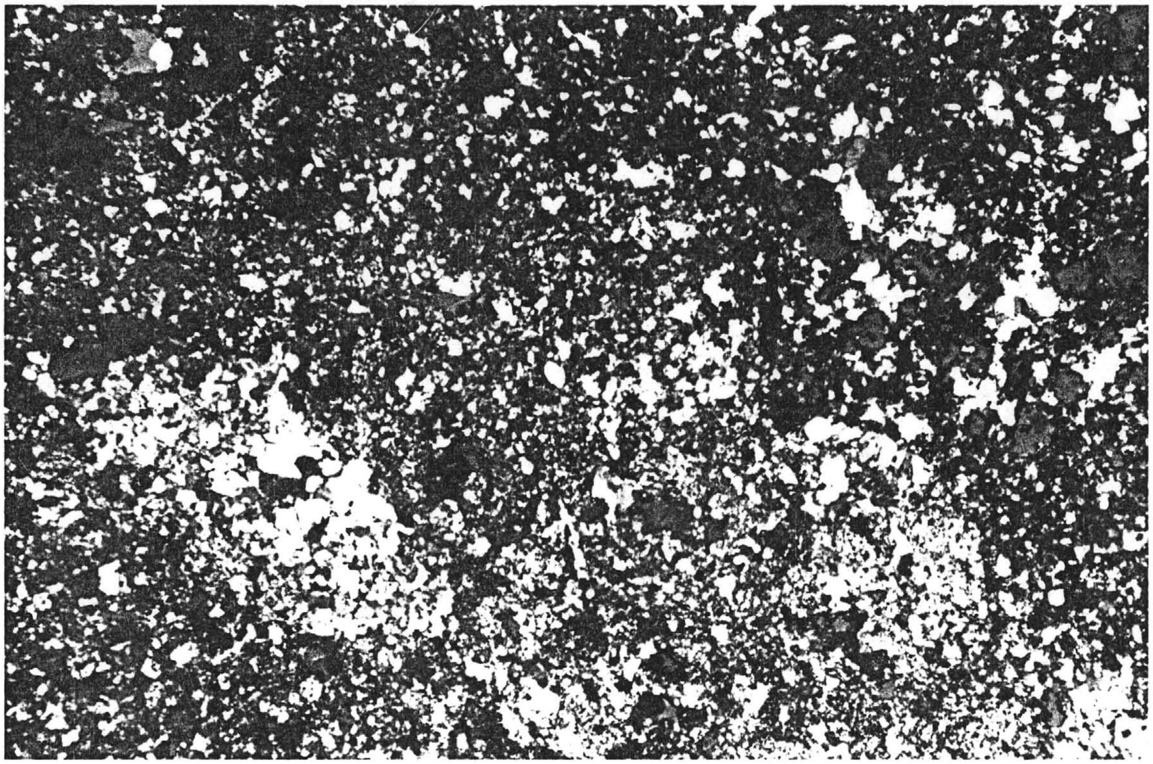


Plate k) 164 ' Matrix quartz and overgrowths of goethite. Note pod of coarser quartz altering to finer-grained quartz and the presence of vugs with goethite. Transmitted light (crossed nicols). 25X

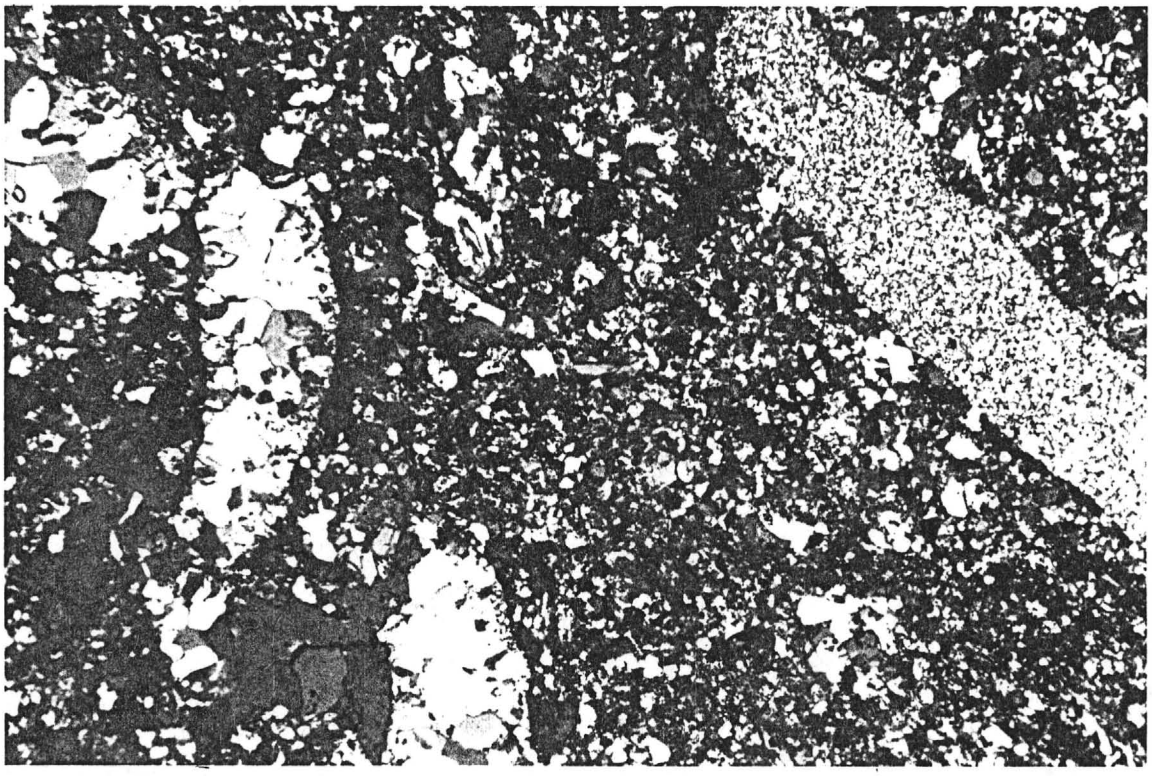


Plate l) 164 ' Matrix quartz, veinlets of quartz and pods of quartz which have been totally altered to fine-grained quartz. Ribbon textures of quartz and goethite overgrowths are present. Transmitted light (crossed nicols). 25X

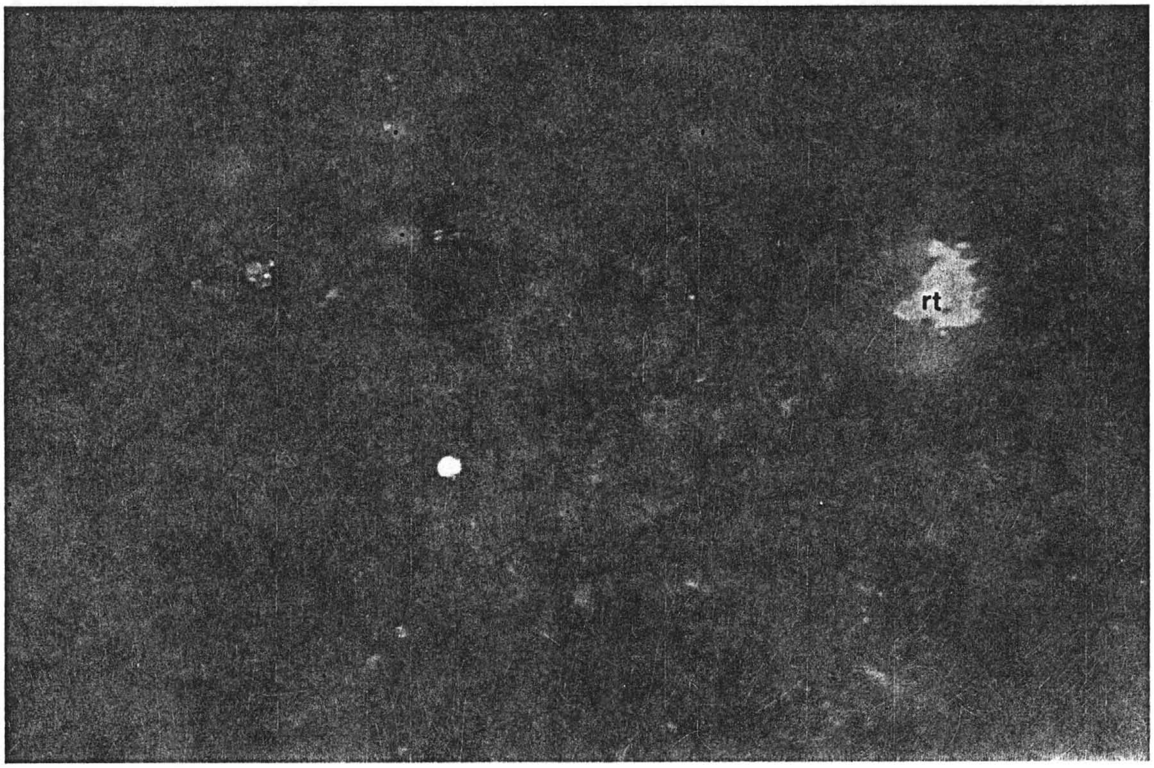


Plate m) 164' Gold and amorphous goethite/hematite masses in quartz matrix. Anhedral rutile is also present. Reflected light. 400X

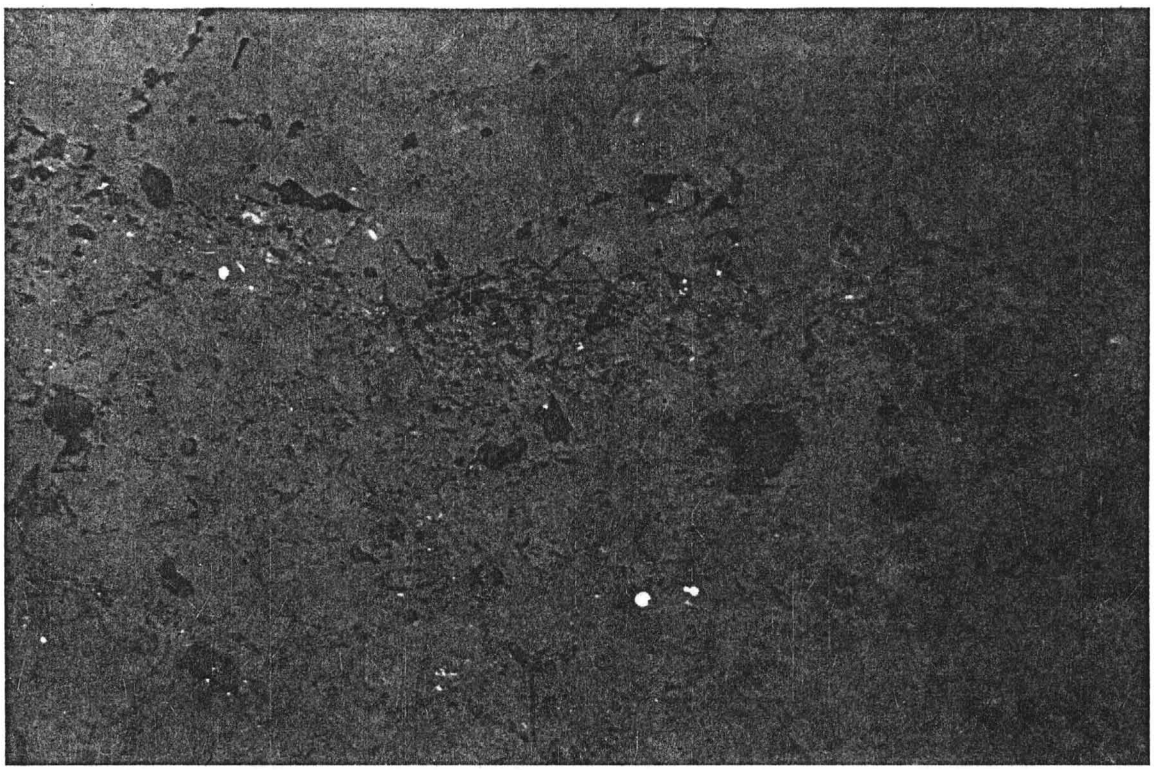


Plate n) 164 ' Fine-grained, rounded quartz grains of gold in quartz-goethite matrix, adjacent to a quartz vein. Reflected light . 160X

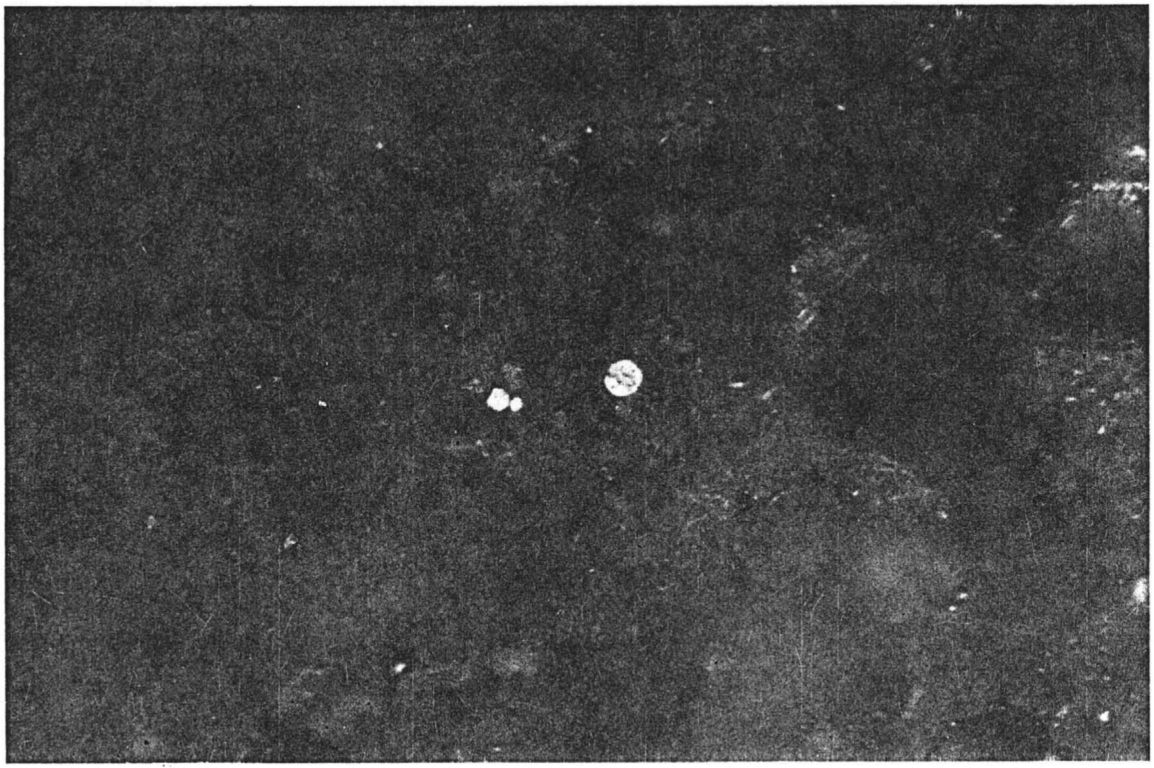


Plate o) 164' Round, almost euhedral/hexagonal, gold grains (same as Plate n). Reflected light. 400X

M3 193'

Ore Minerals		Gangue Minerals	
Hematite	30%	Quartz	65%
Goethite	1%		
Rutile	4%		
Pyrite	tr		
Gold	tr		

Textures

Quartz - Three forms of quartz are present : 1) clasts of fine-grained (.02mm) quartz, 2) medium-grained (.25mm) quartz matrix 3) vein quartz (Plate p). Clasts of fine-grained quartz commonly have cores of coarser quartz and are brecciated by hematite. Quartz in the matrix has sutured grain boundaries, undulose extinction and ribbon texures (Plate q). Fine-grained quartz is common along grain boundaries and margins in the matrix. Vein quartz is coarse-grained (up to 2mm) and subhedral with irregular grain boundaries and slightly undulose extinction. Growth zoning preservation produces fortification textures (Plate p). A spherule body of quartz is present adjacent to the vein (Plate p). Porosity is present at the vein centre.

Hematite - Colloform and subhedral hematite occur in this slide (Plate r). Spectacular colloform hematite rims quartz grains and clasts to give a hematite 'net' (Plates r,t). The colloform hematite is being replaced by the fine-grained quartz. Subhedral hematite cubes with hollow cores are common. Hematite also occurs as fine veinlets.

Goethite - Goethite occurs as fine, anhedral grains but is rare.

Rutile - Rutile occurs as brecciated fragments in the hematite net. In some areas it is very common (Plate r).

Pyrite - Rare, fine-grained (.02 - .05 mm) euhedral pyrite is present in the quartz grains rimmed by colloform hematite. Hematite is replacing the pyrite along pyrite rims (Plate t).

Gold - Fine-grained blebs of whitish gold are present in quartz rimmed by hematite (Plate s).

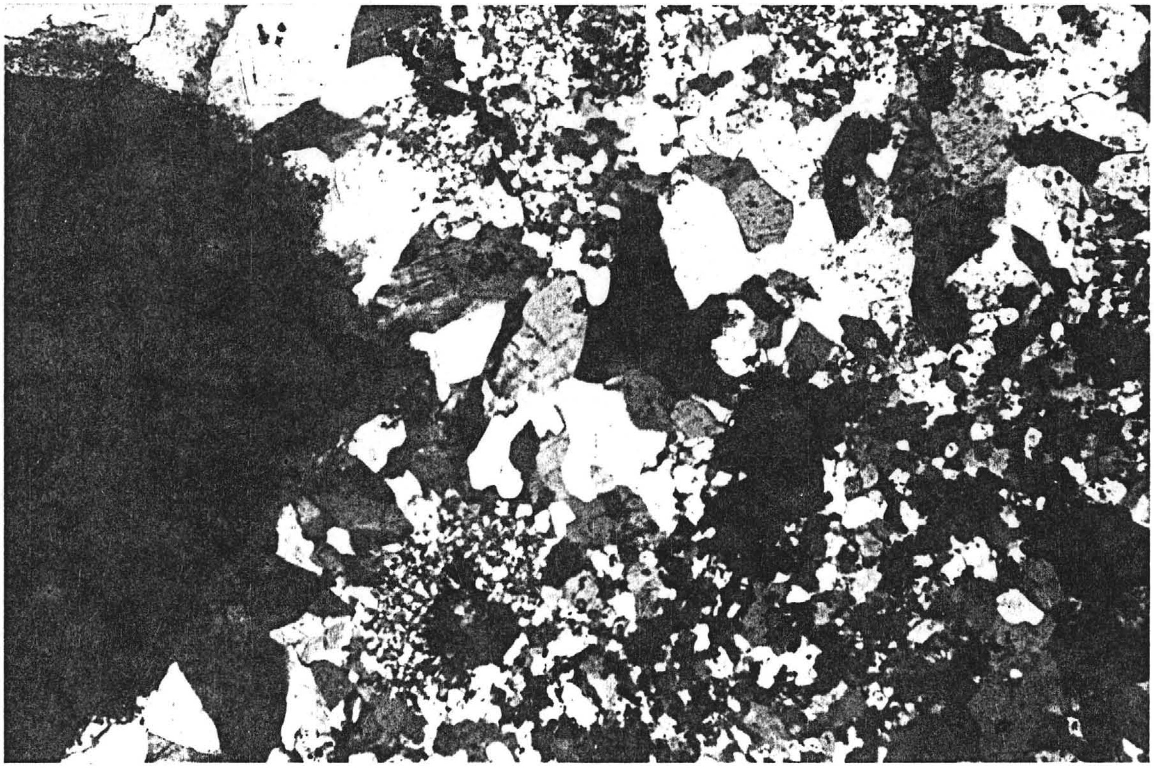


Plate p) 193 ' Coarse-grained vein quartz with growth zoning filling open space. Fine-grained quartz matrix and a quartz spherule are present. Transmitted light (crossed nicols). 25X

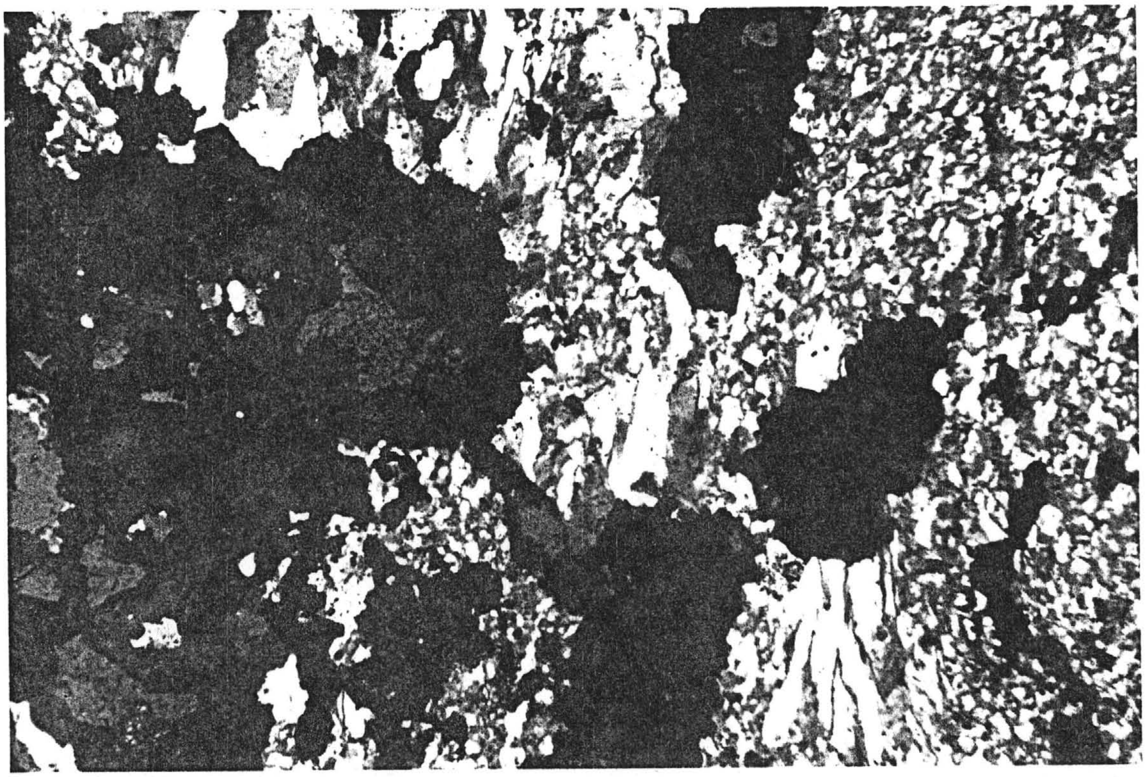


Plate q) 193 ' Fine-grained quartz matrix and ribbon quartz in pressure shadows around colloform hematite. Transmitted light (crossed nicols). 100X

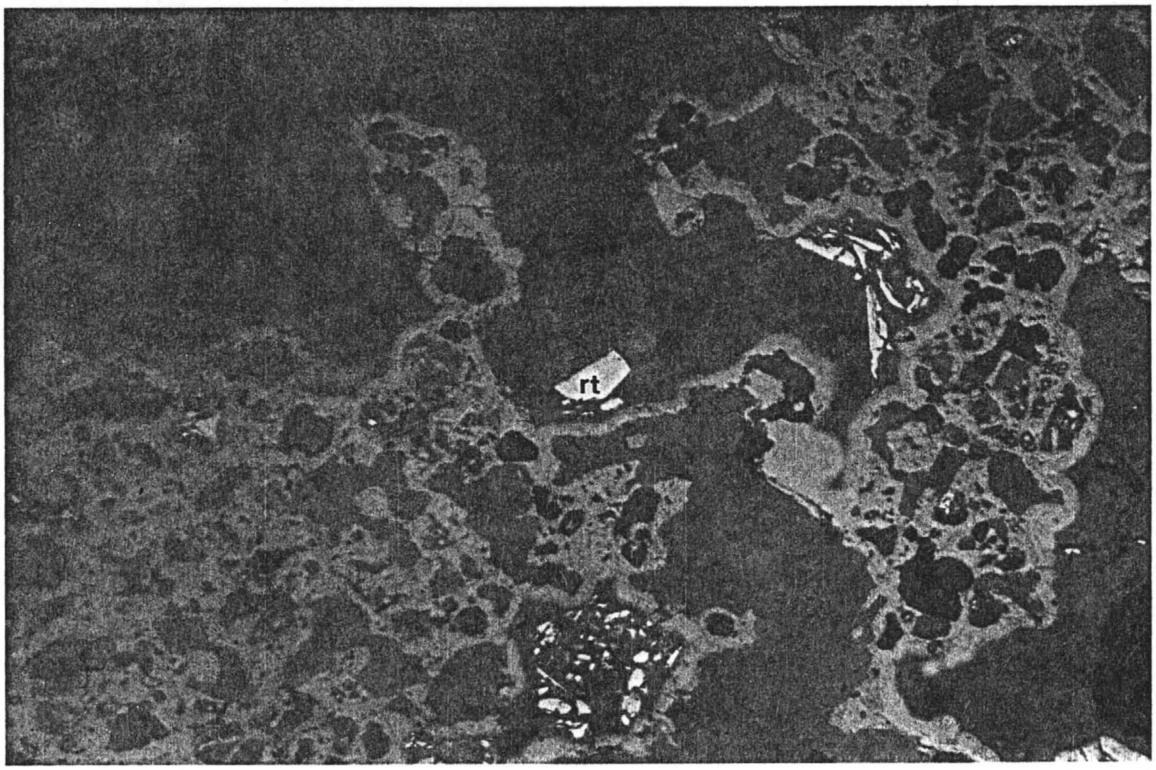


Plate r) 193 ' Net texture of colloform hematite and brecciated rutile. Reflected light. 160X

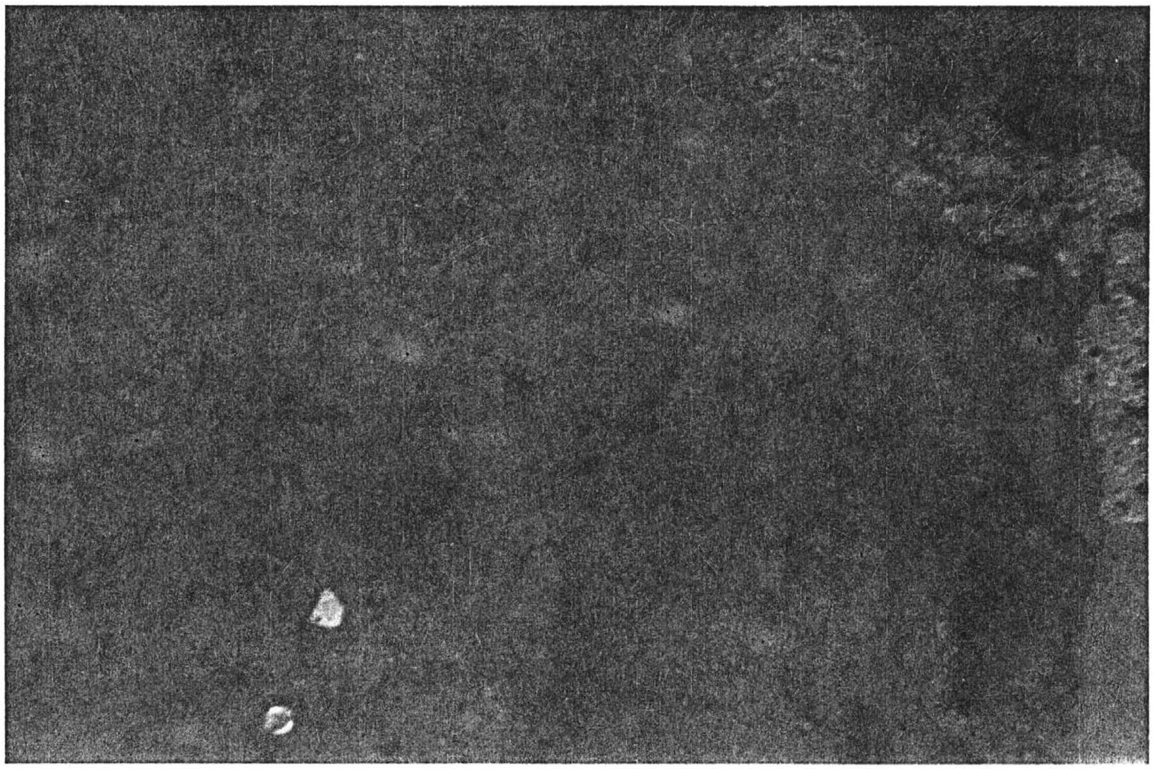


Plate s) 193 ' Fine-grained whitish gold ? in quartz matrix. Goethite is also present. Reflected light. 400X

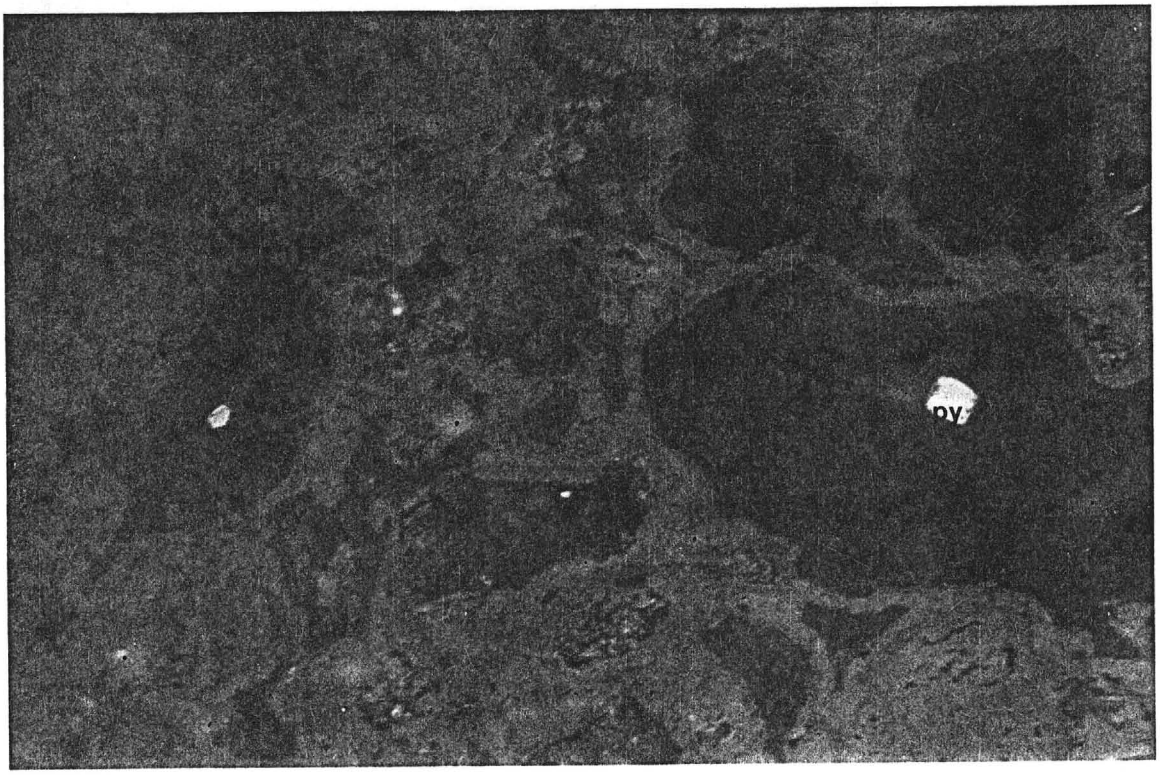


Plate t) 193 ' Colloform hematite net rimming quartz grains. Euhedral pyrite in the quartz grains is being replaced by hematite. Reflected light. 400X

M3 231'

Ore Minerals		Gangue Minerals	
Hematite	25%	Quartz	70%
Goethite	5%		
Rutile	2%		
Gold ?	tr		
Electrum ?	tr		

Textures

Quartz - Two forms of quartz are present. Fine-grained (up to .02mm) quartz occurs as the matrix. These grains are elongate with serated grain boundaries. The matrix is commonly brecciated by hematitic stringers. Coarse-grained (up to .8mm) vein/pod quartz with inclusions is common. Alteration of coarse-grained quartz to fine-grained quartz is present at grain boundaries and margins. Comb texture is present in veinlets. Several coarse grains have undulose extinction and serated grain boundaries.

Hematite - Colloform hematite occurs as net texture rimming pods of fine-grained quartz, and coarse-grained quartz (Plate u). Subhedral hematite cubes with hollow cores are common and nearly massive in some areas (Plate u) .

Goethite - Goethite occurs as anhedral masses (.4mm) in quartz veins.

Rutile - Medium-grained (av. .5mm) rutile occurs as anhedral, brecciated grains and fragments (Plate u). These grains are commonly rimmed by the colloform hematite.

Gold - A fine (.04mm) gold grain is associated with colloform hematite and fine-grained quartz (Plate v). This gold is whitish and may have some silver.

Electrum - Fine (.02mm) anhedral grains associated with the fine-grained matrix.

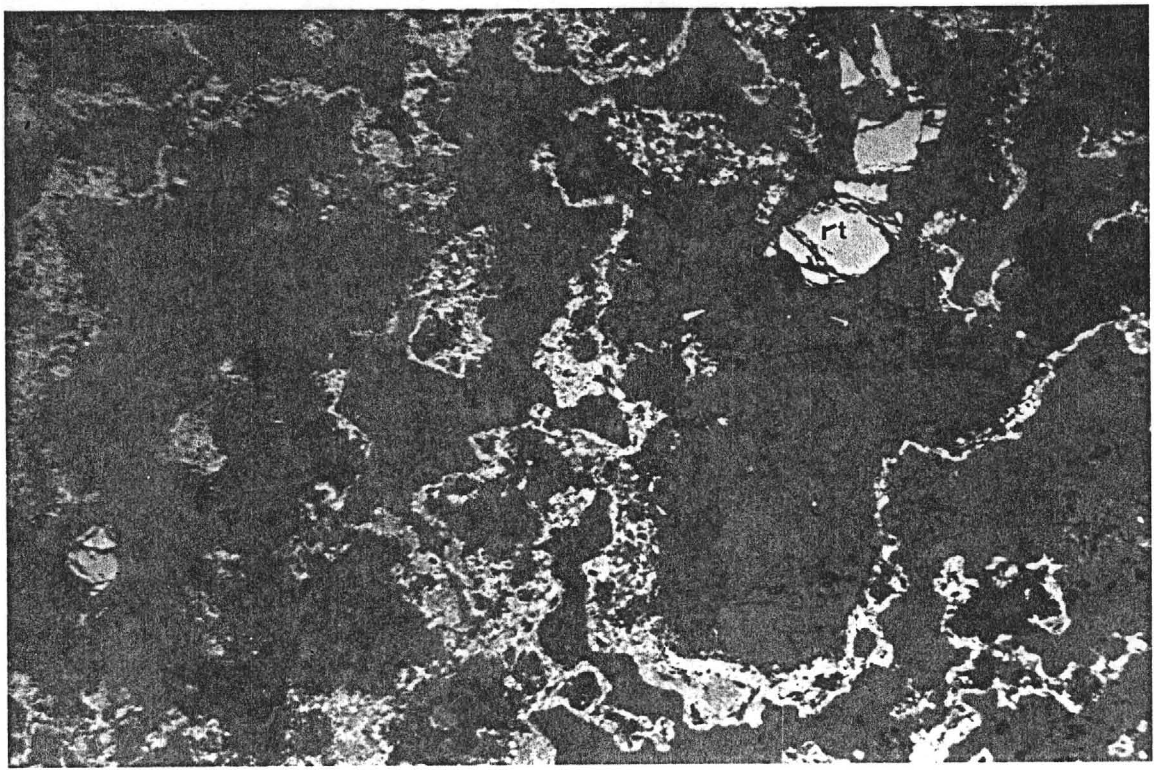


Plate u) 231 ' Colloform hematite net , amorphous goethite and brecciated rutile. Reflected light. 160X

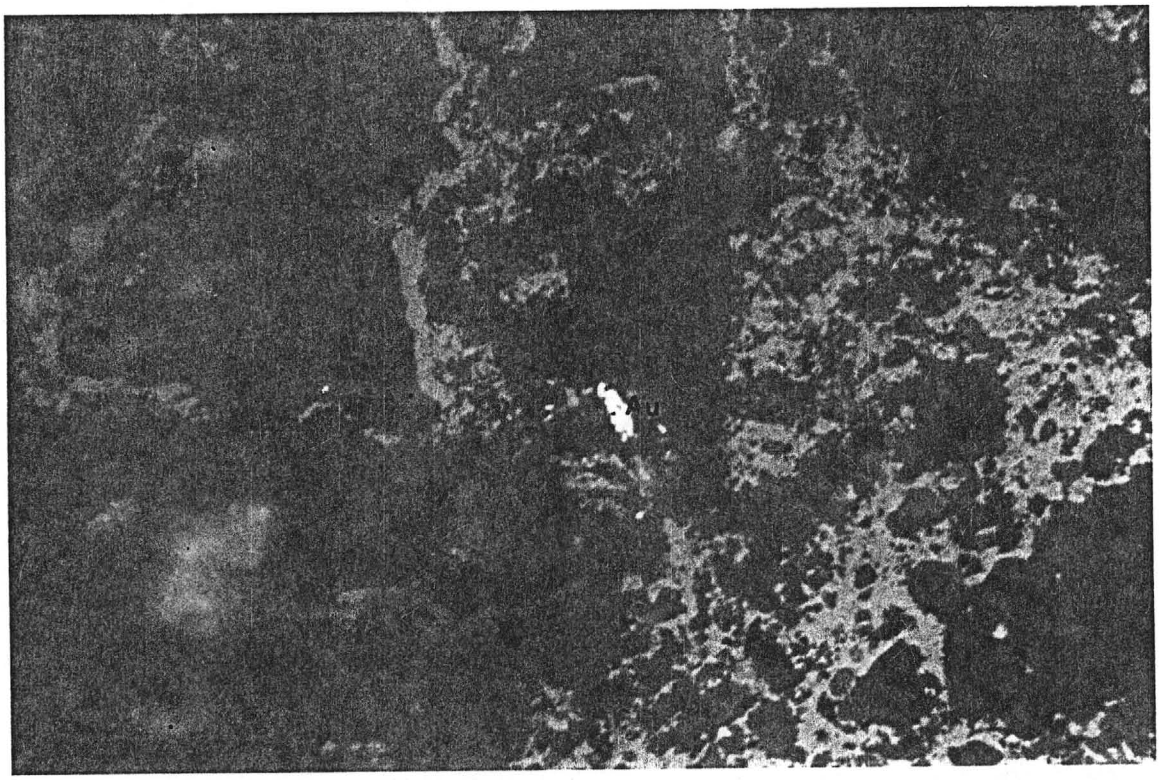


Plate v) 231 ' Whitish gold grain in colloform hematite and quartz. Reflected light. 400X

BFD III

A PRELIMINARY REPORT ON THIN SECTIONS OF THE SILICEOUS ROCK OF THE GOLD STOPE UVX MINE, JEROME, ARIZONA

PETER MCLEAN

SEPTEMBER 15, 1986

TABLE OF CONTENTS;

DISCUSSION

1. Was there any carbonate present in the past ?

The occurrence of hematite rhombs indicates the presence of carbonate in the past. These hematite rhombs are only in drill-hole 901-3 and only in three sections. The specific composition of the original carbonate is undetectable as replacement is complete and preserved cleavage traces provide no clue to the parent mineral.

2. Is there any mineralogic associations between gold and hematite.

The tentatively identified ore minerals and sulphides were predominantly associated with hematite and coarse-grained quartz. The composition of the ore minerals is still to be determined using SEM techniques.

3. Textural associations.

Tentatively identified electrum, and sulphides are predominantly associated with hematite and coarse-grained quartz which is usually in veinlets, as vug-filling constituents and rimming clasts of brecciated, fine-grained quartz.

4. Alteration.

The only evidence of alteration is 1) replacement of carbonate by hematite 2) crumbling of coarse-grained quartz, sutured grain boundaries, undulose extinction, hexagonal form and banding of some quartz grains suggest moderate deformation and recrystallization 3) abundance of limonite overgrowths.

5. Paragenetic sequence.

a) Bedding of hematite and quartz in slides 515 and 321 suggest an initial deposition of quartz, carbonate and perhaps hematite,

b) Replacement of carbonate by hematite

c) Minor metamorphism and deformation resulting in recrystallization and grain-size reduction of quartz

d) Brecciation of rock by this deformation and possibly contemporary infilling of these fractures by hematite

e) Infilling of porosity (vugs and fractures) by quartz

f) Limonite overgrowths

RECOMMENDATIONS FOR FURTHER WORK

The main objective of this study, to locate the gold in the UVX cherts, was not accomplished. The gold or other ore minerals present are just too fine-grained to be identified with standard optical microscopes. I recommend looking at several slides with the scanning electron microscope. This is available at Western and this work could be done in the fall of 1987.

Drill Hole 901-3

279'

Modal Analysis

Quartz - 90 % Fine-grained, 80 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 2 %

Description

This slide is dominated by fine-grained quartz and stringers of hematite (Plate 1). Areas of coarse-grained quartz are commonly associated with hematitic stringers but it can occur isolated. Large hematite rhombs (.4-.5 mm) display remnant carbonate cleavage and quartz cores (Plates 2, 3). Clasts of fine-grained matrix are incorporated into the coarse-grained quartz-hematite veinlets as this slide is extensively brecciated (Plate 1). Quartz also occurs filling vugs which commonly have a vacant core.

In reflected light, no gold or sulphide minerals confirmed by direct observation. Possible sulphides are commonly seen as bright, fine specks in the hematite-quartz stringers.

Plate 1 Slide 279'. Fine-grained quartz and hematite stringers. Coarse-grained quartz is present associated with hematite. Note the clasts of fine-grained quartz rimmed by hematite. 20 X, Crossed nicols (XN)

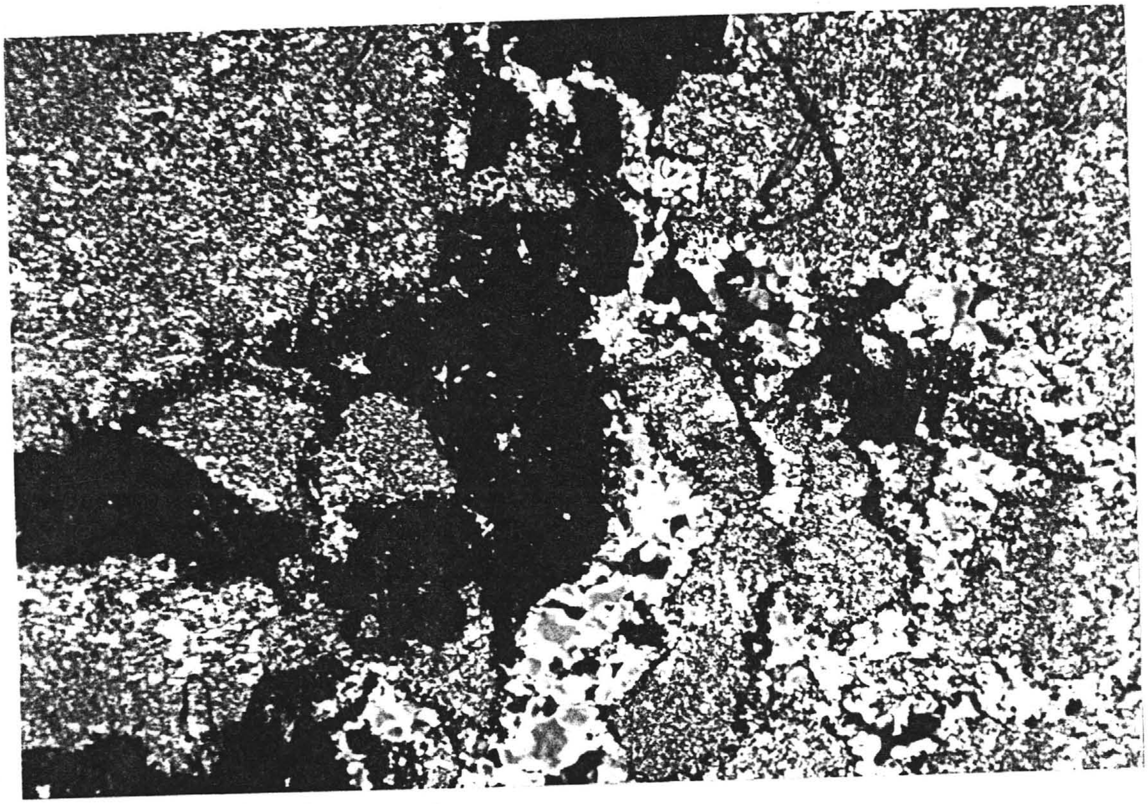


Plate 2 Slide 279'. Hematite rhombs with remnant cleavage traces. This is replacement of carbonate by hematite. 80 X, XN

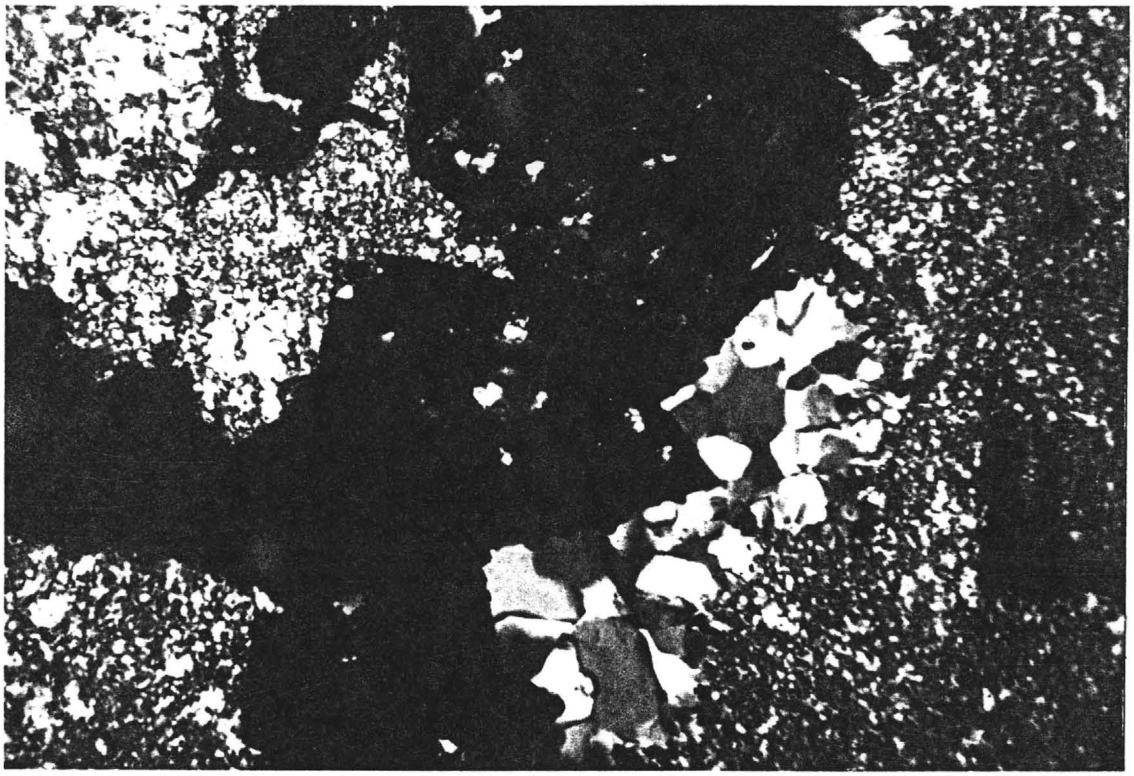
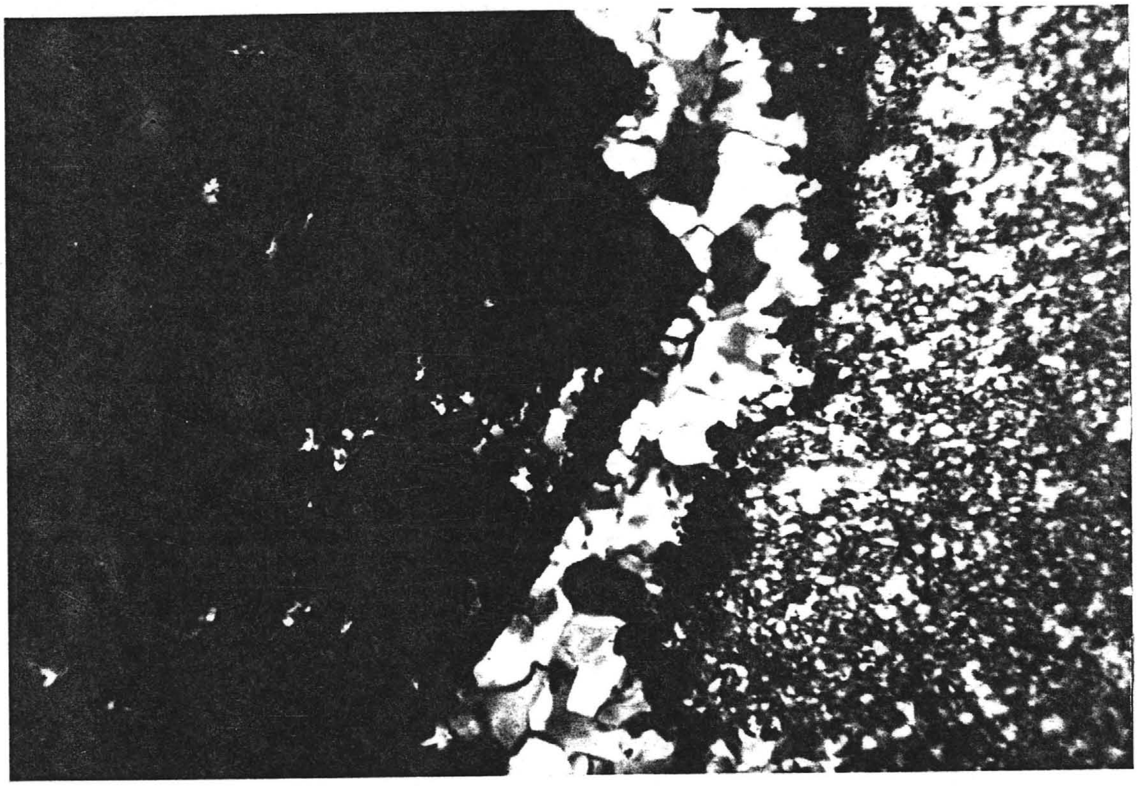


Plate 3 Slide 279'. Hematite rhombs with cleavage traces. Note hexagonal quartz in these hematite-rich stringers in the fine-grained matrix of quartz. 80 X, XN



281'

Modal Analysis

Quartz - 75 % Fine-grained, 65 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 2%

Description

This slide is dominated by a fine-grained quartz matrix with stringers of coarse-grained quartz and hematite. The slide is extensively brecciated by these quartz-hematite stringers and portions of the matrix appear incorporated and rimmed by hematite (Plate 4). Matrix quartz is very fine-grained, somewhat fibrous and displays a preferred orientation (Plate 5). Clasts of fine-grained matrix appear to have been rotated by the hematitic stringers (Plate 5). Coarse-grained quartz (up to 1mm) commonly has sutured boundaries and undulose extinction and 120° interfacial angles. In some areas, coarse-grained quartz is breaking down into fine-grained quartz (Plate 4). Hematite occurs as anhedral, fibrous crystals and as euhedral rhombs (Plate 6).

There is no identifiable gold or sulphide minerals present in this slide. Scattered, bright very fine-grained crystals may be sulphides. These are commonly in the main quartz-hematite stringers.

Plate 4 Slide 281'. Hematite brecciation of the fine-grained quartz matrix. Note that regions within the fine-grained clasts are coarser grained and appear to be crumbling. 20X, XN

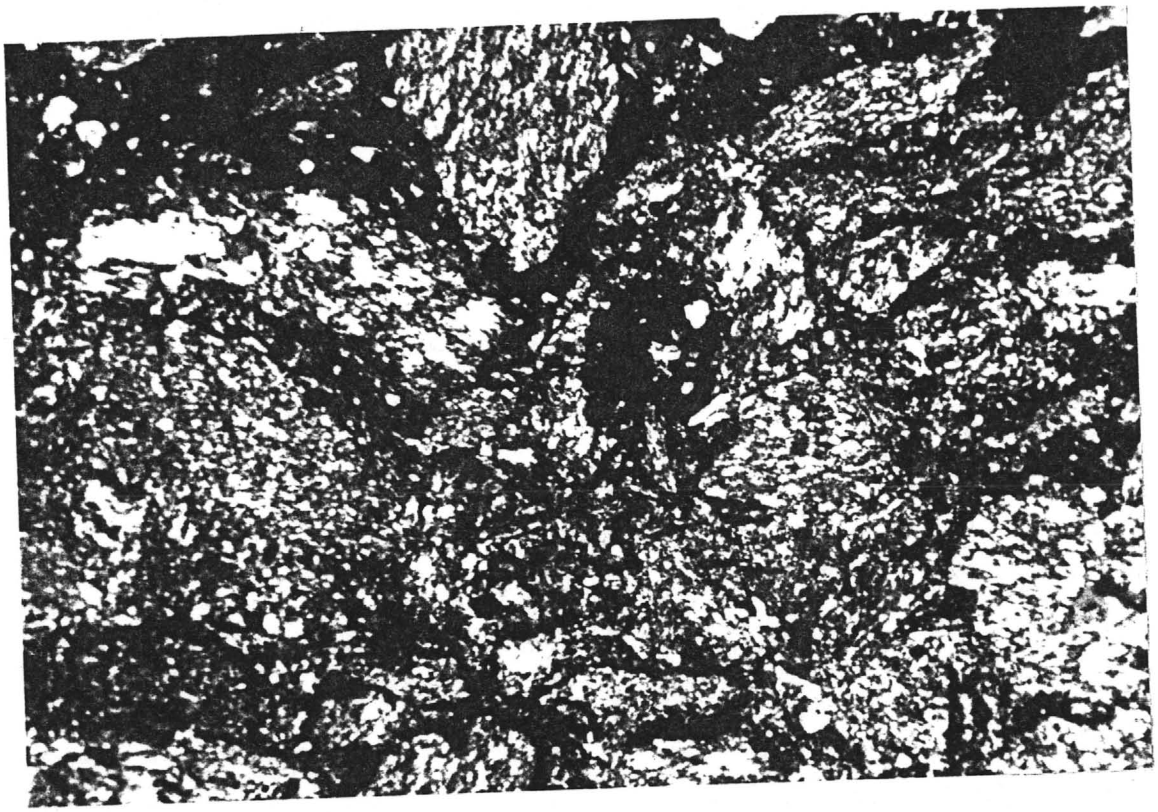


Plate 5 Slide 281'. Clasts of fine-grained quartz. The fine-grained quartz is somewhat fibrous and has a preferred orientation represented by the large clast. Several clasts appear rotated. 20 X, XN

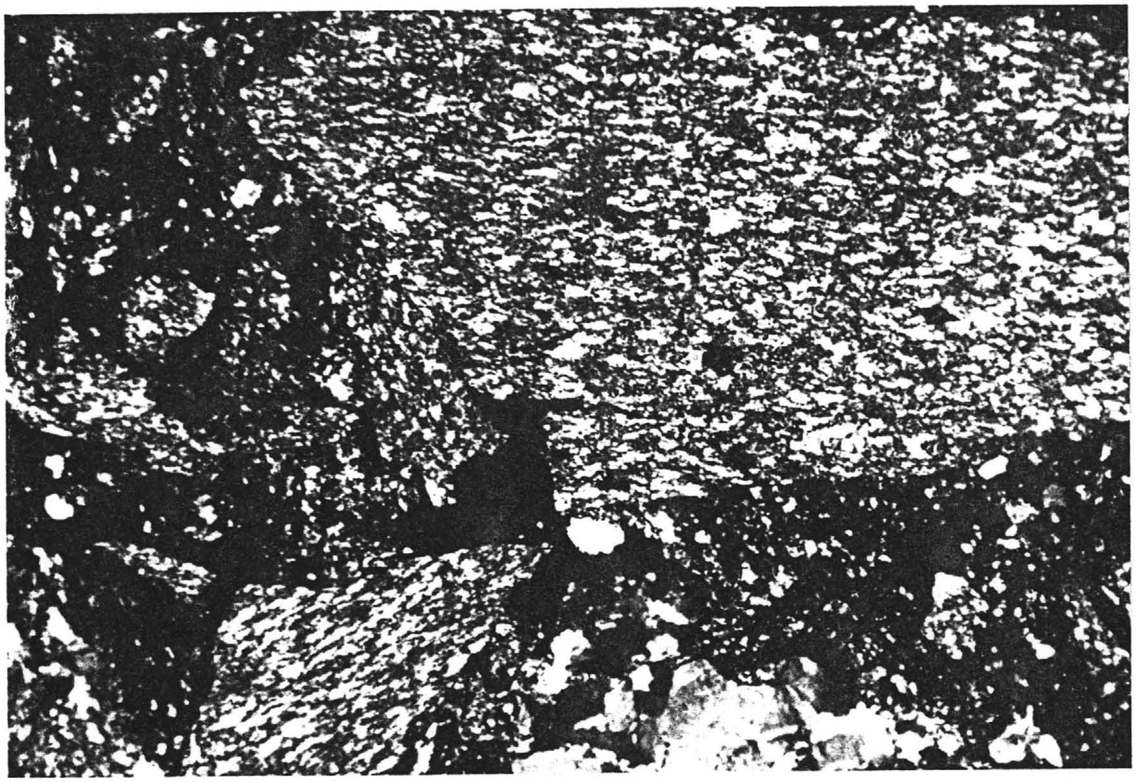


Plate 6 Slide 281'. Euhedral rhombs of hematite. Cleavage traces are somewhat preserved. 20 X, XN

290'

Modal analysis

Quartz - 90 % Fine-grained, 80 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 1%

Description

This slide is predominantly fine-grained quartz with stringers of hematite and coarse-grained coarse-grained quartz (Plate 7). Coarse-grained quartz is intergrown with fine-grained quartz and appears to be altering or decaying to the fine-grained quartz (Plate 7,8). Hematite is commonly fine-grained, occurs as stringers and vein linings and rimming quartz grains (Plate 8). Remnant hematite bands outline euhedral rhombs (Plate 9). Colloform hematite is also present. Portions of this slide are extensively brecciated (Plate 10).

There is no definite gold, sulphides or ore minerals in this slide. Minute specks predominantly in quartz-hematite stringers may be sulphides.

Plate 7 Slide 290'. Fine-grained quartz matrix,, coarse-grained quartz veinlets and hematite stringers. Note some coarse-grained quartz is crumbling or altering to fine-grained quartz. 20 X, XN

Plate 8 Slide 290'. Hematite, coarse-grained quartz and fine-grained quartz matrix. Note the clasts of coarse-grained quartz in the hematite crumbling or altering to fine-grained quartz, and the hematite lining the veinlet. 20 X, XN

Plate 9 Slide 290'. Remnant rhombs outlined by fine bands of hematite in a quartz veinlet. The bands of hematite appear to outline growth rings. Note the dark hematite lining the veinlet. 20 X, Plane-polarized light (PPL)

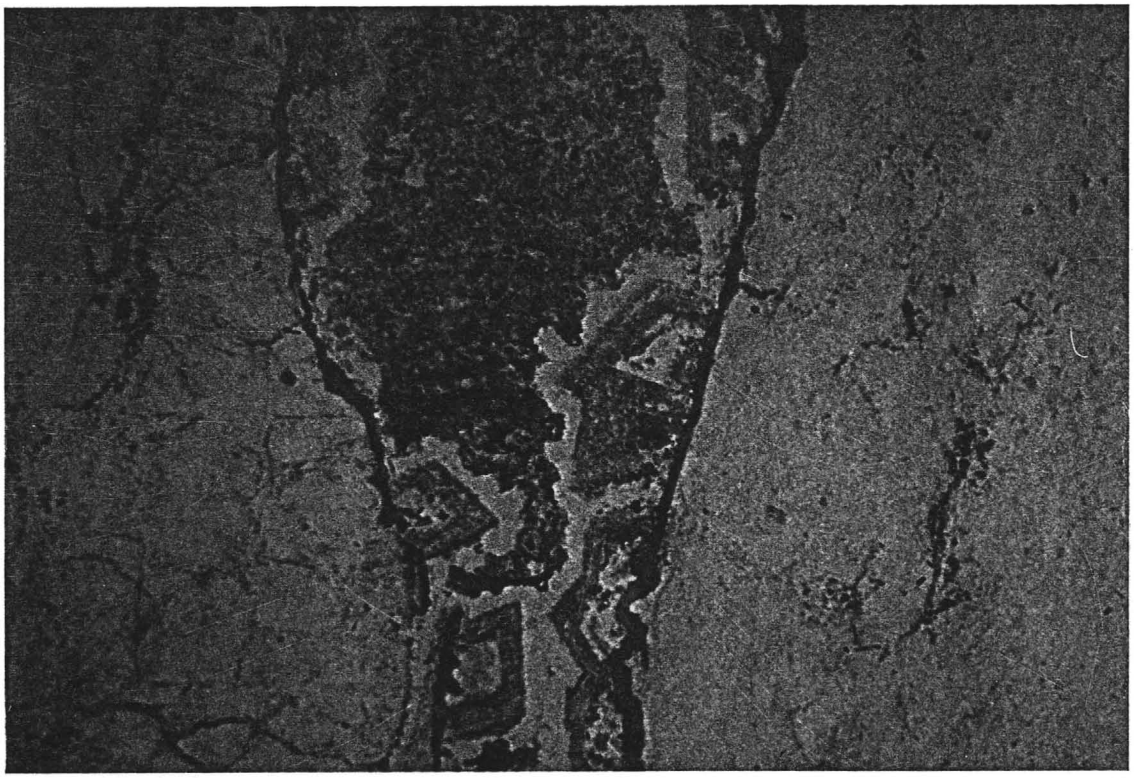
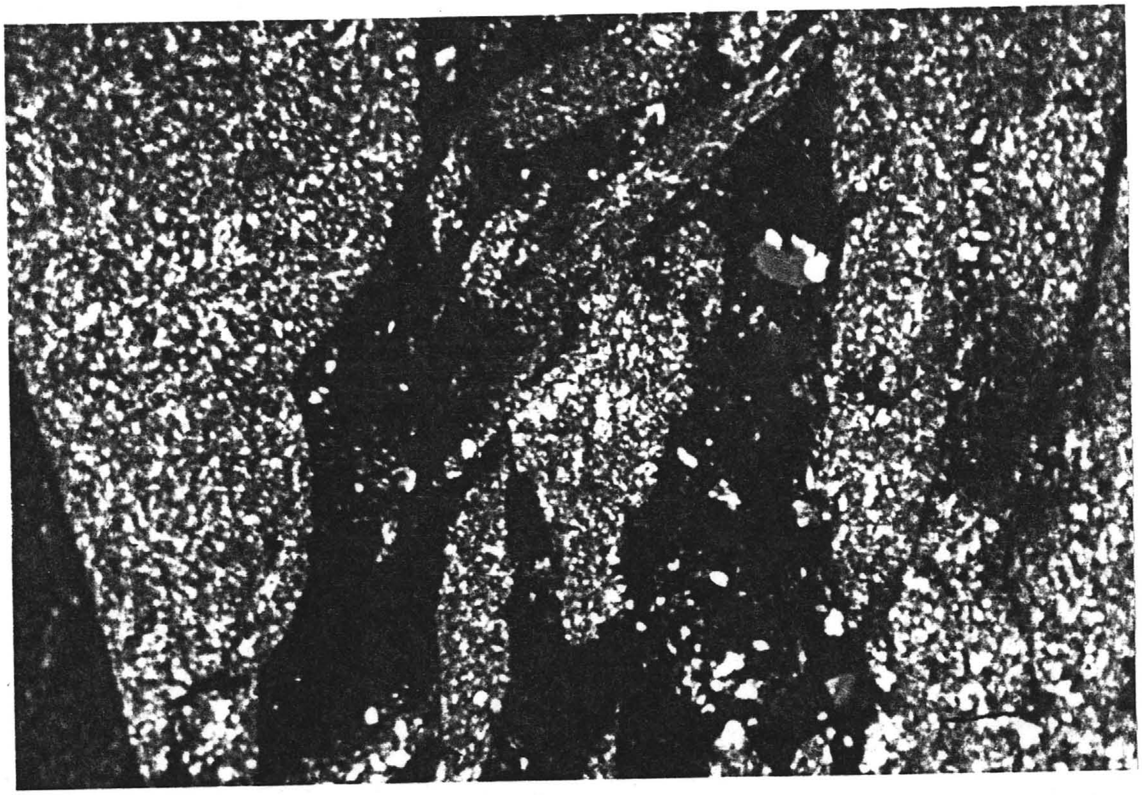


Plate 10 Slide 290'. Brecciation of the fine-grained quartz matrix outlined by hematite. 20 X, XN



307'

Modal Analysis

Quartz - 98 % Fine-grained, 60 %

Coarse-grained, 38 %

Hematite - 2 %

Porosity - 2 %

Description

This slide is dominated by fine-grained quartz although coarse-grained quartz does occur filling vugs and fractures (Plate 11). Brecciation is minor and outlined by quartz stringers and veinlets. Coarse-grained quartz occurs as hexagonal crystals with 120 interfacial angles and as anhedral crystals with sutured grain boundaries and undulose extinction (Plate 12). Coarse-grains are commonly crumbling or altering to fine-grained quartz. Hematite is scarce and when found is almost always associated with coarse-grained quartz. Iron staining (limonite ?) is abundant in some areas (Plate 12). This is in regions of coarse-grained quartz and outlines the hexagonal form. Fine-grained, euhedral, pyrite cubes are present (Plate 13). Numerous other grains appear to be sulphides and perhaps some electrum is present. One grain appeared to be gold but positive identification was impossible optically.

Plate 11 Slide 307'. Fine-grained quartz matrix with coarse-grained quartz infilling vugs and fractures. 20 X, XN

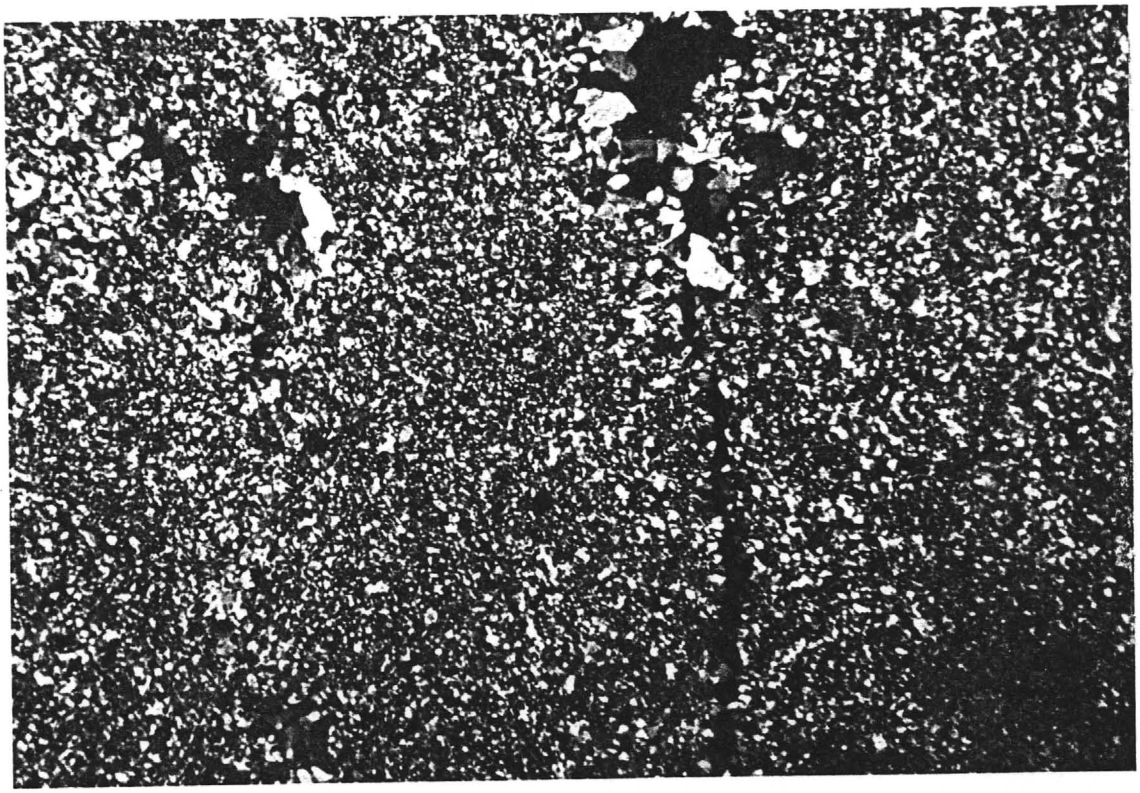


Plate 12 Slide 307'. Possible limonite staining outlining hexagonal quartz infilling a vug. 80 X, PPL

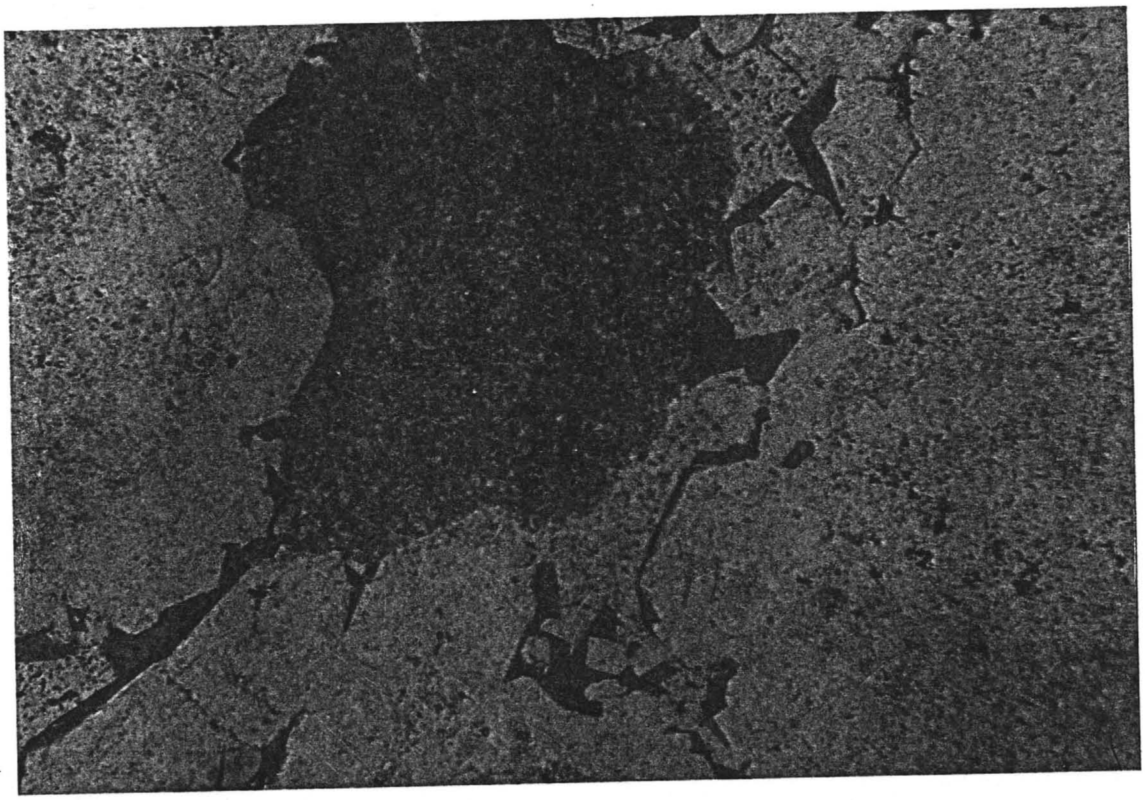
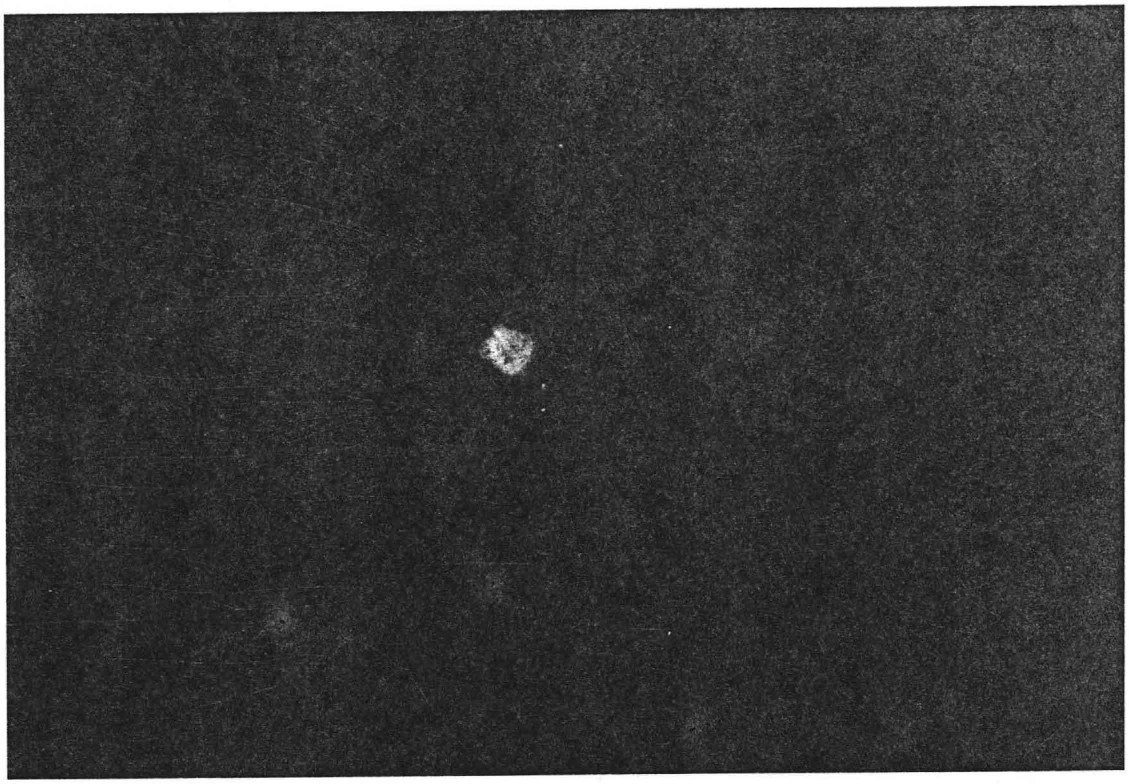


Plate 13 Slide 307'. Fine-grained, euhedral pyrite cube.128X

Reflected light



311'

Modal Analysis

Quartz - 80 % Fine-grained, 30 %

Coarse-grained, 50 %

Hematite - 20 %

Porosity - 5 %

Description

This slide is dominated by quartz clasts ranging in size from .25-3.0 mm and averaging 0.5mm . Fine-grained quartz is restricted to one end of the is sharp (Plate 14). Coarse-grained quartz have sutured grain boundaries, numerous inclusions and display undulose extinction. Quartz commonly fills vugs and fractures (Plate 15). Several large fractures cross-cut the region of fine-grained quartz and incorporate coarse quartz grains. Coarse-grained quartz is crumbling or altering to fine-grained quartz. Hematite occurs in veinlets and it is commonly very fine-grained and fibrous. Iron staining rimming hexagonal quartz is present.

No positive identification of gold or other ore minerals. Several subhedral, fine grains may be pyrite.

Plate 14 Slide 311'. Fine-grained quartz to the left of the veinlet. Limonite outlines hexagonal quartz and fractures. 20 X, XN

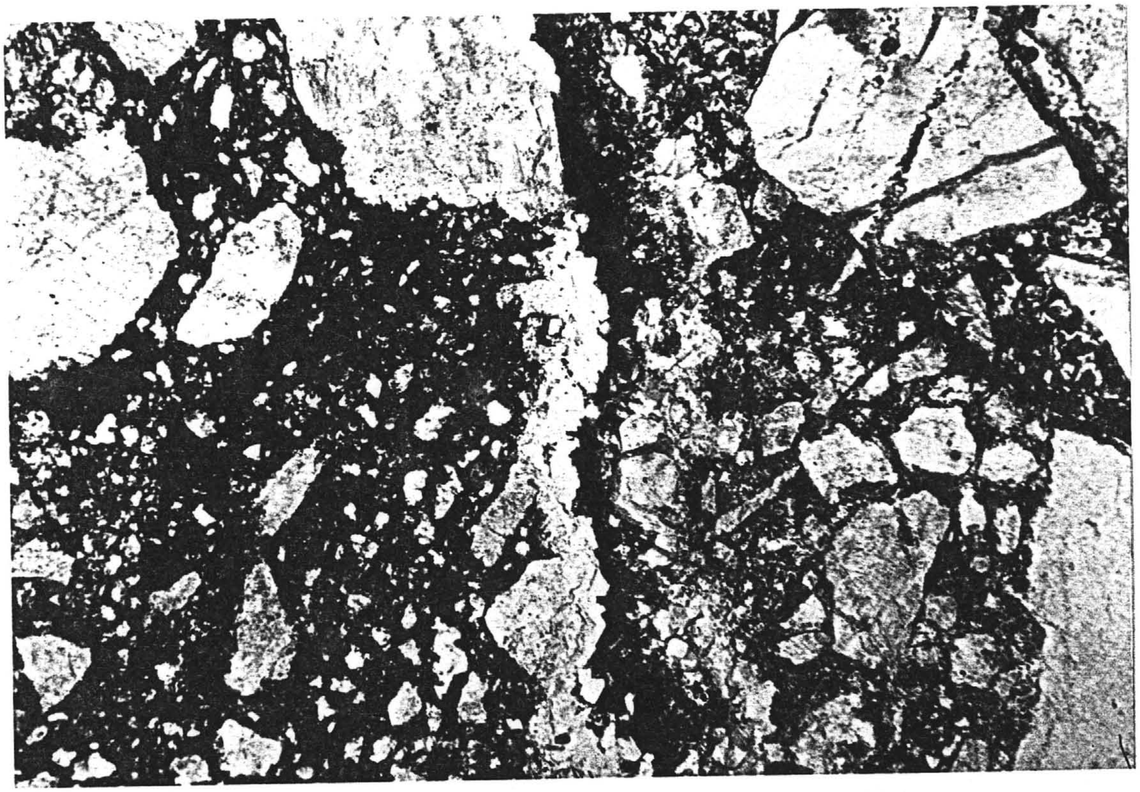
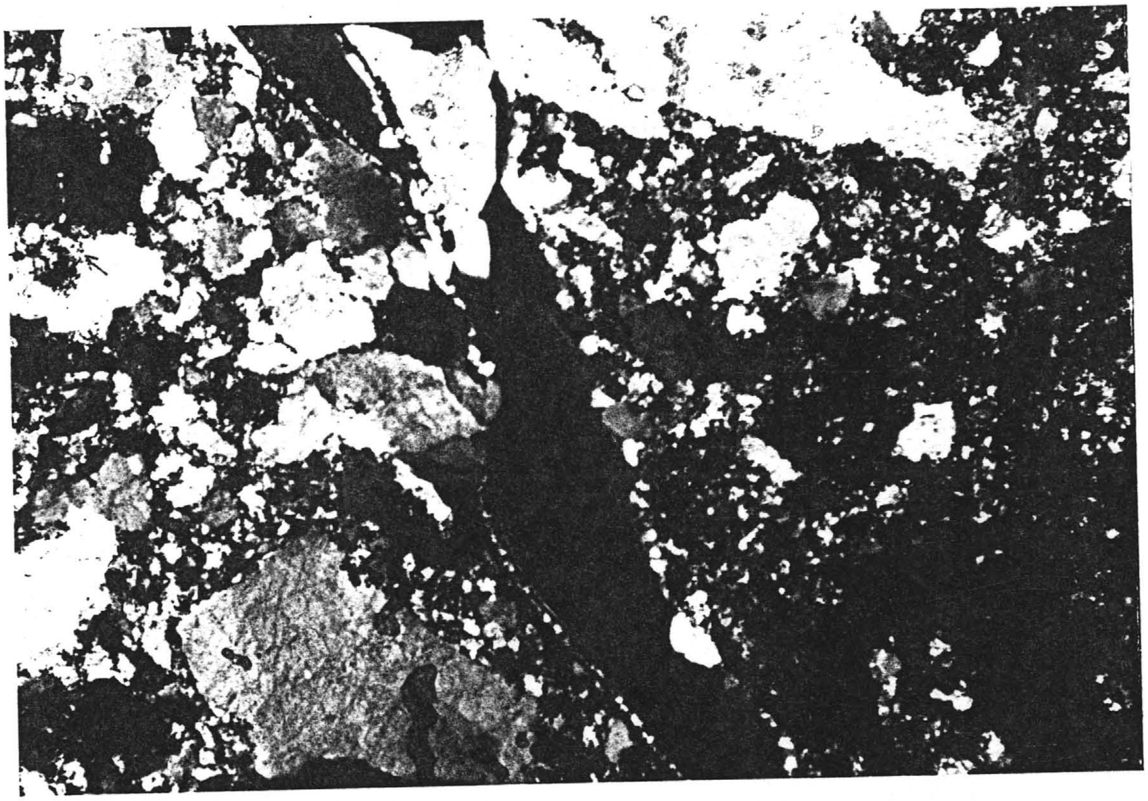


Plate 15 Slide 311'. Quartz filling fractures and vugs. Some quartz is altering to fine-grained quartz (arrow). 20 X, XN



316'

Modal Analysis

Quartz - 80 % Fine-grained, 45 %

Coarse-grained, 35%

Hematite/Limonite - 20 %

Porosity - 20 %

Description

This slide is dominated by quartz which ranges in size up to .4mm and averages .2mm. There is very little fine-grained quartz matrix and coarse-grained clasts. The quartz has sutured boundaries, hexagonal and anhedral form, undulose extinction and commonly hematitic overgrowths. Numerous vugs are being filled by quartz and some quartz is decaying to fine-grained quartz. The hematite is very fine-grained, fibrous and occurs as overgrowths and rimming quartz. Iron staining occurs around some quartz grains. Some hematite is quite yellow, this is likely limonite.

No positive identification of gold, sulphides or other ore minerals. Some possible anhedral sulphides were seen in association with coarse-grained quartz and hematite.

321'

Modal Analysis

Quartz - 85 % Fine-grained 55%

Coarse-grained 30%

Hematite/Limonite - 15 %

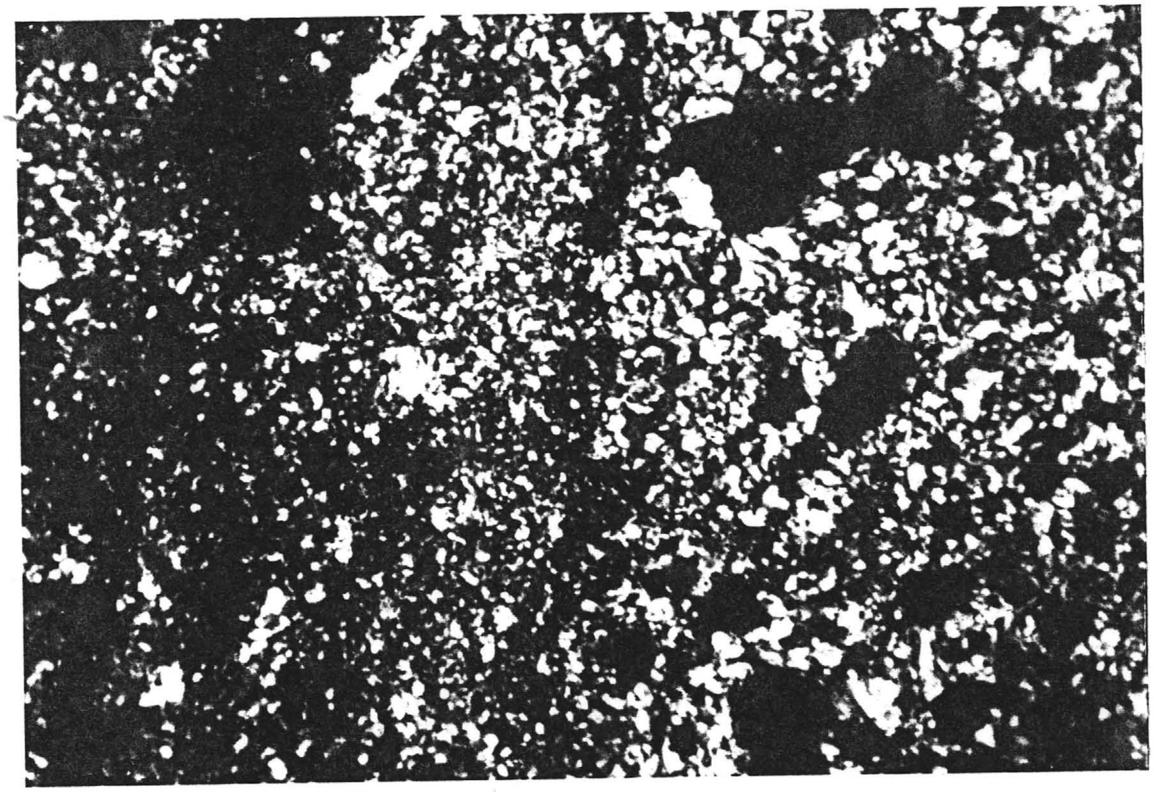
Porosity - 10 %

Description

This slide is dominated by fine-grained quart z with limonitic overgrowths. Quartz grains are up to .4mm but average .1mm. Coarse-grained quartz tends to be concentrated in pods or pockets commonly surrounding vugs. These coarse grains also have sutured boundaries, undulose extinction and can be banded. Quartz also occurs as discontinuous veinlets where it is commonly hexagonal. Coarse-grained quartz is intergrown with fine-grained quartz and appears altering or crumbling to the fine-grained quartz. Some bedding features have been preserved in this slide. Beds consist of alternating fine-grained and coarse-grained quartz and less frequently coarse-grained quartz with hematite (Plate 16). Hematite and limonite are very fine-grained and are most commonly associated with concentrations of coarse-grained quartz.

Fine-grained sulphides are possibly associated with coarse-grained quartz and the vugs. No positive identification of gold, sulphides or other ore minerals.

Plate 16 Slide 321'. Possible bedding, banded quartz and numerous vugs. 20 X, XN



Drill Hole 806-1

486'

Modal Analysis

Quartz - 90 % Fine-grained, 50 %

Coarse-grained, 40 %

Hematite - 10 %

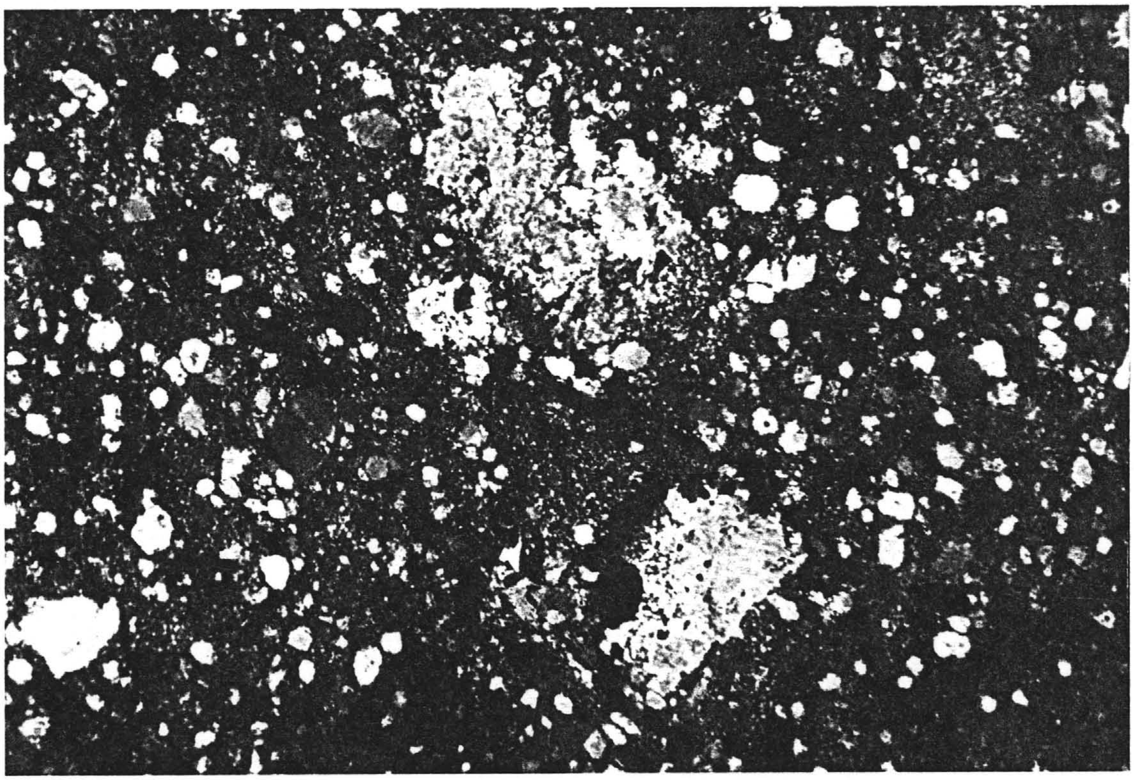
Porosity - 5 %

Description

This slide is predominantly a fine-grained quartz matrix and coarse quartz clasts (Plate 17). The quartz clasts range from .1 - .3 mm and average .2 mm . Quartz grain boundaries are commonly serrated and tend to be altering to fine-grained quartz (Plate 17). The quartz clasts are generally round and contain numerous inclusions. The slide is matrix supported but in areas, clast supported. Quartz veinlets are present and the vein quartz is anhedral with sutured boundaries. Hematite and limonite are fine-grained and occur as stingers and throughout the fine-grained quartz matrix.

No positive identification of gold, sulphides or other ore minerals. Sporadic occurences of a fine-grained, very reflective, anhedral mineral were present associated with fine-grained limonite and quartz surrounding the quartz clasts. Rarely, this mineral was present overprinting quartz clasts.

Plate 17 Slide 486'. Fine grained quartz matrix with coarse quartz clasts. Coarse quartz is altering to fine-grained quartz. 20 X, XN



515'

Modal Analysis

Quartz - 80 % Fine-grained, 40 %

Coarse-grained, 40 %

Hematite - 20 %

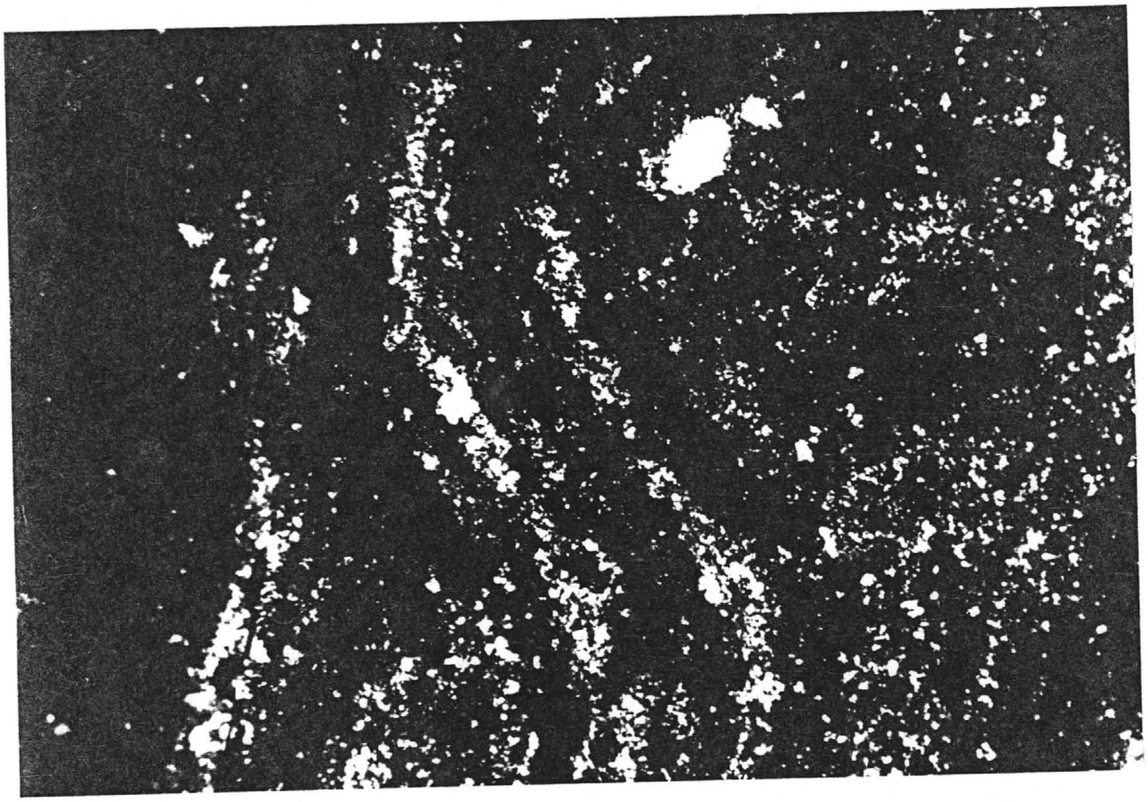
Porosity - 10 %

Description

This slide is predominantly fine-grained and coarse-grained quartz with one region rich in hematite and limonite. Quartz vary in size up to .7mm and average .1mm . Pods of very fine-grained quartz are present rimmed by hematite. Coarse-grained quartz is intergrown with fine-grained quartz and appears to be altering to it . The hematite-rich portion of the slide appears bedded with alternating beds of fine-grained quartz and hematite (Plate 18). The beds are generally .1mm wide and are slumped and disrupted (Plate 18). The hematite and limonite are very fine-grained and amorphous.

Positive identification of gold, sulphides or ore minerals was not possible. Several grains of electrum are tentatively identified in the hematite/limonite-rich beds. The suspected electrum is anhedral to euhedral and averages .02mm .

Plate 18 Slide 515'. Beds of hematite and quartz. This may also be soft sediment deformation as the beds commonly pinch and swell. 20 X, PPL



517'

Modal Analysis

Quartz - 90 % Fine-grained, 80%

Coarse-grained, 10%

Hematite - 10 %

Porosity - 10 %

Description

This slide is dominated by fine-grained quartz matrix and hematite stringers (Plate 19). The quartz matrix is very fine-grained and coarser quartz averages .4mm . Coarse-grained quartz is commonly elongate, associted with vugs, and is intergrown with fine-grained quartz (Plate 20). The coarse-grained quartz appears to be altering to the fine-grained quartz. Elongate quartz also has undulose extinction. Coarse-grained, hexagonal quartz is present at the rims of pods of fine-grained quartz. Hematite/limonite overgrowths on coarse-grained quartz are common.

Stringers of hematite and limonite have brecciated the fine-grained matrix (Plate 21). The hematie and limonite are commonly fine-grained.

Evidence of minor faulting is present in this slide (Plate 22). A small dextral fault with an offset of approximately .5mm is displacing fine quartz veinlets. The trend of the fault is roughly 310 when the top is properly aligned. Beyond the fine-grained quartz, the fault is obscured by hematite.

Aggregates of fine-grained tentatively identified electrum are present in the hematite-limonite-rich areas. These grains are generally anhedral. Gold, sulphides or ore minerals were not indentified.

Plate 19 Slide 517'. Fine-grained quartz and hematite stringers. Coarse-grained quartz is present as are numerous vugs. 20 X, XN

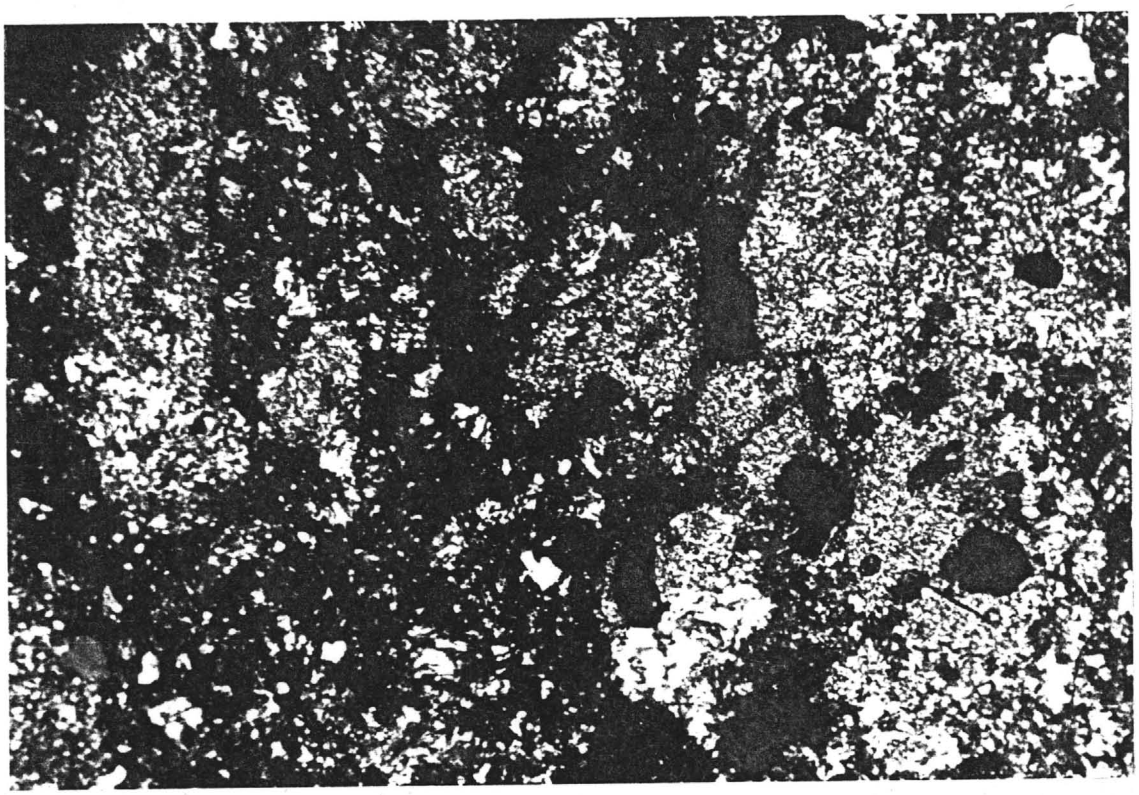


Plate 20 Slide 517'. Coarse, elongate quarrtz in a fine-grained quartz matrix. The ends of the elongate quartz are altering to fine-grained quartz. 20 X, XN

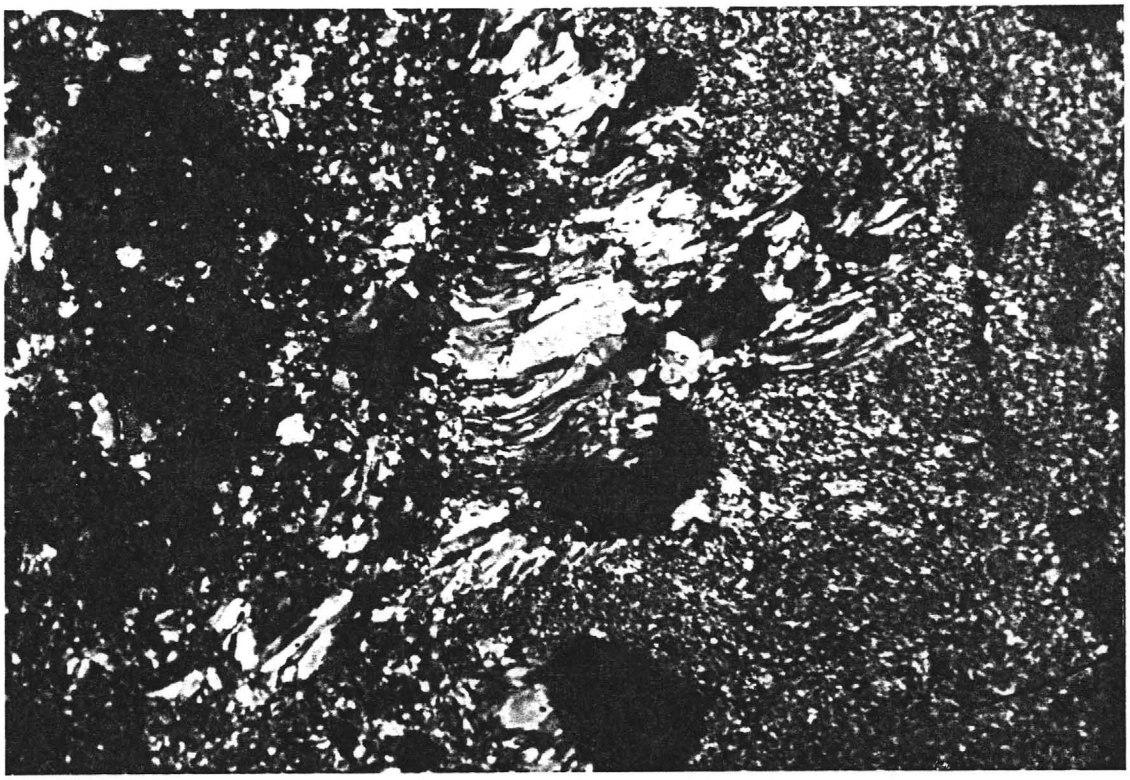


Plate 21 Slide 517'. Stringers of hematite and limonite brecciating the slide. Note regions in the fine-grained clasts are coarse-grained. The dark shadows are the slide numbers. 20 X, XN

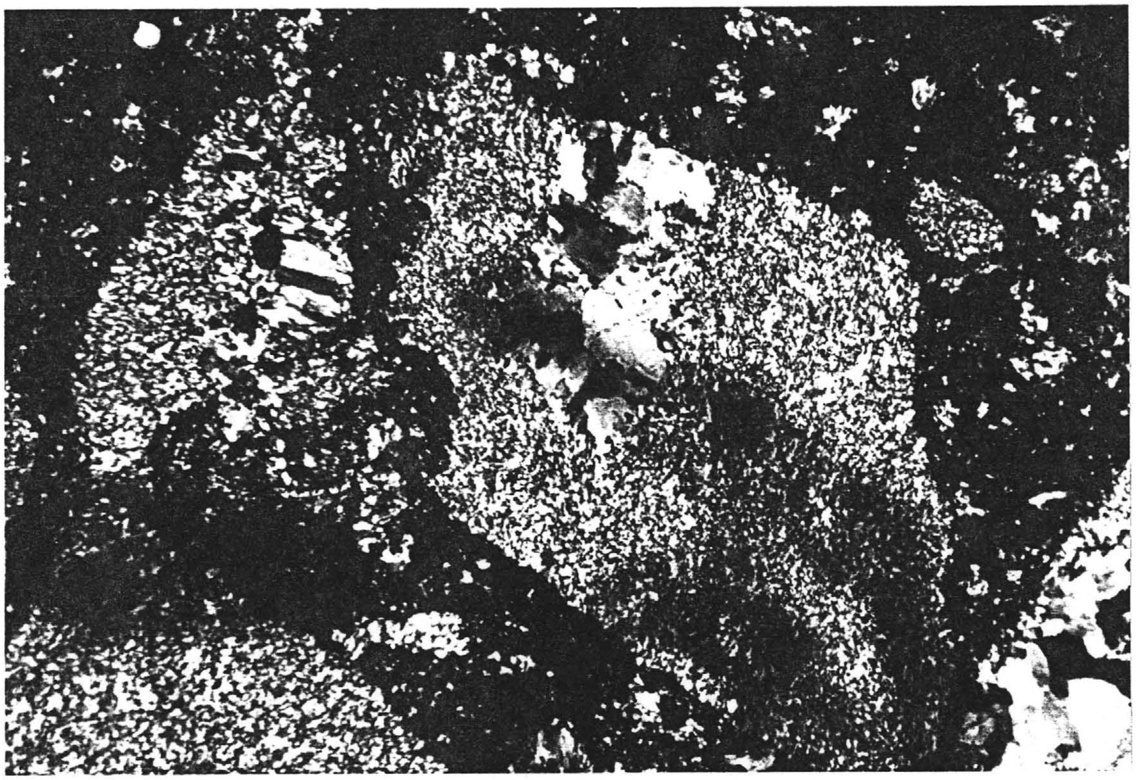
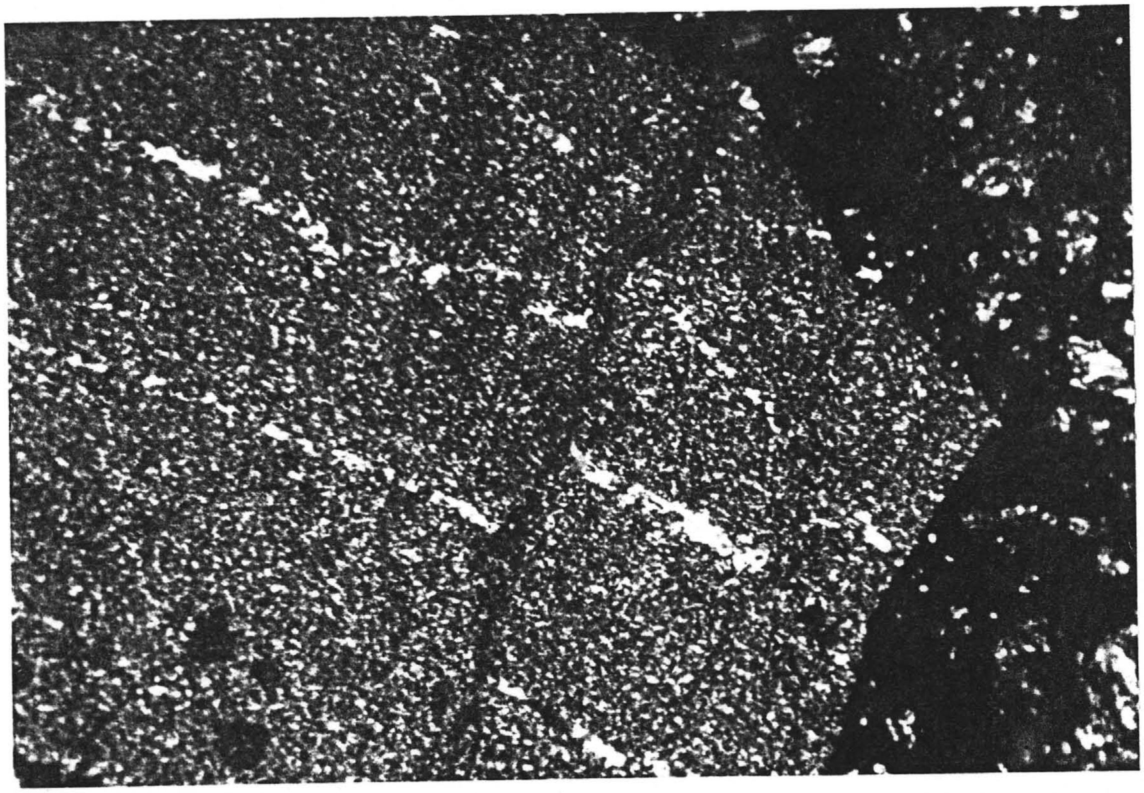


Plate 22 Slide 517'. Fault through a large clast of fine-grained quartz. The offset is approximately .5mm . 20X XN



533'

Modal Analysis

Quartz - 90 % Fine-grained, 80%

Coarse-grained, 10%

Hematite - 10 %

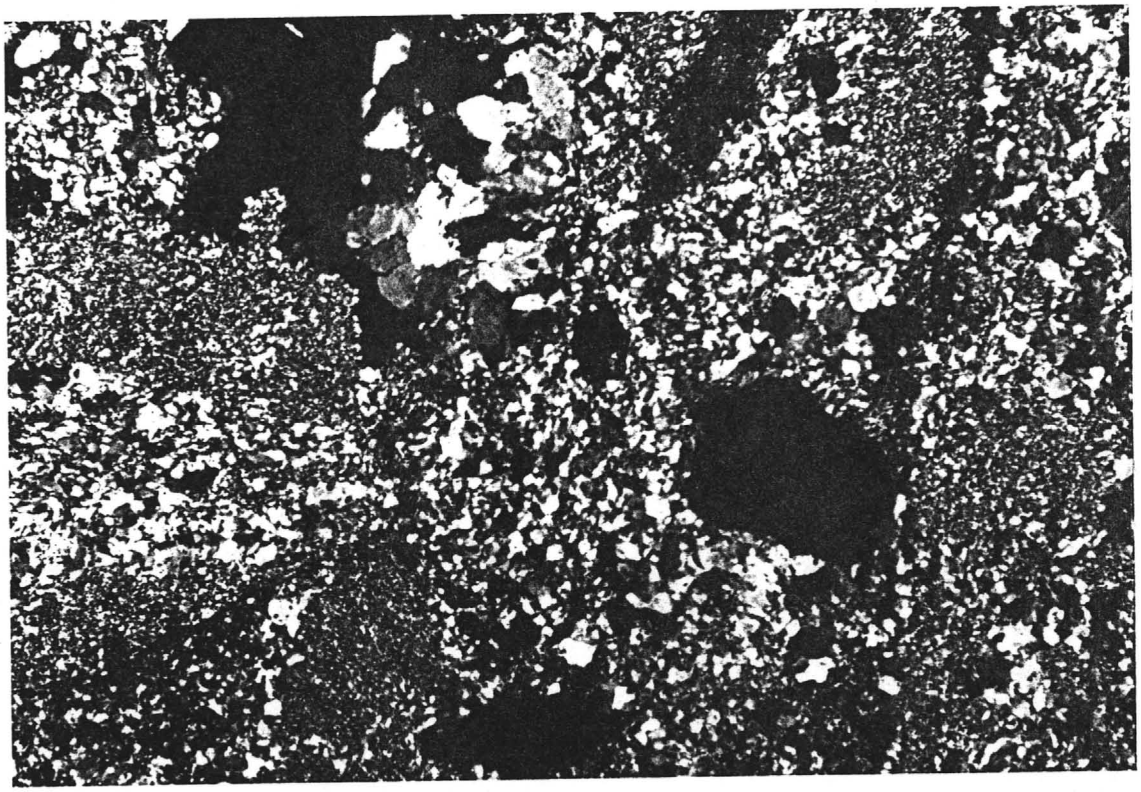
Porosity - 20 %

Description

This slide is dominated by fine-grained quartz with larger quartz clasts, hematite and numerous vugs (Plate 23). Numerous quartz veinlets and concentrations of coarse-grained quartz are present. Veinlets range to .8mm wide and several millimeters long. Coarse-grained quartz in concentrations average .3 mm, have sutured grain boundaries, occassionally 120 interfacial angles. The concentrations of coarse-grained quartz are up to 2mm in diameter. Quartz is also filling vugs (Plate 21). Vugs are rimmed by fine-grained hematite and limonite. Hematite and limonite also occur as fine stringers. There may be some potassic feldspar present. The optic sign was definitely biaxial but quartz can also have a biaxial optic sign.

No positive identification of gold, sulphides or ore minerals. Tentatively identified electrum occurs sporadically in the hematite rich areas.

Plate 23 Slide 533'. Fine-grained quartz, large quartz clasts and numerous vugs. Note the quartz infilling the vugs. 20 X, XN



547'

Modal Analysis

Quartz - 90 % Fine-grained, 65%

Coarse-grained, 25%

Hematite - 10 %

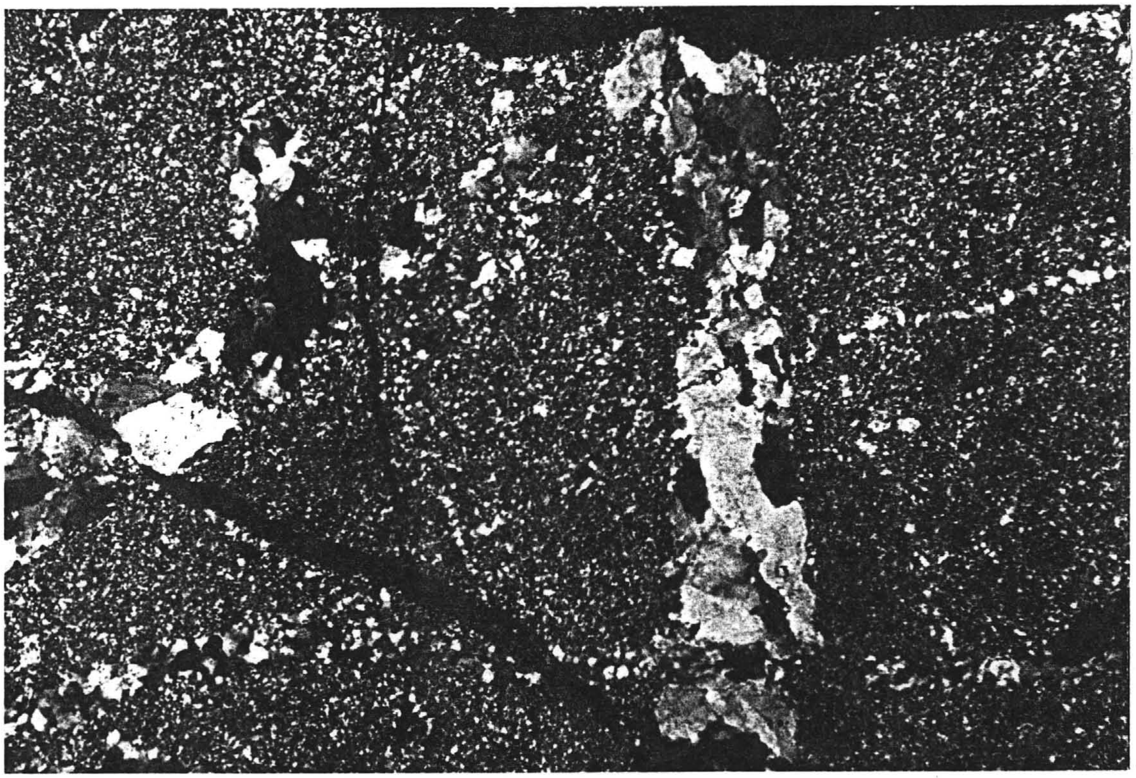
K-Feldspar - < 1 %

Description

This slide is predominantly fine-grained quartz with pods and veinlets of coarse-grained quartz. The quartz-grains have sutured boundaries, undulose extinction, can be banded and are commonly intergrown with finer-grained quartz. Veinlets .5 mm wide cross-cut the entire Veinlets trend in all directions and some coarse-grained quartz is filling vugs (Plate 24). Little hematite is found in the fine-grained quartz matrix. It tends to occur in veinlets, and commonly rims the pockets of coarse-grained quartz.

No positive identification of gold, sulphides or ore minerals. Possible sulphides are present in the coarse-grained quartz and hematite however these are very infrequent.

Plate 24 Slide 547'. Fine-grained matrix of quartz, veinlets of coarse-grained quartz and vugs and fractures. 20 X, XN



554'

Modal Analysis

Hematite - 60 %

Quartz - 40 % Fine-grained, 25%

Coarse-grained, 15%

Description

This slide is predominantly fine-grained hematite and limonite with clasts of fine-grained quartz. Coarse-grained quartz is present in the hematite-rich areas commonly with undulose extinction and sutured grain boundaries. Clasts are extensively brecciated by stringers of hematite and limonite (Plate 25). Frequently, these clasts are partially coarse-grained quartz undergoing grain-size reduction. Coarse quartz grains have limonite overgrowths and some clasts have extensive iron staining which is directly related to the amount of brecciation. Clasts vary up to 8 mm in size.

Hematite and limonite is fine-grained and brecciates the entire slide. Some hematite is orangish-red and displays fine banding and appears to be folded in one instance (Plate 26). This banded hematite is cross-cut by minute veinlets of darker hematite. No positive identification of gold, sulphides or other ore minerals. Sporadic occurrences of possible fine-grained sulphides are in the hematite.

Plate 25 Slide 554'. Limonite-stained clast of fine-grained quartz brecciated with hematite and coarse-grained quartz. Some fragments appear to fit onto the main clast. 20 X, PPL

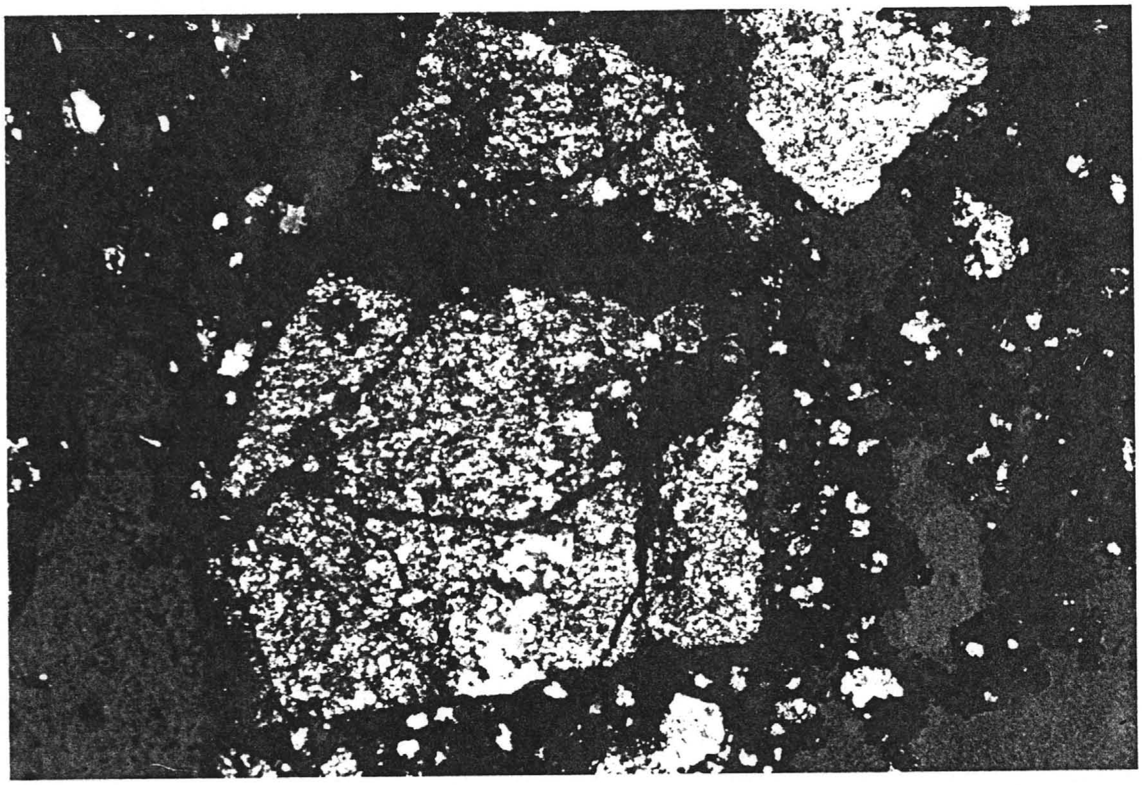
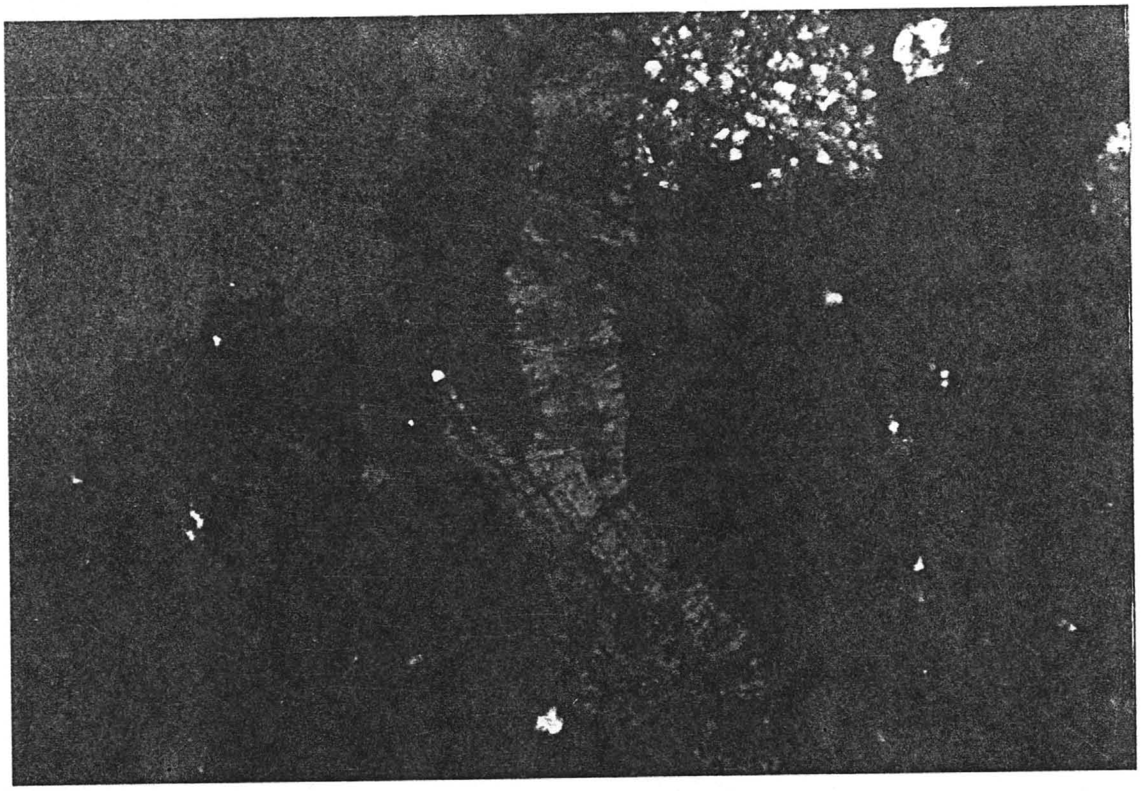


Plate 26 Slide 554'. Colloform hematite with fine banding and fractures. 80 X, X nicols.



577'

Modal Analysis

Quartz - 95 % Fine-grained, 55%

Coarse-grained, 40%

Hematite - 5 %

Porosity - 15 %

Description

This slide is dominated by quartz varying up to 1.0 mm in diameter and averaging .1 mm . Fine-grained quartz occurs as pods or clasts while the coarser grained quartz is filling vugs and fractures. The coarser quartz has sutured grain boundaries, undulose extinction and rarely 120 interfacial angles. The coarser quartz also has limonite overprints and when it occurs as clasts, is commonly bisected by fine-grained quartz.

Hematite is fine-grained and commonly associated with vugs and porosity.

No positive identification of gold, sulphides or ore minerals. Sporadic reflections are present in the coarse-grained quartz and hematite and may be fine sulphide minerals.

Conde

ALTERATION OF THE DIORITE SILL,
U.V.X. MINE,
JEROME, ARIZONA

by

STEPHEN G. HARDING

Submitted in partial fulfillment of
the requirements for the degree of
Honours Bachelor of Science

Department of Geology
The University of Western Ontario
London, Ontario

April, 1987

ABSTRACT

A diorite sill intrudes brecciated gold-bearing chert flanking the base metal massive sulphide deposit in the United Verde Extension Mine, Jerome, Arizona. The diorite has three distinct assemblages of secondary minerals: 1) kaolinite-chlorite epidote in the centre of the diorite, with kaolinite pseudomorphing plagioclase, and epidote and chlorite pseudomorphing amphibole and biotite; 2) kaolinite-sericite-chlorite grading to kaolinite-sericite in broken plagioclase grains in the margins of the sill; 3) fine grained kaolinite and quartz with no relict feldspar or mafic minerals at the edge of the sill. Hematite on fracture planes increases outward from the centre to edge of the diorite sill. Native copper occurs along fracture planes in the centre.

The secondary mineral assemblages represent hydrothermal alteration of the diorite by fluids convected and discharged by the cooling diorite sill during emplacement into a marine volcanic succession. This is essentially hydration of the main mass of the sill by pervasive intake of sea water, and focused silification at its edges by expulsion of that sea water modified by its convection through the sill. Later downward percolation of meteoric water extended the distribution of clay minerals and deposited hematite and native copper in fractures. Localization of gold in fractured chert bordering the diorite may represent optimum focus of the hydrothermal fluid flow which altered the sill.

ACKNOWLEDGMENTS

This study was made possible by D. C. White, Consulting Geologist at the United Verde Extension Mine. He provided the topic, drill core samples, and cross sections and plan views of the mine. We are very grateful to Mr. White and A. F. Budge (Mining) Ltd. for the opportunity to work on this project.

Many thanks are extended to Dr. R. W. Hodder, thesis advisor, for introducing the topic and providing helpful suggestions and criticisms during the course of the study.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of Purpose

Gold at the United Verde Extension Mine is concentrated in brecciated chert which is both hanging wall and footwall to a diorite sill at the edge of a base metal massive sulphide deposit. The purpose of this thesis is to describe the mineral assemblages and texture of the sill and to interpret the nature of these assemblages and textures with respect to regional metamorphism, hydrothermal alteration, and weathering, as one way to assess the role of the diorite sill in localization of gold in adjacent chert.

1.2 Location and Access

The U.V.X. Mine is in the Verde mining district on the immediate east edge of the Jerome townsite, Yavapai County, Arizona (Figure 1). It is one quarter mile east of the United Verde Mine and on the downthrown side of the Verde Fault. Jerome can be reached by Highway 89A from Flagstaff to the north and Prescott to the west. Present access to the diorite sill is by the 800 and 950 levels off the Edith Shaft.

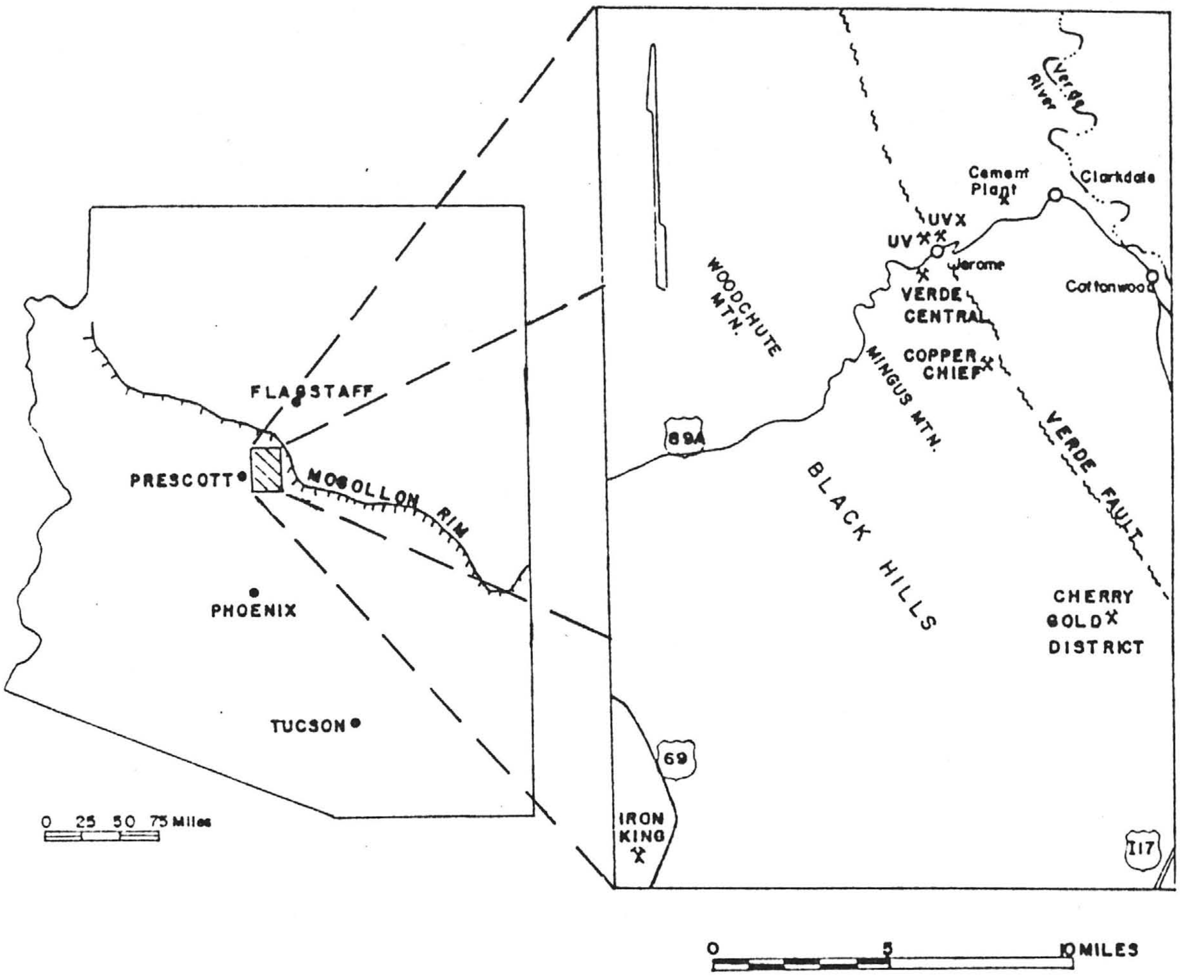


Figure 1. Location map of the U.V.X. Mine.
(from Armstrong and Handverger, 1986)

1.3 Mine History

The U.V.X. Mine was initially discovered by J.S. Douglas and G. Tener in 1914 when they sank a shaft and drifted in the hanging wall of the Verde Fault searching of an off-faulted part of the United Verde ore body (Anderson and Creasey, 1958). The mine originally exploited a high grade deposit of chalcocite and cuprite from 1915 to 1938 yielding 3.9 million short tons of 10.2% Cu, 0.04 oz/t Au, and 1.7 oz/t Ag (White, 1986). The gold came principally from one high grade silica-rich area referred to as the "Gold Stope" which produced about 35,000 tons of 0.4 oz/t Au and 2.0 oz/t Ag (White, 1986). The mine closed in 1938 when the copper deposit was exhausted.

Recent exploration was carried out by Phelps Dodge from 1981 to 1983. Current work has been done by DMEA Ltd. for A. F. Budge (Mining) Ltd. and has concentrated on sampling gold occurrences on either side of the diorite sill which separates gold bearing chert flanking the previously mined base metal deposit (White, 1986). The "Gold Stope" is within this chert.

1.4 Previous Work

Early geologic work in the Jerome area is summarized by Anderson and Creasey (1958). They provide a detailed account of rock types, structure and base metal massive sulphide deposits, and conclude the ore bodies are epigenetic. Anderson and Nash (1972) reinterpreted the data in view of exhalative hypotheses and concluded the ores are syngenetic. Norman (1977) subsequently returned to a hydrothermal replacement model. Recent work in the Jerome area by Lindberg (1986) and Armstrong and Handverger (1986) supports syngenesis followed by deformation. Present work on gold distribution in the U.V.X. Mine is reported by D. C. White (1986).

1.5 Methods of Study

Core samples were taken from five drill holes which cut various sections of the diorite sill from the 800 and 950 levels off the Edith Shaft (Figure 2). Thin sections were made from these samples at regular intervals across the sill. Mineral assemblages and textures were examined for variation and X-ray diffraction was used to determine the clay and mica compositions in some samples. Two samples were stained with a mixture of alizarin red and potassium ferro-cyanide to determine carbonate mineral composition.

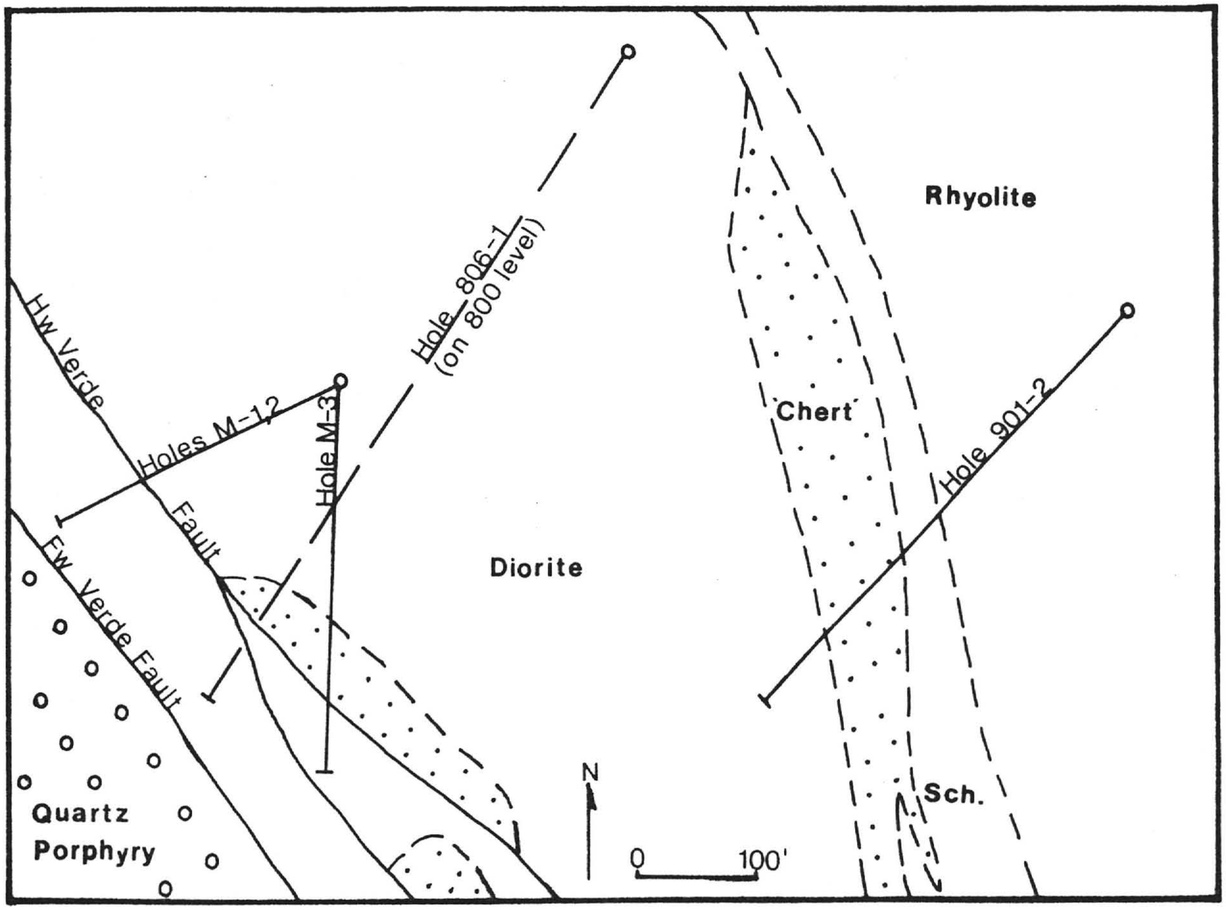


Figure 2. Plan view of the 950' level of the U.V.X. Mine showing sample locations. (modified from White, 1986)

CHAPTER TWO

REGIONAL GEOLOGY

2.1 Geology of the Jerome Area

Jerome and the Verde Mining District are in the Transition Zone between the Mogollon Rim of the Colorado Plateau to the northeast, and the Basin and Range to the southwest (Figure 3). The rocks are a volcanic-plutonic complex of early Proterozoic age (Armstrong and Handverger, 1986).

The oldest rocks are those of the Ash Creek Group which are 20,000 feet of volcanic and volcaniclastic strata (Anderson et al., 1971). The base is Gaddes Basalt, overlain by Buzzard Rhyolite which is succeeded and interfingered with Shea Basalt and Deception Rhyolite. The Deception Rhyolite has several divisions, with a basal andesite breccia, chloritic rocks, breccia, Cleopatra Quartz Porphyry and Upper Deception Rhyolite. The U.V.X, United Verde, and several smaller ore bodies are within Deception Rhyolite. The Grapevine Gulch Formation overlies Deception Rhyolite and the ore bodies and is volcaniclastic and epiclastic rocks, cherts, dacite flows, and hypabyssal intrusive rocks. Mafic sills intrude into this layered sequence and all of these rocks are in the greenschist facies of

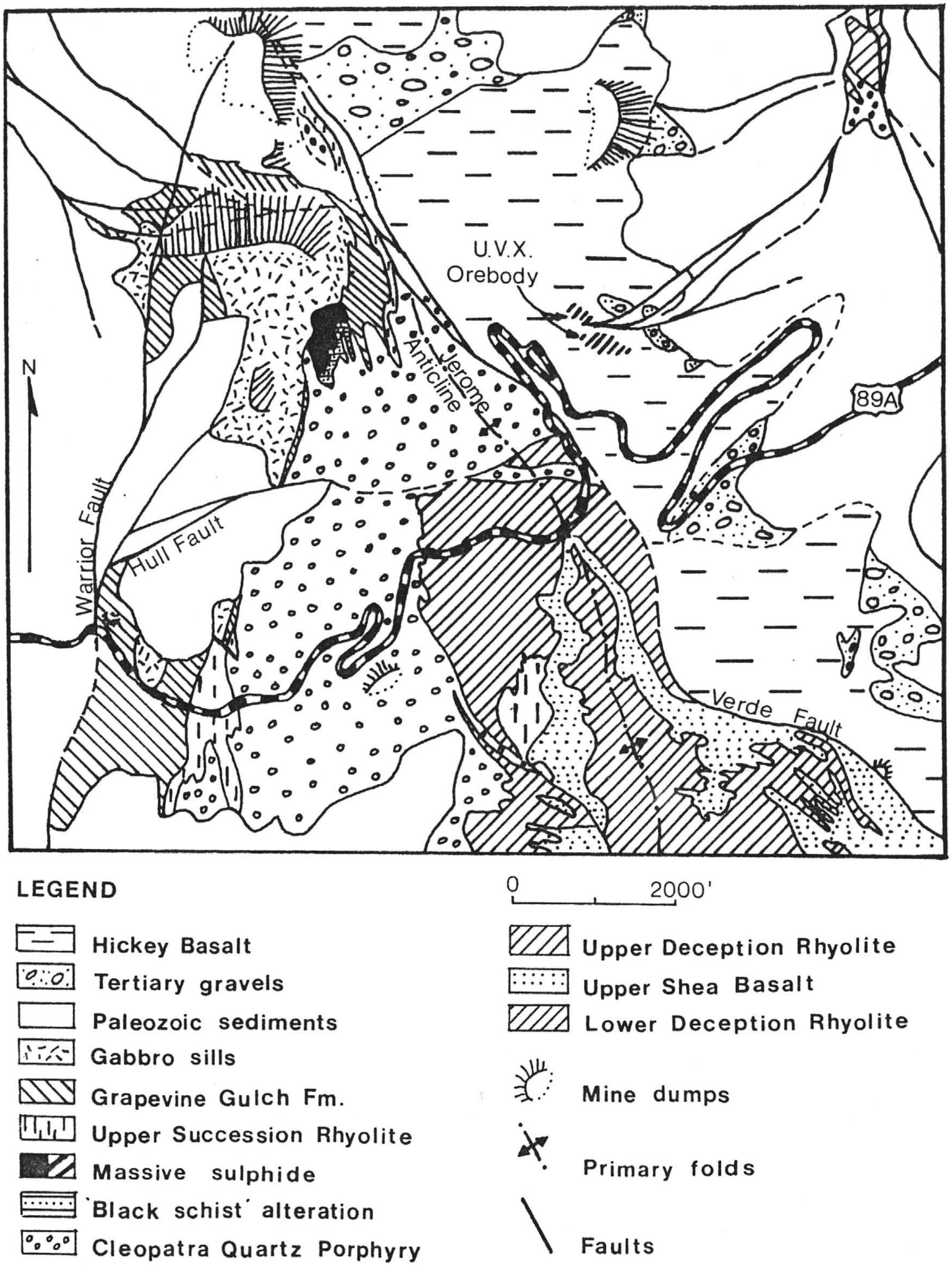


Figure 3. Geology of the Jerome area.
(modified from Lindberg, 1986)

regional metamorphism (White, 1986).

Some faults are pre- and syn-folding and associated with growth of the volcanic rock sequence (Lindberg, 1986). One such fault is the Verde Fault (Figure 3) which flanks the U.V.X. and U.V. ore bodies. Proterozoic rocks have polyphase folds with the major folds trending north-northwest (Lindberg, 1986) as in the Jerome Anticline (Figure 3). Smaller cross folds trend east-northeast.

A major unconformity marks the boundary between Proterozoic and Paleozoic rocks. The latter are mainly sandstone and dolomite. Above these, there is another unconformity overlain by Tertiary gravels and conglomerates, and the Hickey Basalt. Phanerozoic faulting occurred in two stages. The first was high angle reverse faulting associated with Larimide uplift from Late Cretaceous to Eocene, and the second is normal faulting which started in the Miocene and continues to the present (Lindberg, 1986).

2.2 Place of Diorite in the U.V.X. Mine

Diorite of the U.V.X. Mine is on the hanging wall side of the Verde Fault and bordered by brecciated chert which coalesces to the south and with depth (Figure 4). The diorite appears sill-like and is folded with the surrounding rocks, and unconformably overlain by Tertiary conglomerates.

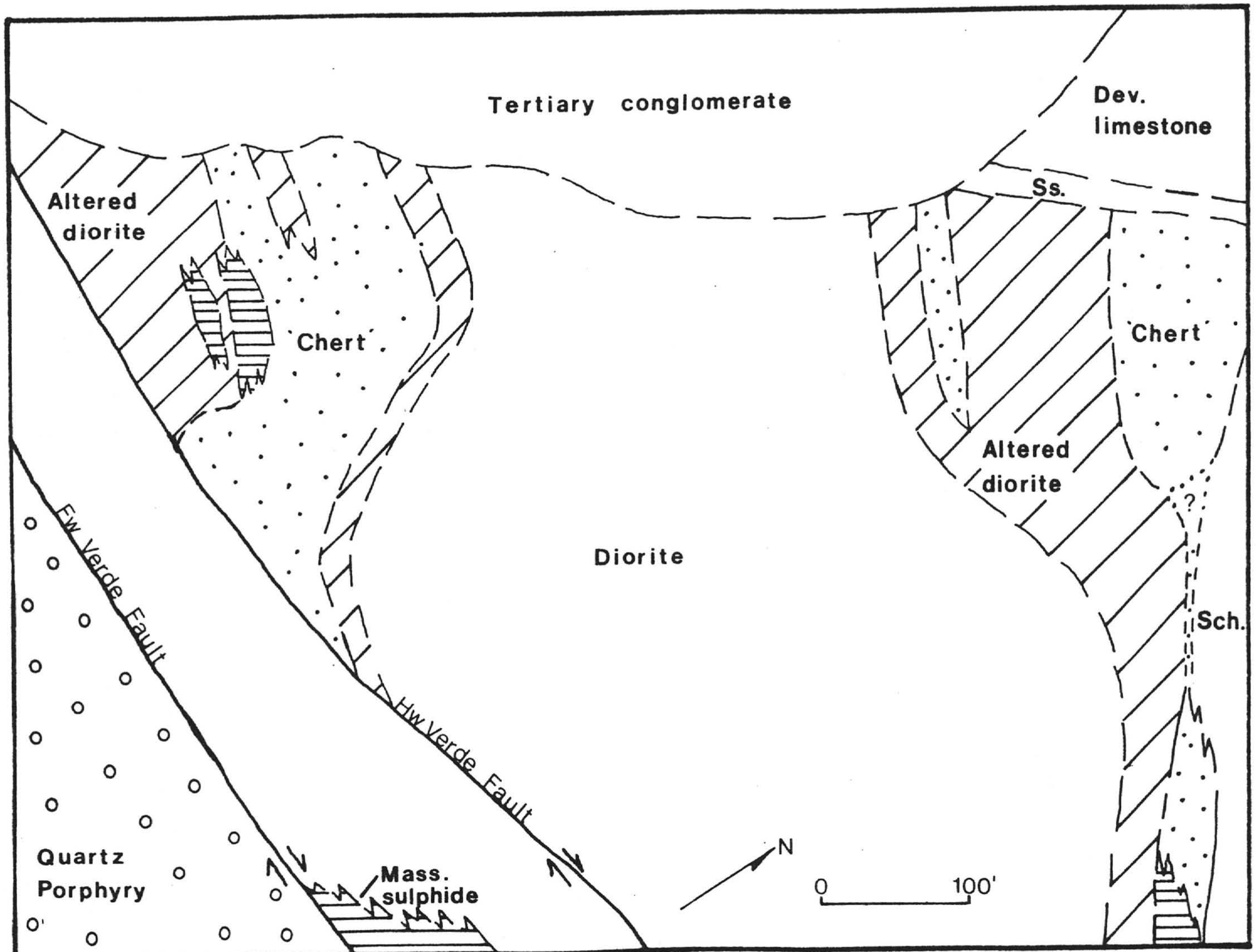


Figure 4. Cross-section of the U.V.X. Mine. (modified from White, 1986)

2.3 Ore Bodies

The base metal massive sulphide deposit of the U.V.X. Mine is lens-shaped, trending eastward and thinning with depth (Anderson and Creasey, 1958). It is within Cleopatra Quartz Porphyry, and a limited part of the Grapevine Gulch Formation (Anderson and Nash, 1972). Ore minerals are chalcocite and cuprite and the consensus is that Proterozoic chalcopyrite was converted to chalcocite by supergene enrichment during the Tertiary (Lindberg, 1986). The diorite sill wedges against the massive sulphide body. Diorite is associated spatially with all of the major ore bodies in the district.

The U.V.X. Mine workings include the "Gold Stope", 500 feet southwest of the Edith Shaft and a few hundred feet northeast of the massive sulphide body. This is in brecciated chert and is approximately 150 feet high, 350 feet long, and 15 feet thick, bounded by diorite to the southeast and to the northwest by manganiferous, cherty ironstone of the Grapevine Gulch Formation (White, 1986). Current exploration is directed toward locating more of these gold concentrations which appears to be in quartz-healed fractures in chert clasts, and possibly in the siliceous limonitic matrix as a fine disseminated native metal, with or without electrum (White, 1986).

CHAPTER THREE

THE DIORITE SILL

3.1 General Statement

Samples of diorite were taken from core in five drill holes which collectively penetrate the diorite sill and both hanging wall and footwall cherts (Figure 2). The diorite is described from the centre, or least altered part outward to the most altered part bordering the chert. Drill hole 806-1 is used as a reference for location of samples through its variable thickness of approximately 200 to 600 feet.

3.2 Mineral Assemblages and Textures

The centre of the diorite is light grey-green in colour with flecks of red. Sample 806-1-300 (Figure 2) is typical with 25% original plagioclase of Ab_{68} in grains up to 2.0 mm long, some of which have albite twinning (Plate 1A). These grains are partly filled with kaolinite. Chlorite is approximately 20% of the rock, as small anhedral grains filling in between plagioclase and in relict mafic minerals. Figure 5 shows the variation in modal abundance of kaolinite and chlorite, as well as sericite along hole 806-1. Epidote, 20%, is in anhedral grains, 0.2 mm in

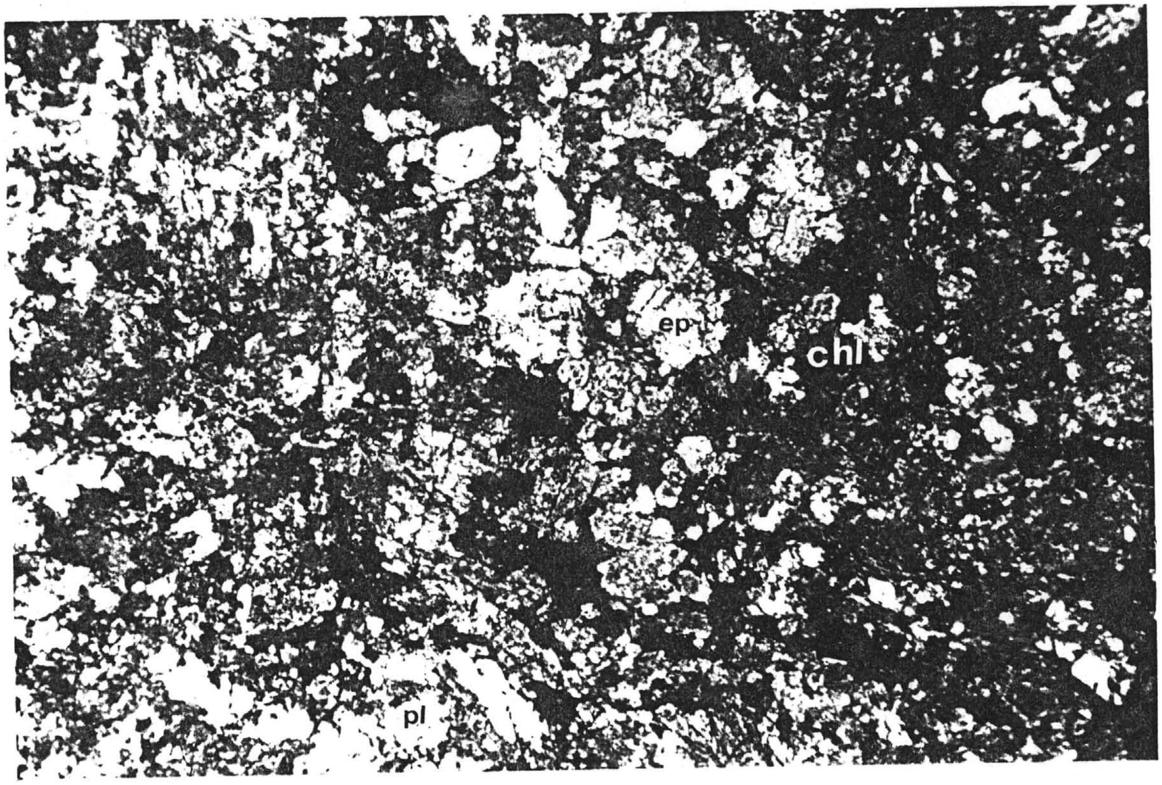
DESCRIPTION

Plate 1A Plagioclase, with epidote and chlorite pseudomorphing amphibole and biotite. Crossed-polars. (X 4)

Plage 1B Plagioclase partly occupied by kaolinite, surrounded by fine grained kaolinite and chlorite. Crossed-polars.(X 4)

PLATE 1

A



0.37mm

B

0.37mm

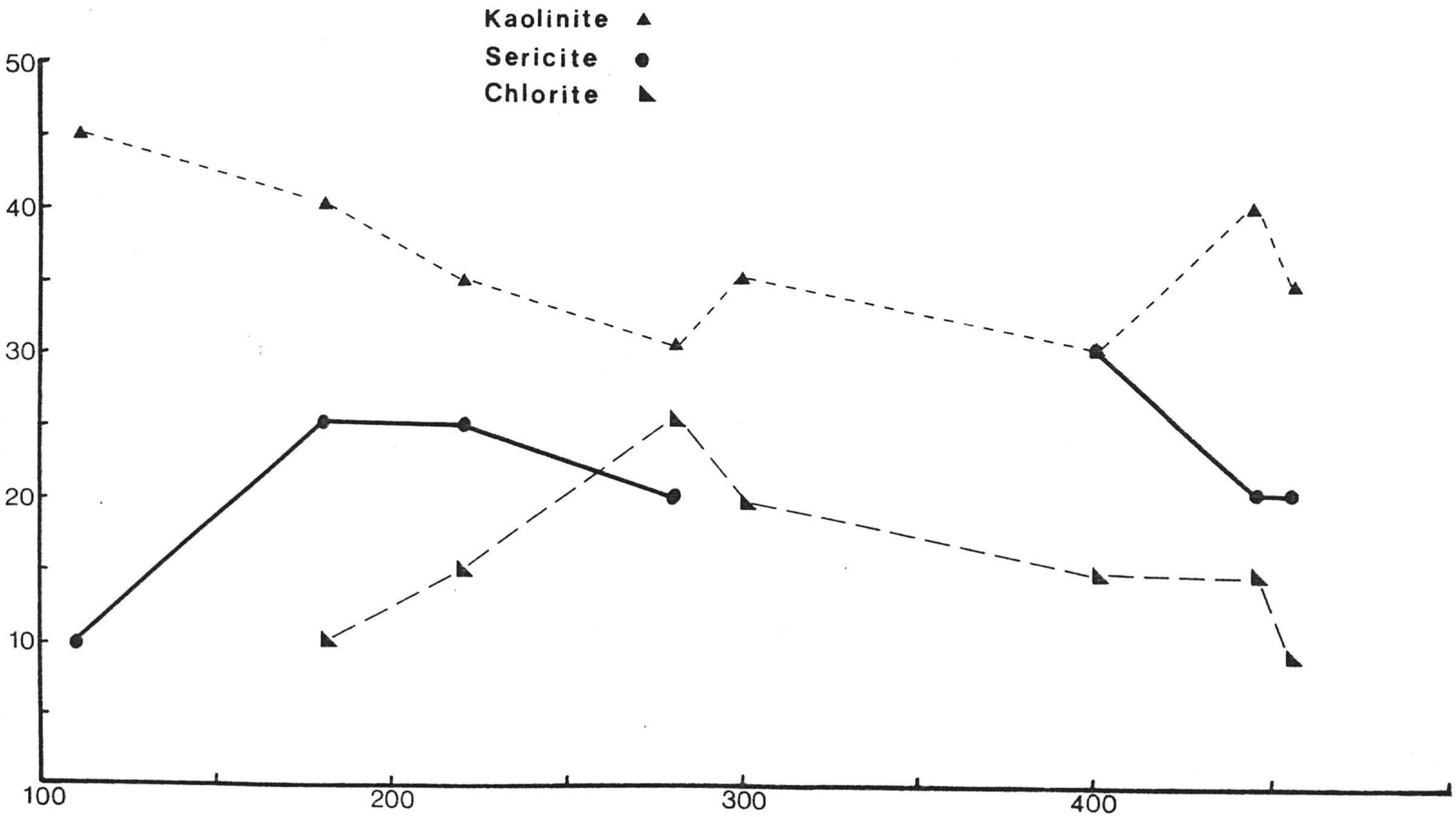


Figure 5. Graph of selected mineral abundances along Hole 806-1.

diameter, which are grouped together, within what is probably relict amphibole, and usually it is associated with chlorite (Plate 1A). Approximately 35% of the sample is fine grained kaolinite. Leucoxene, 5%, is in grains up to 1.0 mm in size and occupies sites of ilmenite. Sample 806-1-300 also contains minor amounts of anhedral carbonate, quartz, and feldspar. There is a trace of hematite in tiny veinlets.

Sample 901-2-300 is also typical of the centre of the diorite sill and has plagioclase grains which are subhedral to anhedral, up to 2.5 mm long, and fractured (Plate 1B). They have albite or carlsbad twins and are andesine in composition. Kaolinite partly occupies the plagioclase grains. There are some relict grains of a mafic mineral, probably an amphibole, which are 1.0 mm long and are completely epidote, chlorite, and kaolinite (Plate 2A). Chlorite, 20%, occurs as fracture fillings (Plate 2A) and this sample includes two veins, 2.5 mm wide, of chlorite, quartz and feldspar. Quartz and feldspar have sutured grain boundaries and 120° triple point junctions, and are fresh. The remainder of the sample is fine grained kaolinite and chlorite.

Twenty feet outward from the centre of the sill, kaolinite and chlorite increase to 35% and 25% respectively (Figure 5) and there is only a minor amount of epidote. In sample 901-2-270 plagioclase sites are almost completely

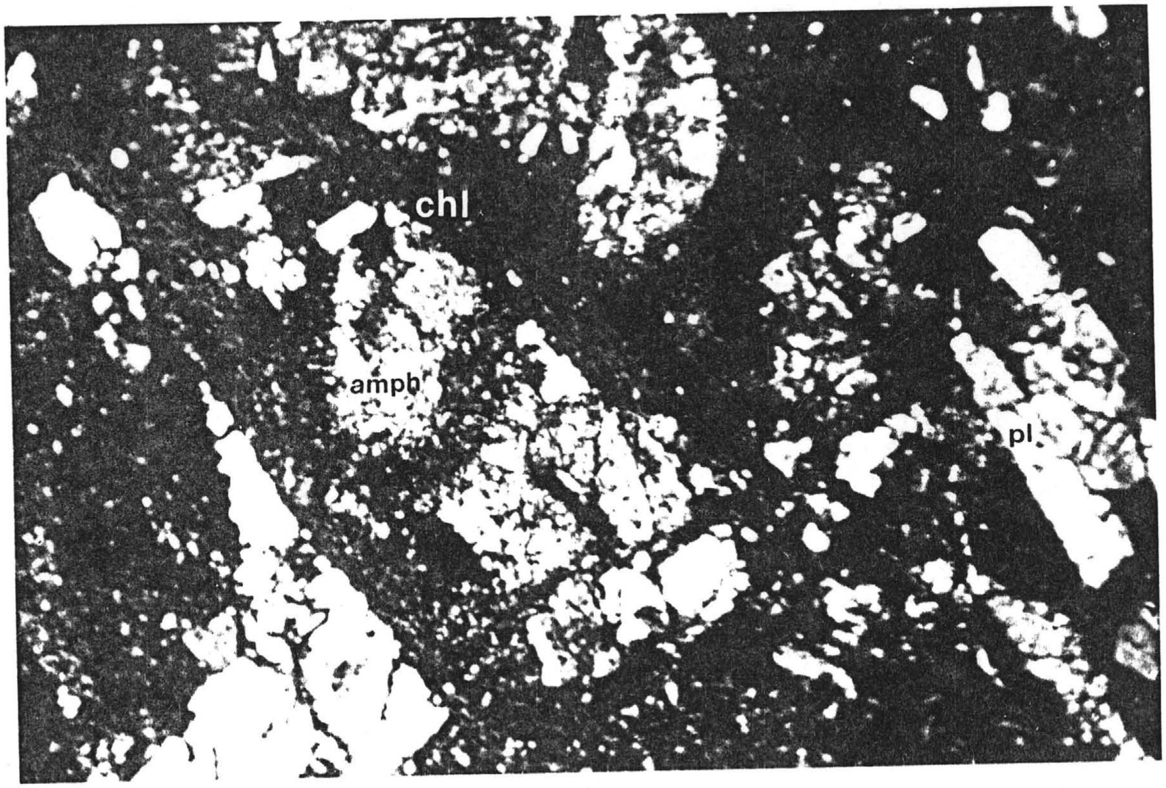
DESCRIPTION

Plate 2A Relict amphibole pseudomorphed by epidote, chlorite, and kaolinite. Chlorite in fractures. Crossed-polars.(X 4)

Plage 2B Plagioclase almost entirely pseudomorphed by kaolinite, and chlorite with a preferred orientation. PPL (X 4)

PLATE 2

A



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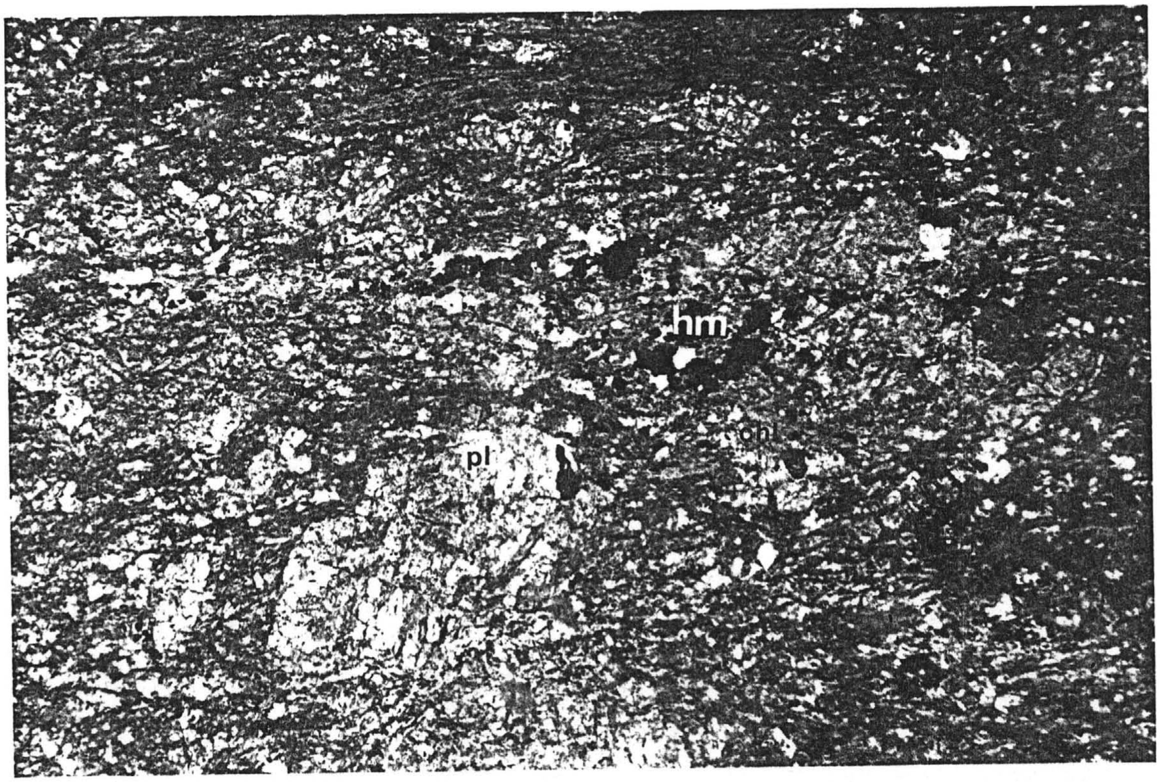
B



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occupied by kaolinite and trace sericite (Plate 2B). Chlorite is in elongate aggregates of grains with a preferred orientation (Plate 2B). This sample is cut by a 2.5 mm wide vein of hematite. Sample 806-1-280 is also representative of this part of the sill, and in it Kaolinite with minor sericite completely occupies plagioclase sites, although original grain boundaries are still visible (Plate 3A). Chlorite, 25%, is in fractures. Carbonate makes up 8% of the rock and is in very thin, discontinuous veinlets (Plate 3A), and in cavities up to 2.5 mm in diameter. Staining with a combination of alizarin-red and potassium ferrocyanide identifies carbonate in the veinlets as calcite with minor ferro-dolomite and carbonate in cavities as ferro-dolomite. Hematite, 5%, fills fractures and also stains the adjacent minerals. Leucoxene occurs throughout the rock pseudomorphing ilmenite (Plate 3B). Minor, very small, fresh quartz and feldspar grains are also present.

At approximately 100 feet outward from the centre of the sill kaolinite, sericite, and hematite increase to a total of 70%, chlorite decreases to 15% and carbonate minerals are absent. Sample 806-1-220 is typical of this part of the sill and contains 35% kaolinite and 25% sericite in predominantly relict plagioclase grains which are fractured and have indistinct grain boundaries (Plate 4A). Chlorite, 15%, occurs as very small anhedral grains between relict plagioclase, and along hematite veins. There is

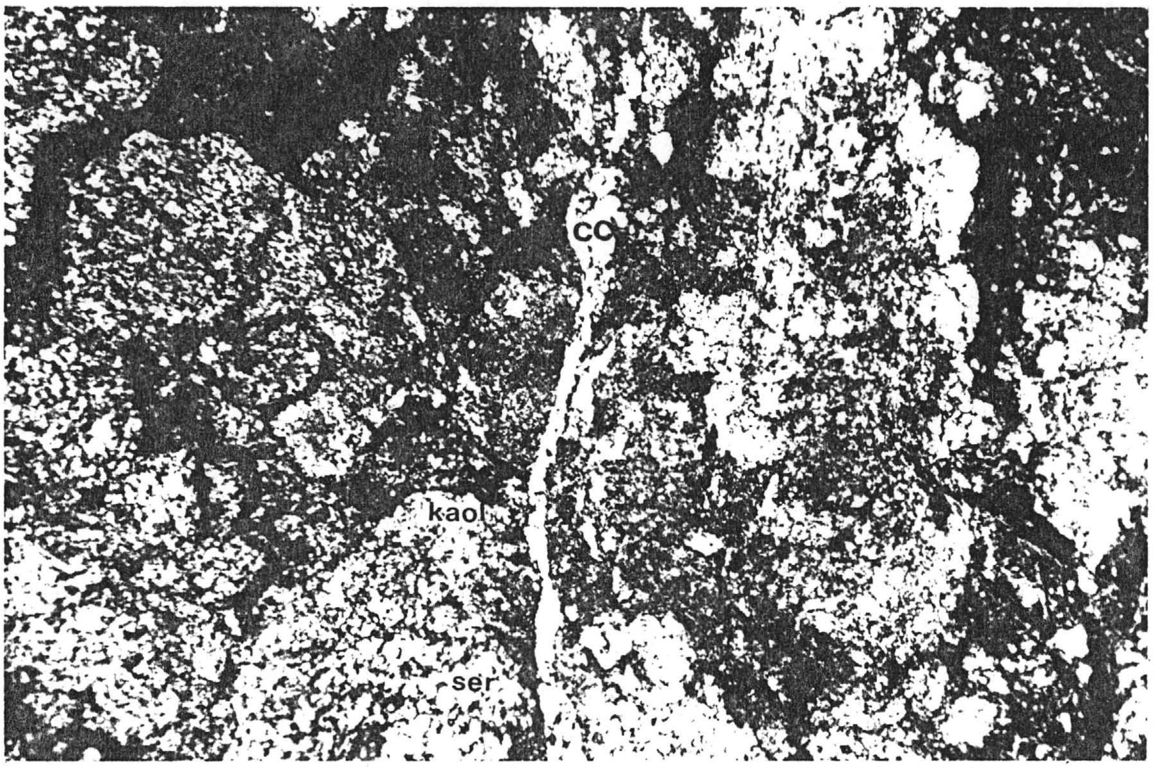
DESCRIPTION

Plate 3A Calcite veinlet between relict plagioclase, replaced by kaolinite and sericite. Crossed-polars. (X 4)

Plate 3B Leucoxene pseudomorphing ilmenite. PPL (X 10)

PLATE 3

A



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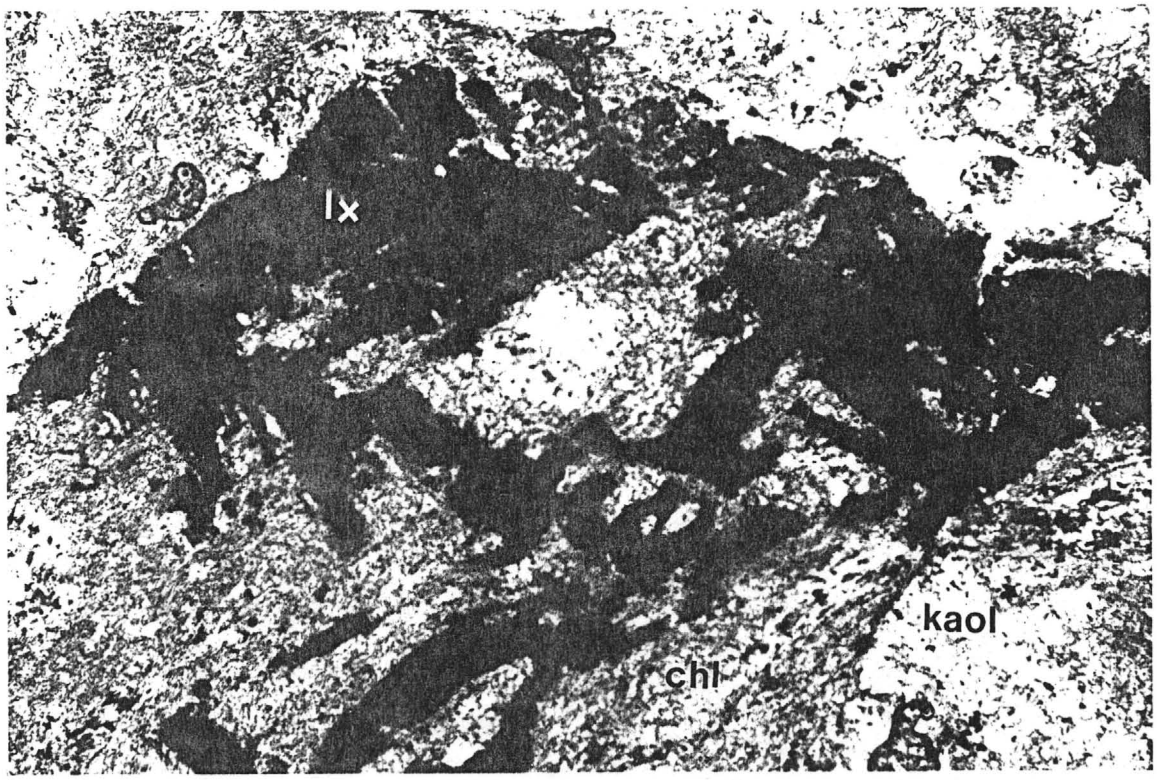

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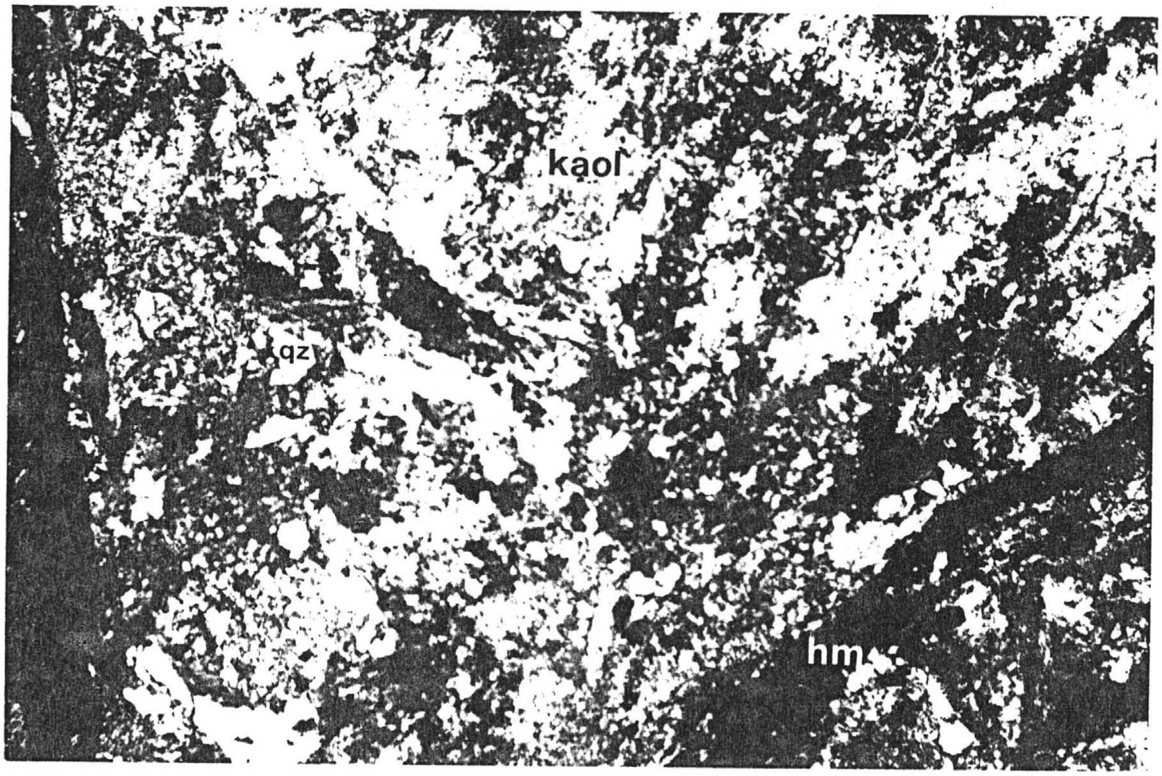
DESCRIPTION

Plate 4A Fractured relict plagioclase grains pseudomorphed by kaolinite and sericite, surrounded by fine grained quartz and feldspar, and cut by hematite veins. Crossed-polars. (X 4)

Plate 4B Relict plagioclase grains, with indistinct grain boundaries, pseudomorphed by kaolinite and sericite. Crossed-polars. (X 4)

PLATE 4

A



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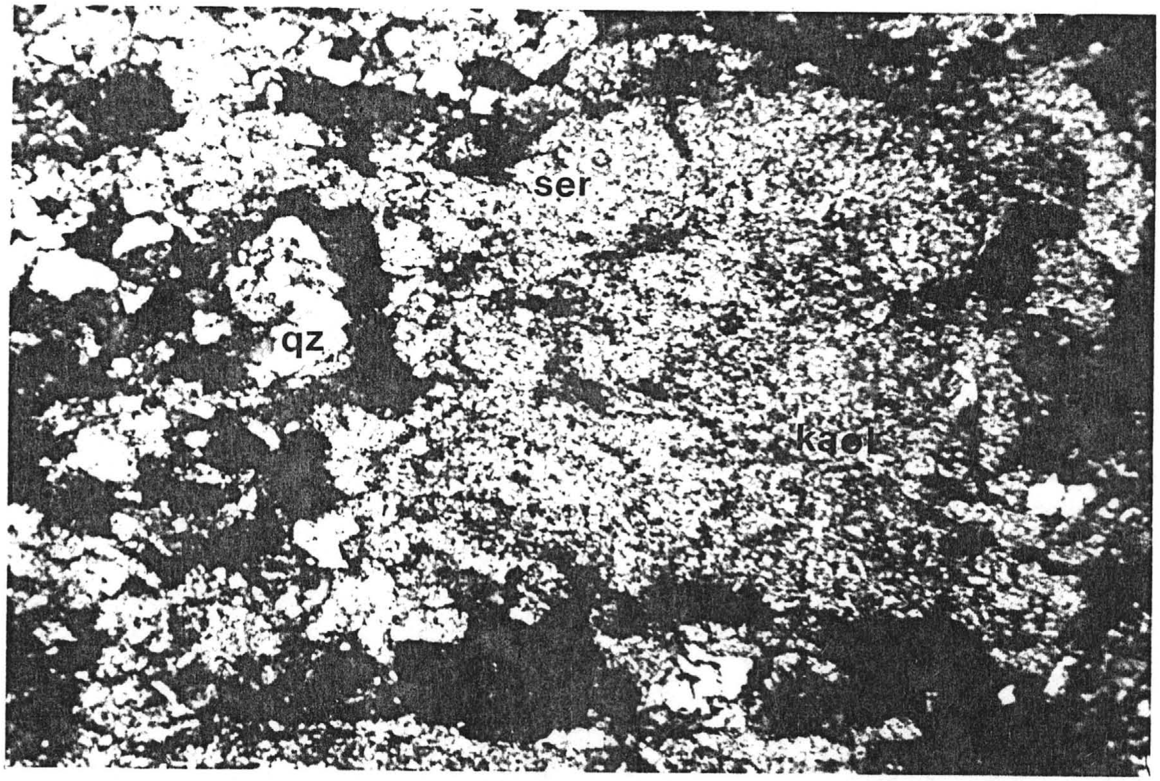

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approximately 8% quartz and feldspar present as anhedral grains, less than 0.2 mm long, and randomly distributed. Hematite is in veins averaging 0.5 mm wide (Plate 4A) and as tiny grains. Leucoxene occurs in grains up to 1.0 mm in diameter.

The diorite is a light green-white and tan colour approximately 120 feet from the centre of the sill as in sample 806-1-445. This contains 40% kaolinite and 20% sericite in relict plagioclase grains where grain boundaries are vague. Chlorite, 15%, is in tiny fractures. Quartz and feldspar, total 10%, and are very small, 0.2 mm, anhedral grains which are fresh. Hematite, 10%, is in veins and stains the rock. Leucoxene has decreased to 5%. Sample 806-1-180 is very similar but relict plagioclase grains are also outlined by goethite and there is trace carbonate present. This rock also has limonite staining.

Approximately 160 feet from the centre of the sill, there is a very pronounced change in colour from greenish-white to white and red. Hematite veins, up to 2.0 mm wide, cut the rock and stain the diorite red. Chlorite is absent. Sample M2-51 is typical and contains 40% sericite and 20% kaolinite in anhedral, broken relict plagioclase grains (Plate 4B). X-ray diffraction was used on this sample to identify the secondary minerals in these relict grains. Very small, 0.3 mm, anhedral quartz and feldspar grains make up about 20% of the sample. The remaining 20%

is hematite as anhedral grains and in veins. There are traces of malachite and minor leucoxene.

The diorite changes to a light grey-white colour with virtually no hematite at approximately 180 feet from the centre of the sill. Sample M2-56-5 is representative and contains 60% kaolinite with trace sericite. There are no visible relict grains (Plate 5A). Unaltered quartz and feldspar grains, up to 0.3 mm in diameter, are approximately 30% of the rock and are randomly distributed. Leucoxene occurs as small, less than 0.5 mm, anhedral grains, and hematite is fine grained and in tiny fractures. Sample 806-1-110 is very similar but also contains 0.2 mm wide veins of malachite.

The edge of the diorite in contact with chert is reddish-white in colour. This is represented by sample M2-75 (Plate 5B) which contains approximately 50% very fine grained kaolinite and 45% quartz, also very fine grained. Slightly larger quartz grains occur in veinlets up to 0.4 mm wide and in aggregates (Plate 5B). Hematite is fine grained and dispersed, although some is in fractures.

Brecciated chert is adjacent to the edge of the diorite sill and is almost entirely quartz (Plate 6).

3.3 Metals Within the Diorite

The only metallic mineral observed in the diorite sill is a minor amount of native copper between 340 and 400

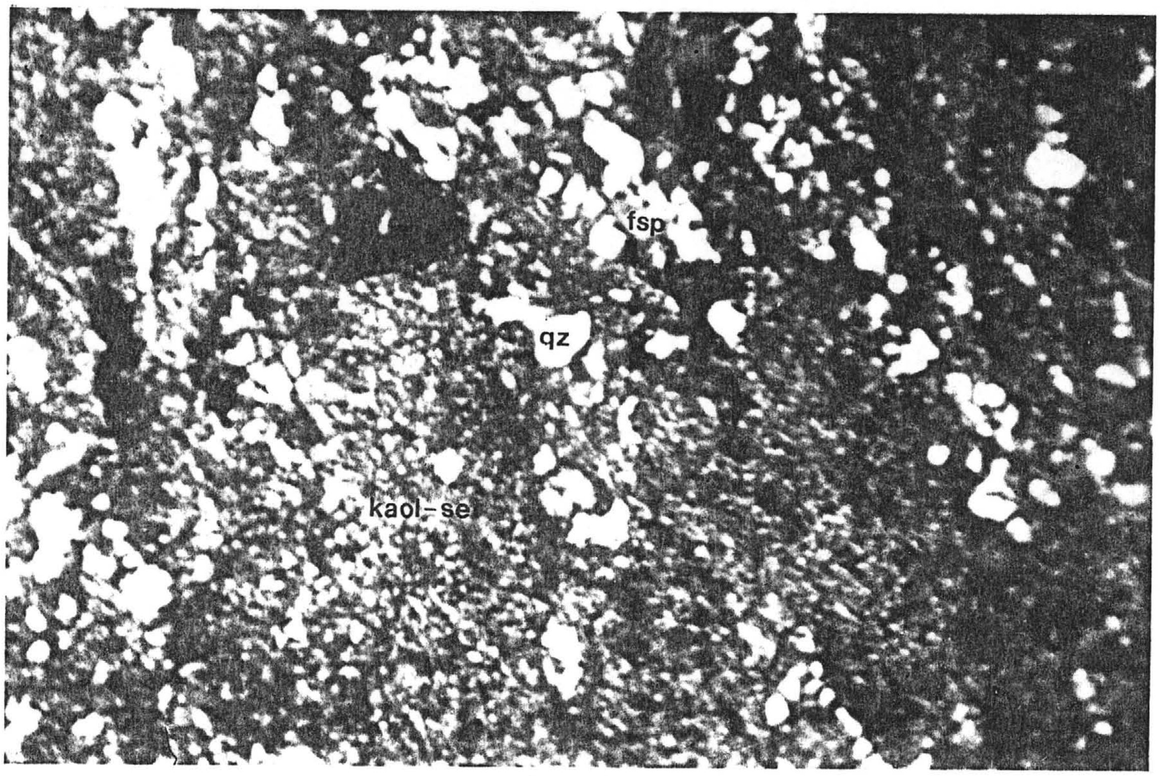
DESCRIPTION

Plate 5A Kaolinite and sericite pseudomorphing plagioclase with no visible relict grains. Crossed-polars. (X 4)

Plate 5B Fine grained kaolinite cut by quartz veinlets and aggregates of quartz grains. Crossed-polars. (X 4)

PLATE 5

A



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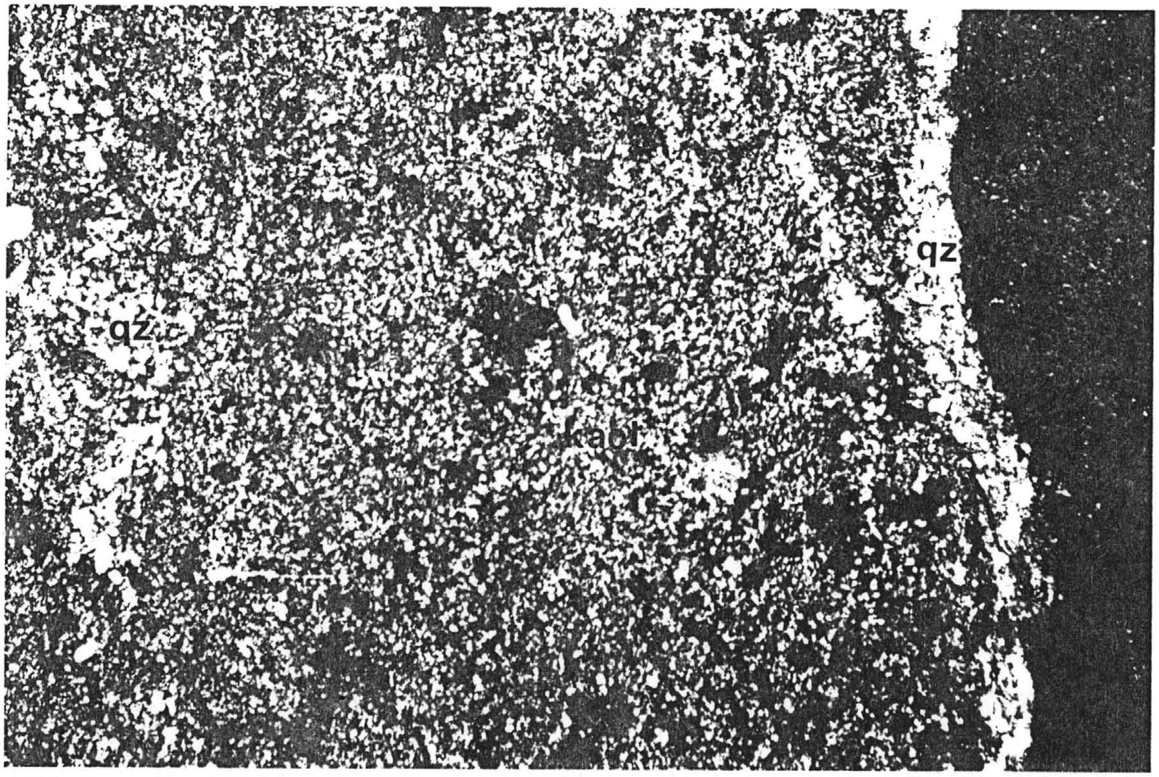

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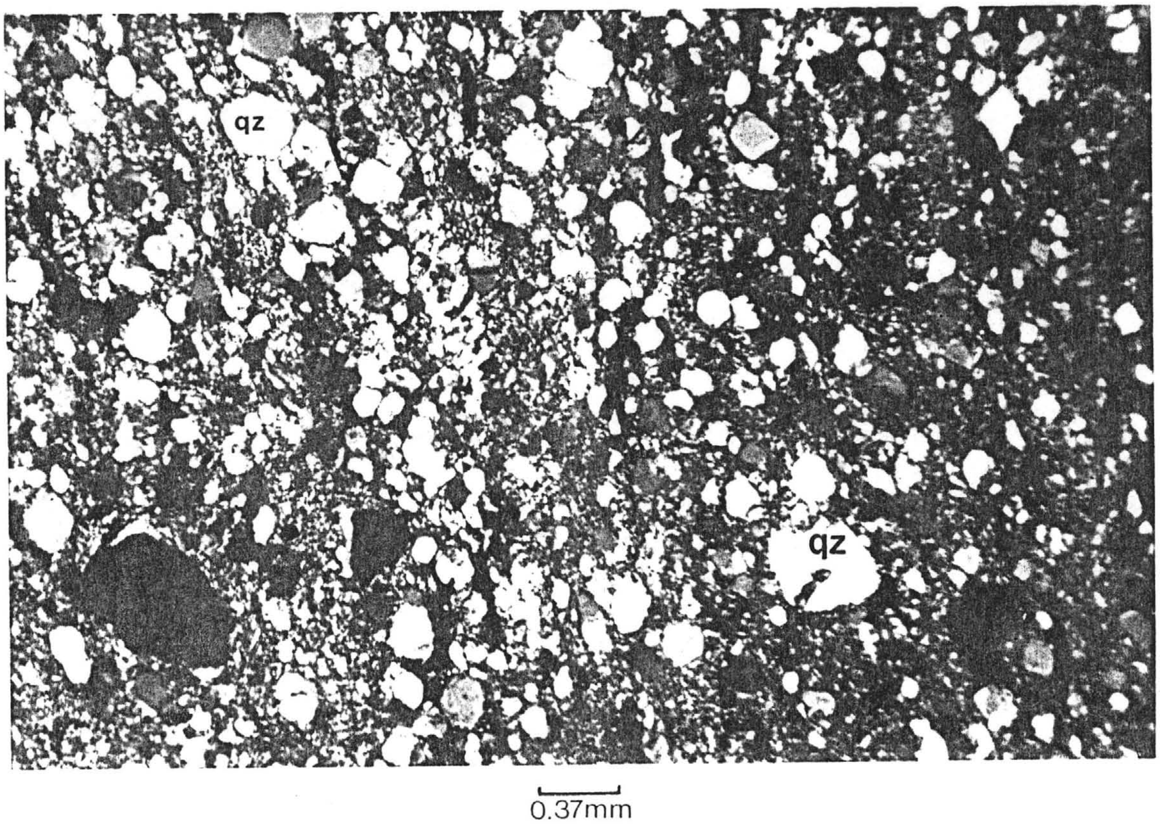
DESCRIPTION

Plate 6   Brecciated chert. Crossed-polars. (X 4)

PLATE 6



feet in hole 901-2. This copper forms isolated dendrites along fracture planes. In sample 901-2-400 native copper also occurs with hematite and malachite.

CHAPTER FOUR

SECONDARY MINERAL ASSEMBLAGES

4.1 General Statement

The diorite sill has three zones of secondary mineral assemblages: propylitic, argillic, and silicic. These are characterized by the minerals kaolinite-chlorite-epidote, kaolinite-sericite-chlorite, and kaolinite-quartz respectively, and they are arranged in this order from centre to edge of the sill. Affects of regional metamorphism are difficult to distinguish from hydrothermal alteration, as both processes may involve H^+ metasomatism which replaces plagioclase and mafic minerals with micas, chlorite, and epidote and releases silica. These are typical minerals of the greenschist facies of regional metamorphism. For example, the diorite sill, in particular its centre, contains chlorite, epidote, and sericite, pseudomorphing plagioclase and amphibole, with minor quartz, calcite, and dolomite. Sutured grain boundaries and 120° triple point junctions in a quartz-feldspar vein and the preferred orientation of chlorite in one sample are possible textures associated with metamorphism. However, this mineral assemblage and textures are also characteristic of propylitic hydrothermal alteration. The other two secondary mineral assemblages are, however, not typical of regional metamorphism to the greenschist facies but are consistent with hydrothermal alteration.

4.2 Propylitic Assemblage

A propylitic mineral assemblage is characteristic of the centre of the diorite sill and contains the minerals chlorite, epidote, kaolinite, quartz, carbonate, and leucoxene. Plagioclase grains are partly occupied by kaolinite, and chlorite and epidote have replaced amphibole with only relict grains remaining. Chlorite also pseudomorphs biotite. Calcite and dolomite are in thin veinlets and cavities, and hematite is also in fractures. Some quartz and feldspar grains are in veinlets. Leucoxene pseudomorphs ilmenite.

4.3 Argillic Assemblage

Argillic alteration is approximately 160 feet thick and between the propylitic centre and silicic edge and is represented by kaolinite, sericite, chlorite, quartz, feldspar, and leucoxene. Kaolinite and sericite completely occupy plagioclase grains, and relict grain boundaries are broken and difficult to distinguish as kaolinite content increases toward the margin of the sill. Chlorite is prominent as fracture fillings and decreases outward. Hematite is more abundant in fractures and leucoxene is still prominent pseudomorphing ilmenite.

4.4 Silicic Assemblage

The edges of the diorite sill are approximately 30 to 40 feet thick and characterized by kaolinite and quartz. Quartz is fine grained in veinlets and aggregates and kaolinite is also fined grained with no relict textures.

4.5 Fracture Controlled Minerals

The affects of weathering by meteoric water circulation are difficult to distinguish from metamorphic and hydrothermal effects. However, pervasive kaolinite, a bleaching of the rock's colour, and hematite and limonite on planar fractures in the edges of the diorite sill may be a result of downward percolating ground water. Native copper within the diorite is also attributable to ground water circulation.

CHAPTER FIVE

DISCUSSION

5.1 General Statement

This chapter examines the possible methods of alteration by regional metamorphism, hydrothermal alteration, and weathering in the production of the secondary mineral assemblages.

5.2 Regional Metamorphism

The mineral assemblage in the centre of the sill is typical of the greenschist facies of regional metamorphism. It is also characteristic of hydrothermal alteration to a propylitic assemblage. The diorite is folded with the surrounding layered rock sequence and may have been metamorphosed with the folding (Anderson and Nash, 1972). Metamorphism may have been an early sea floor spilitization as the volcanic rocks of the area are a submarine succession. There is no clear distinction between this type of early metamorphism and hydrothermal altertion, and the preferred interpretation here is that the greenschist mineral assemblage is an early, diffuse hydrothermal alteration assemblage, essentially an early hydration of the diorite sill during or shortly after emplacement.

5.3 Hydrothermal Alteration

A diorite sill emplaced into a marine, sub-volcanic environment will cool by a combination of simple conduction of heat into the cooler enveloping rock, and by convective heat transfer by fluids which would be a hydrothermal system around that intrusion (McBirney, 1984). This fluid is sea water, and penetration can occur to depths of 3 to 5 km which provides an efficient means of igneous cooling and results in low to medium grade hydration (Andrews and Fyfe, 1976). The alteration of the diorite sill is similar to the modern example of sea water alteration of oceanic basalts (i.e. Fyfe and Lonsdale, 1981). Heat from the intrusion sets up a convective circulation of fluids, as the water flowed into the diorite through fractures and primary porosity. The circulation is caused by the heating of water making it less dense, and causing it to rise in a focused flow through the intrusion (Taylor and Forester, 1971). The most active circulation and, therefore, most intense alteration was along the margins of the diorite.

The diorite was essentially hydrated with primary minerals altered to hydrous silicite minerals, accompanied by an expulsion of silica, much in the manner of hydration of an ultramafic body accompanied by the formation of a siliceous, carbonate, and oxide-rich margin (Einsele, 1985). At low temperatures, up to 100°C, K will precipitate in clays and sericite (Fyfe and Lonsdale, 1981) and this accounts for the large amount of kaolinite and sericite in the margins of the diorite sill. Hematite oxidizes primarily in the sill margins and this indicates the sill was near surface since magnetite is more likely to form at depth (Fyfe and Lonsdale, 1981). These can be compared to massive sulphide deposits in Cyprus, where host rocks are hydrothermally altered pillow lavas which grade upward and outward into zones of hematitization and silicification (Andrews and Fyfe, 1976). Fluids followed fractures evidenced by hematite veins in the argillic zone, and quartz and carbonate veinlets in the argillic and propylitic zones. Oceans are near saturation with $CaCO_3$ and as solubility decreases with increasing temperature, the $CaCO_3$ will precipitate (Fyfe and Lonsdale, 1981). Calcite and dolomite are precipitated in veinlets and cavities in the margins and centre of the sill. Mg also precipitates near the centre and forms the chlorite.

As the diorite intrusion cooled, heat and magmatic fluids were released and these could also affect the alteration of the diorite sill.

5.4 Weathering

Supergene alteration is weathering by downward percolation of meteoric waters. The affects are difficult to separate from retrograde hydrothermal alteration. The evidence for this includes dendritic native copper on fractures, limonite and goethite which are hydrous and are most prominent in hole 806-1 near the present top of the diorite. The broad distribution of kaolinite may also be partly weathering of prograde hydrothermal alteration assemblages.

CHAPTER SIX

CONCLUSIONS

1. The centre of the diorite sill has a propylitic assemblage of kaolinite-chlorite-epidote which grades outward into an argillic assemblage of kaolinite-sericite-chlorite which extends to the margins of the diorite. The edges of the diorite have a silicic assemblage of kaolinite-quartz.

2. Alteration was primarily by hydrothermal fluids associated with the emplacement of the diorite. This was probably seawater convected by heat from the diorite sill during and after emplacement into a submarine volcanic succession. This is comparable to the more dramatic intense hydration of ultramafic bodies and the silification of their margins.

3. The latest stage alteration includes supergene weathering and downward percolation of meteoric waters which has continued to the present day.

4. It is conceivable that the "chert" which flanks the diorite may in reality be the most intense silicic alteration at the edge of the diorite and not a chemical sedimentary rock.

5. The significance of the diorite sill to gold concentration may be in hydrothermal fluid flow caused by the sill's heat. Such fluid may have leached and transported gold to sites of deposition within structural and chemical inhomogeneites at the sill margins.

CHAPTER SEVEN

RECOMMENDATIONS

Further work should be concentrated not in the diorite sill, but along the highly altered margins and in the "chert" which may in fact be intensely altered diorite. The irregularities along the sill margins may represent soft deformation as the sill was emplaced into still wet sediments, and should be examined to note any variations in gold concentration.

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A PRELIMINARY REPORT ON THIN SECTIONS

OF THE SILICEOUS ROCK OF THE GOLD STOPE

UVX MINE,

JEROME, ARIZONA

PETER MCLEAN

SEPTEMBER 15, 1986

TABLE OF CONTENTS;

DISCUSSION

1. Was there any carbonate present in the past ?

The occurrence of hematite rhombs indicates the presence of carbonate in the past. These hematite rhombs are only in drill-hole 901-3 and only in three sections. The specific composition of the original carbonate is undetectable as replacement is complete and preserved cleavage traces provide no clue to the parent mineral.

2. Is there any mineralogic associations between gold and hematite.

The tentatively identified ore minerals and sulphides were predominantly associated with hematite and coarse-grained quartz. The composition of the ore minerals is still to be determined using SEM techniques.

3. Textural associations.

Tentatively identified electrum, and sulphides are predominantly associated with hematite and coarse-grained quartz which is usually in veinlets, as vug-filling constituents and rimming clasts of brecciated, fine-grained quartz.

4. Alteration.

The only evidence of alteration is 1) replacement of carbonate by hematite 2) crumbling of coarse-grained quartz, sutured grain boundaries, undulose extinction, hexagonal form and banding of some quartz grains suggest moderate deformation and recrystallization 3) abundance of limonite overgrowths.

5. Paragenetic sequence.

a) Bedding of hematite and quartz in slides 515 and 321 suggest an initial deposition of quartz, carbonate and perhaps hematite,

b) Replacement of carbonate by hematite

c) Minor metamorphism and deformation resulting in recrystallization and grain-size reduction of quartz

d) Brecciation of rock by this deformation and possibly contemporary infilling of these fractures by hematite

e) Infilling of porosity (vugs and fractures) by quartz

f) Limonite overgrowths

Drill Hole 901-3

279'

Modal Analysis

Quartz - 90 % Fine-grained, 80 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 2 %

Description

This slide is dominated by fine-grained quartz and stringers of hematite (Plate 1). Areas of coarse-grained quartz are commonly associated with hematitic stringers but it can occur isolated. Large hematite rhombs (.4-.5 mm) display remnant carbonate cleavage and quartz cores (Plates 2, 3). Clasts of fine-grained matrix are incorporated into the coarse-grained quartz-hematite veinlets as this slide is extensively brecciated (Plate 1). Quartz also occurs filling vugs which commonly have a vacant core.

In reflected light, no gold or sulphide minerals confirmed by direct observation. Possible sulphides are commonly seen as bright, fine specks in the hematite-quartz stringers.

Plate 1 Slide 279'. Fine-grained quartz and hematite stringers. Coarse-grained quartz is present associated with hematite. Note the clasts of fine-grained quartz rimmed by hematite. 20 X, Crossed nicols (XN)

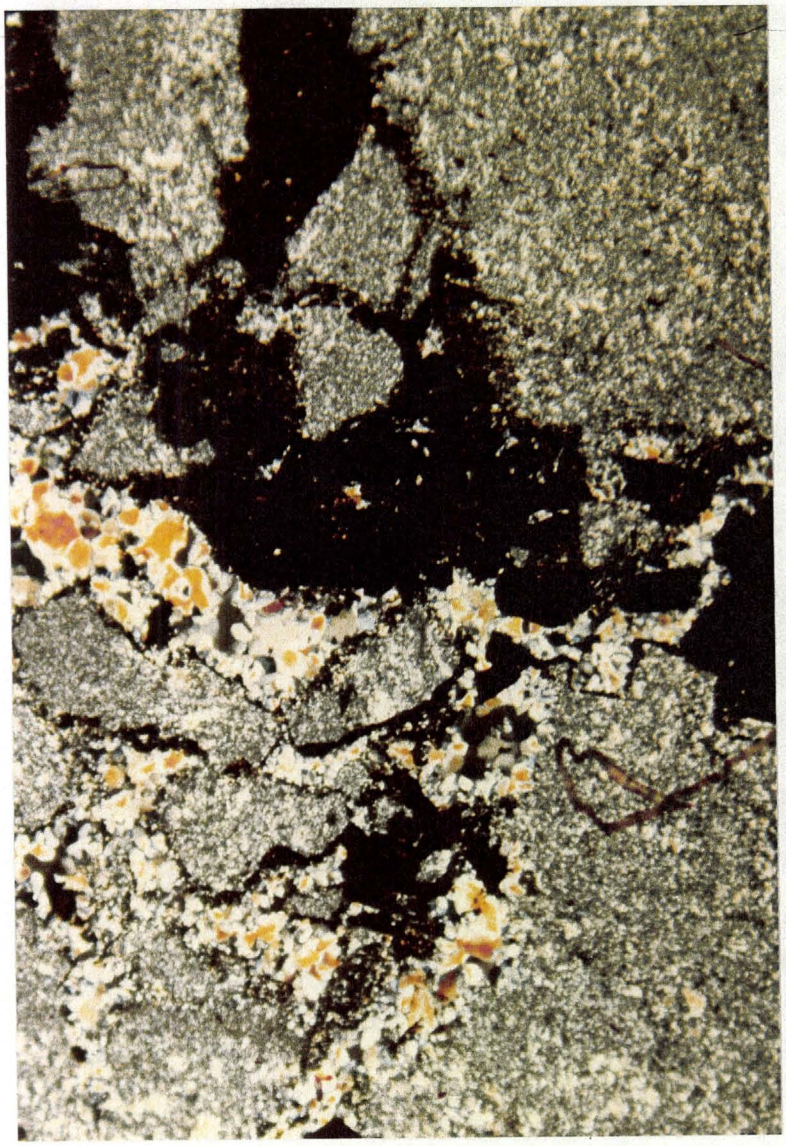
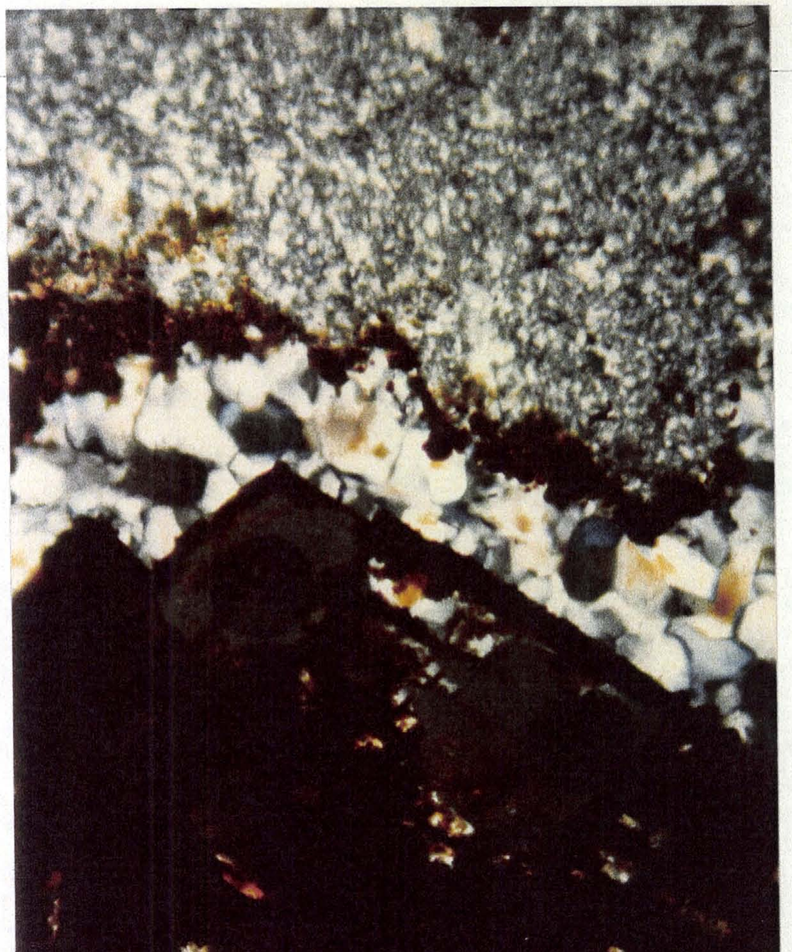


Plate 2 Slide 279'. Hematite rhombs with remnant cleavage traces. This is replacement of carbonate by hematite. 80 X, XN

Plate 3 Slide 279'. Hematite rhombs with cleavage traces.
Note hexagonal quartz in these hematite-rich stringers in the fine-grained matrix of quartz. 80 X, XN



281'

Modal Analysis

Quartz - 75 % Fine-grained, 65 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 2%

Description

This slide is dominated by a fine-grained quartz matrix with stringers of coarse-grained quartz and hematite. The slide is extensively brecciated by these quartz-hematite stringers and portions of the matrix appear incorporated and rimmed by hematite (Plate 4). Matrix quartz is very fine-grained, somewhat fibrous and displays a preferred orientation (Plate 5). Clasts of fine-grained matrix appear to have been rotated by the hematitic stringers (Plate 5). Coarse-grained quartz (up to 1mm) commonly has sutured boundaries and undulose extinction and 120 interfacial angles. In some areas, coarse-grained quartz is breaking down into fine-grained quartz (Plate 4). Hematite occurs as anhedral, fibrous crystals and as euhedral rhombs (Plate 6).

There is no identifiable gold or sulphide minerals present in this slide. Scattered, bright very fine-grained crystals may be sulphides. These are commonly in the main quartz-hematite stringers.

Plate 4 Slide 281'. Hematite brecciation of the fine-grained quartz matrix. Note that regions within the fine-grained clasts are coarser grained and appear to be crumbling. 20X, XN

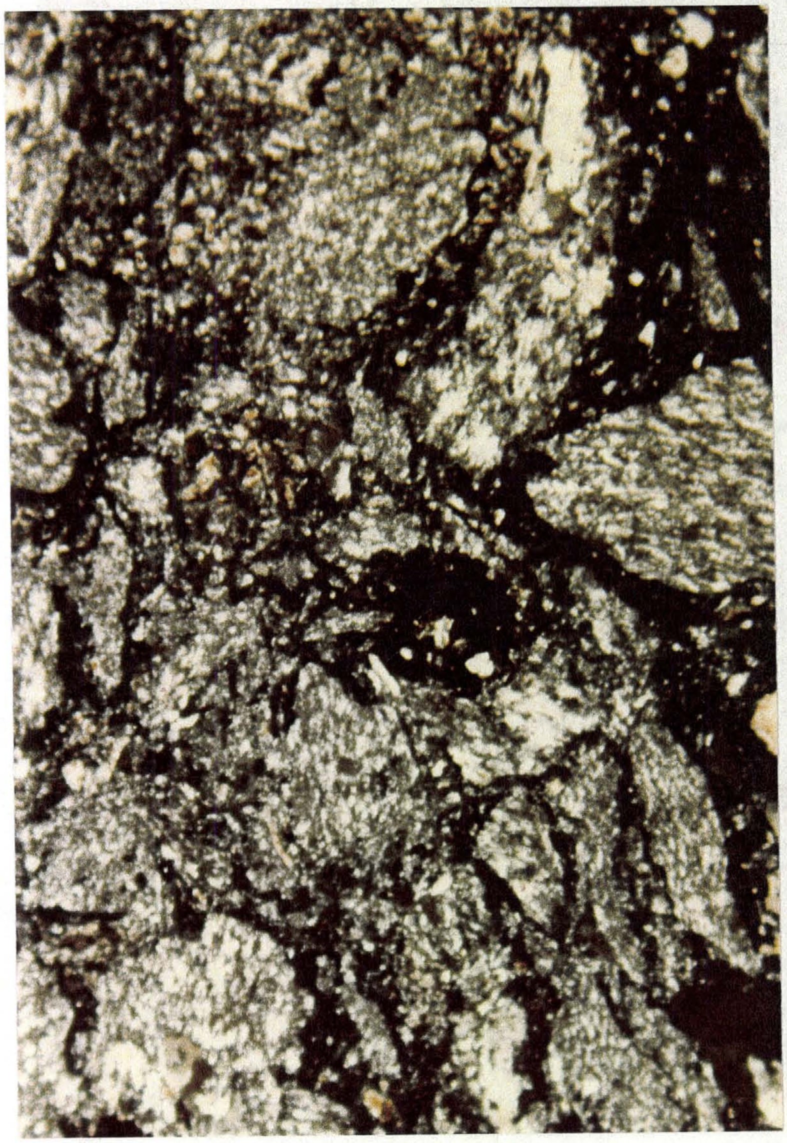


Plate 5 Slide 281'. Clasts of fine-grained quartz. The fine-grained quartz is somewhat fibrous and has a preferred orientation represented by the large clast. Several clasts appear rotated. 20 X, XN

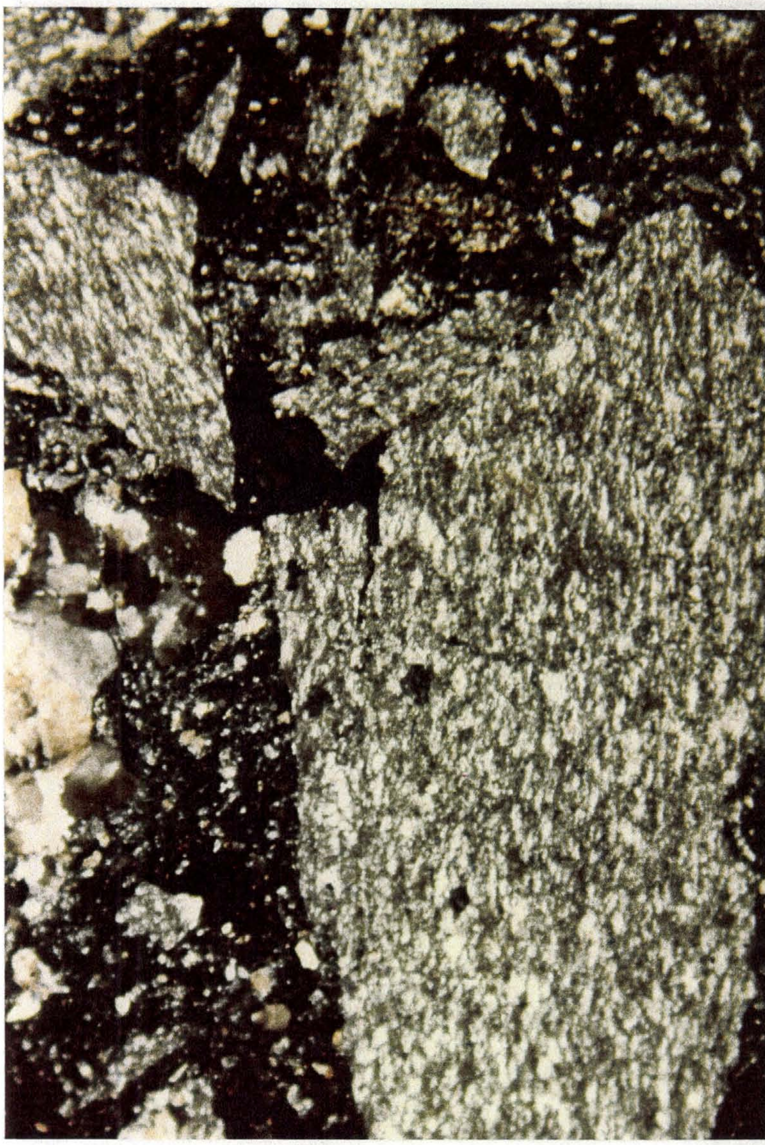
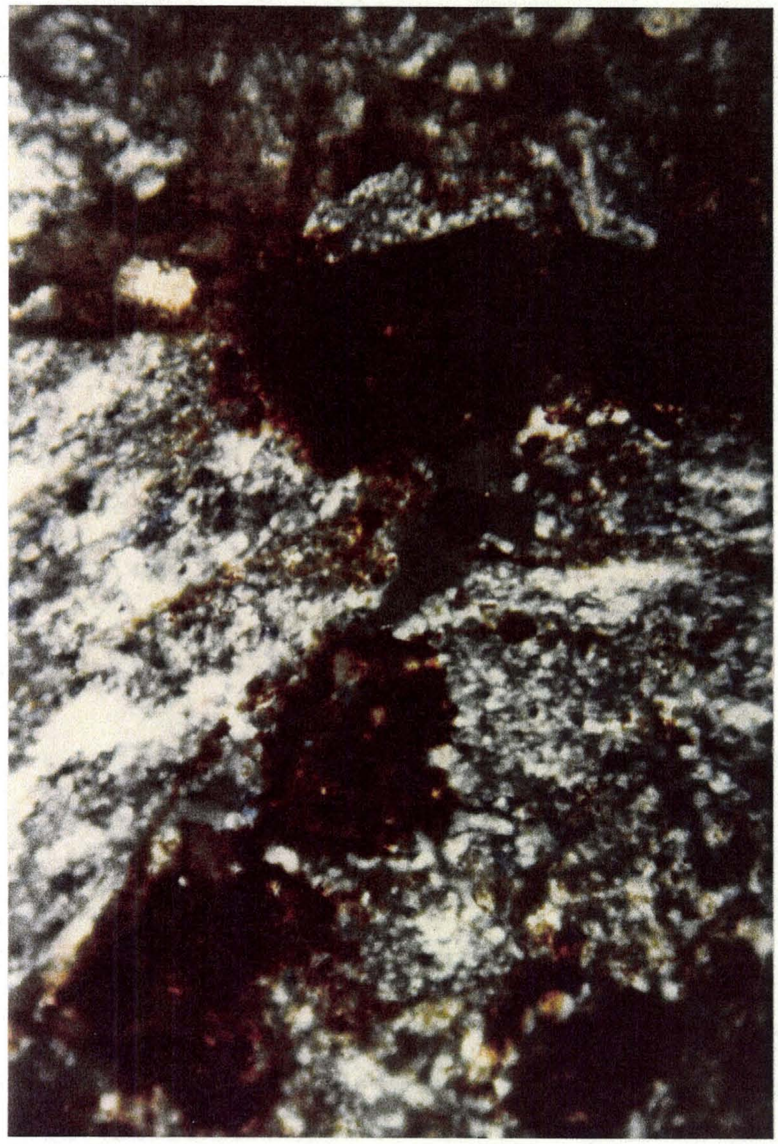


Plate 6 Slide 281'. Euhedral rhombs of hematite. Cleavage traces are somewhat preserved. 20 X, XN



290'

Modal analysis

Quartz - 90 % Fine-grained, 80 %

Coarse-grained, 10 %

Hematite - 10 %

Porosity - 1%

Description

This slide is predominantly fine-grained quartz with stringers of hematite and coarse-grained quartz (Plate 7). Coarse-grained quartz is intergrown with fine-grained quartz and appears to be altering or decaying to the fine-grained quartz (Plate 7,8). Hematite is commonly fine-grained, occurs as stringers and vein linings and rimming quartz grains (Plate 8). Remnant hematite bands outline euhedral rhombs (Plate 9). Colloform hematite is also present. Portions of this slide are extensively brecciated (Plate 10).

There is no definite gold, sulphides or ore minerals in this slide. Minute specks predominantly in quartz-hematite stringers may be sulphides.

Plate 7 Slide 290'. Fine-grained quartz matrix,, coarse-grained quartz veinlets and hematite stringers. Note some coarse-grained quartz is crumbling or altering to fine-grained quartz. 20 X, XN

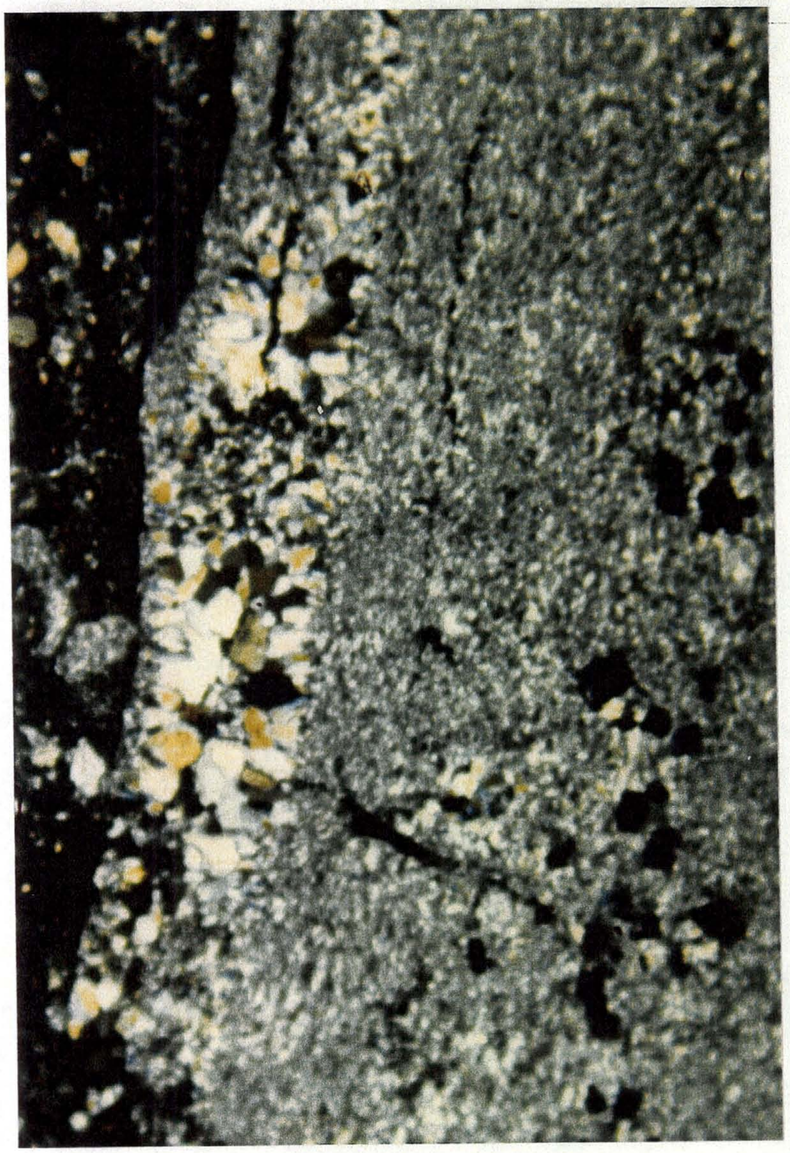


Plate 8 Slide 290'. Hematite, coarse-grained quartz and fine-grained quartz matrix. Note the clasts of coarse-grained quartz in the hematite crumbling or altering to fine-grained quartz, and the hematite lining the veinlet. 20 X, XN

Plate 9 Slide 290'. Remnant rhombs outlined by fine bands of hematite in a quartz veinlet. The bands of hematite appear to outline growth rings. Note the dark hematite lining the veinlet. 20 X, Plane-polarized light (PPL)

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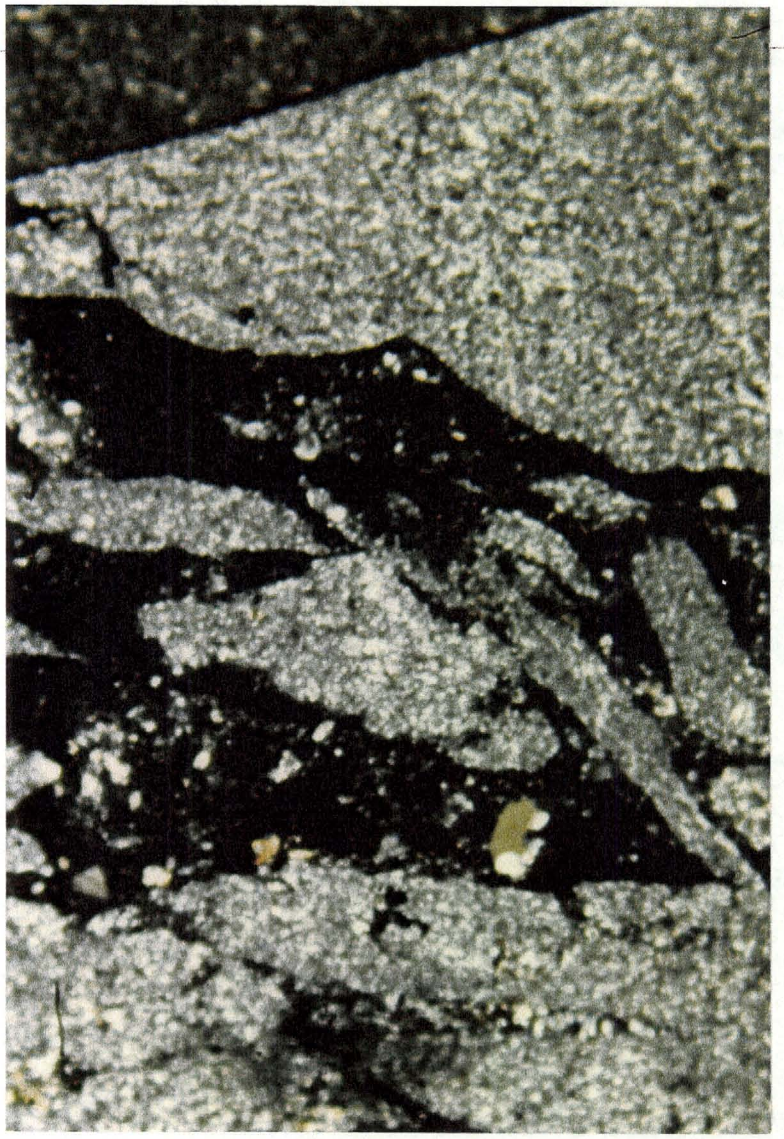
Plate 10 Slide 290'. Brecciation of the fine-grained quartz matrix outlined by hematite. 20 X, XN



307'

Modal Analysis

Quartz - 98 % Fine-grained, 60 %

Coarse-grained, 38 %

Hematite - 2 %

Porosity - 2 %

Description

This slide is dominated by fine-grained quartz although coarse-grained quartz does occur filling vugs and fractures (Plate 11). Brecciation is minor and outlined by quartz stringers and veinlets. Coarse-grained quartz occurs as hexagonal crystals with 120 interfacial angles and as anhedral crystals with sutured grain boundaries and undulose extinction (Plate 12). Coarse-grains are commonly crumbling or altering to fine-grained quartz. Hematite is scarce and when found is almost always associated with coarse-grained quartz. Iron staining (limonite ?) is abundant in some areas (Plate 12). This is in regions of coarse-grained quartz and outlines the hexagonal form. Fine-grained, euhedral, pyrite cubes are present (Plate 13). Numerous other grains appear to be sulphides and perhaps some electrum is present. One grain appeared to be gold but positive identification was impossible optically.

Plate 11 Slide 307'. Fine-grained quartz matrix with coarse-grained quartz infilling vugs and fractures. 20 X, XN

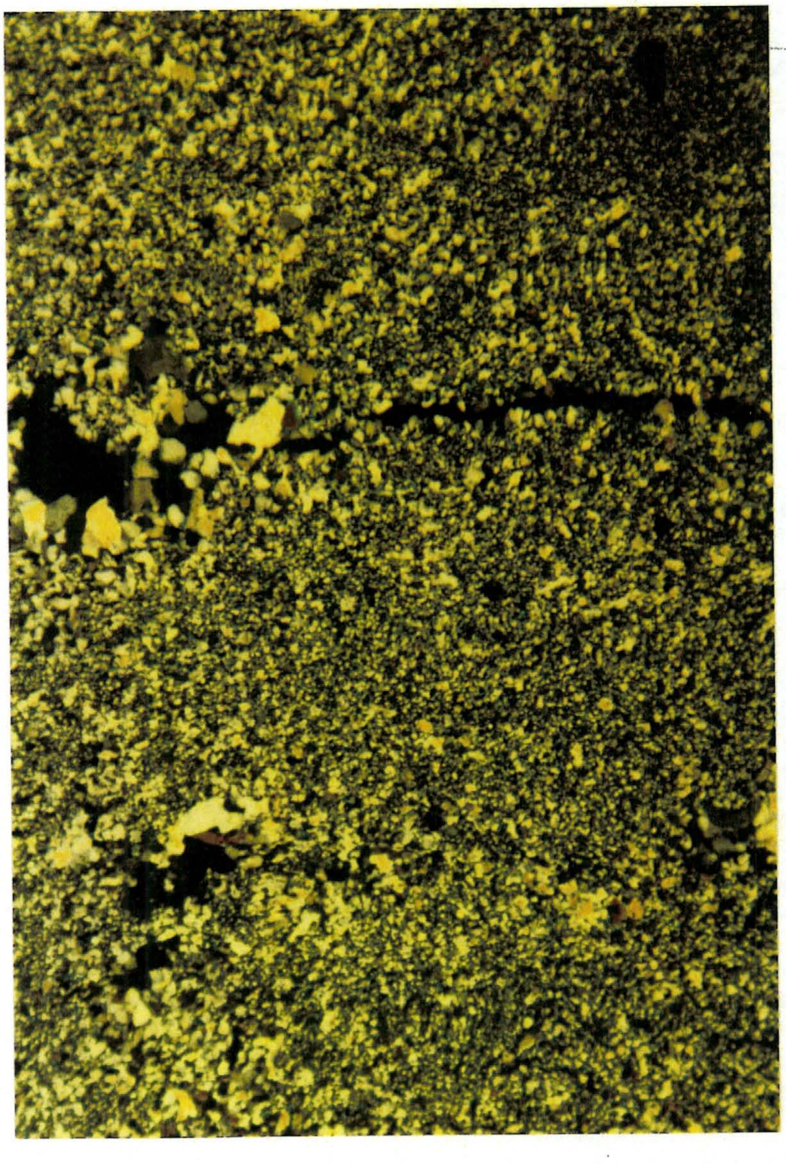


Plate 12 Slide 307'. Possible limonite staining outlining hexagonal quartz infilling a vug. 80 X, PPL

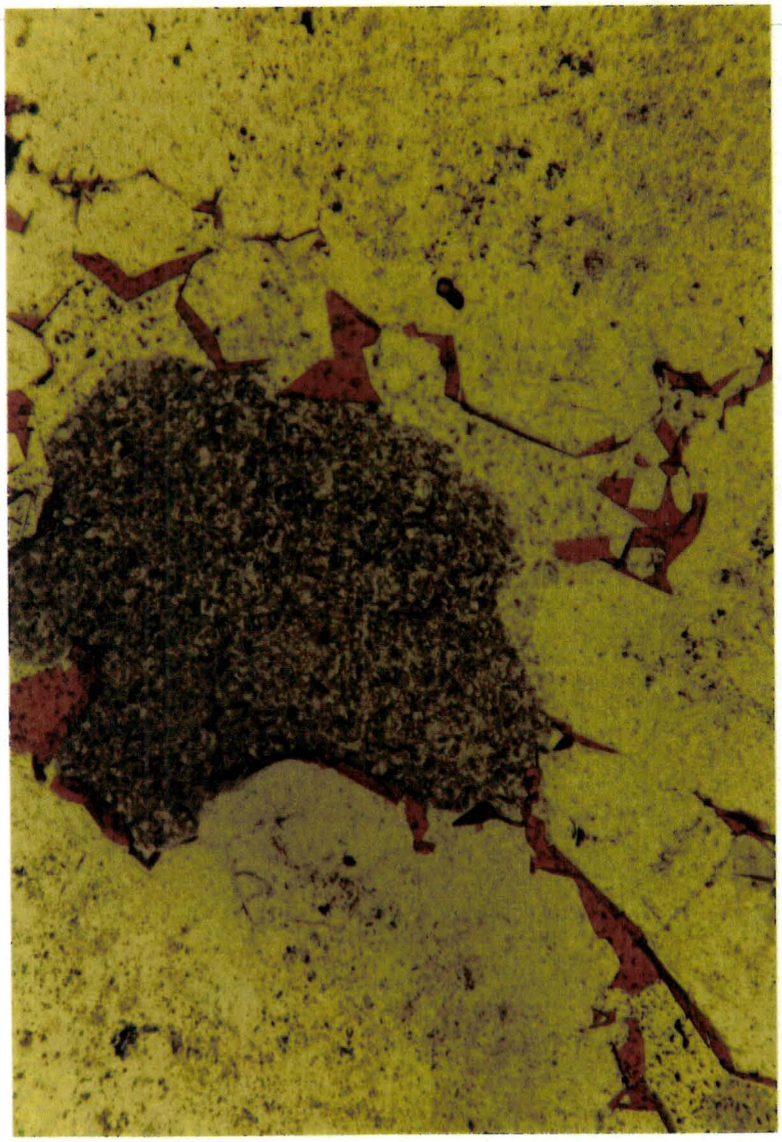
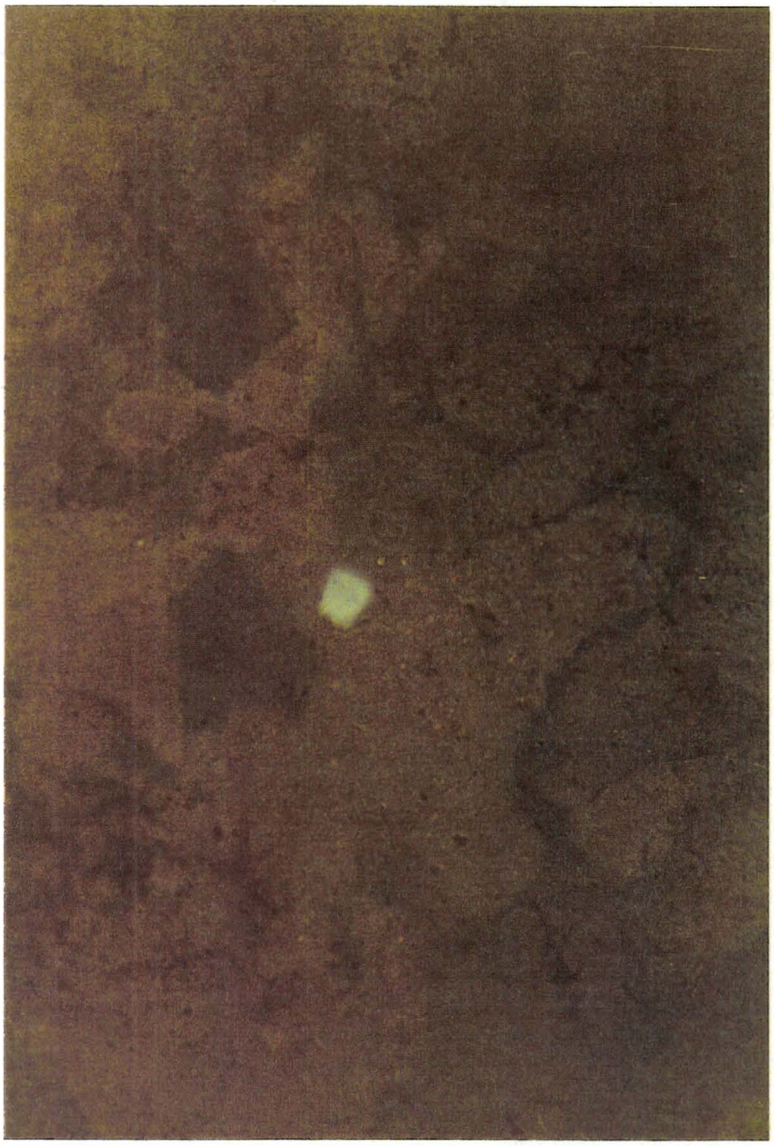


Plate 13 Slide 307'. Fine-grained, euhedral pyrite cube.128X

Reflected light



311'

Modal Analysis

Quartz - 80 % Fine-grained, 30 %

Coarse-grained, 50 %

Hematite - 20 %

Porosity - 5 %

Description

This slide is dominated by quartz clasts ranging in size from .25-3.0 mm and averaging 0.5mm. Fine-grained quartz is restricted to one end of the slide and the contact is sharp (Plate 14). Coarse-grained quartz have sutured grain boundaries, numerous inclusions and display undulose extinction. Quartz commonly fills vugs and fractures (Plate 15). Several large fractures cross-cut the region of fine-grained quartz and incorporate coarse quartz grains. Coarse-grained quartz is crumbling or altering to fine-grained quartz. Hematite occurs in veinlets and it is commonly very fine-grained and fibrous. Iron staining rimming hexagonal quartz is present.

No positive identification of gold or other ore minerals. Several subhedral, fine grains may be pyrite.

Plate 14 Slide 311'. Fine-grained quartz to the left of the veinlet. Limonite outlines hexagonal quartz and fractures. 20 X, XN

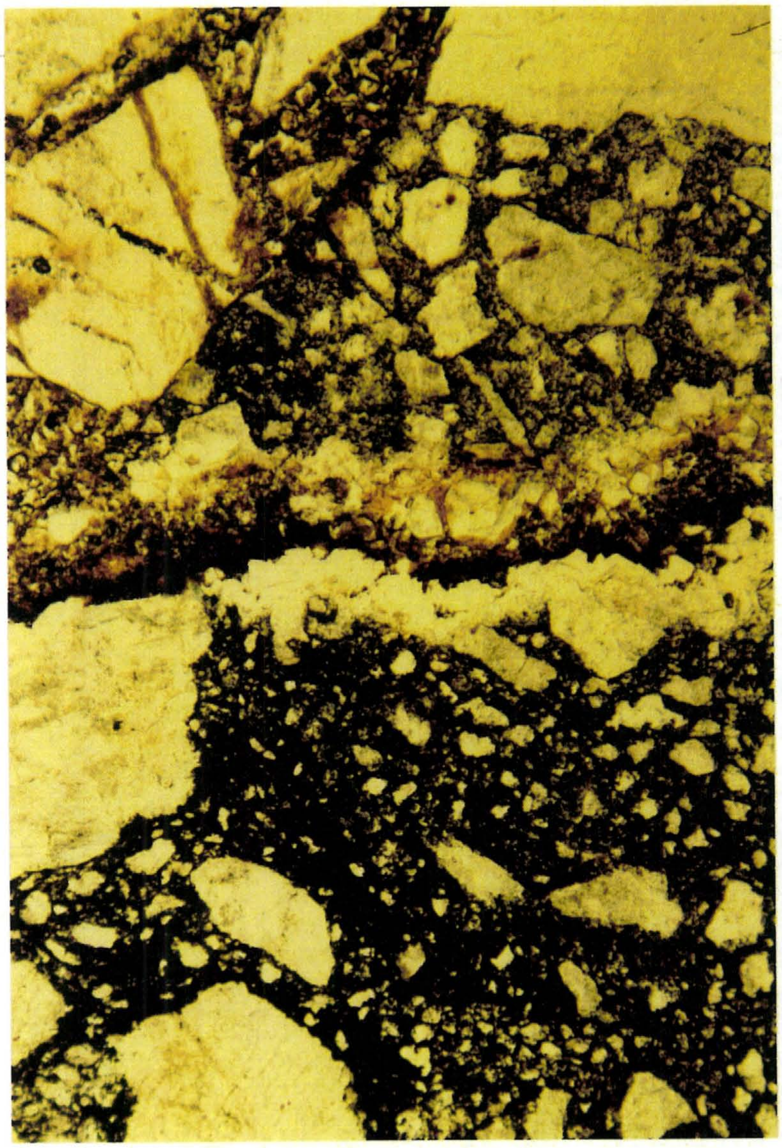


Plate 15 Slide 311'. Quartz filling fractures and vugs. Some quartz is altering to fine-grained quartz (arrow). 20 X, XN

316'

Modal Analysis

Quartz - 80 % Fine-grained, 45 %

Coarse-grained, 35%

Hematite/Limonite - 20 %

Porosity - 20 %

Description

This slide is dominated by quartz which ranges in size up to .4mm and averages .2mm. There is very little fine-grained quartz matrix and coarse-grained clasts. The quartz has sutured boundaries, hexagonal and anhedral form, undulose extinction and commonly hematitic overgrowths. Numerous vugs are being filled by quartz and some quartz is decaying to fine-grained quartz. The hematite is very fine-grained, fibrous and occurs as overgrowths and rimming quartz. Iron staining occurs around some quartz grains. Some hematite is quite yellow, this is likely limonite.

No positive identification of gold, sulphides or other ore minerals. Some possible anhedral sulphides were seen in association with coarse-grained quartz and hematite.

321'

Modal Analysis

Quartz - 85 % Fine-grained 55%

Coarse-grained 30%

Hematite/Limonite - 15 %

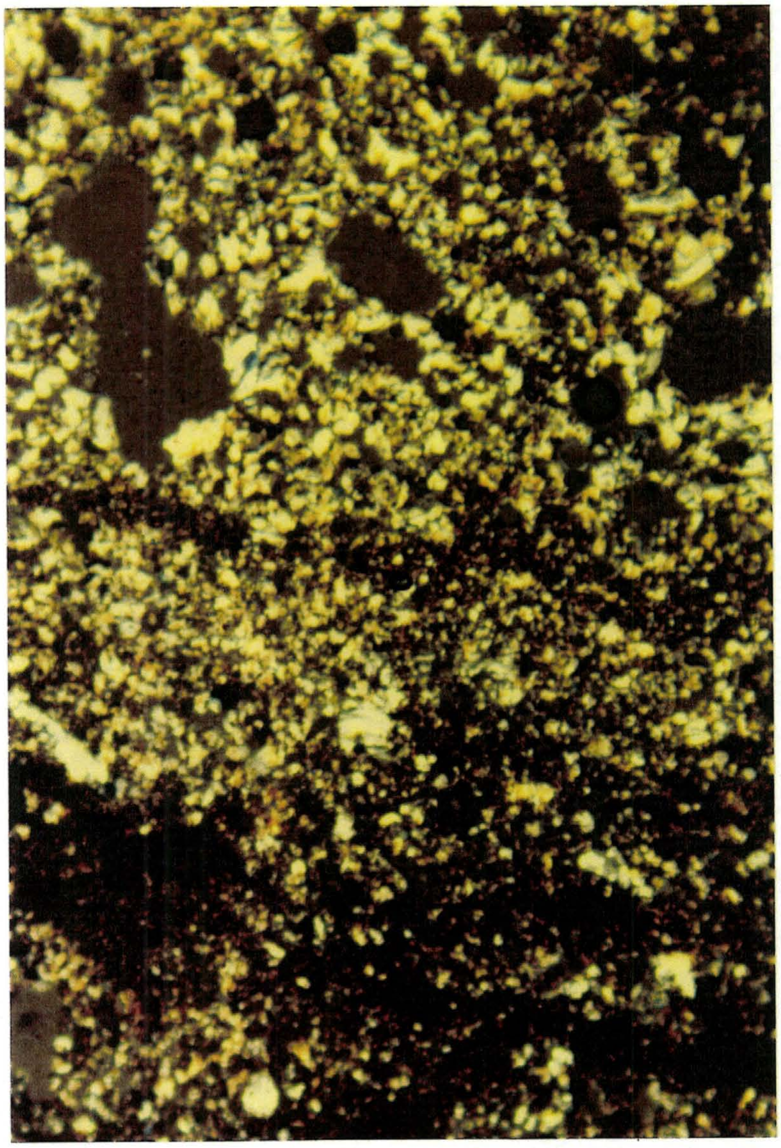
Porosity - 10 %

Description

This slide is dominated by fine-grained quartz with limonitic overgrowths. Quartz grains are up to .4mm but average .1mm. Coarse-grained quartz tends to be concentrated in pods or pockets commonly surrounding vugs. These coarse grains also have sutured boundaries, undulose extinction and can be banded. Quartz also occurs as discontinuous veinlets where it is commonly hexagonal. Coarse-grained quartz is intergrown with fine-grained quartz and appears altering or crumbling to the fine-grained quartz. 'Some bedding features have been preserved in this slide. Beds consist of alternating fine-grained and coarse-grained quartz and less frequently coarse-grained quartz with hematite (Plate 16). Hematite and limonite are very fine-grained and are most commonly associated with concentrations of coarse-grained quartz.

Fine-grained sulphides are possibly associated with coarse-grained quartz and the vugs. No positive identification of gold, sulphides or other ore minerals.

Plate 16 Slide 321'. Possible bedding, banded quartz and numerous vugs. 20 X, XN



Drill Hole 806-1

486'

Modal Analysis

Quartz - 90 % Fine-grained, 50 %

Coarse-grained, 40 %

Hematite - 10 %

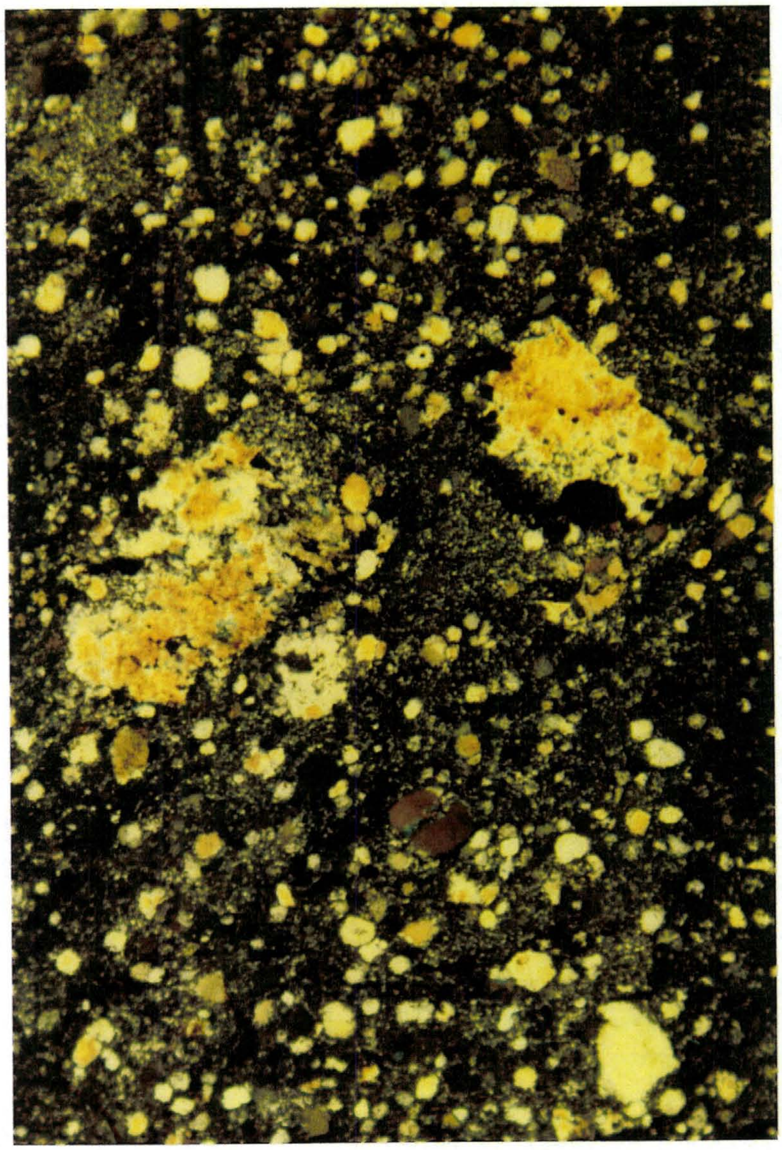
Porosity - 5 %

Description

This slide is predominantly a fine-grained quartz matrix and coarse quartz clasts (Plate 17). The quartz clasts range from .1 - .3 mm and average .2 mm . Quartz grain boundaries are commonly serrated and tend to be altering to fine-grained quartz (Plate 17). The quartz clasts are generally round and contain numerous inclusions. The slide is matrix supported but in areas, clast supported. Quartz veinlets are present and the vein quartz is anhedral with sutured boundaries. Hematite and limonite are fine-grained and occur as stingers and throughout the fine-grained quartz matrix.

No positive identification of gold, sulphides or other ore minerals. Sporadic occurences of a fine-grained, very reflective, anhedral mineral were present associated with fine-grained limonite and quartz surrounding the quartz clasts. Rarely, this mineral was present overprinting quartz clasts.

Plate 17 Slide 486'. Fine grained quartz matrix with coarse quartz clasts. Coarse quartz is altering to fine-grained quartz. 20 X, XN



515'

Modal Analysis

Quartz - 80 % Fine-grained, 40 %

Coarse-grained, 40 %

Hematite - 20 %

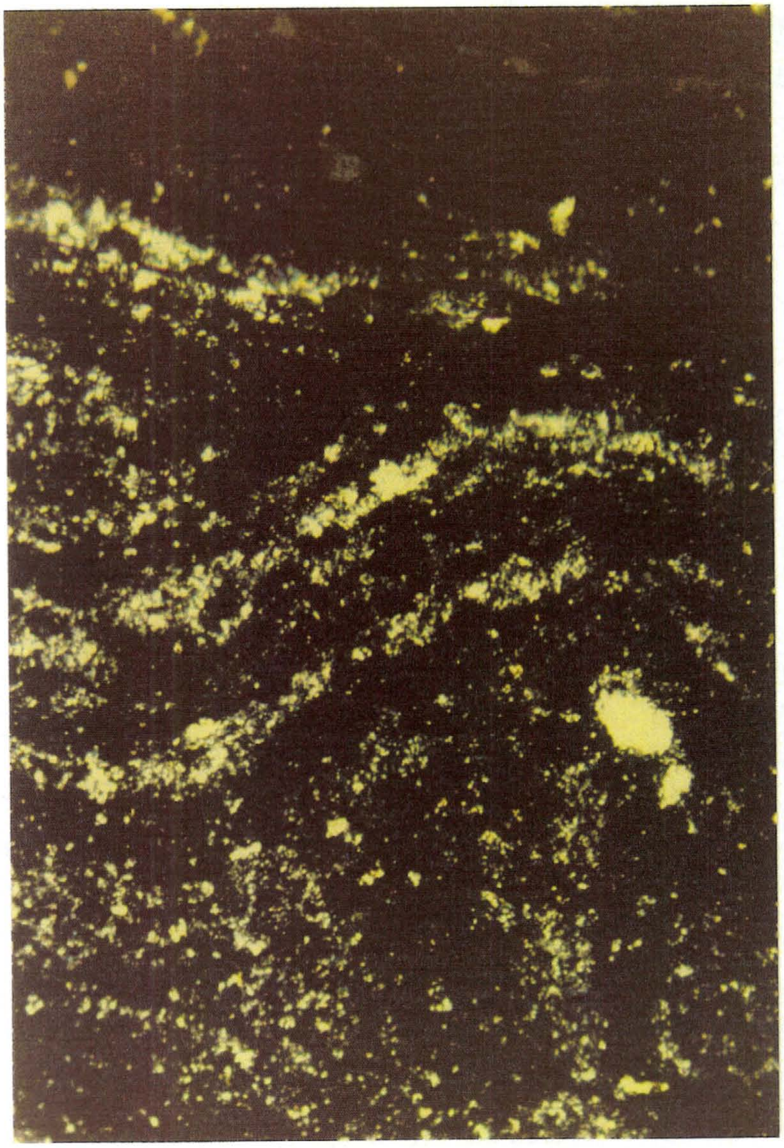
Porosity - 10 %

Description

This slide is predominantly fine-grained and coarse-grained quartz with one region rich in hematite and limonite. Quartz vary in size up to .7mm and average .1mm . Pods of very fine-grained quartz are present rimmed by hematite. Coarse-grained quartz is intergrown with fine-grained quartz and appears to be altering to it . The hematite-rich portion of the slide appears bedded with alternating beds of fine-grained quartz and hematite (Plate 18). The beds are generally .1mm wide and are slumped and disrupted (Plate 18). The hematite and limonite are very fine-grained and amorphous.

Positive identification of gold, sulphides or ore minerals was not possible. Several grains of electrum are tentatively identified in the hematite/limonite-rich beds. The suspected electrum is anhedral to euhedral and averages .02mm .

Plate 18 Slide 515'. Beds of hematite and quartz. This may also be soft sediment deformation as the beds commonly pinch and swell. 20 X, PPL



517'

Modal Analysis

Quartz - 90 % Fine-grained, 80%

Coarse-grained, 10%

Hematite - 10 %

Porosity - 10 %

Description

This slide is dominated by fine-grained quartz matrix and hematite stringers (Plate 19). The quartz matrix is very fine-grained and coarser quartz averages .4mm . Coarse-grained quartz is commonly elongate, associted with vugs, and is intergrown with fine-grained quartz (Plate 20). The coarse-grained quartz appears to be altering to the fine-grained quartz. Elongate quartz also has undulose extinction. Coarse-grained, hexagonal quartz is present at the rims of pods of fine-grained quartz. Hematite/limonite overgrowthhs on coarse-grained quartz are common.

Stringers of hematite and limonite have brecciated the fine-grained matrix (Plate 21). The hematie and limonite are commonly fine-grained.

Evidence of minor faulting is present in this slide (Plate 22). A small dextral fault with an offset of approximately .5mm is displacing fine quartz veinlets. The trend of the fault is roughly 310 when the top is properly aligned. Beyond the fine-grained quartz, the fault is obscured by hematite.

Aggregates of fine-grained tentatively identified electrum are present in the hematite-limonite-rich areas. These grains are generally anhedral. Gold, sulphides or ore minerals were not indentified.

Plate 19 Slide 517'. Fine-grained quartz and hematite stringers. Coarse-grained quartz is present as are numerous vugs. 20 X, XN

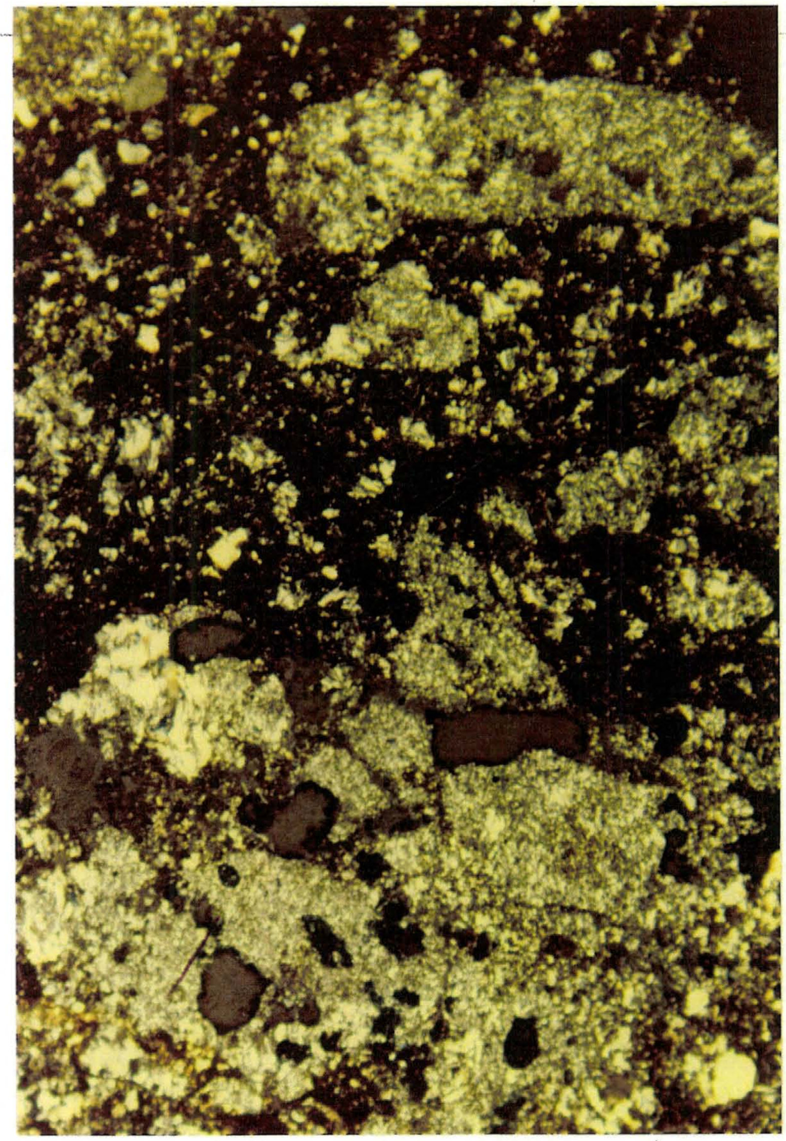


Plate 20 Slide 517'. Coarse, elongate quarrtz in a fine-grained quartz matrix. The ends of the elongate quartz are altering to fine-grained quartz. 20 X, XN

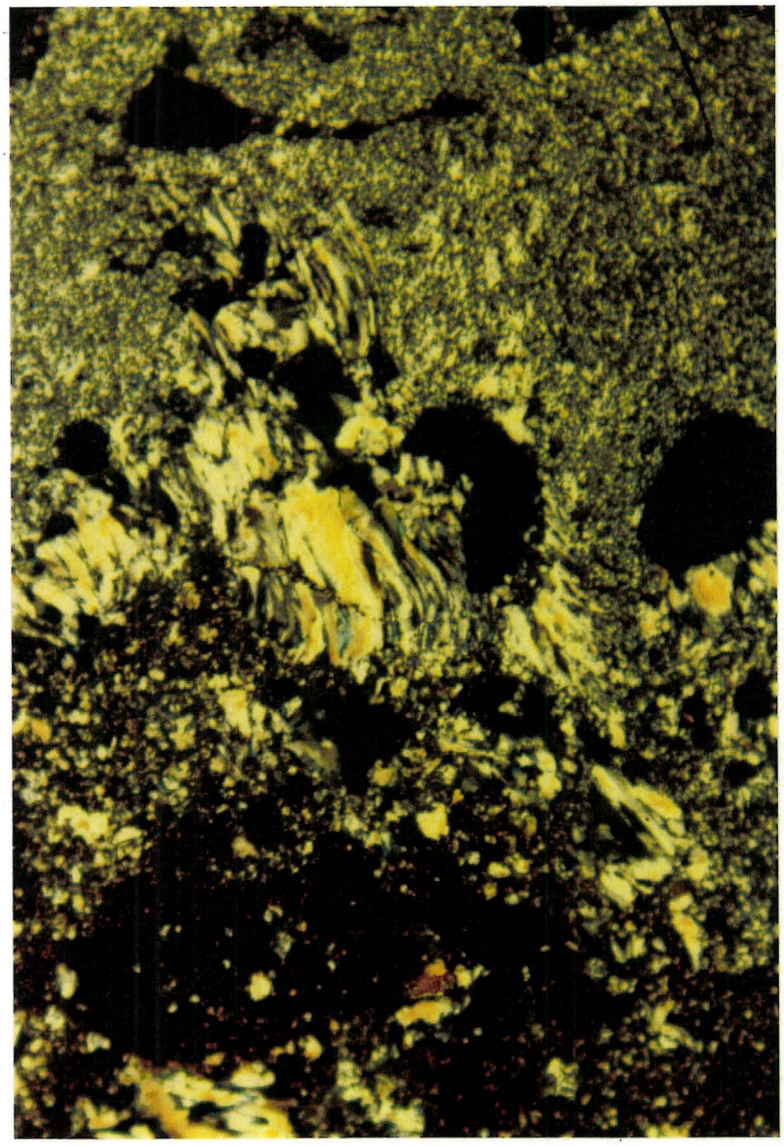


Plate 21 Slide 517'. Stringers of hematite and limonite brecciating the slide. Note regions in the fine-grained clasts are coarse-grained. The dark shadows are the slide numbers. 20 X, XN

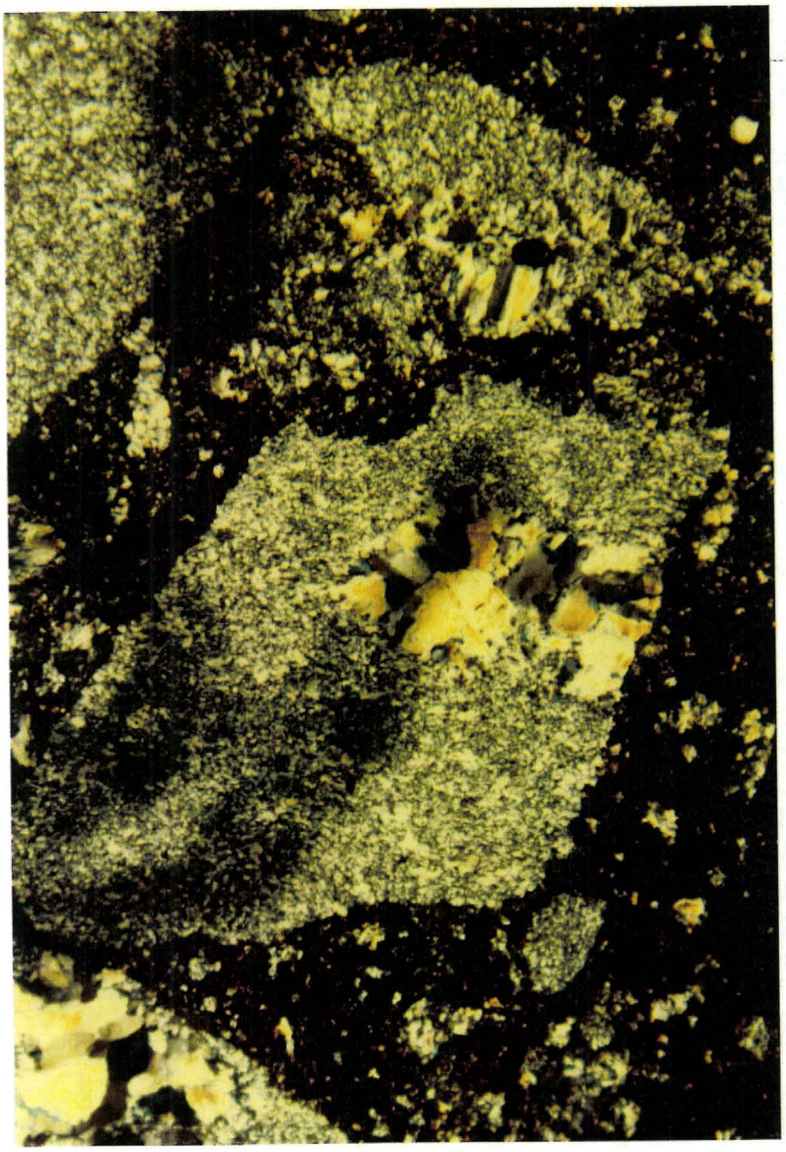
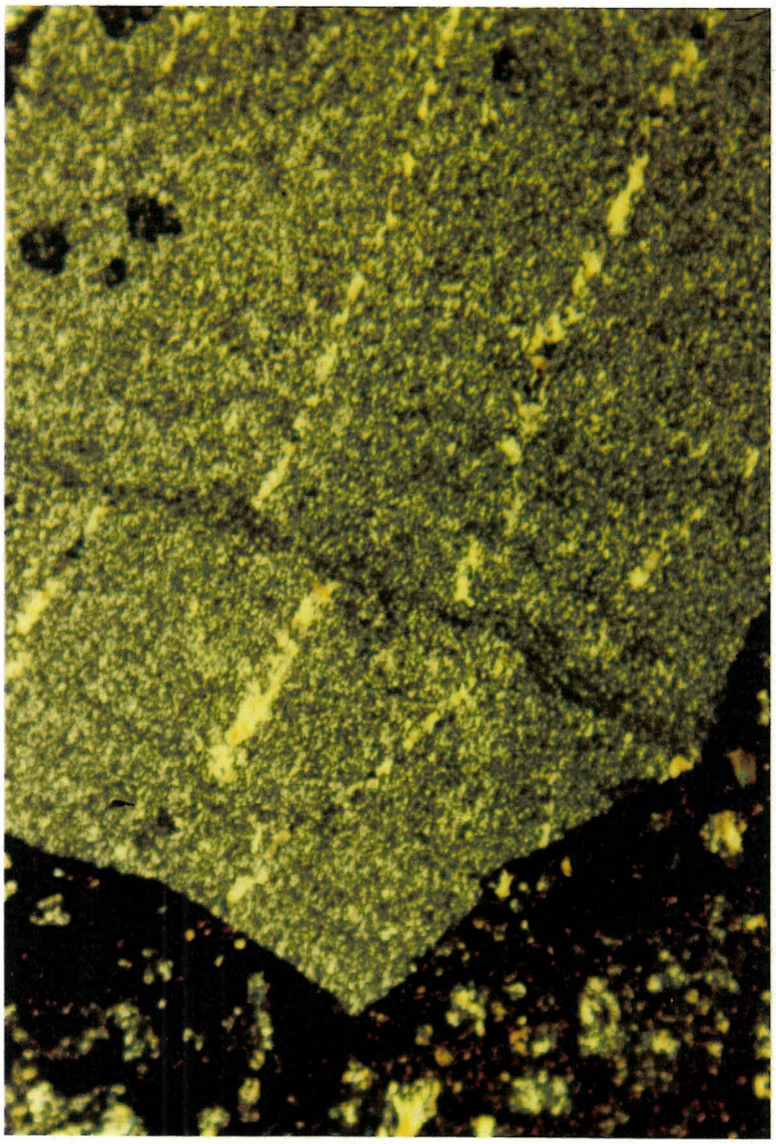


Plate 22 Slide 517'. Fault through a large clast of fine-grained quartz. The offset is approximately .5mm . 20X XN



533'

Modal Analysis

Quartz - 90 % Fine-grained, 80%

Coarse-grained, 10%

Hematite - 10 %

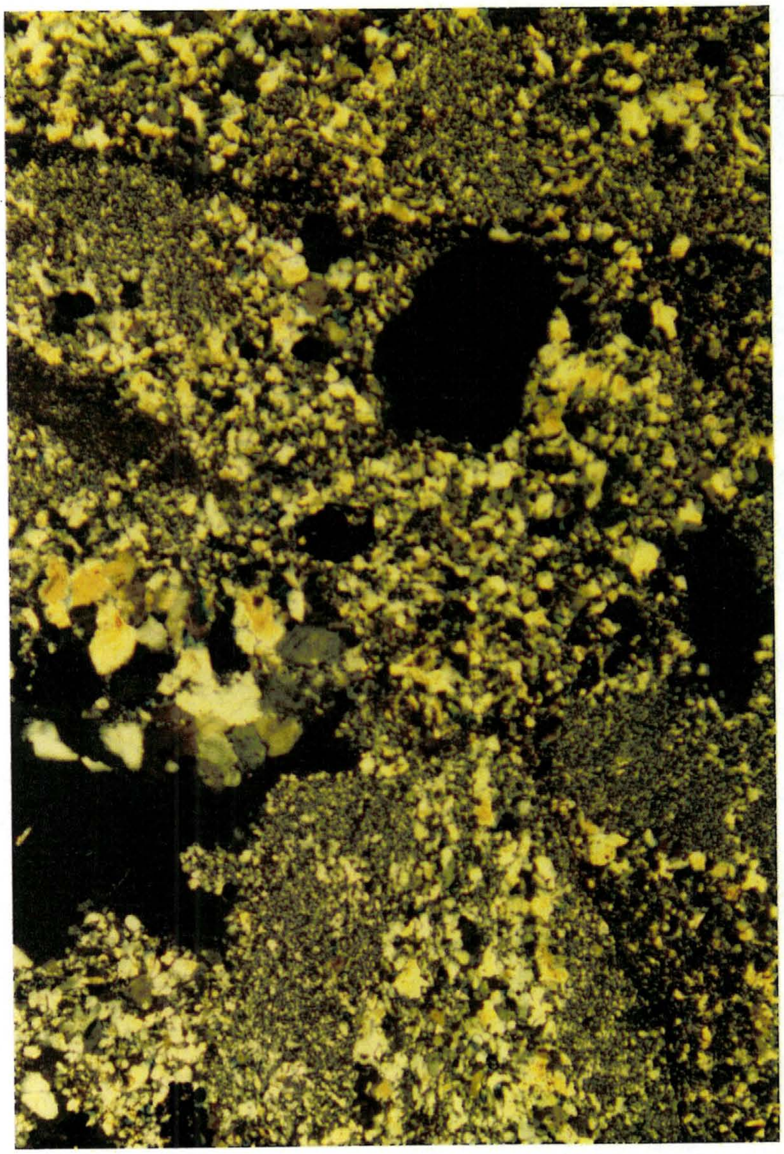
Porosity - 20 %

Description

This slide is dominated by fine-grained quartz with larger quartz clasts, hematite and numerous vugs (Plate 23). Numerous quartz veinlets and concentrations of coarse-grained quartz are present. Veinlets range to .8mm wide and several millimeters long. Coarse-grained quartz in concentrations average .3 mm, have sutured grain boundaries, occassionally 120 interfacial angles. The concentrations of coarse-grained quartz are up to 2mm in diameter. Quartz is also filling vugs (Plate 22). Vugs are rimmed by fine-grained hematite and limonite. Hematite and limonite also occur as fine stringers. There may be some potassic feldspar present. The optic sign was definitely biaxial but quartz can also have a biaxial optic sign.

No positive identification of gold, sulphides or ore minerals. Tentatively identified electrum occurs sporadically in the hematite rich areas.

Plate 23 Slide 533'. Fine-grained quartz, large quartz clasts and numerous vugs. Note the quartz infilling the vugs. 20 X, XN



547°

Modal Analysis

Quartz - 90 % Fine-grained, 65%

Coarse-grained, 25%

Hematite - 10 %

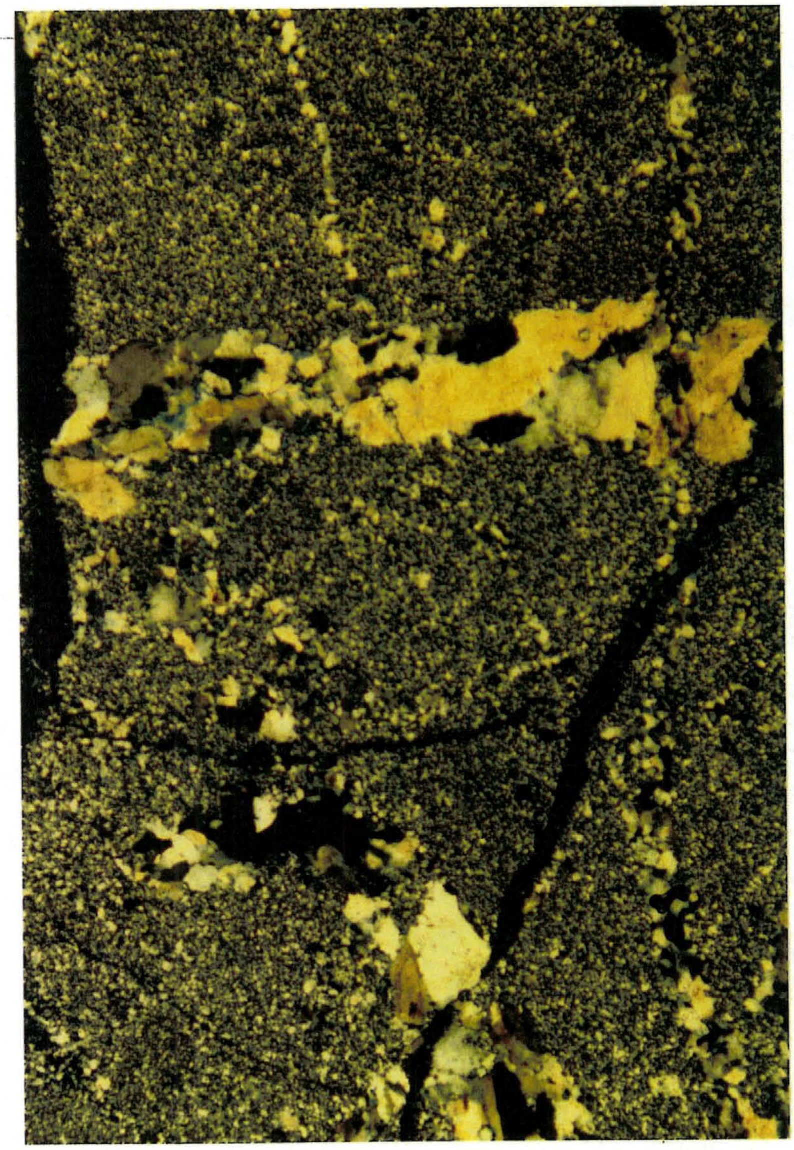
K-Feldspar - < 1 %

Description

This slide is predominantly fine-grained quartz with pods and veinlets of coarse-grained quartz. The quartz-grains have sutured boundaries, undulose extinction, can be banded and are commonly intergrown with finer-grained quartz. Veinlets .5 mm wide cross-cut the entire slide, trend in all directions and some coarse-grained quartz is filling vugs (Plate 22). Little hematite is found in the fine-grained quartz matrix. It tends to occur in veinlets, and commonly rims the pockets of coarse-grained quartz.

No positive identification of gold, sulphides or ore minerals. Possible sulphides are present in the coarse-grained quartz and hematite however these are very infrequent.

Plate 24 Slide 547'. Fine-grained matrix of quartz, veinlets of coarse-grained quartz and vugs and fractures. 20 X, XN



554'

Modal Analysis

Hematite - 60 %

Quartz - 40 % Fine-grained, 25%

Coarse-grained, 15%

Description

This slide is predominantly fine-grained hematite and limonite with clasts of fine-grained quartz. Coarse-grained quartz is present in the hematite-rich areas commonly with undulose extinction and sutured grain boundaries. Clasts are extensively brecciated by stringers of hematite and limonite (Plate 25). Frequently, these clasts are partially coarse-grained quartz undergoing grain-size reduction. Coarse quartz grains have limonite overgrowths and some clasts have extensive iron staining which is directly related to the amount of brecciation. Clasts vary up to 8 mm in size.

Hematite and limonite is fine-grained and brecciates the entire slide. Some hematite is orangish-red and displays fine banding and appears to be folded in one instance (Plate 26). This banded hematite is cross-cut by minute veinlets of darker hematite. No positive identification of gold, sulphides or other ore minerals. Sporadic occurrences of possible fine-grained sulphides are in the hematite.

Plate 25 Slide 554'. Limonite-stained clast of fine-grained quartz brecciated with hematite and coarse-grained quartz. Some fragments appear to fit onto the main clast. 20 X, PPL

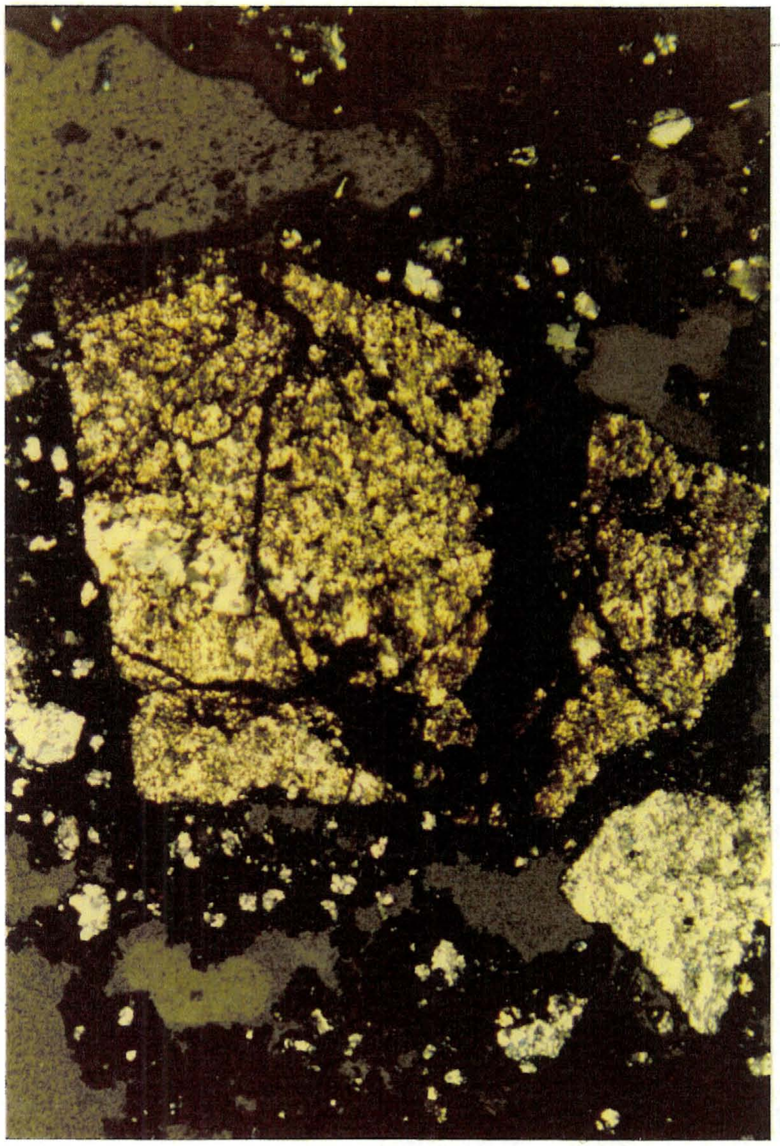


Plate 26 Slide 554'. Colloform hematite with fine banding and fractures. 80 X, X nicols.

577'

Modal Analysis

Quartz - 95 % Fine-grained, 55%

Coarse-grained, 40%

Hematite - 5 %

Porosity - 15 %

Description

This slide is dominated by quartz varying up to 1.0 mm in diameter and averaging .1 mm . Fine-grained quartz occurs as pods or clasts while the coarser grained quartz is filling vugs and fractures. The coarser quartz has sutured grain boundaries, undulose extinction and rarely 120 interfacial angles. The coarser quartz also has limonite overprints and when it occurs as clasts, is commonly bisected by fine-grained quartz.

Hematite is fine-grained and commonly associated with vugs and porosity.

No positive identification of gold, sulphides or ore minerals. Sporadic reflections are present in the coarse-grained quartz and hematite and may be fine sulphide minerals.

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University of Arizona Bulletin

ARIZONA BUREAU OF MINES

SOME ARIZONA ORE DEPOSITS

(PARTIAL COPY)

Papers Prepared for and Presented at the Regional Meeting of the A.I.M. &M.E. held at Tucson, Arizona, Nov. 1-5, 1938.

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the original ore bodies has been thoroughly saturated with the products of sulphide oxidation.

In the process of replacement the grain structure, bedding, and the included unreplaced chert lenses of the limestone are frequently beautifully preserved in the resulting sulphide.

Porphyry Ore Bodies

There is a fairly large mineralized area within the stock of Sacramento Hill. Ore in the western section of this area has been removed by steam-shovel and glory-hole mining. That in the eastern section is being mined by block caving. These ore bodies are secondarily enriched by chalcocite and are partly in the porphyry mass of Sacramento Hill and partly in the contact breccia around it. The protore contains less than 0.50 per cent copper. The stock of Sacramento Hill was highly silicified, sericitized, and pyritized, and the small amounts of chalcopyrite and bornite in the protore are responsible for the copper of the secondary enrichment. The great irregularity of the contact between the gossan and the secondarily enriched zone is worthy of note.

The porphyry on the north side of Mule Pass Gulch is not nearly so pyritized or silicified as the part in which the porphyry ore bodies occur, no secondary enrichment has taken place, and drilling found no mineralization of economic value.

Ore Guides

The ore guides in limestone may be summarized as follows:

Manganese oxides as outcrops or along fracture zones can be used as ore guides. The ore associated with them may be below or to one side of the occurrence.

Silica breccia and hematite, or both, are usually closer to ore than manganese. To get to the ore, usually found in connection with them, it is necessary to prospect down the fracture zones or the replaced bedding along which they occur.

Limonitic gossans and calcite-filled cracks in the limestone over oxidized slumped ore bodies are direct guides and point down to the possible ore.

As the calcite-filled cracks and slumping are due to either the oxidation of a sulphide ore body, pyrite body, or a solution cave, ore is not present under all of them.

Caves encountered underground are near guides, because the difference between a solution cave and a slump cave can generally be recognized.

Boxwork siderite is the result of the acid solutions which are formed when a sulphide ore body is being oxidized. The iron sulphates reacting with the limestone form siderite and gypsum. The gypsum is usually carried off in solution. The siderite forming below the sulphide which is being altered points upward as a guide. Since, however, the same solutions may come from a mass of pyrite or from a sulphide ore body, ore may or may not be present.

Granite-porphyry dikes and sills are guides to ore. By following them on both sides ore may be encountered in embayments.

Fracture zones, where they are rather steep and dip more or less normally to the bedding, are well worth following if they are at all mineralized.

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Jerome District[17]

By Louis E. Reber, Jr.[18]

Location and Extent

The United Verde and United Verde Extension, the chief mines of the Jerome or Verde mining district, are at Jerome, in Yavapai County, in north-central Arizona. Jerome is on the northeasterly slope of the Black Hills, facing across the broad Verde Valley to the northern Arizona plateau escarpment. The mean altitude of

[17] Paper prepared for, and originally presented at, the regional meeting of the A.I.M.&M.E. held at Tucson, Arizona, November 1-5, 1938.

[18] Geologist, Phelps Dodge Corp.

Jerome is about 5,200 feet, and the smelter towns of Clarkdale and Clemenceau are in the valley, about 2,000 feet lower, while the highway to Prescott climbs nearly 2,000 feet higher to cross the Black Hills. The Verde Tunnel and Smelter Railroad connects Jerome with Clarkdale which is on a branch of the Santa Fe.

The Jerome mining district includes an area of about 20 square miles, extending about 8 miles southeasterly along the steep side of the valley from near Jerome, generally between the 4,500- and 6,000-foot elevation contours. This area corresponds approximately with a belt of exposed pre-Cambrian rocks, bounded on the lower side by the great Verde fault and on the upper side by nearly flat-lying Paleozoic beds. The primary mineralization is confined to the pre-Cambrian rocks, which have been sufficiently prospected to delimit roughly the area of persistent scattered mineralization of the district and to show that it does not extend far beyond the exposed area. The southeasterly limit of the district is characterized by the gradual fading out of the scattered mineralization in the exposed belt. A short distance farther south is the Cherry Creek district of small gold veins which lie in a zone paralleling and including the contact of the Bradshaw granite.

Distribution of Ore Mineralization

Within the district practically all the important mineralization occurs on or near boundaries of the intrusive Cleopatra quartz porphyry, two belts of which cross the district. This stronger mineralization does not appear to persist along the contacts beyond the limit of general mineralization, however.

The United Verde ore zone is on the north side of the north porphyry belt. The United Verde Extension (U.V.X.) ore zone is a downthrown fault segment of the same ore zone and shows the same relation to the porphyry. These two segments of the original United Verde ore zone account for over 99 per cent of the total production of the district. The Jerome Verde Mine is in an outlying ore body in the U.V.X. ore zone. The Verde Central ore zone is on the south side of the north porphyry belt. On the same contact, north and east of the Verde Central, the Hull-Cleopatra Dillon tunnel developed several small ore bodies, and several hundred tons were mined.

The Copper Chief-Equator (Iron King) ore zone is on the south side of the south porphyry belt. Small ore bodies, chiefly on the Green Monster property, farther north in the south porphyry belt, yielded perhaps a few hundred tons of ore. Several small veins have been worked for oxidized gold-silver ore. The Shea vein, which is near the Copper Chief, made some production, and the Grand Island Company shipped 100 tons of good ore from a small lens in the Copper Chief flat fault.

Away from the quartz-porphyry belts, two or three of the prospecting companies developed enough ore to supply the stockholders with specimens.

United Verde Ore Zone

Location and development.—The United Verde Mine is west of Jerome. The outcrop of its ore zone was in a notch where the head of Bitter Creek cut into the relatively steep valley slope above the Verde fault (Pl. VIII). The open-pit work has removed most of the top of the ore zone, nearly to the 600-foot level. The collar of No. 3 Shaft, from which the mine levels are measured, was at an altitude of 5,500 feet. The ore zone is thoroughly developed by means of level work and diamond-drill holes to the 3,000-foot level with some work on the 3,300-foot level (altitude 2,200 feet), and a small amount of somewhat deeper diamond drilling. There is extensive stoping to the 2,550- and a little on the 2,700-foot level. Much ore remains in pillars throughout the mine.

On the 1,000-foot level the Hopewell tunnel, with a standard-gauge railroad over a mile in length, connects the mine ore bins with the surface and the railroad to the smelter. The new No. 7 Shaft, not yet in operation, comes to the surface east of the ore zone, on the 300 level bench, near the outcrop of the Verde fault (Pl. IX).

An adit tunnel on the 500-foot level connects the principal working shaft (No. 6) with the main surface plant.

There is work along the Verde fault in the Hermit claim on the 500-, 600-, 700-, and 1,000-foot levels.

Structure and extent.—The United Verde ore zone, as developed in the United Verde Mine, consists of a very irregular pipelike body of massive sulphide, quartz, and mixed sulphide and rock, with a steep north-northwesterly plunge. Quartz predominates on the hanging wall or diorite side of the main sulphide mass, with the mixed material on the footwall or quartz-porphyry side. In plan the mineralized zone ranges from more than 500,000 square feet or about 12 acres to less than 300,000 square feet, with an average near 400,000 square feet. The massive sulphide itself has an average cross section of approximately 250,000 square feet.

The downward trend of the ore zone is determined by a steeply dipping, very irregularly interfingering intrusive contact between rhyolitic quartz porphyry to the south and a series of banded tuffs and sedimentary material ("bedded sediments") to the north. It is located where the average strike of the contact changes from northerly to northeasterly. The more regularly curving contact of the diorite mass, which approximately parallels the rhyolitic porphyry-bedded-sediment contact, forms a clean-cut limit to the northerly or hanging-wall side of the ore zone. On the footwall or quartz-porphyry side the boundary is very irregular and interfingering, largely controlled by the schistosity of the porphyry, the average trend of which is about N. 10 degrees W. with steep easterly to vertical dips (Pl. XII).

In the upper part of the mine an embayment in the diorite and a band of relatively strong schistosity in the quartz porphyry combined to give the ore zone a roughly lenticular cross section, with the longer axis corresponding to the trend of the schistosity (Pl. X).

In the lower levels the more open curve of the diorite, the less intense but more uniform schistosity of the quartz porphyry, the tendency of the schistosity to approach parallelism to the contact, and, no doubt, less irregularity in the original porphyry contact, were jointly responsible for the crescent-shaped outline of the ore zone with the elongation more or less paralleling the diorite and much less interfingering with the porphyry (Pl. XI).

Although other sulphides are present, the copper content of the ore as a rule depends on the abundance of chalcopyrite. Pyrite, generally with appreciable sphalerite, constitutes the sulphide gangue. Black chlorite rock, with some quartz porphyry and quartz, is the predominant rock gangue. About one seventh of the volume of the mineralized zone is commercial copper ore, and a somewhat smaller amount is possible low-grade zinc ore.

Replacement.—As may be inferred from the preceding description of the structural features that control the form of the ore zone, the mineralization is very clearly of the replacement type. Characteristic structures and textures of the replaced rock are commonly preserved by the massive sulphide, and residual shreds of rock or unreplaced quartz phenocrysts are present in many places. Such evidence bearing on the former distribution of rock types in the ore zone aids the unraveling of the complicated history of the mineralization, which in turn serves to explain the occurrence and distribution of the commercial ore.

Sequence of mineralization.—Several definite stages of deposition can be recognized, although the extent to which they represent distinct periods in the sequence, rather than parts of a more or less continuously progressive change, is not clear.

Paragenesis or sequence of mineral deposition, as conventionally determined by the microscopic study of polished surfaces, may prove misleading unless interpreted in the light of detailed study of the occurrence and distribution of the material in place. The correct understanding of the most significant features of a complicated chronology may depend much more upon field study than upon the microscope. Nevertheless the results of microscope work are also essential to a complete understanding.

Microscope work by Benedict,[19] Lindgren,[20] and Hansen,[21] supplies such data.

Two points not made clear by the microscope are significant. First, although breccia filling and replacement of earlier by later sulphides were quantitatively important, rock replacement was most important from beginning to end, so that in a broad way the distribution and structure of any generation of sulphides was

[19] P. C. Benedict, *Geology of Deception Gulch and the Verde Central Mine*, unpublished thesis, Mass. Inst. of Technology, 1923.

[20] Waldemar Lindgren (U.S.G.S. Bull. 782, 1926).

[21] M. G. Hansen, *Microscopical Examination of the United Verde Sulphide Orebody*, unpublished report to United Verde Copper Company, December, 1927.

primarily controlled by the location of the most accessible unreplaced rock left by preceding generations. Second, the bulk of the black chlorite was formed after deposition of most of the lean pyrite and before most of the chalcopyrite.

The most plausible interpretation of the mineralization is then as follows: The first solutions followed sections of the porphyry contact nearest the diorite and deposited quartz with negligible quantities of pyrite and chalcopyrite and probably specularite. The quartz favored replacement of the bedded sediments but in places left a narrow unreplaced strip against the diorite.

The second period of mineralization deposited pyrite with important quantities of dark red-brown sphalerite or marmatite and a little chalcopyrite, with probably some local quartz as well as intergrown quartz and dolomite similar to that of the sixth period. Microscopic arsenopyrite preceded the pyrite. This period is responsible for the major part of the ore zone, and probably a large part of the possible zinc ore, but no commercial copper ore. Some bedded sediments were replaced, but the pyrite appears to have shown a preference to replacement of the porphyry. For the above reason, or because it was already sealed off by the quartz, the strip of bedded sediments along the diorite remained unreplaced. Microscopic magnetite and a very small amount of specularite following the pyrite were perhaps precursors of the change from sulphide to high-iron chlorite deposition.

The third period represents a definite break in sulphide deposition. Solutions working out from the footwall of the pyrite sulphide mass completely replaced an enormous volume of quartz porphyry and some tongues of the bedded sediments with a nearly black, high-iron variety of chlorite.

In the fourth period were deposited much pure chalcopyrite and considerable chalcopyrite intergrown with nearly black sphalerite or marmatite and in places with galena and probably some pyrite. The chalcopyrite appears to have most readily replaced the black chlorite rock or "black schist." This period was responsible for most of the commercial ore. Numerous tongues and lenses of "black schist" interfingering with the earlier sulphide were completely replaced, material additions were made to the total volume of massive sulphide, and some scattering mineralization formed ore bodies in the schist but very rarely penetrated the quartz porphyry.

The structure that controlled the form of the ore zone in the upper and lower levels is also significant. In the upper levels there was evidently much more interfingering of replaced and unreplaced rock before the chalcopyrite came in, and by further replacement it penetrated deep into the earlier lean sulphides. In the lower levels the earlier sulphide mass was comparatively tight, and for the most part the chalcopyrite was forced to build onto the footwall of the pyrite or spread out into the schist. Probably the greater steepness and regularity of the diorite wall in the lower levels also militated against a more favorable distribution of the early sulphide.

After the fourth-period mineralization numerous small andesite or fine-grained diorite dikes cut through the ore zone and surrounding rocks along nearly vertical east-west fractures at intervals of 100 to 200 feet or less. These dikes range in thickness from a few inches to 20 feet, although most of them are less than 2½ feet. Such dikes are common throughout the district but nowhere else so abundant. Though somewhat mineralized locally, characteristic differences in the fracturing where they cut high-grade chalcopyrite from that in the lean pyrite are believed to prove them younger than the principal chalcopyrite stage of deposition.

During the fifth period small masses of quartz, in part associated with considerable bornite and probably some other sulphides, were deposited. Microscopic primary chalcocite is intergrown with bornite, and recrystallized black chlorite is an occasional associate.

The sixth and last period was characterized by widespread deposition of intergrown quartz and dolomite or calcite in part associated with chalcopyrite; pyrite; a relatively clear, glassy, pale brown or greenish variety of sphalerite; and tennantite. This mineralization is most conspicuous in the chlorite rock or black schist and probably added materially to the volume of schist ore. The tennantite, predominantly arsenical, contains some antimony and about 40 ounces of silver to the ton, but it rarely affects the silver content of the ore. The same mineral association deposited in fractures in the older quartz and sulphides and in small gash veins in the schist, in places with margins of fibrous serpentine, is the final phase.

Changes with depth.—The ore zone in the U.V.X. Mine probably represents a segment from over 2,000 feet above the top of that exposed in the United Verde Mine. Probably a large part of the chalcocite ore was of fairly good grade before enrichment. As in the highest levels in the United Verde, there was probably a smaller-than-average area of mineralization, with a higher-than-average proportion of chalcopyrite.

In the United Verde Mine the size of the ore zone and the amount of copper ore both vary greatly from level to level. Both increase where the plunge of the ore body is less steep than average.

In a very broad way, the trend is a diminishing one from the top to the bottom of the mine as regards quantity of ore, and from about the halfway point to the bottom as regards the size of the ore zone. The ore zone at the bottom is somewhat larger than the minimum between the halfway point and the surface.

The structural features are no doubt to some extent responsible for the diminishing quantity of ore.

If the lower-level trend of the ore zone and the dip of the east end of the diorite persist, the ore zone may leave the diorite altogether, in which case some scattering of the ore zone, with perhaps discontinuous lenses of massive sulphide, would be expected.

This change would probably mean less commercial ore in proportion to the total copper mineralization but might have some favorable aspects. There is a chance for the ore zone to flatten out before it entirely leaves the diorite.

A mineralized zone, with an area of about 10,000 square feet of massive sulphide, quartz, and mineralized schist, encountered on the 3,000-foot level, west of the diorite on the U.V.X., Haynes property, may represent the top of a branch from the main ore zone. If so, the ore zone may become stronger below the junction.

The Haynes-area mineralization includes considerable magnetite and a small amount of pyrrhotite, although otherwise typical of the main ore zone. This may be the precursor of an unfavorable mineralogical change with depth. The mineralization has been remarkably constant for a vertical range of over a mile, from the highest primary mineralization in the U.V.X. Mine to the bottom of the United Verde. Microscopic pyrrhotite in the main ore zone on the 3,000-foot level and more microscopic magnetite and specularite than above, tend to confirm the Haynes showing.

Analyses.—The analyses in Table 3, though not exact averages, give the approximate chemical composition of the material of the primary mineralized area. The last two show the change effected in replacement of quartz porphyry by chlorite.

In addition to the material represented by the analyses, a considerable volume of lean siliceous sulphide and quartz and a smaller amount of mineralized bedded sediments make up the volume of the mineralized zone.

Abundant black chlorite in the ore added greatly to smelting difficulties. In 1927 the concentrating plant was added to the smelter at Clarkdale primarily to eliminate excess black schist from the smelting charge rather than to treat lower grade ore.

Sulphide enrichment.—Although apparently unenriched massive pyrite was in places close under the oxides, it is believed that chalcocite enrichment appreciably affected the chalcopyrite ore as deep as the 500-foot level. Possibly a considerable part of the highest grade ore on the 300-foot level was chalcocite. Detailed records of the early mining are lacking, and pit operations encountered most of the highest grade pillar material as crushed and broken fragments often mixed with old stope fill. Much chalcocite and considerable bornite were present in the most crushed material from the pillars under the 300-, and less extensively under the 400-foot levels. Conditions did not permit even an approximate estimate of the total amount or the mode of occurrence of the chalcocite and bornite encountered in the pit.

Bornite and steely chalcocite were found as lumps and boulders in loose, porous material showing evidence of intense fire action. The time from the first mine fires to the opening of the pit was about thirty years, during much of which the material was extremely hot. The appearance and occurrence of the bornite sug-

TABLE 3.—AVERAGE ANALYSES (PER CENT).

	Cu	Zn	SiO_2	Fe	Al_2O_3	S	CaO	MgO	K_2O	Na_2O	H_2O	CO_2
Lean massive sulphide..........	0.70	1.33	11.00	35.00	1.39	37.00	2.07	......	......	......	......	......
Zincky massive sulphide......	1.16	6.72	11.50	33.00	1.18	38.00	0.78	......	......	......	......	......
Massive sulph. copper ore....	4.99	2.40	11.80	31.40	3.50	32.60	1.80	......	......	......	......	......
Siliceous sulph. copper ore...	5.44	1.90	37.20	21.40	3.70	21.30	0.64	......	......	......	......	......
Schist copper ore..........	4.73	0.70	22.90	20.70	12.70	15.40	1.22	......	......	......	......	......
Quartz porphyry copper ore	2.79	0.90	40.10	15.70	12.50	10.80	1.05	......	......	......	......	......
Quartz porphyry..........	0.02	0.04	72.08	2.21	14.57	0.06	1.98	1.48	2.38	1.26	2.67	1.35
Black schist (chlorite)........	0.03	0.26	26.23	15.59	25.99	0.11	0.11	18.16	......	......	8.55	0.04

gested that it might have formed in the fire area. Boyd[22] in 1935 concluded that all or nearly all of the bornite and probably much of the chalcocite were formed by fire action. He produced bornite by maintaining chalcopyrite at a temperature of 500 degrees Centigrade in a reducing atmosphere for four to five hours. With further heating some bornite changed to chalcocite. It is thus likely that much of the chalcocite in the pit was not due to original secondary enrichment. Furthermore, the absence in the oxide zone of any such accumulation of quartz as characterized the gossan over the U.V.X. chalcocite, makes it probable that the former chalcocite zone over the United Verde was much weaker than that of the U.V.X., and that enrichment before the pre-Cambrian faulting accounts for this difference.

Sooty chalcocite and covellite, sufficient to affect ore values, were found in crushed material below the 500-foot level. This enrichment was of comparatively recent date and presumably due largely to fire-zone conditions.

A body of disseminated ore in the quartz porphyry adjoining the main ore zone, about 500 feet in vertical extent and containing about 1,000,000 tons of 1.5 per-cent ore, was formed by secondary enrichment of very lean disseminated pyrite. The very small amount of leached capping and the prevalence of traces of oxidized copper mineral throughout indicate this enrichment to be not related to the present erosion cycle.

The distribution of the gold and silver in the open pit and comparison with primary ore at greater depth led to the conclusion that there has been secondary enrichment of both gold and silver. Possibly the precious-metal enrichment also had some relation to artificial stimulation by fire-zone conditions.

Oxide zone.—The gossan of the United Verde ore zone occurred as a blanket about 100 feet in average thickness with the low point slightly below the 160-foot level of the mine. It consisted largely of rather highly colored, soft limonitic material with lenses and boulders of hard iron oxide. At the south end copper carbonate minerals were conspicuous where mineralized black schist interfingers with the quartz porphyry. On the north end massive primary quartz cropped out against the diorite. Lower and to the south of the massive quartz and to some extent along the east side of the gossan, were a few prominent exposures of brecciated, honeycombed quartz. The greater part of the soft gossan was no doubt covered with soil and boulders of the hard limonite.

High-grade gold-silver ore was mined from parts of the soft gossan, and several places showed high concentrations of native silver immediately overlying the sulphides. When mined from the open pit, almost all of the soft gossan proved to be of commercial grade. Portions with relatively low gold-silver were generally high enough in silica to make converter flux.

[22] L. H. Boyd, *Microscopic Examination of Certain Ores from the United Verde Fire Stopes*, unpublished thesis, Colorado School of Mines, December, 1935.

The following analysis (in per cent) is of oxide ore shipped during 1918:

Cu	Fe	Zn	SiO_2	Al_2O_3	S
1.42	31.5	0.2	34.1	5.7	4.2

The Hermit claim has about 230,000 tons of oxidized copper ore, chiefly azurite and malachite with some chrysocolla, copper pitch, and black copper oxide, in basalt and prebasalt gravel in the hanging wall of the fault. The copper was evidently transported from the top of the United Verde ore zone.

U.V.X. Ore Zone

Location and development.—The U.V.X. Mine is below the fault on Bitter Creek where it parallels the lower side of Jerome (Pl. VIII). The collar altitude of the original Daisy shaft is 5,050 feet, and the bottom of the mine is the 1,900-foot level at 3,200 feet altitude. Some diamond-drill work has been done in the ore zone below the 1,900-foot level, and the outlying area, formerly Jerome Verde property, is explored most extensively on the 1,400- and 1,700-foot levels. The Josephine tunnel, with a standard-gauge railroad 2¼ miles long, connects the shaft ore bins with the surface.

Structure and extent.—The Daisy shaft passed through the fault into the pre-Cambrian rocks at 4,600 feet altitude, whereas the main shafts are in younger rocks to about 4,300 feet altitude.

The top of the ore zone ranges from a little above the 700-foot level to a little below the 800 level, with 500 to 700 feet of overlying younger rocks. Although a wedge of Paleozoic formations overlies part of the ore zone, most of it was exposed by a deep Tertiary canyon so that prebasalt gravel rests directly on the gossan (Pl. XIV).

The ore zone on the 800-foot level, near the top of the pre-Cambrian (Pl. IX), is of about the same size or a little larger than the top of the United Verde ore zone.

The form and trend of the U.V.X. ore zone has been controlled primarily by the greenstone-quartz porphyry contact and to a less degree by the margin of the diorite. The general east-west trend of the interfingering porphyry contact and the local schistosity parallel to that trend account for the direction of the long axis of the main ore body.

As shown on the 1,300-foot-level map (Pl. XIII), the main ore body, with maximum east-west length of about 500 feet and width of about 200 feet, constitutes the most important part of the ore zone. From the main ore body bands of mineralization extend northwesterly around the northeast side of the diorite and penetrate re-entrants in the diorite. In the upper part of the ore zone the northeast diorite contact dips northeast and the southeast contact dips generally southeast; the re-entrants are to some extent southeasterly plunging troughs in the diorite. Small veinlike tongues with a northwesterly plunge extend south and east of the main ore body along shear zones related to the interfingering of porphyry and greenstone.

In the lower part of the ore zone, the southeast or south side of the diorite has a northerly dip and the east part a westerly dip that corresponds with dips in the United Verde. The ore zone which consists of lenses of massive sulphide joined by weaker mineralization plunges northward. The pinching out of the main lens of massive sulphides below the 1,600-foot level, at an altitude of about 3,450 feet, forms a sag in the footwall of the ore zone entirely comparable to the footwall structure in the United Verde Mine. The deeper sulphide lenses are generally closer to the diorite, though also related to the porphyry-greenstone contact. Unlike the United Verde Mine, the U.V.X. Mine contains much fine-grained, schistose marginal diorite, some of which has been mineralized. The apparent penetration of the diorite by massive sulphide, however, is partly due to faulting.

Faulting.—From near the pre-Cambrian surface to below the 1,900-foot level the U.V.X. ore zone is progressively cut off by the Verde fault.

The possibility of pre-Cambrian postmineral faulting was always given due consideration but not regarded seriously until work in the U.V.X. Mine proved the complete cutoff of the ore zone by the fault and began to suggest that there was no footwall continuation. The predominant trend of striations and rolls in the fault indicates a direction of movement not more than 10 to 20 degrees southeast of the dip. This direction, with the measurable vertical component, pointed to the position of the footwall segment, although the evidence was not deemed conclusive enough to justify definitely limiting prospecting along the fault. Exploratory work by 1926 made it fairly certain that there was no segment of the ore zone under the fault and established the corollary of pre-Cambrian displacement. By projecting all geologic data on fault-plane sections, the writer showed conclusively in 1928 that the opposite sides of the fault could not be made to match by reversing the Tertiary movement, regardless of assumptions as to lateral movement. This fact established the former continuity of the United Verde and U.V.X. ore deposits beyond reasonable doubt. Projecting the United Verde ore zone and the plane of the fault to an intersection above the outcrop gives a vertical displacement of about 4,000 feet, or possibly anywhere between 3,500 and 4,500 feet. Projecting the base of the Paleozoic rocks to the plane of the fault from opposite sides gives 1,600 feet for the Tertiary vertical displacement, which is probably exact within 50 feet. Hence the pre-Cambrian displacement was 2,400 feet plus or minus 500 feet. These figures check with Ransome's interpretation.[23]

In general nearly 90 per cent of the Tertiary Verde fault movement is connected along the Verde fault, a single plane with heavy gouge sometimes referred to as the main footwall break. The remainder of the Tertiary and possibly some of the pre-Cam-

[23] F. L. Ransome, *Ore Deposits of the Southwest* (16th Int. Geol. Cong., 1932), Guidebook 14, pp. 20-21 and Pl. 4.

brian movement is distributed over a braided system of small hanging-wall breaks that are extremely difficult to map accurately and may have considerably affected the structural details of the sulphide masses.

Due to several much stronger hanging-wall branches farther north and up the dip of the fault, the footwall strand under the small sulphide body mined from the United Verde 500-foot level represents only about half of the total Tertiary displacement.

Sulphide zone.—The top of the sulphides of the main ore body is about 50 feet below the 1,200-foot level. Over the most important vein ore body, it is near the 1,100-foot level. Small sulphide masses in the quartz and some sulphide in the southeast veins range from altitudes of 4,300 to 4,400 feet, with a few fairly close to the pre-Cambrian surface.

Although primary quartz and residual pyrite are present, the primary mineralization is masked by intense secondary enrichment throughout much of the mine. There was enough primary material in the deeper parts of the mine, however, to permit comparison with the United Verde deposit.

The hard, dense, lean pyrite with microscopic quartz, which is conspicuous in the United Verde ore zone, is scarce in the U.V.X. ore zone, which contains a greater abundance of quartz-carbonate gangue. Most of the minerals of the United Verde deposit are present in the U.V.X., and all of the primary material in the U.V.X. deposit can be duplicated in the United Verde deposit. The black chlorite rock or "black schist," with the characteristic interfingering pattern, is extensively developed by replacement of quartz porphyry and siliceous greenstone in the vicinity of the main U.V.X. ore body. Farther north it replaces less siliceous greenstone and minor quantities of schistose diorite as well as quartz porphyry.

The sequence of mineralization appears to have been similar to that in the United Verde Mine.

The typical lean primary sulphide in the U.V.X. Mine consisted of pyrite with minor quantities of sphalerite and chalcopyrite (2 to 4 per cent zinc and ½ to 1½ per cent copper), in places banded, with admixture of quartz carbonate, and cut by numerous quartz-carbonate veinlets.

The lower part of at least one of the smaller ore bodies was very good, clean, primary chalcopyrite ore. Some and perhaps much of the slightly enriched ore owed its value to primary chalcopyrite. The proportion of chalcopyrite in the primary material does not differ greatly from that in the United Verde Mine.

The study of polished sections by Lindgren[24] and Schwartz[25] indicates the quantitative importance of pyrite replacement, and

[24] Waldemar Lindgren, *Ore Deposits of the Jerome and Bradshaw Mountains Quadrangles, Arizona* (U.S.G.S. Bull. 782, 1926), pp. 54-97.

[25] G. M. Schwartz, "Oxidized Copper Ores of U.V.X. Mine," *Econ. Geol.*, XXXIII (January, 1938), pp. 21-33.

Lindgren[26] has expressed the view that there never was much chalcopyrite in the ore. The writer believes that chalcopyrite replacement was most important in portions of the high-grade chalcocite ore. If this is true, proportion of primary chalcopyrite in the U.V.X. deposit corresponds to a better-than-average section of the United Verde deposit.

Sulphide enrichment.—The intensity and extent of the secondary enrichment in the U.V.X. Mine formed an almost unique deposit of chalcocite that places the mine in the front rank of high-grade copper mines. Outside of the main ore body the principal lenticular veinlike body was a small bonanza in itself, and numerous smaller bodies helped to swell the high-grade total.

The decrease of chalcocite with depth, the general scarcity of chalcopyrite or sphalerite where chalcocite was most abundant, and the intense kaolinic alteration of the wall rocks, varying with the abundance of chalcocite, conclusively indicate formation by the process of secondary enrichment, which is also confirmed by microscopic evidence.

The evidence only shows that all but a very little of the chalcocite was formed before the deposit was covered by the Paleozoic sediments. Since then, except for a fleeting instant in geologic time, after the precipitous prebasalt canyon barely cut into the top of the gossan, the deposit has been continuously buried. A minute quantity of sooty chalcocite and covellite has been formed by underground-water circulation since the faulting. The basal Tapeats sandstone is not believed to be older than middle Cambrian, and important secondary enrichment could have taken place in early Cambrian time. The same reasoning applies to the date of the earlier postmineral faulting; but evidence from comparison with the United Verde deposit indicates that the greater part of the U.V.X. enrichment preceded that faulting; and minor deformation, thrust faulting, and probable interrelation of the intrusive rocks point to a not very late pre-Cambrian age for the primary mineralization and make it most probable that the age of the enrichment was truly pre-Cambrian.

Oxide zone.—The bottom limit of the oxide zone in the U.V.X. Mine is extremely variable, ranging from an altitude of about 3,850 feet over the main ore body to more than 4,400 feet at the tops of some of the smaller sulphide bodies. Above the 1,200-foot level, however, dense fine-grained primary quartz, much of which carries very little sulphide, becomes more and more predominant. Within the quartz were a number of irregular lenses of high-grade quartz-chalcocite ore, some of very limited vertical extent. In the higher bodies malachite, locally with a little cuprite, was conspicuous but generally unimportant.

The gossan or capping over the main ore body is extremely siliceous and includes much massive quartz which in part shows repeated brecciation and recementation, but in part is difficult to distinguish from the undisturbed primary quartz. Somewhat

[26] Waldemar Lindgren, unpublished report of U.V.X. Mine, August, 1926.

cavernous, hard quartz breccia with considerable limonitic material is more abundant than the cleaner quartz. Soft limonitic material, comparable to most of the United Verde gossan, occurs only very locally, although predominant close to the top of the sulphides, with much native copper in places. The vertical extent of the gossan ranges from 450 to 500 feet. Some of the smaller quartzy ore bodies were capped with 40 to 50 feet of relatively irony gossan, but in a few places the chalcocite merged into massive quartz with no obvious leaching or slumping.

The veinlike tongues extending south and east from the main ore bodies, not terminated by weaker mineralization, were overlain by 50 to 100 feet of thoroughly leached, kaolinized rock with more or less limonitic material. The vertical range of the ore bodies was from near the 1,300-foot level to a few floors above the 800-foot level. Oxidized copper minerals which were prevalent throughout, in some of the higher parts accounted for over half the copper content and entirely masked the finely divided chalcocite. All the more common oxidized copper minerals were present, with malachite, chrysocolla, and azurite most abundant. In the deeper parts sulphides with some small stringers and lenses of massive chalcocite and bornite were generally more conspicuous.

Such partially oxidized copper ore yielded nearly one eighth of the production of the mine, whereas ore with all the copper in oxide minerals, mined from the prebasalt gravel or conglomerate in the northwest part of the mine amounted to about 2 per cent. The conglomerate ore was formed at a comparatively recent date by ground water carrying copper presumably from the top of the United Verde ore zone and is similar to ore developed by the United Verde along the fault.

Unlike the United Verde gossan, even the soft limonitic material was rarely commercial gold-silver ore in the U.V.X., although some high-grade native silver ore occurred above the chalcocite of the main ore body.

The "gold stope" ore body was a tabular veinlike body along the diorite contact, bottoming in a trough in the diorite, and in part limited by massive quartz. The typical ore was fine-grained friable quartz sand with almost no residual iron oxide. The maximum length was about 350 feet, the width from 5 to 20 feet, and the vertical extent nearly 200 feet. It extended above and below the 950 level from an elevation of about 4,060 feet to about 4,250 feet. It may have averaged $10 per ton in gold, with some relatively high-grade sections. Evidently, the local conditions were exceptionally favorable to concentration of gold.

Copper Chief-Iron King Ore Zone

Location and development.—The Copper Chief and Iron King or Equator mines are 3½ miles south-southeast from Jerome (Pl. VIII). The two mines are separated by a property boundary that divides the ore zone, with the Copper Chief to the west and the Iron King to the east. The collar of the Copper Chief shaft was within the principal gossan area at an altitude of about 5,750 feet. On the bottom level, about 350 feet lower, an adit tunnel connects the shaft with the surface 850 feet to the south. There was fairly extensive stoping of oxide ore from the 240-foot level to the surface on the Copper Chief side of the property line. Mill holing of ore and waste fill has formed a considerable pit at the surface corresponding to the original extent of the gossan. All the Copper Chief work above the 240-foot level is inaccessible. On the 300-foot level are some stopes in massive sulphide.

The Iron King Mine was worked through an adit from the east about 80 feet above the Copper Chief adit, with a length of about 500 feet from the portal to the property line. Stoping extends from about 15 feet below the tunnel to about 70 feet above, with several raises, winzes, and sublevels.

Structure and extent.—The Copper Chief-Iron King ore zone extends for about 800 feet along a vertical premineral fault contact that trends about N. 80 degrees E. between quartz porphyry on the north and banded greenstone tuff on the south. It has been formed very largely by replacement of the greenstone; the quartz porphyry makes a fairly regular, nearly vertical north wall. West of the property line the deposit has the form of the west half of a fairly regular lens, with the south side somewhat ragged due to the influence of the low-angle northerly dip of the greenstone banding. The surface gossan was about 60 feet wide near the property line and extended about 250 feet west. The deposit has a somewhat smaller horizontal area at the top of the massive sulphide, about 240 feet down, and bottoms on the banding of the greenstone at about 320 feet.

Near the property line the top of the gossan plunges to the east, leaving on the surface only a narrow streak that follows the contact down to a mass of gossan at the portal of the Iron King tunnel and a few less-definite streaks along the trend of the south side. In the Iron King end the south or footwall side of the ore zone is more completely controlled by the rock banding so that vertical sections tend to have an unsymmetrical inverted crescent form, with the bottom progressively thinner eastward until it pinches out.

At or near the bottom the porphyry contact leaves the steep fault and continues with a relatively flat north or northwesterly dip. No downward continuation of the mineralization has been found other than a very small chimney or pluglike mass of lean sulphide, about 600 square feet in area, which trends vertically downward in the greenstone.

Copper Chief fault.—The Copper Chief fault, which has a very flat west to northwesterly dip, cuts through the Iron King tunnel near the portal, passes under the ore zone, and shows on the Copper Chief tunnel level. It can be traced on the surface for about ¼ mile to the north and ¾ mile to the southwest from the Iron King portal (Pl. VIII). A rather extensive diamond drilling campaign was based on the possibility of the fault having cut the ore zone and someone's opinion that the fault represented a large overthrust from the northwest. At a later date the Iron King winzes were unwatered and the small chimney of massive sulphide rediscovered on the 100-foot sublevel. A small amount of work to improve the exposure of the fault brought to light evidence of grooving and drag and gave a nearly exact measure of the amount and direction of the fault displacement. This indicated a horizontal throw of a little over 300 feet in a direction more nearly east than southeast. The negative result of the exploratory work indicated by this determination made it fairly certain that there was no displacement of the bottom of the main sulphide lens.

Sulphide zone.—Although there is much less fine-grained jaspery quartz, and black chlorite is conspicuously absent; the general character of the sulphide mineralization has enough in common with that in the United Verde to indicate a close relationship. Any type of sulphide aggregate in the Copper Chief-Iron King ore zone is duplicated somewhere in the United Verde.

Sulphide enrichment was limited on the Copper Chief side to a 2- to 4-foot layer where sooty chalcocite and covellite merged downward into crumbly pyrite and upward into oxidized material, in places with some concentration of copper and lead carbonate, and to a similar but generally thinner layer on the Iron King side. Some of this material was high in silver.

Probably about half of the sulphide in the ore zone was ore. Nearly all of it was in the Iron King end, from which about 30,000 tons were smelted. The Copper Chief shipped a few hundred tons of sulphide ore when there was a good copper market, and more recently lessees have shipped about 6,000 tons of low-grade sulphide to the U.V.X. company for flux.

Oxide zone.—The oxide ore mined by the Copper Chief and Equator companies was very similar to the soft limonitic gossan of the United Verde, although the average lead content was no doubt somewhat higher. The few thousand tons of lower grade oxide left in the Iron King by the Equator Company and now being taken out by a lessee are decidedly less irony and considerably higher in lead.

Verde Central Ore Zone

Location and development.—The Verde Central Mine is south of Walnut Gulch near the Jerome-Prescott highway and about 4,000 feet south of the United Verde Mine.

The collar of the main shaft is at an altitude of about 5,500 feet. The bottom level is the 1,900 foot at an altitude of 3,594 feet. In addition to the development of the productive area, there is extensive exploratory work to the south on both the 100- and 1,000-foot levels and a long crosscut to the west on the 1,450-foot level.

Structure and extent.—The Verde Central ore zone, like the United Verde and U.V.X. zones, is where the contact of the quartz porphyry is extraordinarily irregular or interfingering, although

on the footwall instead of the hanging wall of the porphyry mass. The exceptionally long tongue of porphyry extending south from above the Verde Central and the change in the average trend of the contact are probably most significant. The Verde Central was a "blind" prospect because the plunge of the interfingering contact zone brought the mineralization into the workings below the surface. The surface showing of irony gossan, altered black schist, and quartz with some oxidized copper minerals, around the end of the porphyry tongue on top of the hill to the south at an altitude of about 5,850 feet, undoubtedly is the outcrop of the Verde Central ore zone (Pl. IX).

There are two types of ore in the mine. One on the contact extending south from near the shaft is patchy mineralization in black schist. This has produced an ore body which extended from above the 800- to below the 1,000-foot level, with a length of about 200 feet and a mean width of about 9 feet.

The other type, the one responsible for most of the Verde Central ore, consists of a tabular, veinlike body of quartz, pyrite, and chalcopyrite in varying proportions, which though irregular in detail and varying in width from 5 to 30 or 40 feet, is essentially continuous for a maximum length of over 1,000 feet on the 1,000-foot level. It begins to show near the top of the mine, and is still fairly strong at the bottom. Although there is much less chalcopyrite than quartz or pyrite, its distribution is such that bodies of good size and an average copper content of nearly 3 per cent can be mined. Below the 600-foot level, ore of this character made up a fair proportion of the vein. Mining more selectively to produce higher grade ore would be very difficult, however.

It required abnormally high copper prices to enable the Verde Central to enter production, and the net profit on the copper produced plus any additional profit that may result from the developed ore remaining in the mine, must fall far short of returning the cost of the exploratory work.

Sequence of mineralization—Three stages of deposition—quartz, pyrite, and chalcopyrite—or four, if the black chlorite be included, correspond to the principal periods of deposition in the United Verde deposit. A vertical channel pattern of the ore shoots in the vein points to a definite separation between the pyrite and the chalcopyrite periods, although there is not much indication of the black chlorite solutions having followed the main pyrite channels as might be expected from comparison with the United Verde. For the most part, the black chlorite appears to have worked out from the porphyry contacts. What appears to be an abnormally low precious-metal content may be a function of the scarcity or absence of the other sulphides common as minor constituents of the United Verde deposit.

Supergene, secondary sulphides and oxide zone minerals are of negligible interest or importance in the Verde Central ore bodies, although a few burro loads of carbonate ore and chalcocite were found associated with the outcrop of the ore zone.

SHEA ORE ZONE

Location and development.—The Shea Mine is about 1,500 feet south of the Copper Chief outcrop. The shaft follows a south-dipping vein for 1,220 feet at an average dip of 42 degrees, attaining a vertical depth of 825 feet. The lower tunnel level, which reaches the surface about 1,300 feet east of the shaft, has almost 3,000 feet of drifts. The total of all the level work is about 7,000 feet.

Structure and extent.—Though replacement was no doubt a factor, the Shea vein is a clean-cut quartz vein that follows a premineral fault of a probable throw of more than 100 feet. The vein can be traced for about 1,200 feet east from the portal of the main adit, making the known length over 3,400 feet. The most westerly 650 feet of the adit level drift is on a different fracture. The surface exposure ends less than 200 feet west of the shaft where blanketed by the flat Copper Chief overthrust fault. Farther west the vein is weak immediately under the fault, and the fissure has not been positively identified on the surface west of the flat fault outcrop. In the most westerly part of the mine and from some distance west of the tunnel portal to the east limit of exposure, the quartz is lenticular and discontinuous. It may not average more than a foot in thickness throughout the mine, although the maximum in the vicinity of the ore shoot exceeds 5 feet.

The vein is for the most part within a large area of the dark, moderately fine-grained dioritic rock which has been called the Shea diabase. Near the shaft, it cuts across the north-south granite-porphyry dike belt.

The flat fault has been explored from the mine workings near the surface and drifted on for short distances from two deeper points, one about 500 and one about 1,200 feet west of the outcrop. This latter indicates an average dip of only 13 degrees for the flat fault.

Mineralization.—A large part of the vein consists of coarsely crystalline white quartz with sparsely scattered pyrite and only a few spots or bunches of very coarse intergrown ankerite or siderite and pyrite, usually with some chalcopyrite. Locally, there is also a little arsenopyrite and some tetrahedrite. The tetrahedrite (or freibergite) carries 600 ounces or more of silver per ton. It contains only a little arsenic. Where the sulphide mineralization is strongest and the tetrahedrite most abundant, the vein has a banded structure due to variation in the abundance of the minerals. Near the ore shoot there was a very little galena which, at least in part, occurred in quartz veinlets cutting the older quartz; it may belong to a distinctly later period, possibly related to the barite found in the flat fault.

In one locality only did the mineralization justify mining. This was from about 300 to 400 feet west of the shaft on the 300-foot level up to where the vein was cut off by the flat fault. Near the top, native silver was associated with the tetrahedrite. About

$65,000 worth of silver, copper, and gold was obtained from 1,200 to 1,300 tons of sorted shipping ore. Eighty per cent of the value was silver.

From near the Iron King tunnel to near the Shea shaft a quartz vein in the Copper Chief flat fault has largely replaced the gouge. This vein, which is several feet in maximum thickness, is similar to the Shea vein, although entirely barren quartz predominates to an even greater extent. Farther southwest only small stringers of quartz occur in the fault except at one spot, near the Grand Island shaft, where a short, thick lens produced over 100 tons of high-grade copper-gold ore. There was relatively little tetrahedrite, and the pyrite carried the gold.

Work in the flat fault vein more or less over the Shea ore shoot exposed a mass of at least several tons of barite in the flat vein and perhaps partly in the bent-over top of the Shea vein. The barite, which was not definitely associated with any other vein material, appeared to be younger.

ORIGIN OF PRIMARY MINERALIZATION

Conclusive evidence shows that practically all the Jerome district mineralization was replacement of pre-existing material by solutions. General knowledge of metalliferous ore deposits makes it practically certain that the source of the ore-bearing solutions was related to igneous rocks or igneous magma reservoirs. The particular igneous rock or inferred magma reservoir to which the ore solutions are related is speculative.

The location of the Jerome district with respect to the main mass of the Bradshaw granite and granitic material to the north and northwest makes the Bradshaw granite magma a very plausible deep-seated source for the solutions so far as location in space is concerned. It is reasonable to suppose that its magma may have been in an actively molten condition over a long period of time.

There is little reason to doubt that the vein mineralization of the district represents a late manifestation of the same mineralization that formed the massive sulphide bodies. The time location of the north-south granite-porphyry dikes between the vein formation and the earlier mineralization, together with the probable close affiliations of these dikes to the Bradshaw granite, indicates that the district mineralization was not widely separated in time from the intrusion of the granite.

Either the United Verde diorite or the Cleopatra quartz porphyry may very plausibly have been early differentiation products of the known Bradshaw granite. The diorite is similar to diorite closely associated with the granite in the quadrangle to the south.[27]

As the last important intrusive preceding the mineralization and because of its conspicuous association with the ore zone in the United Verde and U.V.X. mines, the United Verde diorite deserves

[27] T. A. Jaggar, Jr., and C. Palache, *U.S.G.S. Geol. Atlas*, Bradshaw Mountains Folio (No. 126), 1905.

first consideration. Otherwise there is little to suggest any genetic association. Away from the main ore zone the mineralization shows remarkably little tendency to favor diorite contacts. On the other hand, association of mineralization with the Cleopatra quartz porphyry is so widespread and conspicuous that it appears fairly certain that the association is more than a purely structural one, and in the main ore zone itself the evidence indicates that the first mineralizing solutions followed the porphyry contact more than the diorite contact.

The diorite does not occur very extensively in the district or surrounding area. The quartz porphyry is much more extensive, but probably its occurrence is largely within a radius of 5 miles from the center of the district.

It appears most probable that the ore-bearing solutions and the Cleopatra quartz porphyry had a common deep-seated origin in the Bradshaw granite magma.

General Geology

State of knowledge.—An article published by Provot[28] in 1916 correctly interprets the broader geological features of the district.

Reber's[29] 1920 paper was the result of more detailed study and observation. Dr. Lingren's[30] description, resulting from field work in 1922, is much more comprehensive and involves some corrections as well as important additions to the earlier papers.

Rickard's[31] early description of the U.V.X. Mine and Benedict and Fearing's[32] paper on the Verde Central Mine are of special local significance.

Even Dr. Lindgren's excellent and comprehensive description is subject to numerous minor corrections, as well as some very significant additions, in the light of all the information available to date. Hansen's[33] article outlines the most important of these additions.

It may never be possible to interpret some of the more obscure pre-Cambrian relationships with absolute certainty. Further detailed field work and much additional petrographic study are required. From a strictly practical viewpoint, however, the information now available is fairly adequate.

28 F. A. Provot, "A Geological Reconnaissance of the Jerome District" (Arizona), Abs., *E.&M.J.*, CXXV (1916), 1028.

29 L. E. Reber, Jr., "The Geology and Ore Deposits of the Jerome District" (Arizona), 1920, *T.A.I.M.E.*, LXVI (1922), 3-26.

30 Waldemar Lindgren, *Ore Deposits of the Jerome and Bradshaw Mountains Quadrangles, Arizona* (U.S.G.S. Bull. 782, 1926), pp. 54-97.

31 T. A. Rickard, "The Story of the U.V.X. Bonanza," *M. and S. P.*, CXVI (1918), No. 1, 9-17; No. 2, 47-52.

32 J. L. Fearing, Jr., and P. C. Benedict, *Geology of the Verde Central Mine* (E. & M. J. Press, April 11, 1925), CXIX, 609-11.

33 M. G. Hansen, "Geology and Ore Deposits of the United Verde Mine," *Mining Congress Journal*, XVI (April, 1930), No. 4, 306-10.

The following chronological outline, though necessarily in part somewhat speculative and subject to some valid differences of opinion, summarizes what is believed to be the best interpretation now possible.

Chronological Outline of Geologic History

Pre-Cambrian.—1. Outpouring of a series of lava flows of widely varying composition, with some interbedded volcanic ash (tuff) and sedimentary material. Formation name, "Greenstone."

South end of district believed oldest because of prevalence of north to northwesterly dips throughout the district.

2. Outpouring of a great series predominantly of rhyolite lava flows and volcanic agglomerates of remarkably uniform composition, characterized by microscopic or very small visible quartz phenocrysts. Included with "Greenstone" on Plate VIII.

Because of the prevalently green color of the fresh rock and the difficulty often experienced in identifying the metamorphic material, the noncommital term, "greenstone," has been used for formations "1," "2," and "5," as well as "4" when not considered separately. It is also sometimes applied to material lacking the distinctive banding in "3." On the areal map, Plate VIII, "4" is shown separately.

3. Deposition of a series of volcanic tuffs and sedimentary material, for the most part distinctly bedded; at least some of the bedding is due to deposition in water. Formation name "Bedded Sediments." There were probably some contemporaneous lava flows.

In Haynes Gulch, north of the United Verde Mine, which is the type locality, there are some beds in which clastic sedimentary material undoubtedly predominates and one or two horizons showing well-rounded pebbles up to 1 inch in diameter. There is also at least one horizon containing from ½ to 2 feet of very typical "Lake Superior banded jaspilite or iron formation," which is much more extensively developed, in what is presumably the same horizon, south of the Yaeger Mine on the west side of the Black Hills.

3a. Period of regional deformation and folding with development of schistosity.

4. Intrusion of hornblende syenite, older diorite, and "Shea diabase."

The "older diorite," and hornblende syenite are not distinguished from the greenstone on the areal map (Pl. VIII).

5. Outpouring of a series of siliceous lava flows, first rhyolite, then predominantly dacite.

In addition to the large area shown on the map (Pl. VIII), small areas of this rhyolite occur as far north as the Copper Chief Mine.

5a. Some regional deformation.

6. Intrusion of Cleopatra quartz porphyry as a large continuous mass crossing the north end of the district, approximately on the greenstone-bedded sediments contact and a number of very ir-

regular intrusions forming a discontinuous belt crossing the south end of the district.

The area where porphyry predominates is shown as though it were a continuous belt (Pl. VIII).

The Cleopatra quartz porphyry is a rhyolite porphyry not very unlike the older rhyolites in composition. Its intrusive character and the distinctive appearance due to the prevalence of abundant large quartz phenocrysts as well as apparent significance in relation to the mineralization justify the distinctive name.

Ransome[34] has questioned the intrusive character of the north belt of porphyry. It is believed that evidence in the United Verde Mine indicating the intrusion of the bedded sediments by the porphyry is adequately conclusive in itself. It is fairly certain that all the greenstone along the south contact is surface volcanic material, and the nature of the contact is such that at least one of the rocks must be intrusive. The absence of any abrupt changes within the porphyry mass suggesting flow boundaries is also significant.

6a. Period of deformation, with somewhat local development of schistosity, and perhaps development of anticlinal structure more or less corresponding to area of general district mineralization.

The degree of schistosity in the porphyry varies greatly although most of it within the district is more or less schistose while such as known to the east of the mineralized area is relatively massive. This, as well as the prevalent N. 10 to 20 degrees W. trend of the schistosity in the northerly part of the district, is not inconsistent with the anticlinal structure suggested by the trend of several of the contacts and boundaries, but the prevalent east-west schistosity farther to the south is difficult to reconcile.

7. Intrusion of United Verde diorite.

8. General replacement deposition of fine-grained "jaspery quartz" by mineralizing solutions.

9. Somewhat widespread deposition of pyrite followed by less widespread deposition of brown sphalerite and probably more or less localized deposition of quartz carbonate.

10. Fairly widespread deposition of high-iron black chlorite.

11. Deposition of chalcopyrite with more or less pyrite followed by black sphalerite and galena locally.

12. Intrusion of numerous small andesite dikes, with prevalent east-west trend.

The composition of these dikes is very similar to that of the United Verde diorite.

13. Deposition of quartz followed by less widespread deposition of bornite.

14. Fairly widespread deposition of quartz, carbonate with a small amount of pyrite, and less widespread deposition of chalcopyrite, in part associated with light-colored sphalerite and very local tennantite.

[34] F. L. Ransome, unpublished report on United Verde Extension Mine.

15. Intrusion of Bradshaw granite.

This is hypothetical, although suggested by inferred relationship of north-south dikes.

16. Intrusion of granite-porphyry dikes along generally north-south dike zone.

These dikes are known only along a single rather definite belt or zone which has only been traced about 4 miles south of the Shea Mine but no doubt continues much farther. The actual trend is a little east of north to north of the Copper Chief Mine where it curves to a little north of east and then pinches out close to the Verde fault. Both microscopically and to the naked eye the rock from the larger dikes appears identical with a phase of the Bradshaw granite occurring to the southeast except for the absence of biotite and the local occurrence of hornblende phenocrysts.

17. Formation of quartz veins, typically with more or less coarsely intergrown ankerite, pyrite, chalcopyrite, tetrahedrite, and other minor constituents.

These veins generally follow premineral faults or other fractures, with a more or less east-west trend.

17a. Copper Chief thrust fault movement and perhaps also nearly horizontal movement on faults near Verde Central and very small thrusts in United Verde Mine.

18. Formation of additional quartz veins, more or less similar to 17.

19. Deposition of barite in the Shea Mine.

This, the only barite known in the district, may be younger than pre-Cambrian.

20. Extensive erosion with development of oxide and chalcocite zones in sulphide deposits.

21. Gentle submergence and deposition of youngest pre-Cambrian sedimentary formations.

This is purely by inference from the most probable age of mineralization.

21a. Gentle uplift followed by great faulting, with movement on the order of 2,400 feet vertical displacement along the Verde fault, which cut off and shifted the upper portion of the United Verde ore chimney to the northeast as well as downward.

22. Perhaps some pre-Cambrian erosion and further secondary enrichment of sulphide deposits.

Paleozoic.—1. Continued erosion and gradual submergence with perhaps some further secondary enrichment of sulphide deposits.

2. Deposition of great thickness of Paleozoic sediments interrupted by periods of uplift and erosion without perceptible tilting, initiated by the deposition of the basal Tapeats sandstone in Middle Cambrian time.

Mesozoic.—Either continuous erosion or some submergence and deposition of Mesozoic sediments which were later entirely removed.

Tertiary.—1. Continued erosion with gentle tilting so that Paleozoic sediments were completely removed from the Bradshaw Mountain area to the south, but a maximum thickness of nearly 1,000 feet was left close to Jerome and progressively greater thicknesses farther north.

1a. Development of early Tertiary Verde Valley with deep gulches near Jerome, one of which slightly penetrated the pre-Cambrian formations and partially exposed the top of the U.V.X. downfaulted segment of the Verde ore zone.

2. Interruption of drainage and filling of gulches with prebasalt gravels.

3. Outpouring of series of basalt flows, which totaled over 800 feet in thickness, with some interflow weathering and erosion.

4. Tertiary faulting. Development of the Tertiary Verde fault belt and gradual lowering of the Verde Valley area with contemporaneous filling of the valley with the Verde lake beds to a thickness of over 2,000 feet and contemporaneous gravel deposition from the fault scarps merging into the lake beds. Also some further outpouring of basalt during the lake-bed deposition.

Movement of the main Verde fault added to the separation of the two segments of the Verde ore zone and erosion of the fault scarp exposed the top of the United Verde segment to very active attack, resulting in the destruction of most of the pre-existing oxide and chalcocite zones. The redeposition of copper dissolved from the outcrop, in oxidized form in the limestone and in bouldery gravel in gulches below the fault, resulted in the formation of the Dundee deposit and the carbonate veins in U.V.X. ground near the Columbia shaft.

Quaternary.—Rejuvenation of drainage leading to present erosion cycle. Final draining of Verde Lake, dissection of lake beds, and more intense erosion of steep slope due to fault belt. Further erosion of top of United Verde ore zone and deposition of oxidized copper in basalt and prebasalt gravels in and along Verde fault and appreciable sooty chalcocite enrichment in U.V.X. ore zone. This secondary copper deposition was perhaps initiated during the preceding period.

Significant Dates in Human History

United Verde Mine and Jerome District.—

1875. Discovery of showings by U.S. Army scouts.
1876. Location of first mining claims.
1880-85. Working of United Verde gossan for silver.
1883. Operation of first copper smelter.
1888. Completion of railroad from Ashfork to Prescott. Supplies hauled 28 miles from Granite, near Prescott.
1889. Purchase of United Verde Mine by William A. Clark.
1894. First mine fire on 300 level of United Verde Mine. Completion of narrow-gauge railroad to Jerome.
1900. Start of fairly active prospecting of district.
1904-5. Operation of Equator Mining Company smelter in south end of district.

1914. Completion of standard-gauge railroad to Clarkdale.
1914-20. Very active prospecting throughout district.
1915. Removal of United Verde smelting operations from above the mine to new plant at Clarkdale.
1916. Copper Chief 125-ton cyanide mill in operation. Finally closed down in 1923.
1919. Beginning of United Verde open-pit operation.
1920. Completion of standard-gauge railroad to Jerome.
1921. Completion of direct highway from Jerome to Prescott.
1924-27. Series of large "coyote" blasts in open-pit stripping.
1927. Addition of flotation concentrator to Clarkdale plant.
1929. January—Verde Central 350-ton flotation mill in operation. Closed in 1930. July—Cave-in of upper levels of United Verde Mine. United Verde peak copper production—142,290,000 pounds of copper from 1,737,000 tons of ore, for year.
1931. Purchase of Verde Central property by United Verde.
1935. Purchase of United Verde property by Phelps Dodge Corporation.
1938. United Verde open-pit work nearing completion.

United Verde Extension.—

About 1900. Verde Queen smelter treating carbonate ore from near Columbia shaft. (Later U.V.X. property.)
1900. Location of Little Daisy fraction by J. J. Fisher, the first U.V.X. claim.
1902. Organization of U.V.X. Company.
1912. Reorganization of U.V.X. Company by J. S. Douglas and G. E. Tener.
1914. First important ore discovery in U.V.X. Mine.
1915. Discovery of main ore body.
1917. U.V.X. peak copper production—63,243,000 pounds of copper from 115,064 tons, for year. First production from Jerome Verde, main top ore body (mined out in 1920).
1918. Completion of U.V.X. smelter at Clemenceau.
1929. U.V.X. peak tonnage production—59,127,000 pounds of copper from 358,650 tons of ore, for year.
1930. Addition of 200-ton flotation mill to plant at Clemenceau.
1937. January—U.V.X. smelter permanently closed.
1938. May—U.V.X. Mine permanently closed.

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U.V.X.

ORE RESERVES

PROBABLE ORE

8-31-38

(4 months after closure)

Florencia	10,000 Tons	@ 10% to 6% Cu.	Main ore body vicinity
800 Level (826, 829, 803, etc.)	10,000 Tons	@ 6% to 4% Cu.	Verde area, siliceous ore
Gold Ore	6,000 Tons 4,000 Tons	@ .40 oz. Au. @ .15 oz. Au.	Gold Stope Pillars & HW
Conglomerate Ore	8,000 Tons	@ 8% to 6% (Country Abandoned)	600 & 550 levels

In addition probably 100,000 Tons low-grade silicious material in the quartz zone on the 950 and 800 levels. Some of this will be gold ore (.10 oz) with no copper, and the balance low-grade copper ore (1% to 2%.) Verde area

UVX: Drilling Summary

Hole No.	From	To	Width (ft)	Gold oz/t	Silver oz/t	Value @ $350 gold $6 silver	With (ft)	From	To	Gold oz/t	Silver oz/t	Value @ $350 gold $6 silver
UVX-1 (P-D)	165	260	95	0.072	0.59	$28.74	20	240	260	0.196	1.54	$77.84
UVX-2 (P-D) 1983	170	303	133	0.073	0.25	$27.05	35	268	303	0.177	0.39	$64.29
	482	516	34	0.063	2.14	$34.89						
	615	647	32	0.093	0.52	$35.67						
1104-1 (Budge)	193	285	92	0.055	0.43	$21.83	15	240	255	0.112	0.53	$42.38
1104-2 (Budge) 1985	209	252	43	0.082	0.49	$31.64	14	238	252	0.144	0.38	$52.68
	326	334	8	0.065	0.83	$27.73						
	572	587	15	0.042	1.26	$22.26						
	598	610	12	0.091	0.77	$36.47						
1104-3 (Budge)	227	276	49	0.087	0.30	$32.25	9	227	236	0.143	0.32	$51.97
901-1	332	358	26	0.058	1.39	$28.64	6	335	341	0.145	0.65	$54.65
901-3	300	326	26	0.081	2.08	$40.82	7	314	321	0.183	3.13	$82.81
806-1 (Budge) 1986	504	578	74	0.102	1.28	$43.38	13	514	527	0.236	2.24	$96.04
							10	568	578	0.177	0.88	$67.23

	Width (ft)	Gold oz/t	Silver oz/t	Value		Width (ft)	Gold oz/t	Silver oz/t	Value
Weighted average of 10 zones; widths over 20 ft.	51.2	0.078	0.77	$32.07	Weighted average of 9 zones	14.3	0.171	0.96	$65.71

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Mineralized Gold oz/t	Mineralized Silver oz/t	Mineralized Copper %
806-1	1-86	578	580	2	0.061	0.74	$23.96						
		580	584	4	0.068	2.29	$35.50						
		584	587	3	0.031	0.96	$15.68						
		587	590	3	0.048	1.25	$22.86						
		590	592	2	0.038	1.45	$20.86						
		592	594	2	0.060	1.49	$28.14	578	594	16	0.052	1.45	
	sludge	578	583	5	0.060	1.06		504	594	90	0.094	1.31	
	sludge	583	588	5	0.079	0.44							
	sludge	588	593	5	0.046	1.32							
		601	606	5	< 0.001	1.44	$8.64						
		606	608	2	0.016	0.60	$8.72						
		608	610	2	0.010	0.75	$7.70						
		610	613	3	< 0.001	0.76	$4.56						
		613	615	2	0.014	0.81	$9.34						
		615	617	2	0.009	0.66	$6.84						
		617	620	3	< 0.001	0.61	$3.66						
		620	626	6	< 0.001	0.51	$3.06						
		626	628	2	< 0.001	0.17	$1.02						
		630	632	2	0.014	0.30	$6.28						
	sludge	608	613	5	0.033	0.56							
	sludge	613	623	10	< 0.001	0.39							

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	To	Interval	Gold oz/t	Silver oz/t	Copper %
806-1	1-86	533	536	3	0.060	1.48	$28.08						
		536	539	3	0.060	1.49	$28.14						
		539	541	2	0.030	1.53	$18.78						
		541	543	2	0.070	1.28	$30.08						
		543	544	1	0.065	0.96	$26.56						
		544	546	2	0.160	1.18	$58.28						
		546	548	2	0.105	1.11	$40.26						
		548	550	2	0.129	1.15	$48.18						
		550	552	2	0.054	0.91	$22.74						
		552	554	2	0.011	0.66	$7.48	504	554	50	0.104	1.37	
	sludge	504	509	5	0.014	0.40							
	sludge	512	518	6	0.097	1.33							
	sludge	518	523	5	0.122	1.72							
	sludge	523	528	5	0.069	1.05							
	sludge	528	533	5	0.071	0.62							
		554	555	1	0.017	0.62	$9.16						
		555	558	3	0.070	1.24	$29.84						
		558	560	2	0.059	1.39	$27.22						
		560	562	2	0.043	1.72	$24.08						
		562	565	3	0.024	1.31	$15.54						
		565	568	3	0.058	1.04	$24.80						
		568	570	2	0.221	1.05	$77.02						
		570	572	2	0.202	0.90	$70.04						
		572	574	2	0.099	1.40	$40.08						
		574	576	2	0.095	0.56	$33.76	568	578	10	0.177	0.88	
		576	578	2	0.270	0.48	$89.28	554	578	24	0.102	1.10	
								504	578	74	0.103	1.28	
	sludge	533	538	5	0.047	1.11							
	sludge	538	543	5	0.061	1.30							
	sludge	543	548	5	0.051	1.04							
	sludge	548	553	5	0.061	1.01							
	sludge	553	558	5	0.060	0.74							
	sludge	558	563	5	0.050	0.98							
	sludge	563	568	5	0.051	1.00							
	sludge	568	573	5	0.136	0.71							
	sludge	573	578	5	0.127	0.87							

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Gold oz/t	Silver oz/t
806-1	12-85	82	84	2	< 0.001	0.18	$1.08					
	and	84	87	3	< 0.001	0.18	$1.08					
	1-86	87	90	3	< 0.001	0.85	$5.10					
		90	92	2	< 0.001	0.81	$4.86					
		92	94	2	< 0.001	0.70	$4.20					
		94	96	2	< 0.001	0.70	$4.20					
		96	98	2	< 0.001	0.67	$4.02					
		98	101	3	< 0.001	0.65	$3.90					
		101	103	2	< 0.001	0.48	$2.88					
		103	106	3	< 0.001	0.69	$4.14					
		106	108	2	< 0.001	0.86	$5.16					
		108	112	4	< 0.001	0.32	$1.92					
	samples	806	353		< 0.001	0.29	$1.74					
		806	363		< 0.001	0.65	$3.90					
		806	373		< 0.001	0.40	$2.40					
		806	383		< 0.001	0.61	$3.66					
		806	393		< 0.001	0.61	$3.66					
		806	403		< 0.001	0.51	$3.06					
		806	413		< 0.001	0.62	$3.72					
		806	423		< 0.001	0.35	$2.10					
		458	461	3	0.006	0.18	$3.00					
		474	477	3	0.001	0.36	$2.48					
		477	481	4	< 0.001	0.31	$1.86					
		481	482	1	0.009	0.31	$4.74					
		482	487	5	0.002	0.92	$6.16					
		487	492	5	0.008	1.18	$9.64					
		492	497	5	0.005	0.95	$7.30					
		497	499	2	0.002	0.73	$5.02					
		499	501	2	0.003	0.60	$4.56					
		501	504	3	0.004	0.60	$4.88					
	sludge	501	504	3	0.004	0.53	$4.46					
		504	509	5	0.070	1.34	$30.44					
		509	514	5	0.035	0.79	$15.94					
		514	516	2	0.325	2.54	$119.24					
		516	518	2	0.140	0.76	$49.36					
		518	522	4	0.275	2.67	$104.02					
		522	525	3	0.210	2.27	$80.82					
		525	527	2	0.205	2.54	$80.84	514	527	13	0.236	2.24
		527	531	4	0.009	0.74	$7.32					
		531	533	2	0.085	1.33	$35.18					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	To	Interval	Gold oz/t	Silver oz/t	Copper %
901-2	11-85	417	421	4	< 0.001	0.19	$1.14						0.458
901-3	11-85	268	272	4	< 0.001	0.47	$2.82						
		272	274	2	< 0.001	0.72	$4.32						
		274	276	2	< 0.001	0.76	$4.56						
		276	278	2	< 0.001	0.95	$5.70						
		278	280	2	< 0.001	0.62	$3.72						
		280	282	2	< 0.001	0.44	$2.64						
		282	284	2	< 0.001	0.70	$4.20						
		284	288	4	< 0.001	0.62	$3.72						
		288	291	3	< 0.001	0.35	$2.10						
		291	293	2	0.010	0.79	$7.94						
		293	295	2	0.016	1.18	$12.20						
		295	300	5	0.008	1.14	$9.40						
		300	302	2	0.037	2.06	$24.20						
		302	306	4	0.070	1.55	$31.70						
		306	309	3	0.032	2.82	$27.16						
		309	312	3	0.029	1.17	$16.30						
		312	314	2	0.064	1.39	$28.82						
		314	316	2	0.241	3.74	$99.56	314	321	7	0.183	3.126	
		316	321	5	0.160	2.88	$68.48						
		321	326	5	0.031	1.42	$18.44	300	326	26	0.081	2.079	
		326	331	5	0.008	0.24	$4.00						
		339	343	4	< 0.001	0.24	$1.44						

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Gold oz/t	Silver oz/t	Copper %
1104-3	11-85	415	420	5	Nil	0.01	$0.06						
		420	422	2	0.006	0.03	$2.10						
		422	425	3	0.003	0.18	$2.04						
901-1	9-85	325	329	4	< 0.001	0.19	$1.14						
		329	332	3	< 0.001	0.51	$3.06						
		332	335	3	0.015	0.40	$7.20						
		335	338	3	0.180	0.50	$60.60						
		338	341	3	0.110	0.80	$40.00	335	341	6	0.145	0.65	
		341	344	3	0.045	3.62	$36.12						
		344	347	3	0.025	3.08	$26.48						
		347	350	3	0.025	1.22	$15.32						
		350	353	3	0.010	1.10	$9.80						
		353	355	2	0.020	1.02	$12.52						
		355	358	3	0.075	0.64	$27.84	332	358	26	0.058	1.39	
901-2	11-85	239	242	3	< 0.001	0.34	$2.04						
		242	244	2	0.006	0.29	$3.66						
		244	247	3	0.017	0.81	$10.30						
		247	248	1	0.016	0.33	$7.10						
		248	250	2	0.004	0.29	$3.02						
		250	254	4	0.001	0.15	$1.22						0.174
		254	256	2	< 0.001	0.20	$1.20						0.360
		256	258	2	< 0.001	0.21	$1.26						1.160
		258	260	2	< 0.001	0.12	$0.72						1.400
		260	265	5	< 0.001	< 0.01	$0.00						
		276	279	3	< 0.001	0.13	$0.78						
		287	290	3	< 0.001	0.09	$0.54						
		313	316	3	0.003	0.14	$1.80						
		326	329	3	< 0.001	0.14	$0.84						
		341	343	2	0.001	0.05	$0.62						1.400
		355	357	2	0.002	0.20	$1.84						2.250
		357	359	2	< 0.001	0.19	$1.14						3.620
		367	369	2	0.006	0.06	$2.28						1.300
		376	378	2	0.002	0.12	$1.36						0.232
		386	388	2	0.003	0.19	$2.10						1.980
		398	402	4	0.002	0.19	$1.78						0.498

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized				
								From	To	Interval	Gold oz/t	Silver oz/t
1104-3	11-85	212	217	5	< 0.001	0.09	$0.54					
		217	222	5	0.002	0.12	$1.36					
		222	227	5	0.013	0.24	$5.60					
		227	229	2	0.156	0.39	$52.26					
		229	233	4	0.159	0.31	$52.74					
		233	236	3	0.114	0.30	$38.28	227	236	9	0.143	0.32
		236	238	2	0.001	0.35	$2.42					
		238	241	3	0.058	0.27	$20.18					
		241	244	3	0.132	0.41	$44.70					
		244	246	2	0.204	0.37	$67.50	227	246	19	0.119	0.34
		246	248	2	0.070	0.39	$24.74					
		248	250	2	0.053	0.30	$18.76					
		250	253	3	0.082	0.17	$27.26					
		253	255	2	0.042	0.60	$17.04					
		255	258	3	0.064	0.30	$22.28					
		258	260	2	0.064	0.29	$22.22					
		260	263	3	0.077	0.20	$25.84					
		263	266	3	0.065	0.25	$22.30					
		266	269	3	0.096	0.16	$31.68					
		269	271	2	0.034	0.30	$12.68					
		271	274	3	0.083	0.31	$28.42					
		274	276	2	0.045	0.20	$15.60	227	276	49	0.087	0.30
		276	278	2	0.023	0.41	$9.82					
		278	281	3	0.003	0.60	$4.56					
		281	283	2	0.018	0.53	$8.94					
		283	285	2	0.003	0.54	$4.20					
		285	287	2	0.009	0.55	$6.18					
		287	289	2	0.008	0.53	$5.74					
		289	292	3	0.018	0.52	$8.88					
		292	298	6	0.081	0.43	$28.50					
		298	300	2	0.008	0.58	$6.04					
		300	302	2	0.003	0.49	$3.90					
		302	304	2	0.012	0.43	$6.42					
		304	307	3	0.007	0.49	$5.18					
		307	310	3	0.036	0.46	$14.28					
		310	312	2	0.013	0.41	$6.62					
		312	314	2	0.003	0.12	$1.68					
		314	316	2	0.014	0.37	$6.70					
		316	321	5	0.023	0.41	$9.82					
		321	325	4	0.019	0.29	$7.82					
		325	328	3	0.015	0.56	$8.16					
		328	330	2	0.034	0.39	$13.22					
		330	333	3	0.054	0.56	$20.64					
		333	335	2	0.005	0.58	$5.08					
		335	339	4	0.009	0.24	$4.32					
		366	370	4	0.003	0.09	$1.50					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Mineralized Gold oz/t	Mineralized Silver oz/t
		601	604	3	0.040	0.74	$17.24					
		604	608	4	0.160	0.90	$56.60					
		608	610	2	0.045	0.65	$18.30	598	610	12	0.091	0.77
		610	613	3	0.015	0.32	$6.72					
		613	615	2	0.010	0.33	$5.18					
		615	618	3	0.110	0.77	$39.82	598	618	20	0.060	0.66
		618	620	2	0.010	1.79	$13.94					
		620	622	2	< 0.005	0.46	$2.76					
		622	624	2	< 0.005	0.32	$1.92					
		624	626	2	0.020	0.58	$9.88					
		626	628	2	< 0.005	0.53	$3.18					
		628	630	2	0.005	0.39	$3.94					
		630	633	3	0.030	0.64	$13.44					
		633	635	2	< 0.005	0.62	$3.72					
		635	638	3	0.015	0.53	$7.98					
		638	640	2	< 0.005	0.45	$2.70					
		640	642	2	0.035	0.47	$14.02					
		642	646	4	< 0.005	0.25	$1.50					
		646	651	5	< 0.005	0.21	$1.26					
		657	661	4	< 0.005	0.22	$1.32					
		666	670	4	< 0.005	0.27	$1.62					
		678	682	4	< 0.005	0.11	$0.66					
		690	693	3	< 0.005	0.18	$1.08					
		700	702	2	< 0.005	0.17	$1.02					
		705	710	5	< 0.005	0.56	$3.36					
		710	712	2	< 0.005	0.66	$3.96					
		712	716	4	0.005	0.52	$4.72					
		716	719	3	0.030	0.62	$13.32					
		722	725	3	< 0.005	0.69	$4.14					
		725	730	5	0.005	0.55	$4.90					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Mineralized Gold oz/t	Mineralized Silver oz/t
1104-2	9-85	308	310	2	0.005	0.95	$7.30					
		310	312	2	< 0.005	0.61	$3.66					
		312	314	2	< 0.005	0.62	$3.72					
		314	316	2	0.010	0.71	$7.46					
		316	318	2	0.010	0.70	$7.40					
		318	320	2	< 0.005	0.40	$2.40					
		320	322	2	< 0.005	0.53	$3.18					
		322	324	2	0.010	0.84	$8.24					
		324	326	2	0.010	0.62	$6.92					
		326	328	2	0.040	1.87	$24.02					
		328	330	2	0.090	0.59	$32.34					
		330	332	2	0.080	0.42	$28.12					
		332	334	2	0.050	0.43	$18.58	326	334	8	0.065	0.83
		334	336	2	0.010	0.60	$6.80					
		336	338	2	< 0.005	0.39	$2.34					
		338	340	2	< 0.005	0.55	$3.30					
		340	342	2	< 0.005	0.74	$4.44					
		342	344	2	< 0.005	0.58	$3.48					
		344	346	2	< 0.005	0.48	$2.88					
		346	349	3	< 0.005	0.44	$2.64					
		349	350	1	< 0.005	0.42	$2.52					
		350	354	4	< 0.005	0.18	$1.08					
		517	521	4	< 0.005	0.29	$1.74					
		521	526	5	0.060	1.52	$28.32					
		526	529	3	0.040	1.94	$24.44					
		529	534	5	0.010	0.82	$8.12					
		534	538	4	0.030	1.45	$18.30					
		538	542	4	0.010	0.70	$7.40					
		542	545	3	0.005	0.66	$5.56					
		545	548	3	0.010	0.83	$8.18					
		548	551	3	0.010	1.03	$9.38					
		551	557	6	< 0.005	0.41	$2.46					
		557	563	6	0.005	0.38	$3.88					
		563	567	4	0.010	0.74	$7.64					
		567	569	2	< 0.005	0.38	$2.28					
		569	572	3	< 0.005	0.58	$3.48					
		572	575	3	0.030	1.19	$16.74					
		575	578	3	0.035	1.35	$19.30					
		578	581	3	0.045	1.45	$23.10					
		581	584	3	0.070	1.63	$32.18					
		584	587	3	0.030	0.66	$13.56					
		587	590	3	< 0.005	0.46	$2.76					
		590	593	3	< 0.005	0.36	$2.16					
		593	598	5	0.010	0.46	$5.96					
		598	601	3	0.080	0.70	$29.80					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	To	Interval	Gold oz/t	Silver oz/t
1104-1	8-85	512	516	4	< 0.005	0.05	$0.30					
		531	534	3	< 0.005	0.18	$1.08					
		555	559	4	< 0.005	0.32	$1.92					
1104-2	9-85	205	209	4	0.010	0.15	$4.10					
		209	214	5	0.050	0.58	$19.48					
		214	220	6	0.050	0.71	$20.26					
		220	222	2	0.105	0.64	$37.44					
		222	224	2	0.030	0.83	$14.58					
		224	226	2	0.070	0.58	$25.88					
		226	228	2	0.065	0.47	$23.62					
		228	230	2	0.015	0.45	$7.50					
		230	232	2	0.070	0.33	$24.38					
		232	234	2	0.040	0.33	$14.78					
		234	236	2	0.050	0.40	$18.40					
		236	238	2	0.045	0.29	$16.14					
		238	240	2	0.210	0.53	$70.38					
		240	242	2	0.230	0.44	$76.24					
		242	244	2	0.135	0.20	$44.40					
		244	246	2	0.115	0.42	$39.32					
		246	248	2	0.085	0.45	$29.90	238	246	8.0	0.173	0.40
		248	250	2	0.120	0.28	$40.08	238	252	14.0	0.144	0.38
		250	252	2	0.110	0.37	$37.42	209	252	43.0	0.082	0.49
		252	254	2	< 0.005	0.16	$0.96					
		254	258	4	0.065	0.55	$24.10					
		258	262	4	< 0.005	0.16	$0.96					
		262	266	4	< 0.005	0.15	$0.90					
		266	270	4	< 0.005	0.14	$0.84					
		270	274	4	< 0.005	0.15	$0.90					
		274	275	1	< 0.005	0.46	$2.76					
		275	277	2	0.005	0.43	$4.18					
		277	279	2	0.025	0.38	$10.28					
		279	281	2	0.015	0.48	$7.68					
		281	283	2	< 0.005	0.48	$2.88					
		283	286	3	< 0.005	0.35	$2.10					
		287	290	3	0.005	0.34	$3.64					
		290	294	4	< 0.005	0.47	$2.82					
		294	296	2	< 0.005	0.45	$2.70					
		296	298	2	< 0.005	0.60	$3.60					
		298	300	2	< 0.005	0.69	$4.14					
		300	302	2	0.005	0.71	$5.86					
		302	304	2	0.005	0.83	$6.58					
		304	306	2	< 0.005	0.32	$1.92					
		306	308	2	< 0.005	0.31	$1.86					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Mineralized Gold oz/t	Mineralized Silver oz/t
UVX-2	1983	657	667	10	< 0.003	0.24	$1.44					
		667	679	12	< 0.003	0.01	$0.06					
		679	686	7	< 0.003	< 0.01	$0.00					
1104-1	8-85	193	200	7	0.065	0.44	$23.44					
		200	205	5	0.040	0.42	$15.32					
		205	210	5	0.070	0.35	$24.50					
		210	215	5	0.110	0.36	$37.36	193	215	22.0	0.071	0.40
		215	220	5	0.045	0.43	$16.98	193	225	32.0	0.063	0.40
		220	225	5	0.050	0.41	$18.46					
		225	230	5	0.010	0.74	$7.64					
		230	235	5	0.005	0.63	$5.38					
		235	240	5	0.025	0.57	$11.42					
		240	245	5	0.105	0.57	$37.02					
		245	250	5	0.115	0.42	$39.32					
		250	255	5	0.115	0.59	$40.34	240	255	15.0	0.112	0.53
		255	260	5	0.055	0.33	$19.58	240	260	20.0	0.098	0.48
		260	265	5	0.010	0.54	$6.44					
		265	270	5	< 0.005	0.31	$1.86					
		270	275	5	0.015	0.31	$6.66					
		275	280	5	0.105	0.23	$34.98					
		280	285	5	0.050	0.12	$16.72					
		285	290	5	0.015	0.19	$5.94					
		290	295	5	< 0.005	0.30	$1.80					
		295	300	5	< 0.005	0.29	$1.74					
		300	305	5	0.010	0.43	$5.78					
		305	310	5	< 0.005	0.50	$3.00					
		310	314	4	< 0.005	0.35	$2.10					
		314	319	5	< 0.005	0.34	$2.04					
		319	327	8	< 0.005	0.33	$1.98					
		327	331	4	< 0.005	0.40	$2.40					
		331	335	4	< 0.005	0.07	$0.42					
		355	362	7	< 0.005	0.10	$0.60					
		362	365	3	0.020	0.58	$9.88					
		365	370	5	0.010	0.50	$6.20					
		370	375	5	0.030	0.54	$12.84					
		375	380	5	0.035	0.62	$14.92					
		380	385	5	0.050	0.46	$18.76					
		385	390	5	< 0.005	0.25	$1.50					
		390	395	5	0.015	0.32	$6.72					
		395	400	5	0.015	0.25	$6.30					
		400	405	5	< 0.005	0.50	$3.00					
		405	410	5	0.035	0.60	$14.80					
		410	413	3	< 0.005	0.53	$3.18					
		413	420	7	< 0.005	0.29	$1.74					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Mineralized Gold oz/t	Mineralized Silver oz/t
UVX-2	1983	365	372	7	ND	0.15	$0.90					
		372	382	10	ND	0.16	$0.96					
		382	392	10	ND	0.08	$0.48					
		392	396	4	ND	ND	$0.00					
		396	400	4	ND	ND	$0.00					
		400	410	10	ND	0.28	$1.68					
		410	424	14	0.003	ND	$0.96					
		424	434	10	ND	0.07	$0.42					
		434	445	11	ND	0.06	$0.36					
		445	462	17			$0.00					
		462	467	5	0.010	0.08	$3.68					
		467	470	3	0.008	0.12	$3.28					
		470	472	2	0.008	0.03	$2.74					
		472	482	10	0.016	0.16	$6.08					
		482	497	15	0.060	3.50	$40.20					
		497	498	1	0.146	0.68	$50.80					
		498	502	4	0.098	1.12	$38.08					
		502	507	5	0.044	1.05	$20.38					
		507	512	5	0.032	0.98	$16.12					
		512	516	4	0.082	1.27	$33.86	482	516	34.0	0.063	2.14
		516	520	4	0.018	0.92	$11.28					
		520	525	5	0.046	1.42	$23.24					
		525	530	5	0.018	1.43	$14.34					
		530	536	6	0.071	1.96	$34.48					
		536	538	2	0.024	1.01	$13.74					
		538	542	4	0.012	0.97	$9.66					
		542	545	3	0.014	0.92	$10.00					
		545	550	5	0.060	2.12	$31.92					
		550	555	5	0.030	1.47	$18.42					
		555	560	5	0.025	0.69	$12.14					
		560	565	5	0.205	2.82	$82.52	560	565	5	0.205	2.82
		565	567	2	0.015	1.67	$14.82					
		567	572	5	0.005	2.08	$14.08					
		572	581	9	< 0.003	1.62	$9.72					
		581	583	2	0.020	1.28	$14.08					
		583	588	5	0.010	1.13	$9.98					
		588	595	7	< 0.003	0.56	$3.36					
		595	602	7	< 0.003	0.70	$4.20					
		602	607	5	0.010	0.71	$7.46					
		607	615	8	0.040	0.64	$16.64					
		615	617	2	0.065	0.62	$24.52					
		617	626	9	0.080	0.52	$28.72					
		626	628	2	0.090	0.55	$32.10					
		628	632	4	0.030	0.63	$13.38					
		632	639	7	0.160	0.52	$54.32					
		639	642	3	0.085	0.90	$32.60					
		642	647	5	0.090	0.17	$29.82	615	647	32.0	0.093	0.52
		647	657	10	< 0.003	0.68	$4.08					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	Mineralized To	Mineralized Interval	Gold oz/t	Silver oz/t
UVX-1	1983	380	385	5	< 0.003	0.06	$0.36					
		385	390	5	< 0.003	0.08	$0.48					
		390	393	3	< 0.003	0.06	$0.36					
UVX-2	1983	0	10	10	< 0.003	ND	$0.00					
		10	20	10	< 0.003	0.19	$1.14					
		20	30	10	< 0.003	0.13	$0.78					
		30	40	10	< 0.003	0.06	$0.36					
		40	50	10	< 0.003	0.07	$0.42					
		50	60	10	< 0.003	0.07	$0.42					
		60	70	10	< 0.003	0.17	$1.02					
		70	80	10	< 0.003	0.05	$0.30					
		80	90	10	< 0.003	0.05	$0.30					
		90	100	10	< 0.003	ND	$0.00					
		100	110	10	< 0.003	0.07	$0.42					
		110	120	10	< 0.003	0.21	$1.26					
		120	130	10	< 0.003	0.19	$1.14					
		130	140	10	< 0.003	0.15	$0.90					
		140	150	10	< 0.003	0.21	$1.26					
		150	160	10	< 0.003	0.23	$1.38					
		160	170	10	0.006	0.42	$4.44					
		170	180	10	0.035	0.20	$12.40					
		180	190	10	0.044	0.26	$15.64					
		190	200	10	0.032	0.20	$11.44					
		200	210	10	0.040	0.18	$13.88					
		210	220	10	0.050	0.13	$16.78					
		220	230	10	0.038	0.13	$12.94					
		230	240	10	0.026	0.14	$9.16					
		240	250	10	0.038	0.14	$13.00					
		250	255	5	0.012	0.23	$5.22					
		255	261	6	0.044	0.28	$15.76					
		261	265	4	0.038	0.46	$14.92					
		265	268	3	0.015	0.42	$7.32					
		268	271	3	0.070	0.87	$27.62					
		271	277	6	0.200	0.48	$66.88					
		277	279	2	0.520	0.52	$169.52					
		279	282	3	0.200	0.33	$65.98					
		282	288	6	0.140	0.36	$46.96					
		288	295.5	7.5	0.226	0.29	$74.06					
		295.5	303	7.5	0.079	0.26	$26.84	268	303	35.0	0.177	0.39
		303	320	17	0.015	0.25	$6.30					
		320	325	5	0.003	0.26	$2.52					
		325	335	10	ND	0.31	$1.86					
		335	346	11	0.012	ND	$3.84					
		346	356	10	ND	ND	$0.00					
		356	365	9	ND	ND	$0.00					

Hole No.	Date drilled	From	To	Interval	Gold oz/t	Silver oz/t	Value/ton @ $320 gold $6 silver	Mineralized From	To	Interval	Gold oz/t	Silver oz/t
UVX-1	1983	150	155	5	0.006	0.26	$3.48					
		155	160	5	0.006	0.22	$3.24					
		160	165	5	0.012	0.16	$4.80					
		165	170	5	0.055	0.16	$18.56					
		170	175	5	0.038	0.25	$13.66					
		175	180	5	0.050	0.21	$17.26					
		180	185	5	0.038	0.20	$13.36					
		185	190	5	0.053	0.08	$17.44					
		190	195	5	0.093	0.88	$35.04					
		195	200	5	0.058	0.17	$19.58	185	200	15	0.068	0.38
		200	205	5	0.026	0.17	$9.34					
		205	210	5	0.032	0.14	$11.08					
		210	215	5	0.018	0.23	$7.14					
		215	220	5	0.006	0.20	$3.12					
		220	225	5	0.070	0.72	$26.72					
		225	230	5	0.020	0.65	$10.30					
		230	235	5	0.012	0.52	$6.96					
		235	240	5	0.009	0.40	$5.28					
		240	245	5	0.160	0.14	$52.04					
		245	250	5	0.540	1.89	$184.14					
		250	255	5	0.029	2.32	$23.20					
		255	260	5	0.055	1.79	$28.34	240	260	20	0.196	1.54
		260	265	5	0.012	1.38	$12.12					
		265	270	5	0.009	0.59	$6.42					
		270	275	5	0.006	0.31	$3.78					
		275	280	5	< 0.003	0.38	$2.28					
		280	285	5	< 0.003	0.39	$2.34					
		285	290	5	< 0.003	0.20	$1.20					
		290	295	5	< 0.003	0.30	$1.80					
		295	300	5	< 0.003	0.40	$2.40					
		300	305	5	< 0.003	0.26	$1.56					
		305	310	5	< 0.003	0.41	$2.46					
		310	315	5	< 0.003	0.26	$1.56					
		315	320	5	< 0.003	0.28	$1.68					
		320	325	5	< 0.003	0.26	$1.56					
		325	330	5	< 0.003	0.22	$1.32					
		330	335	5	< 0.003	0.26	$1.56					
		335	340	5	< 0.003	0.29	$1.74					
		340	345	5	< 0.003	0.34	$2.04					
		345	350	5	< 0.003	0.26	$1.56					
		350	355	5	< 0.003	0.23	$1.38					
		355	360	5	< 0.003	0.40	$2.40					
		360	365	5	< 0.003	0.19	$1.14					
		365	370	5	< 0.003	0.17	$1.02					
		370	375	5	< 0.003	0.17	$1.02					
		375	380	5	0.009	0.07	$3.30					

UVX: Select core sample Analyses

Sample number	Au (oz/t)	Ag (oz/t)	SiO2 (%)	Al2O3 (%)	Fe2O3 (%)	FeO (%)	CaO (%)	Na2O (%)	K2O (%)	MgO (%)	As (ppm)
1104-1-280-285	0.050	0.12	98.9	0.04	0.36		0.02	< 0.01	0.02		30.0
1104-1-285-290	0.015	0.19	93.6	0.35	1.60		0.04	0.01	0.03		260.0
1104-1-245-250	0.115	0.42	92.5	0.26	0.90		0.02	0.01	0.02		220.0
901-3-268-272	< 0.001	0.47	71.9	16.60	2.80	0.10	0.10	0.06	2.30	0.44	< 500.0
901-3-272-274	< 0.001	0.72	89.0	1.50	8.70	0.07	0.05	0.03	0.26	0.05	1000.0
901-3-300-302	0.030	1.46	95.3	0.13	0.76	0.10	0.02	< 0.01	0.08	0.01	< 500.0
901-3-314-316	0.250	3.24	94.8	0.07	0.70	0.07	< 0.01	< 0.01	0.09	< 0.01	
901-3-339-343	< 0.001	0.24	59.2	26.30	2.70	0.15	0.12	0.12	1.50	0.26	
806-1-224			52.8	17.40	6.80	5.50	5.10	2.50	0.90	4.50	

UVX: Select core sample Analyses

Sample number	Au (oz/t)	Ag (oz/t)	SiO2 (%)	Al2O3 (%)	Fe2O3 (%)	FeO (%)	CaO (%)	Na2O (%)	K2O (%)	MgO (%)
1104-1-280-285	0.050	0.12	98.9	0.04	0.36		0.02	< 0.01	0.02	
1104-1-285-290	0.015	0.19	93.6	0.35	1.60		0.04	0.01	0.03	
1104-1-245-250	0.115	0.42	92.5	0.26	0.90		0.02	0.01	0.02	
901-3-268-272	< 0.001	0.47	71.9	16.60	2.80	0.10	0.10	0.06	2.30	0.44
901-3-272-274	< 0.001	0.72	89.0	1.50	8.70	0.07	0.05	0.03	0.26	0.05
901-3-293-295	0.015	0.88								
901-3-300-302	0.030	1.46	95.3	0.13	0.76	0.10	0.02	< 0.01	0.08	0.01
901-3-302-306	0.085	0.79								
901-3-306-309	0.035	1.20								
901-3-309-312	0.025	0.84								
901-3-312-314	0.065	1.32								
901-3-314-316	0.250	3.24	94.8	0.07	0.70	0.07	< 0.01	< 0.01	0.09	< 0.01
901-3-316-321	0.170	2.50								
901-3-321-326	0.030	0.61								
901-3-326-331	< 0.005	0.17								
901-3-339-343	< 0.001	0.24	59.2	26.30	2.70	0.15	0.12	0.12	1.50	0.26
806-1-224			52.8	17.40	6.80	5.50	5.10	2.50	0.90	4.50
806-1-509-514	0.050	0.71								
806-1-514-516	0.335	2.44								
806-1-518-522	0.260	2.62	90.5	0.13	7.9	0.15	0.08	0.02	< 0.01	0.03
806-1-544-546	0.100	1.04	98.2	0.08	1.3	0.05	0.02	< 0.01	< 0.01	0.01
806-1-552-554	0.010	0.61	40.0	0.65	49.4	0.15	0.11	0.02	< 0.01	0.07
806-1-560-562	0.040	1.38	86.2	1.60	7.4	0.15	0.05	0.03	< 0.01	0.02
806-1-576-578	0.250	0.61	99.4	0.05	0.4	0.05	0.01	< 0.01	< 0.01	< 0.01
806-1-578-580	0.055	0.53								