

APPENDIX 2a:

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PETROGRAPHIC REPORTS

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REPORT TITLE	Petrographic Descriptions for Fifteen Drill Core Rock Samples of Oenpelli Dolerite, Kombolgie Sandstone, and Nimbuwah Complex (West Arnhem Land, Northern Territory)
REPORT #	2372
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SIGNED



for Mason Geoscience Pty. Ltd.

DATE	28 October 1997
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Petrographic Descriptions for Fifteen Drill Core Rock Samples of Oenpelli Dolerite, Kombolgie Sandstone, and Nimbuwah Complex (West Arnhem Land, Northern Territory)

SUMMARY

1. Rock Samples

- Fifteen drill core rock samples of Oenpelli Dolerite, Kombolgie Sandstone and Nimbuwah Complex (West Arnhem Land, Northern Territory) have been studied using petrographic and limited mineragraphic and X-ray diffraction methods.

2. Brief Results

- Oenpelli Dolerite

- Oenpelli Dolerite was composed of abundant plagioclase and clinopyroxene, possibly olivine, and variable amounts of Fe-Ti oxides (magnetite, ilmenite), hornblende, biotite, quartz, K-feldspar, apatite, and zircon. Classic ophitic to subophitic massive doleritic textures were locally porphyritic in plagioclase. Micrographic intergrowths of quartz and K-feldspar were relatively abundant in places. Fractionation of the basic magma to a granophyric residuum confirms that the parental basaltic magma was of silica-oversaturated (quartz tholeiite) magmatic affinity.
- Low-temperature selective pervasive alteration ranges from moderate to severe in intensity. Commonly the rock has been replaced by assemblages dominated by illitic clay after plagioclase, chlorite after ferromagnesian, and leucoxene after Fe-Ti oxides. Some rocks have suffered virtually complete replacement by serpentine + phyllosilicate (illite/sericite) + hematite. Veins in serpentinised rocks may be filled by assemblages of cross-fibre serpentine, dolomite, hematite and quartz. In other samples, some veins may be filled by assemblages of carbonate (siderite), chlorite, quartz, K-feldspar and trace chalcopyrite.

- Kombolgie Sandstone

- Two samples of Kombolgie Sandstone represent well-sorted quartzose sandstones.
- These rocks have suffered alteration involving cementation by quartz, with variable associated assemblages (e.g. kaolinite + hematite; chlorite + hematite + sericite).

- Nimbuwah Complex

- Two samples from Nimbuwah Complex represent foliated gneissic metamorphic rocks of pelitic to quartzofeldspathic composition. Their foliated granoblastic assemblages of feldspar, quartz, biotite and accessory apatite, with local foliation-parallel felsic metamorphic segregations, formed in response to medium- to high-grade regional metamorphism. One sample represents a foliated tonalitic granitoid with scattered K-feldspar phenocrysts.
- Low-temperature alteration of the Nimbuwah Complex rocks is qualitatively similar to that observed in the Oenpelli Dolerite, with selective pervasive replacement by phyllosilicate (?illitic clay / sericite) and chlorite.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins
SHD001, 16.5m	Illite-altered micrographic quartz dolerite	Cpx,qtz,Kf,hbl,bio,opq,apa,zir	Cla(?ill),act,alb,serp,opq	Car,serp
SHD001, 18.6m	Siderite-K-feldspar veined, illite-chlorite altered micrographic quartz dolerite	Qtz,Kf,mt,ilm,bio,hbl,apa	Cla(?ill),chl,qtz,py,cpy	Car(sid),chl,qtz,Kf,cpy
SHD001, 20m	Quartz veined, chlorite-illite/sericite altered micrographic quartz dolerite	Qtz,apa	Chl,ill/ser,leu,opq,apa	Qtz,chl,car(?sid),opq
SHD001, 42m	Chlorite-illite altered micrographic quartz dolerite	Qtz,Kf,bio,apa	Ill/ser,chl,leu/rut	-
SHD001, 88.6m	Serpentine-dolomite veined, illite-chlorite altered dolerite	Qtz,bio,Kf,apa	Cla(?ill),chl,leu	Serp,dol,qtz
SHD002, 107m	Sericite-chlorite altered porphyritic dolerite	Qtz,apa	Ser,chl,qtz,leu	-
SHD002, 116m	Serpentine-carbonate veined, illite-chlorite altered dolerite	Pla,bio,apa,zir	Cla(?ill),chl/?serp,leu	Serp,dol,hem
SHD002, 123m	Veined, serpentine-hematite altered dolerite	Bio	Serp,ill/ser,opq(hem)	Serp,opq(hem),qtz
SHD002, 146m	Serpentine-hematite altered porphyritic dolerite	Qtz,apa	Serp,ill/ser,opq(hem),leu	-
SHD002, 171m	Clay-hematite altered silica-cemented quartzose sandstone	Qtz	Qtz; Cla,hem	-
SHD002, 188m	Chlorite rock (chlorite-altered crystalline rock)	Zir	Chl,rut	-
SHD002, 201m	Quartz-chlorite-sericite-hematite cemented quartzose sandstone	Qtz	Qtz,chl,ser,opq(hem)	-
SHD002, 221m	Illite-chlorite altered quartzo-feldspathic biotite gneiss	?Zir	Qtz,apa; Cla(?ill),chl,qtz	-
SHD002, 230m	Illite-chlorite altered foliated biotite tonalite	Qtz,pla,Kf,bio,apa,zir	Ill/ser,chl,epi	-
SHD002, 248m	Chlorite-sericite altered feldspar-biotite-quartz gneiss	Qtz	Chl,ser/ill	-

NOTES:

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

**: Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations:

Act = actinolite; alb = albite; apa = apatite; bio = biotite; cal = calcite; car = undifferentiated carbonate minerals; chl = chlorite; cla = undifferentiated clays; cpx = clinopyroxene; cpy = chalcopyrite; dol = dolomite; epi = epidote; hbl = hornblende; hem = hematite; ill = illitic clay mineral; ilm = ilmenite; Kf = K-feldspar; leu = leucosene; mt = magnetite; mus = muscovite; opq = undifferentiated opaque minerals; pla = plagioclase; py = pyrite; qtz = quartz; rut = rutile; ser = sericite; serp = undifferentiated serpentine minerals; sid = siderite; zir = zircon.

1. INTRODUCTION

A collection of fifteen drill core rock samples was received from Mr Daniel Alonso (AFmeco Mining and EXploration Pty Ltd, Winnellie, Northern Territory) on 3 October 1997.

It was indicated that the samples originate from West Arnhem Land, and represent rock formations of interest including Oenpelli Dolerite, Kombolgie Sandstone, and Nimbuwah Complex.

Particular requests were:

- i) Provide PETRO 2 service (standard thin section and routine petrographic description) for samples SHD001, 16.5m, 20.0m, 42.0m, 88.6m, 107m, 116m, 123m, 146m, 171m, 188m, 201m, 221m and 230m.
- ii) Provide PETRO 3 service (polished thin section and combined petrographic and mineragraphic description) for sample SHD001, 18.6m.
- iii) Provide mineral identification by X-ray diffraction (service XRAY 1) for samples SHD002, 171m, 188m, 201m.

The SUMMARY of the report was provided to the Darwin office of AFmeco Mining and EXploration Pty Ltd on 28 October 1997. This report contains the full results of this work.

2. METHODS

The drill core samples were examined in hand specimen and marked for section preparation. Thin sections and a polished thin section, as requested, were obtained from an external commercial laboratory (Amdel Ltd, Thebarton, South Australia). Mineral identifications by X-ray diffraction methods were also obtained from Amdel Ltd, and the report is provided in APPENDIX 1.

At Mason Geoscience Pty Ltd, conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions. Additional reflected light mineragraphic observations were included in a combined petrographic and mineragraphic description where a polished thin section was available.

3. PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages. Where a polished thin section was prepared, a combined petrographic and mineragraphic description is provided.

SAMPLE : SHD001, 16.5m (Altered magnetic Oenpelli Dolerite, West Arnhem Land)

SECTION NO. : SHD001, 16.5m (C69067)

HAND SPECIMEN : The drill core sample represents a medium-grained, massive doleritic igneous rock in which dull pink feldspar patches are scattered uniformly through a drab grey matrix. A single thin fracture cuts the rock, and is filled by dark green minerals.

The sample responds positively to the hand magnet, suggesting a significant amount of magnetite is present.

ROCK NAME : Illite-altered micrographic quartz dolerite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Clinopyroxene (augite, incl. actinolite)	25	Igneous (incl. alteration)
Quartz	10	Igneous
K-feldspar	10	Igneous
Hornblende	3	Igneous
Biotite	<1	Igneous
Opagues (incl. magnetite)	5	Igneous
Apatite	Tr	Igneous
Zircon	Tr	Igneous
Clays (?illite)	40	Alteration
Albite	1	Alteration
Serpentine (incl. opagues)	3	Alteration (after ?olivine) / frac. filling
Carbonate	Tr	Fracture filling

In thin section, this sample displays a well-preserved micrographic doleritic igneous texture, modified by uncommon fracturing and selective pervasive alteration.

Plagioclase was abundant, forming randomly oriented prismatic crystals ~1-2 mm long. All have suffered almost complete replacement by small randomly oriented sheaves of colourless phyllosilicate (probably illite).

Clinopyroxene was moderately abundant, forming large angular grains ~2-3 mm in size. All have suffered partial to complete replacement by turbid dark greenish brown material inferred to be actinolitic in composition. Relict clear kernels of augite are preserved in core areas of some pyroxene crystal sites.

Interstitial areas throughout the rock are filled by clear quartz and slightly turbid reddish brown K-feldspar (weakly stained by submicroscopic hematite). The quartz forms relatively large anhedral grains that are intimately intergrown with the K-feldspar in classic micrographic texture. In places, K-feldspar also forms slightly larger stumpy prismatic crystals.

Hornblende forms angular interstitial grains and subhedral crystals, pleochroic in browns and greens. It fills interstices with the micrographic intergrowths of quartz and K-feldspar, and forms overgrowths on clinopyroxene crystals. A small amount of fibrous actinolite also occurs as interstitial fillings.

Biotite occurs in minor amount as well-crystallised flakes and aggregates of flakes in interstitial areas. Pleochroism varies from dark brown to orange, or green to orange. The pleochroism suggests a relatively oxidised biotite composition.

Opaques occur in two forms:

- i) Most occurs as large angular to skeletal grains up to ~3 mm in size. They are inferred to be magnetite as indicated by the magnetic response of the hand sample.
- ii) A small amount of opaque material occurs as tiny grains concentrated in dense aggregates in green serpentine-altered crystal sites. These are sparsely scattered through the rock, and may have been primary olivine but none is preserved.

Apatite occurs in trace amount as acicular colourless prisms, located mostly in the interstitial areas with quartz and K-feldspar.

Zircon is rare, forming small equant crystals in hornblende.

Cutting the rock is a single vein filled by fibrous green serpentine-type phyllosilicate mineral, and fine-grained dense granular carbonate mineral (probably dolomite).

INTERPRETATION:

This sample represents a quartz doleritic intrusive mafic igneous rock. It was originally composed of abundant plagioclase and augite, with lesser ?olivine and magnetite, and late-forming interstitial quartz, K-feldspar, hornblende, biotite, apatite and zircon. The significant abundance of micrographic interstitial fillings indicates that the magma was relatively differentiated, and the sample probably occurs in the upper part of a differentiated mafic intrusion.

Fracturing of the rock body assisted circulation of hydrothermal fluids, which caused selective clay alteration of plagioclase, alteration of ?olivine to serpentine + opaques, and filling of fractures by serpentine + carbonate.

SAMPLE : SHD001, 18.6m (Oenpelli Dolerite, West Arnhem Land)

SECTION NO. : SHD001, 18.6m (C69068)

HAND SPECIMEN : The drill core rock sample is composed of medium-grained massive mafic igneous rock in which diffuse pink patches of hematite-stained feldspar are scattered through a dull grey altered matrix.

Cutting the rock are veins ~5-10 mm wide, filled by creamish brown mineral and bright red hematite-stained feldspar at vein margins.

The sample responds positively to the hand magnet, suggesting a significant amount of magnetite is present.

ROCK NAME : **Siderite-K-feldspar veined, illite-chlorite altered micrographic quartz dolerite**

PETROGRAPHY AND MINERAGRAPHY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Illite-chlorite altered micrographic quartz dolerite</u>		
Magnetite (incl. leucoxene)	3	Igneous (incl. alteration)
Ilmenite	2	Igneous
Quartz	5	Igneous
K-feldspar (incl. hematite stain)	5	Igneous (incl. alteration)
Biotite	2	Igneous
Hornblende	2	Igneous
Apatite	Tr	Igneous
Illite	50	Alteration (after plagioclase)
Chlorite (incl. quartz)	30	Alteration (after ?pyroxene)
Pyrite	Tr	Alteration
Chalcopryrite	Tr	Alteration
<u>Siderite veins</u>		
Carbonate (siderite)	75	Vein filling
Chlorite	10	Vein filling
Quartz (incl. chalcedony)	10	Vein filling
K-feldspar	5	Vein filling
Chalcopryrite	Tr	Vein filling

In polished thin section, this sample displays a well-preserved massive doleritic igneous texture, modified by veining and strong selective alteration.

Altered micrographic quartz dolerite retains its primary massive doleritic igneous texture. Plagioclase formed randomly oriented prismatic crystals ~1-2 mm long, now completely replaced by tiny flakes and patches of very pale phyllosilicate (probably illite).

Fine-grained green chlorite and interspersed small ragged quartz grains have completely replaced angular large ferromagnesian grains (clinopyroxene, but none is preserved).

Magnetite and ilmenite occurred as intergrown angular grains. Magnetite is now partly to completely replaced by leucoxene, but ilmenite is almost untouched and displays its characteristic pinkish grey bireflectance and strong anisotropism.

Clear quartz and reddish-brown hematite stained K-feldspar occupy interstitial areas, where they form discrete grains and micrographic intergrowths.

Hornblende forms interstitial grains, variably pleochroic in browns and greens. It is commonly associated with small biotite flakes which also display variable pleochroism from dark browns or greens to orange-yellow colours.

Apatite occurs in trace amount as acicular crystals that lace the interstitial areas, particularly the quartz and K-feldspar.

Both pyrite and chalcopyrite form scattered alteration grains. Pyrite forms small cubic crystals, commonly in close association with leucoxene-altered magnetite grains. Chalcopyrite forms small ragged grains.

Siderite veins cut the rock. They are filled mainly by small equant subhedral carbonate grains with high relief and translucent to waxy very pale yellow colour. It is inferred to be siderite, and tends to be concentrated in vein centres as massive granular mosaics.

Chlorite occurs in minor amount as small, very pale green flakes concentrated in monomineralic mats in parts of the vein.

Quartz occurs as small clear anhedral grains that occupy interstices between siderite aggregates. Locally, the quartz displays a very fine-grained fibrous texture suggestive of chalcedonic silica.

K-feldspar occurs as small ragged grains, concentrated along margins of some veins. It is diffusely stained by reddish brown material (submicroscopic hematite).

A trace of chalcopyrite occurs as tiny ragged grains intergrown with siderite.

INTERPRETATION:

This sample represents a quartz doleritic intrusive igneous rock, originally composed of a massive medium-grained assemblage of plagioclase, clinopyroxene, magnetite, ilmenite, quartz, K-feldspar, hornblende, biotite, and apatite. Early-formed plagioclase, pyroxene and Fe-Ti oxides were followed by interstitial fillings of micrographic quartz + K-feldspar, hornblende, biotite, and apatite.

Fracturing of the rock encouraged invasion by hydrothermal fluids. This resulted in strong selective pervasive alteration (plagioclase replaced by illitic clay, pyroxene replaced by chlorite + quartz, magnetite partly replaced by leucoxene). Traces of pyrite and chalcopyrite formed in the alteration assemblage. The fractures were filled by siderite + quartz + chlorite + K-feldspar + trace chalcopyrite.

Client query: *Unknown brown mineral...*

Response: The creamish brown vein-filling mineral is Fe-carbonate (probably siderite).

SAMPLE : SHD001, 20m (Chloritised dolerite and quartz vein, West Arnhem Land)

SECTION NO. : SHD001, 20m (C69069)

HAND SPECIMEN : The drill core sample represents an altered massive mafic crystalline rock, containing scattered cream ragged patches (leucoxene-altered Fe-Ti oxide grains) in a dark grey to greenish black matrix.

Cutting the rock is a cream vein.

ROCK NAME : Quartz veined, chlorite-illite/sericite altered micrographic quartz dolerite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	15	Igneous
Apatite	Tr	Igneous / alteration
Chlorite	43	Alteration
Illite (incl. sericite)	35	Alteration
Leucoxene	5	Alteration (after Fe-Ti oxides)
Quartz	2	Vein filling
Carbonate (?siderite)	Tr	Fracture filling
Opakes	Tr	Alteration / fracture filling

In thin section, this sample displays a relict micrographic doleritic igneous texture, severely modified by strong selective pervasive alteration and veining.

Quartz is moderately abundant and occurs in two forms:

- i) Most occur as angular interstitial unstrained clear pools. They were intimately intergrown with K-feldspar in micrographic texture, but all of the K-feldspar has been replaced by very fine-grained phyllosilicate (illite/sericite). Locally the interstitial quartz pools are abundant, and appear to represent centimetre-sized felsic differentiation patches.
- ii) Some quartz occurs as anhedral grains that fill the vein cutting the rock. Thin fractures near the quartz vein margin are filled by cross-vein fibrous carbonate of Fe-carbonate composition (probably siderite).

Colourless phyllosilicate is abundant. Most occurs as minute flecks that form massive replacements of prismatic crystals (plagioclase, but none is preserved). The phyllosilicate displays relatively low birefringence suggestive of illitic clay, but local larger plates display higher birefringence suggestive of sericitic white mica. Both phases are considered to be present. Sericite is significantly more abundant in the selvedge of the quartz-rich vein, where it has formed as a selvedge alteration mineral.

Chlorite is moderately abundant. Most occurs as exceptionally fine-grained massive drab brownish green replacements of precursor crystals. Large angular ferromagnesian crystal sites most probably were clinopyroxene, but similar chlorite has also replaced plagioclase prisms. Dense fine-grained chlorite is concentrated along margins of the quartz-rich vein.

Leucoxene occurs as cryptocrystalline dense dark brown to opaque replacements of primary angular Fe-Ti oxide crystals scattered through the rock.

Apatite occurs in two forms:

- i) Some occurs as acicular crystals that lace the interstitial quartz-K-feldspar areas. This represents accessory igneous apatite.
- ii) Some apatite occurs as small equant grains, concentrated in aggregates in the selvedge of the quartz vein. This represents alteration apatite.

Opakes are uncommon, forming small subhedral disseminated grains in the wall rock, and small ragged aggregates near the margin of the quartz vein.

INTERPRETATION:

This sample represents a micrographic quartz dolerite, originally composed of plagioclase, pyroxene, quartz, K-feldspar, Fe-Ti oxides and apatite. Other phases may have been present, but have been destroyed by subsequent alteration.

The rock body suffered a fracturing event, which generated widely spaced fractures and allowed invasion by hydrothermal fluids. The veins were filled by quartz + chlorite ± opakes, and the doleritic wall rock suffered strong selective pervasive alteration which generated illite/sericite + chlorite + leucoxene + trace apatite + opakes. Only primary quartz and apatite survived the alteration event. Sericite formed most abundantly in the selvedge of the quartz-rich vein.

SAMPLE : SHD001, 42m (Altered dolerite, West Arnhem Land)

SECTION NO. : SHD001, 42m (C69070)

HAND SPECIMEN : The drill core sample represents a massive, medium-grained, mafic crystalline rock that has suffered pervasive alteration to dull dark greenish grey materials, small scattered pale cream patches (leucoxene after Fe-Ti oxides), and small pinkish altered feldspar patches.

ROCK NAME : Chlorite-illite altered micrographic quartz dolerite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	10	Igneous
K-feldspar (incl. hematite)	10	Igneous (incl. alteration)
Biotite	2	Igneous (incl. alteration)
Apatite	Tr	Igneous
Chlorite	30	Alteration
Illite (incl. ?sericite)	43	Alteration
Leucoxene (incl. rutile)	5	Alteration

In thin section, this sample displays a partly preserved massive micrographic doleritic igneous texture, severely modified by selective pervasive alteration.

Alteration minerals dominate the rock. Fine-grained pleochroic green chlorite forms optically continuous and fine-grained dense massive pseudomorphous replacements after large angular and smaller euhedral ferromagnesian crystals (probably mainly pyroxene).

Fine-grained colourless to very pale green phyllosilicate has completely replaced prismatic feldspar crystals (plagioclase, but none is preserved). The phyllosilicate appears to be an illitic clay, but locally brighter interference colours suggests some sericite may be present.

Quartz and K-feldspar occur as micrographic intergrowths that fill interstices between the altered plagioclase and ferromagnesian crystals. The quartz is quite clear and unstrained, but the K-feldspar has suffered strong alteration by dark reddish brown submicroscopic hematite. Acicular apatite crystals lace the quartz and K-feldspar.

Blocky grains (primary Fe-Ti oxides) are uniformly distributed, and have suffered complete replacement by turbid cryptocrystalline dense dark brown material (leucoxene) and small subrounded grains and aggregates of rutile that display the characteristic high relief, turbid colour, and strong birefringence of this phase. The leucoxene probably has replaced primary magnetite, and the rutile probably has replaced primary ilmenite.

Biotite formed small flakes and aggregates of flakes in interstices, and as intergrowths with Fe-Ti oxide crystals. Most of the flakes have suffered partial replacement by chlorite.

INTERPRETATION:

This sample represents a massive micrographic dolerite, originally composed of plagioclase, ferromagnesians (probably mainly pyroxene), quartz, K-feldspar, Fe-Ti oxides (probably both

magnetite and ilmenite), biotite, and apatite. Other phases may have been present but have been destroyed by alteration.

Invasion by low-temperature hydrothermal fluids resulted in strong selective pervasive alteration, generating chlorite, illite/sericite, and leucoxene/rutile. Most of the primary textures were preserved.

SAMPLE : SHD001, 88.6m (Altered magnetic dolerite with chrysotile, calcite, quartz veins; West Arnhem Land)

SECTION NO. : SHD001, 88.6m (C69071)

HAND SPECIMEN : The drill core sample represents an altered mafic crystalline rock composed of dark greenish grey altered crystals and scattered small ragged cream to pale brown leucoxene patches (altered Fe-Ti oxide grains).

Cutting the rock is a single laminated vein composed of fine-grained cross-fibre dark green serpentine and white carbonate. The vein effervesces only very weakly in reaction with dilute HCl, suggesting calcite is absent.

ROCK NAME : **Serpentine-dolomite veined, illite-chlorite altered dolerite**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	1	Igneous
Biotite	<1	Igneous
K-feldspar (incl. hematite)	Tr	Igneous (incl. alteration)
Apatite	Tr	Igneous
Illite	50	Alteration (after plagioclase)
Chlorite (incl. minor turbid quartz)	40	Alteration (after ferromags.)
Leucoxene	2	Alteration (after Fe-Ti oxides)
Serpentine	2	Vein filling
Carbonate (dolomite)	1	Vein filling
Quartz	1	Vein filling

In thin section, this sample displays a moderately well-preserved massive doleritic igneous texture, modified by strong selective pervasive alteration and veining.

Plagioclase was abundant, forming randomly oriented prismatic crystals ~0.4-2.0 mm in size. All have suffered complete replacement by small ragged colourless phyllosilicate flakes inferred to be illite (birefringence a little too low for sericite).

Ferromagnesian minerals occurred in subequal abundance to plagioclase, but have been completely replaced by very pale green chlorite (length-fast flake orientation, aids distinction from serpentine, see below). In some areas, the chlorite has pseudomorphously replaced large angular ferromagnesian plates (pyroxene, but none is preserved) that subophitically enclosed smaller plagioclase prisms (now replaced by illite). Elsewhere, the chlorite has pseudomorphously replaced small blocky ferromagnesian crystals.

Leucoxene occurs as cryptocrystalline dense turbid brown pseudomorphous replacements of angular to skeletal crystals (primary Fe-Ti oxides, probably both magnetite and ilmenite) that were sparsely scattered through the rock. These are the small pale creamish brown patches observable in hand specimen.

Uncommon small angular interstitial patches are occupied by clear unstrained quartz and intergrown hematite-stained K-feldspar grains. A trace of apatite occurs as acicular crystals that lace the interstitial felsic minerals.

Biotite occurs as small interstitial flakes, pleochroic in drab greenish browns. Most have suffered partial replacement by chlorite.

Cutting the rock is a single vein which displays a laminated texture. Serpentine forms monomineralic multiple cross-fibre veinlets subparallel to the gross vein orientation. Locally, the serpentine also forms dense massive fine-grained patches. The length-slow orientation of the fibres aids distinction of serpentine from chlorite. Quartz and calcite occur as granular intergrowths in other veins that lie subparallel to the gross vein orientation.

INTERPRETATION:

This sample represents a doleritic intrusive igneous rock, originally composed of plagioclase, pyroxene, minor Fe-Ti oxides (magnetite, ilmenite), biotite, quartz, K-feldspar and apatite. The rock was considerably more mafic than samples SHD001-16.5m, -18.6m, -20.0m and -42.0m, and contained less quartz, K-feldspar and biotite as interstitial patches.

The rock body suffered fracturing and invasion by relatively low-temperature hydrothermal fluids. This resulted in selective pervasive alteration of dolerite (plagioclase replaced by illite, ferromagnesian replaced by chlorite, Fe-Ti oxides replaced by leucoxene), and filling of the open fractures by serpentine + quartz + carbonate (dolomite).

SAMPLE : SHD002, 107m (Microporphyrific Oenpelli Dolerite, West Arnhem Land)

SECTION NO. : SHD002, 107m (C69072)

HAND SPECIMEN : The drill core sample represents a dull grey, massive, altered mafic crystalline rock, through which are scattered uncommon large (2-4 mm) waxy pale green altered feldspar phenocrysts, small dark greenish black altered ferromagnesian grains, and tiny pale cream leucoxene spots (altered Fe-Ti oxide grains).

ROCK NAME : Sericite-chlorite altered porphyritic dolerite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	Tr	Igneous
Apatite	Tr	Igneous
Sericite	56	Alteration (after plagioclase)
Chlorite	40	Alteration (after ferromagnesian)
Quartz	2	Alteration (after ferromagnesian)
Leucoxene	1	Alteration (after Fe-Ti oxides)

In thin section, this sample displays a moderately well-preserved porphyritic doleritic igneous texture, modified by selective pervasive alteration.

Plagioclase was abundant, occurring as abundant randomly oriented prismatic crystals ~0.4-1.0 mm long, and more sparsely scattered large stumpy crystals ~7 mm in size. All have suffered complete replacement by tiny randomly oriented phyllosilicate flecks, forming dense massive mats. The moderately high birefringence suggests the phase is sericite rather than illite.

Chlorite is moderately abundant, occurring as optically continuous replacement mats pseudomorphous after large angular ferromagnesian grains (probably pyroxene) that subophitically enclosed plagioclase crystals. Chlorite also forms pseudomorphous replacements of smaller blocky ferromagnesian crystals. Large angular ferromagnesian patches, now weakly pleochroic in drab browns, represent altered ?hornblende which formed as overgrowths on earlier-formed pyroxene and as interstitial fillings.

Quartz occurs in two forms:

- i) A small amount occurs as small ragged grains in granular aggregates in chloritised ferromagnesian crystal sites. These probably were pyroxene crystals.
- ii) Some occurs as uncommon clear angular interstitial grains. These represent relict igneous grains.

Leucoxene occurs in minor amount as dense dark brown to opaque cryptocrystalline replacements of sparsely scattered angular Fe-Ti oxide grains.

Apatite is rare, forming small acicular crystals in interstitial areas.

INTERPRETATION:

This sample represents a porphyritic doleritic intrusive igneous rock, originally composed of scattered large plagioclase phenocrysts in a finer-grained doleritic assemblage of plagioclase, pyroxene, ?hornblende, Fe-Ti oxide grains, and minor interstitial quartz and apatite. The rock was significantly more mafic than most of the micrographic dolerites of SHD001 (see TABLE 1, and descriptions above).

Invasion of the rock body by low-temperature hydrothermal fluids resulted in moderate intense selective pervasive alteration, causing complete replacement of plagioclase by sericite, ferromagnesian minerals by chlorite \pm quartz, and complete replacement of Fe-Ti oxides by leucoxene.

SAMPLE : SHD002, 116m (Altered Oenpelli Dolerite, West Arnhem Land)

SECTION NO. : SHD002, 116m (C69073)

HAND SPECIMEN : The drill core rock sample represents an altered massive mafic crystalline rock, in which indistinct paler altered feldspar crystals and drab dark greenish grey altered ferromagnesian materials are distinguishable.

Cutting the rock are widely-spaced veins filled by dark green to black minerals (serpentine), intergrown fibrous bright red hematite patches, and thin discrete veinlets filled by white carbonate.

ROCK NAME : **Serpentine-carbonate veined, illite-chlorite altered dolerite**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase	10	Relict igneous
Biotite (brown, green)	Tr	Igneous
Zircon	Tr	Igneous
Apatite	Tr	Igneous
Illite	50	Alteration (after plagioclase)
Chlorite (incl. serpentine)	35	Alteration (after ferromagnesian)
Leucoxene	1	Alteration (after Fe-Ti oxides)
Serpentine	2	Vein filling
Opakes (incl. hematite)	Tr	Vein filling
Carbonate (?dolomite)	Tr	Alteration / vein filling

In thin section, this sample displays a partly preserved massive doleritic igneous texture, modified by selective pervasive alteration and veining.

Plagioclase was abundant, forming randomly oriented prismatic crystals ~0.2-1.0 mm long, and uncommon larger phenocrysts ~2 mm in size. All have suffered partial to complete replacement by small ragged phyllosilicate flecks whose low to moderate birefringence suggests illite rather than sericite. Relict primary plagioclase is preserved in some crystals, especially at margins, where normally-zoned polysynthetically twinned rims are observed.

Chlorite is the other principal phase. It occurs in different forms, but most occurs as pseudomorphous optically continuous and massive replacements of primary ferromagnesian crystals that built anhedral angular grains (?pyroxene) and also built small blocky crystals (?pyroxene, ?olivine). In places, the very pale green replacement materials have the appearance of serpentine, but optical distinction in these fine-grained mats is difficult. Small ragged grains and aggregates of carbonate (?dolomite) are intergrown with the chloritic materials.

Leucoxene occurs as cryptocrystalline turbid dark brown to opaque replacements of angular primary Fe-Ti oxide crystals (magnetite or ilmenite or both).

Biotite is present as small interstitial plates and aggregates of flakes. Some are pleochroic from reddish brown to yellow, but these flakes may zone into green flakes and some finer-grained aggregates of green biotite flakes are present.

Apatite is rare, forming small acicular interstitial crystals.

Zircon is rare, forming small equant euhedral crystals with characteristic high relief and very high birefringence.

Very pale green to colourless non-pleochroic serpentine forms cross-fibre vein fillings. Dense aggregates of very fine-grained hematite are concentrated along the cleavages of the cross-fibre serpentine. Carbonate (probably dolomite) forms anhedral clear sparry grains that fill discrete veinlets oriented along margins of the thicker serpentine vein.

INTERPRETATION:

This sample represents a medium-grained massive doleritic intrusive igneous rock, originally composed of uncommon plagioclase phenocrysts in a finer-grained doleritic assemblage of plagioclase, ferromagnesian (?pyroxene, ?olivine), minor Fe-Ti oxides, biotite and apatite.

Fracturing of the rock and invasion by low-temperature hydrothermal fluids resulted in moderately strong selective pervasive alteration and filling of the fractures by cross-fibre serpentine with minor hematite and carbonate. The dolerite wall rock was replaced by illitic clay + chlorite (incl. ?serpentine) + carbonate (?dolomite) + leucoxene.

SAMPLE : SHD002, 123m (Altered dolerite, quartz hematite veins, West Arnhem Land)

SECTION NO. : SHD002, 123m (C69074)

HAND SPECIMEN : The drill core sample represents a massive dark green rock with pervasive dull red tinge. Cutting the rock is a single vein ~1 cm thick, filled by dark green to black material (serpentine) and dull red patches (hematite).

ROCK NAME : Veined, serpentine-hematite altered dolerite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Serpentine-hematite altered dolerite</u>		
Biotite	<1	Relict igneous
Serpentine	50	Alteration
Illite/sericite	40	Alteration
Opagues (hematite)	10	Alteration
<u>Serpentine-hematite-quartz vein</u>		
Serpentine	75	Vein filling
Hematite	20	Vein filling
Quartz	5	Vein filling

In thin section, this sample displays a poorly-preserved massive doleritic igneous texture, modified by strong pervasive alteration and veining.

Serpentine-hematite altered dolerite faintly retains its massive doleritic igneous texture. Fine-grained colourless phyllosilicate occurs as small randomly oriented flakes that have completely replaced randomly oriented feldspar prisms (plagioclase) ~0.5-1.0 mm (some uncommon phenocrysts as large as ~4 mm). The phyllosilicate displays birefringence sufficiently high to suggest sericite, but its identification remains uncertain.

Serpentine is abundant, occurring as fine-grained pale green dense replacement mats throughout the rock. Locally, equant euhedral crystal forms are distinguishable, and ragged angular forms of serpentine-altered ?pyroxene enclosed illite-altered plagioclase crystals.

Opagues occur mostly as small cryptocrystalline replacement patches that are sprinkled through or around margins of serpentine-altered ferromagnesian crystal sites. Denser replacements of larger anhedral to amoeboid grains appear to represent altered primary Fe-Ti oxide crystals.

Biotite is uncommon, forming small angular interstitial flakes. They represent the only relict primary phase.

Serpentine-hematite-quartz vein is filled mainly by cross-fibre green serpentine. Opagues occur as massive dense patches along vein margins, and as trails of small patches along vein margin-parallel horizons within the serpentine. Local deep red colour of the opagues suggests it is hematite. Quartz occurs in significant amount as anhedral small grains concentrated in patches and tortuous bulbous veins within the serpentine.

INTERPRETATION:

This sample represents a doleritic igneous rock that has suffered pervasive low-temperature alteration to the assemblage serpentine + illite/sericite + opaques (hematite). Veins that formed at this time were filled by serpentine + opaques (hematite) + quartz.

SAMPLE : SHD002, 146m (Microporphyrific dolerite and chrysotile veins, West Arnhem Land)

SECTION NO. : SHD002, 146m (C69075)

HAND SPECIMEN : The drill core sample represents an altered porphyritic dolerite, in which indistinct blocky altered feldspar crystals (paler waxy yellow-cream colour) and altered pyroxene plates (darker waxy greenish grey patches) lie in a fine-grained dark reddish grey matrix.

ROCK NAME : **Serpentine-hematite altered porphyritic dolerite**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	<1	Igneous
Apatite	Tr	Igneous
Serpentine	51	Alteration
Illite/sericite	40	Alteration
Opauques (hematite)	5	Alteration
Leucoxene	2	Alteration (after Fe-Ti oxide crystals)

In thin section, this sample displays a partly preserved porphyritic doleritic igneous texture, modified by selective pervasive alteration.

Serpentine is abundant, occurring as fine-grained massive replacement mats throughout the rock. Local uniform distribution of minute opaque specks identifies continuity of precursor subophitic large pyroxene crystals.

Very pale yellowish phyllosilicate materials occur as tiny randomly oriented flakes that have pseudomorphously replaced prismatic feldspar crystals (plagioclase) mostly ~0.5-1.0 mm long, but larger blocky prisms (phenocrysts) ~2-4 mm in size also are present. The identity of the phyllosilicate phase remains uncertain: it may be mainly sericite, as inferred from the moderate birefringence.

Opauques occur in significant amount, mostly as microcrystalline dark red to opaque aggregates (hematite) scattered through the rock. Locally, the hematite is concentrated in larger patches concentrated along indistinct fractures.

Leucoxene occurs as cryptocrystalline turbid dense dark brown to opaque replacements of precursor disseminated angular crystals (Fe-Ti oxide crystals).

Quartz occurs in small amount as angular interstitial clear unstrained grains, sparsely disseminated through the rock. Their size, shape and distribution are consistent with primary accessory quartz grains.

Apatite occurs in trace amount as acicular clear crystals. They also are of primary igneous origin.

INTERPRETATION:

This sample represents a doleritic igneous rock, originally composed of larger phenocrysts of plagioclase and subophitic pyroxene, scattered through a finer-grained groundmass dominated by the same minerals with accessory Fe-Ti oxide/s, quartz and apatite.

Subsequent invasion by low-temperature hydrothermal fluids resulted in severe pervasive alteration, generating phyllosilicate (sericite/illite) after plagioclase, serpentine + hematite after ferromagnesian minerals, and leucoxene after Fe-Ti oxide grains. Accessory primary quartz and apatite survived this event.

SAMPLE : SHD002, 171m (Kaolinised hematized sandstone, West Arnhem Land)

SECTION NO. : SHD002, 171m (C69076)

HAND SPECIMEN : The drill core rock sample is composed of abundant, firmly cemented subrounded quartz grains that are translucent grey to white in colour. Scattered through the rock are porous ferruginous red alteration patches.

ROCK NAME : Clay-hematite altered silica-cemented quartzose sandstone

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	90	Relict clastic / alteration (cement)
Clay	3	Alteration
Hematite	2	Alteration
Voids	5	?Enhanced by preparation

[NOTE: XRD has identified quartz, kaolinite, calcite, and hematite.]

In thin section, this sample displays a well-sorted clastic sedimentary texture, modified by overgrowths and low-grade alteration.

Quartz dominates the sample, and occurs in two forms:

- i) Most occurs as rounded clastic crystal fragments mostly ~0.4-2.0 mm in size.
- ii) A significant amount occurs as overgrowths on the primary rounded grains. These overgrowths have completely occluded the primary interparticle pore spaces.

Fine-grained kaolinite and dark red cryptocrystalline hematite are intimately intergrown in ragged patches scattered through the rock. There is no petrographic evidence to support a precursor clastic particle origin for these patches.

Ragged void spaces are scattered through the rock. They appear to have been generated mainly by preparation, but may represent enhanced pores generated during the alteration event that generated kaolinite and hematite.

INTERPRETATION:

This sample represents a well-sorted, compositionally mature quartzose sandstone. Pore spaces were filled by quartz overgrowths. Alteration generated patches of kaolinite + hematite scattered through the rock.

SAMPLE : SHD002, 188m (Chloritised tectonised dolerite, West Arnhem Land)

SECTION NO. : SHD002, 188m (C69077)

HAND SPECIMEN : The drill core rock sample represents a fine-grained dark green rock in which a patchy precursor crystalline texture has been deformed within a moderate foliation.

ROCK NAME : Chlorite rock (chlorite-altered crystalline rock)

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	99	Alteration
Rutile	Tr	Alteration
Zircon	Tr	Relict primary crystals
[NOTE: XRD has identified chlorite, quartz, calcite, and possible trace K-feldspar and plagioclase.]		

In thin section, this sample displays a massive fibrous crystalline alteration texture, with a faintly preserved precursor blocky crystalline texture.

Chlorite completely dominates the rock, occurring as small randomly oriented flakes in subradiating aggregates that form a dense mat throughout the rock. The flakes are pleochroic from very pale green or colourless to darker green, suggestive of a relatively Fe-rich composition. Locally, the chlorite forms slightly coarser- or finer-grained patches that appear to have pseudomorphously replaced precursor blocky to subrounded crystals. Note that no foliation is evident in the chlorite.

Rutile occurs in trace amount as small deep brown to yellow granules that tend to be concentrated in small disseminated aggregates.

Zircon is rare, forming small stumpy prismatic crystals scattered through the rock.

INTERPRETATION:

This sample represents a precursor crystalline rock that has suffered virtually complete replacement by the dense massive assemblage of chlorite + trace rutile. Small scattered zircon crystals represent the only preserved primary crystals.

The identity of the precursor rock has been obscured by the intensity of alteration. It is possible that it was a doleritic intrusive rock, but there is no clear evidence for this except for the general lack of primary quartz which should have been preserved if originally present.

SAMPLE : SHD002, 201m (Kombolgie Sandstone, West Arnhem Land)

SECTION NO. : SHD002, 201m (C69078)

HAND SPECIMEN : The drill core sample represents a quartzose sandstone composed of abundant small round quartz grains in a dull greenish matrix. Larger grains tend to be concentrated in particular horizons, defining primary sedimentary layering. Minor small vughy quartz patches appear to define indistinct thin veinlets through the rock.

ROCK NAME : Quartz-chlorite-sericite-hematite cemented quartzose sandstone

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	97	Clastic particles / overgrowth cement
Chlorite	1	Alteration (cement)
Sericite	<1	Alteration (cement)
Opauques (incl. hematite)	<1	Alteration (cement)
[NOTE: XRD has identified quartz, chlorite, calcite, and possible trace mica, K-feldspar, siderite, pyrite, and anatase.]		

In thin section, this sample displays a well-preserved framework-supported, well-sorted clastic sedimentary texture, modified by cementation.

Quartz completely dominates the rock, and occurs in two forms. Most occurs as rounded crystal fragments mostly ~1-2 mm in size. They have been firmly cemented by optically continuous overgrowths of quartz, with sutured grain boundaries where overgrowths meet.

Chlorite occurs in minor amount as small flakes concentrated in interparticle pore spaces where it is intergrown with quartz, and around quartz grain margins. The chlorite is pleochroic in very pale greens.

Sericite occurs in trace amount as small colourless flecks, intergrown with the interpore fillings of quartz and chlorite.

Opauques also occur in the interpore fillings, where they form elongate opaque crystals in small aggregates. Some display deep blood red colour under condensed transmitted light, suggestive of hematite.

INTERPRETATION:

This sample represents a well-sorted quartz sandstone that has suffered invasion by low-temperature fluids. This resulted in filling of interparticle pores by quartz + minor chlorite + sericite + hematite.

SAMPLE : SHD002, 221m (Nimbuwah Migmatite, biotite-feldspar schist, West Arnhem Land)

SECTION NO. : SHD002, 221m (C69079)

HAND SPECIMEN : The drill core sample represents a foliated gneissic rock composed of altered dull green materials and thin laminae of altered pale cream grains.

ROCK NAME : Illite-chlorite altered quartzo-feldspathic biotite gneiss

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	30	Metamorphic
Apatite	Tr	Metamorphic
Zircon	Tr	?Relict clastic / ?metamorphic
Phyllosilicate (?illite)	45	Alteration
Quartz	5	Alteration (after ?feldspar)
Chlorite (incl. relict biotite)	20	Alteration (after biotite)

In thin section, this sample displays a well-preserved granoblastic metamorphic texture with foliation of mica and indistinct mineralogical lamination, modified by strong selective pervasive alteration.

Quartz is moderately abundant, and occurs in two forms:

- Most occurs as anhedral grains ~0.2-2.0 mm long, elongated in the trace of the foliation. They are unstrained, and some contain rare small inclusions of pleochroic brown biotite flakes (also see biotite below).
- Some occurs as small ragged grains that form granular mosaics pseudomorphous after precursor ragged grains ~0.4-1.0 mm in size. These appear to have been feldspar grains, possibly K-feldspar, but none is preserved.

Very pale yellowish phyllosilicate (probably illite) occurs as fine-grained massive replacements of precursor ragged grains that probably were plagioclase but none is preserved.

Biotite formed well-crystallised flakes ~0.2-1.0 mm long. They are distributed more-or-less uniformly through the rock, and their preferred orientation contributes to the structure through the rock. All have suffered partial to severe replacement by poorly-crystallised drab brownish green chlorite.

Apatite occurs in trace amount as small subrounded grains that formed part of the granoblastic mosaic with feldspar, quartz and biotite.

Zircon is rare, forming small subrounded grains of probable relict clastic origin.

INTERPRETATION:

This sample represents a medium to high grade regional metamorphic rock, composed of a foliated granoblastic mosaic of feldspar (?plagioclase, ?K-feldspar), quartz, biotite, and

accessory apatite and zircon. Indistinct mineralogical layering, especially of K-feldspar, appears to represent incipient metamorphic differentiation. The nature of the precursor rock has been obscured by the extent of complete metamorphic recrystallisation, but a quartzo-feldspathic sedimentary precursor is inferred.

Subsequent low-temperature alteration of the rock body generated illitic clay after ?plagioclase, poorly-formed chlorite after biotite, and granular quartz after ?K-feldspar.

SAMPLE : SHD002, 230m (Nimbuwah Granitoid, West Arnhem Land).

SECTION NO. : SHD002, 230m (C69080)

HAND SPECIMEN : The drill core rock sample represents a granitoid composed of drab brownish altered feldspar grains, translucent grey quartz grains and foliated biotite flakes, with uncommon scattered large white K-feldspar patches.

ROCK NAME : Illite-chlorite altered foliated biotite tonalite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	20	Igneous
K-feldspar (orthoclase / microcline)	25	Igneous
Plagioclase	15	Relict igneous
Biotite	4	Relict igneous
Apatite	Tr	Igneous
Zircon	Tr	Igneous
Phyllosilicate (?illite, incl. muscovite)	33	Alteration (after plagioclase, biotite)
Chlorite	3	Alteration (after biotite)
Epidote	Tr	Alteration

In thin section, this sample displays a coarse-grained foliated granitoid texture, modified by selective pervasive alteration. Note that the modal abundances given above refer to the thin section, but K-feldspar is considered to be over represented: it may only comprise ~5% of the rock overall.

Plagioclase was moderately abundant, occurring as anhedral equant twinned grains ~2-4 mm in size. All have suffered partial to severe replacement by small ragged flakes of very pale yellowish green phyllosilicate that probably is an illitic clay. Locally, the phyllosilicate forms larger, better-crystallised flakes that appear to be genuine white mica (i.e. muscovite).

K-feldspar is fresh, forming one very large ragged grain ~1 cm in size. The K-feldspar is observed as scattered large patches in hand specimen. The presence of local, poorly developed 'tartan' twinning (i.e. combined albite and pericline twinning) suggests that the K-feldspar formed as orthoclase and has suffered only incipient retrogression to microcline.

Quartz occurs in moderate abundance as anhedral grains ~2-3 mm in size, partly moulded on plagioclase grains. The quartz is quite clear and lacks deformational effects.

Biotite formed large, well-crystallised flakes ~1-2 mm long. Their preferred orientation defines a foliation through the rock. Most flakes display partial replacement along cleavage traces by pleochroic green chlorite.

Apatite occurs in minor amount as small equant subrounded grains ~0.1-0.2 mm in size. They occur mainly in close association with biotite flakes.

Zircon is uncommon, forming tiny euhedral crystals scattered through plagioclase and quartz grains.

INTERPRETATION:

This sample represents a tonalitic granitoid rock, originally composed of the assemblage plagioclase, quartz, biotite, scattered large K-feldspar grains, and accessory apatite and zircon. The strong foliation of biotite flakes, but lack of strain in quartz, suggests that the granitoid magma was emplaced in the presence of a stress field.

Subsequent low-temperature alteration of the rock generated illitic clay \pm muscovite after plagioclase and chlorite after biotite.

SAMPLE : SHD002, 248m (No field notes for this sample, West Arnhem Land)
SECTION NO. : SHD002, 248m (C69081)
HAND SPECIMEN : The drill core sample represents a fine- to medium-grained foliated rock with local metamorphic differentiation generating coarser-grained siliceous laminae. Pervasive alteration has produced a drab green colour throughout the rock.
ROCK NAME : Chlorite-sericite altered feldspar-biotite-quartz gneiss
PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	35	Metamorphic
Chlorite (incl. trace leucoxene)	55	Alteration
Phyllosilicate (sericite/illite)	10	Alteration

In thin section, this sample displays a foliated granoblastic metamorphic texture, with some local metamorphic differentiation along laminae, modified by strong pervasive alteration.

Quartz occurs in two forms:

- i) Most occurs as small anhedral grains ~0.2-0.4 mm in size, distributed more-or-less uniformly through most of the rock.
- ii) A lesser amount occurs as large anhedral grains concentrated in thin laminae. The grains are elongated in the trace of layering and foliation, but display little or no deformation. Fluid inclusions are present in minor numbers: they are relatively large and appear to be filled by large dark dense (?CO₂-rich) vapour bubbles.

Fine-grained pleochroic green chlorite and intergrown fibrous phyllosilicate (probably sericite, but some illite may be present) are intimately intergrown. These phases have formed by complete replacement of small foliated flakes of biotite (which retain their flaky primary shapes), and by replacement of ragged anhedral grains (probably feldspar, but none is preserved).

INTERPRETATION:

This sample represents a foliated granoblastic metamorphic rock, originally composed of feldspar, biotite and quartz. Coarsening of quartz in some laminae is attributed to metamorphic differentiation occurring in those laminae. The nature of the precursor rock has been obscured by the effects of metamorphism (and subsequent alteration, see below), but a pelitic sedimentary precursor rock is inferred.

Invasion of the rock body by low-temperature hydrothermal fluids resulted in complete replacement of feldspar and biotite by chlorite + phyllosilicate (sericite/illite).

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REPORT TITLE	Petrographic Descriptions for Eight Drill Core Rock Samples (EL 2508 and EL 2506, Northern Territory)
REPORT #	2378
CLIENT	Afmeco Mining and Exploration Pty Ltd
ORDER NO.	03321
CONTACT	Mr Daniel Alonso

REPORT BY	Dr Douglas R. Mason
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SIGNED



for Mason Geoscience Pty. Ltd.

DATE	7 November 1997
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Petrographic Descriptions for Eight Drill Core Rock Samples (EL 2506 and EL 2508, Northern Territory)

SUMMARY

1. Rock Samples

- Eight drill core rock samples from ELs 2506 and 2508 (Northern Territory), have been studied using petrographic and limited mineragraphic methods (TABLE 1).

2. Brief Results

- EL 2506

- Primary rock types include quartz dolerite and layered sedimentary rocks (basaltic lithic tuffs, siltstone, and phosphatic sediment).
- Hydrothermal alteration has affected all rocks. Strong pervasive chlorite-hematite alteration has affected the basic rocks (dolerite, basaltic tuffs). The layered sediments were less affected: siltstone has suffered mild hematitic alteration, and phosphatic sediment has suffered only weak hematite-chlorite alteration with local migration of apatite into thin discontinuous fractures.

- EL 2508

- Primary rocks of all three samples were quartzo-feldspathic gneisses of medium- to high-grade. They were medium-grained foliated granoblastic rocks. They were probably composed of quartz, feldspar, biotite, muscovite and possibly minor graphite, but most primary features were destroyed by subsequent deformation and alteration (see next).
- Deformation caused brecciation of the metamorphic rocks, and shearing caused milling of the lithic and crystal fragments. Invasion by hydrothermal fluids caused moderately severe pervasive replacement by sericite + chlorite + minor leucoxene + graphite ± pyrite ± chalcopyrite.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins
EL 2506				
SH003, 102.7m	Veined, chlorite-hematite altered quartz dolerite	Qtz,bio,apa	Chl,leu/rut,hem,qtz,py	Qtz,chl,py,cpy,marc,hem
SH003, 201.3m	Chlorite-hematite altered layered basaltic lithic tuff	Zir	Chl,opq(hem),leu,apa	-
SH003, 203.0m	Chlorite-hematite altered layered basaltic lithic tuff	Zir,?rut	Chl,opq(hem),leu	-
SH003, 213.5m	Interlayered altered basaltic tuff / hematized siltstone / phosphatic sediment:			
"	- Chlorite-hematite altered basaltic tuff	Zir	Chl,opq(hem),ser,apa	-
"	- Hematized siltstone	Qtz	Chl,opq(hem)	Apa,chl,hem
"	- Phosphatic sediment	-	Apa,chl,opq(hem)	Apa,chl,hem
SH003, 213.9m	Chlorite-sericite altered gneiss	-	Zir; Ser,chl,opq(hem),leu,apa	-
"	Chlorite-sericite-hematite altered rock (?sediment)	-	Zir; Chl,ser,opq(hem),apa	-

NOTES:

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

** : Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations:

Apa = apatite; bio = biotite; chl = chlorite; cpy = chalcopyrite; goe = goethite; grp = graphite; hem = hematite; leu = leucoxene; marc = marcasite; mus = muscovite (coarse-grained K-mica); opq = undifferentiated opaques; py = pyrite; qtz = quartz; rut = rutile; ser = sericite (fine-grained K-mica); zir = zircon; ? = uncertain paragenesis.

1. INTRODUCTION

Eight drill core rock samples were received from Mr Daniel Alonso (Afmeco Mining and Exploration Pty Ltd, Darwin, Northern Territory) on 24 October 1997.

It was indicated that the samples originate from two different exploration leases, EL 2506 and EL 2508. Brief field notes accompanied the samples.

Specific requests were:

- i) To prepare a polished thin section for all three samples from drill hole U65-2.
- ii) To prepare one polished thin section and four standard thin sections for the five samples from drill hole SH003.

The SUMMARY of this report and TABLE 1 were provided by facsimile to Mr Alonso at the Darwin office of AFMEX on 7 November 1997. This report contains the full results of this work.

2. METHODS

The samples were examined in hand specimen and marked for section preparation. Thin sections were obtained from an external commercial laboratory (Pontifex & Associates Pty Ltd, Rose Park, South Australia).

At Mason Geoscience Pty Ltd, conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions. Additional reflected light mineragraphic observations were included in a combined petrographic and mineragraphic description where a polished thin section was available.

3. PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages. Where a polished thin section was prepared, a combined petrographic and mineragraphic description is provided.

SAMPLE : SH003, 102.7m (EL 2506, Northern Territory)

SECTION NO. : SH003, 102.7m

HAND SPECIMEN : The drill core sample represents an altered dark green rock with scattered equant white altered grains (leucoxene) and diffuse dark red hematitic alteration patches. Cutting the rock is a set of quartz-filled veins that are locally vuggy.

ROCK NAME : Veined, chlorite-hematite altered quartz dolerite

PETROGRAPHY AND MINERAGRAPY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol.%</u>	<u>Origin</u>
<u>Chlorite-hematite altered quartz dolerite</u>		
Quartz	7	Relict igneous
Biotite	2	Relict igneous
Apatite	Tr	Relict igneous
Chlorite	78	Alteration
Leucoxene/rutile	5	Alteration
Hematite	5	Alteration
Quartz	2	Alteration
Pyrite	Tr	Alteration
<u>Quartz-sulphide vein</u>		
Quartz	97	
Chlorite	2 (0-20)	Vein filling
Chalcopyrite	Tr	Vein filling
Pyrite	Tr	Vein filling
Marcasite	Tr	Vein filling
Hematite	1	Vein filling

In polished thin section, this sample displays a relict massive quartz doleritic igneous texture, modified by strong pervasive alteration and veining.

Chlorite-hematite altered quartz dolerite retains its primary doleritic igneous texture. Angular interstitial clear quartz grains are well preserved, and commonly are intergrown in relict micrographic texture with intensely hematite-altered K-feldspar.

Chlorite dominates the altered dolerite, occurring as fine-grained massive dense green replacements of prismatic randomly oriented plagioclase crystals ~0.5-1.0 mm long. No plagioclase is preserved. Similar but darker green pleochroic chlorite has completely replaced angular to blocky ferromagnesian grains up to ~2 mm in size that probably were pyroxene. Small ragged orange-coloured quartz grains (hematite-stained) may occur as aggregates within the chlorite after pyroxene.

Hematite occurs as cryptocrystalline dark red material that is sprinkled through alteration quartz patches and altered interstitial K-feldspar grains.

Biotite occurs as pleochroic orange to very dark green flakes and aggregates of flakes that occur in the interstitial areas. This represents relict primary biotite.

Leucoxene and better-crystallised rutile occurs as granular aggregates that have pseudomorphously replaced large angular to blocky Fe-Ti oxide grains (magnetite and/or ilmenite) up to ~2 mm in size.

Pyrite is uncommon, forming small ragged aggregates scattered through the rock.

Apatite is rare, occurring as small stumpy elongate crystals in interstitial areas.

Quartz-sulphide veins are dominated by quartz, which occurs mainly as subradiating sprays that project into the veins. A small amount of quartz occurs as very fine-grained microcrystalline laminae that contribute to lamination of the veins.

Chlorite occurs as very fine-grained laminae near the vein margins, or more densely concentrated in thinner veinlets.

Sulphides occur in minor amount. Chalcopyrite occurs as discrete angular grains up to ~0.2 mm in size. Pyrite forms larger ragged aggregates up to ~2 mm in size, and may contain ragged patches of marcasite (which displays its characteristic whiter colour and strongly anisotropic behaviour).

Hematite occurs locally as small cryptocrystalline spheroidal patches sprinkled through quartz, or forms small acicular crystals in subradiating aggregates.

INTERPRETATION:

This sample represents a quartz doleritic intrusive igneous rock, originally composed of abundant plagioclase and pyroxene, with interstitial micrographic quartz and K-feldspar, Fe-Ti oxides, biotite and apatite. The rock body suffered fracturing and invasion by hydrothermal fluids which caused pervasive wall rock replacement by chlorite + minor quartz + hematite + leucoxene/rutile + pyrite. The open fractures were filled by space-filling vein assemblages of quartz + minor chlorite + pyrite + chalcopyrite + marcasite + hematite. The texture and mineralogy are consistent with relatively low-temperature hydrothermal alteration.

SAMPLE : SH003, 201.3m (EL 2506, Northern Territory)

SECTION NO. : SH003, 201.3m

HAND SPECIMEN : The drill core sample represents a laminated green rock in which one particular horizon contains large angular dull green-brown fragments several mm to ~1 cm in size.

ROCK NAME : Chlorite-hematite altered layered basaltic lithic tuff

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite (green to colourless)	85	Alteration
Chlorite (dark drab green, incl. leucox.)	10	Alteration (after lithic fragments)
Opagues (incl. hematite)	5	Alteration
Apatite	Tr	Alteration
Zircon	Tr	Clastic crystal fragments

In thin section, this sample displays a relict layered fine- to coarse-grained clastic texture, modified by intense pervasive alteration.

Chlorite dominates the rock, and occurs in different sites:

- i) Most occurs as small ragged flakes, pleochroic in pale greens and therefore probably relatively Fe-rich. Uncommon colourless patches (i.e. lacking pleochroism) may represent Mg-rich chloritic patches. Although the chloritic areas of the rock are essentially massive, indistinct fragmental texture appears to be defined by faint angular fragment shapes.
- ii) A lesser amount of dark drab brownish green chlorite occurs as cryptocrystalline dense massive replacements of larger angular lithic fragments from several mm up to ~1 cm in size. Submicroscopic turbid dull leucoxene granules pepper the chlorite. The fragments are concentrated in particular horizons. Small, perfectly ovoid structures ~0.2-0.2 mm in size filled by fibrous green chlorite represent filled vesicles, and the basaltic nature of these fragments is further supported by the presence of randomly oriented small acicular shapes considered to represent altered crystallites (?plagioclase, ?pyroxene, but none is preserved).

Opagues occur as fine-grained small ragged aggregates scattered through most of the rock. Larger aggregates may fill discontinuous fractures in the altered lithic fragments. Local fine bladed textures and deep red colour in thinnest blades suggests that the opaque phase is hematite.

Apatite is uncommon, forming small elongate prisms in aggregates intergrown with opagues in scattered patches.

Zircon forms subrounded crystal fragments scattered through the rock. They tend to be concentrated in particular indistinct horizons.

INTERPRETATION:

This sample represents a layered tuffaceous basaltic sediment, originally composed of angular vesicular basaltic fragments and finer fragments concentrated in layers. Whilst most of the clastic components were probably derived from a single basaltic volcanic source, the presence of accessory subrounded zircon crystals suggests that a contribution from an acid crystalline source was also received in the sedimentary basin, either by direct transport and sedimentation or by crustal scavenging by the basaltic magma.

The rock has suffered pervasive low-grade but intense hydrothermal alteration by chlorite + hematite + leucoxene + accessory apatite.

SAMPLE : SH003, 203.0m (EL 2506, Northern Territory)

SECTION NO. : SH003, 203.0m

HAND SPECIMEN : The drill core sample represents a fine-grained dark green rock, in which indistinct layering is defined by variable medium to dark green colour of cm-thick layers, and by the presence of larger dark fragments in particular horizons. Tiny black angular grains are distributed more-or-less uniformly through the rock.

ROCK NAME : Chlorite-hematite altered layered basaltic lithic tuff

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	75	Alteration
Chlorite (drab green, incl. leucox.)	20	Alteration (after lithic fragments)
Opagues (incl. ?hematite)	5	Alteration
Zircon	Tr	Clastic crystal fragments
Rutile	Tr	?Clastic crystal fragments

In thin section, this sample displays a relict fragmental texture that has suffered severe pervasive alteration.

Chlorite dominates the rock, and occurs in two different forms:

- i) Most occurs as small ragged flakes that form a matrix throughout the rock. The flakes are weakly pleochroic in pale greens to colourless, and appears to be of relatively Mg-rich composition.
- ii) A lesser amount of chlorite occurs as cryptocrystalline drab darker brownish green material. Most of this is concentrated in angular altered lithic fragments that range widely in size from <0.2 mm up to several mm. Some are very clear in form with sharp margins, but others are more diffusely altered. In the more sharply-defined fragments, small chlorite-filled ovoid structures <0.2 mm in size are present, and appear to represent filled vesicles. Submicroscopic ?leucoxene is peppered through the fragments.

Opagues occur in significant amount as small ragged patches ~0.1 mm in size, distributed throughout the chloritic matrix areas. The deep red colour of some bladed crystals suggests that most or all of the opagues is hematite.

Small subrounded crystal fragments of zircon (colourless, high relief, high birefringence, growth zoned) and rutile (turbid dull brown, very high birefringence) are scattered through the rock.

INTERPRETATION:

This sample represents a layered basaltic tuffaceous deposit, originally composed of small to large angular vesicular glassy basalt fragments in a finer-grained matrix of possibly ashy materials. Accessory zircon crystal fragments were deposited with the basaltic tuffaceous materials.

Pervasive alteration of the basaltic tuff generated the assemblage chlorite + opaques (?hematite) + leucoxene.

SAMPLE : SH003, 213.5m (EL 2506, Northern Territory)

SECTION NO. : SH003, 213.5m

HAND SPECIMEN : The drill hole sample is composed of dark green materials through which are distributed disrupted layers. One notable layer ~1 cm thick is fine-grained, dull pinkish brown in colour, and displays brittle disruption in the form of pull-apart structures. A thin white layer occurs at the margin of the pinkish brown layer. Other layers are variably dull green in colour.

ROCK NAME : Interlayered altered basaltic tuff / hematised siltstone / phosphatic sediment

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Chlorite-hematite altered basaltic tuff</u>		
Chlorite	78	Alteration
Opagues (?hematite)	20	Alteration
Sericite	2	Alteration
Apatite	Tr	Alteration
Zircon	Tr	Clastic crystal fragments
<u>Hematised siltstone</u>		
Quartz	49	Relict clastic particles
Chlorite	30	Alteration / fracture filling
Opagues (?hematite)	20	Alteration
Apatite	1	Fracture filling
<u>Phosphatic sediment</u>		
Apatite	85	Sedimentary / alteration
Phyllosilicate (?chlorite/?clays)	10	Sedimentary / alteration
Opagues (?hematite)	5	Alteration

In thin section, this sample displays a relict fine clastic sedimentary texture in some layers, but a fine-grained alteration texture occurs in most layers.

Chlorite-hematite altered basaltic tuff represents the matrix of most of the rock. It is composed mostly of very fine-grained massive chlorite with dull green colour in a massive mat. Locally it is concentrated in indistinct angular patches that may represent precursor angular lithic fragments ~0.4-1.0 mm in size, but no primary minerals or textures are preserved to confirm the precursor rock type.

Opagues occur as fine-grained dense patches located between the indistinct altered lithic fragments. Smaller patches may be scattered through the altered lithic fragment sites. The presence of deep red colour in thinner opagues suggests hematite is the principal phase.

Zircon is rare, occurring as large rounded crystal fragments of apparent primary clastic origin.

Hematized siltstone represents the dull pinkish brown disrupted layer observed in hand specimen. It displays a relict fine clastic sedimentary texture, in which small angular quartz particles are distributed through a matrix of dull green chlorite and small ragged opaque aggregates (probably mainly hematite).

Cutting the siltstone are uncommon veinlets filled by small acicular colourless apatite crystals, dense chlorite mats, and dense opaque materials (hematite). These apatite-rich veinlets appear to be closely physically related to apatite-rich layers (see next).

Phosphatic sediment is composed almost entirely of tiny equant apatite grains tens of microns in size that form a fine-grained massive mosaic in a distinct layer at the margin of the siltstone layer. Scattered through the apatite are small ragged patches of dull dark brownish green phyllosilicate (probably chlorite), and small opaque patches (probably hematite as inferred from deep red colour in places) are more liberally distributed.

INTERPRETATION:

This sample is interpreted to represent a layered sequence of sediments. Most of the sequence was composed of fragmental material of inferred basaltic lithic tuffaceous origin. Interlayering of siltstone and phosphatic sediment occurred during deposition of the sequence. Physical disruption of the silty and phosphatic sediments is considered to have occurred during more vigorous deposition of the coarser basaltic tuffaceous deposits.

Pervasive alteration of the rock sequence had particular effects on the different layers:

- i) The basaltic lithic tuff horizons suffered complete replacement by chlorite + opaques (hematite) + minor apatite. All primary textural features, except local fragmental textures, were destroyed. Accessory rounded clastic zircon crystal fragments survived this event.
- ii) Siltstone layers suffered pervasive alteration to chlorite + opaques (hematite), but the fine clastic texture dominated by quartz survived.
- ii) Phosphatic layers recrystallised to a mosaic of apatite + chlorite + opaques (hematite). Local migration of phosphatic components generated nearby fracture fillings of apatite + chlorite + opaques (hematite).

SAMPLE : SH003, 213.9m (EL 2506, Northern Territory)

SECTION NO. : SH003, 213.9m

HAND SPECIMEN : The drill core sample has captured the contact between altered coarser-textured green rock and finer-textured green rock. The coarser-textured rock displays a foliation defined by pale cream lenticles whose preferred orientation defines a foliation that is cut by the adjacent finer-grained green rock.

ROCK NAMES : Chlorite-sericite altered gneiss

Chlorite-sericite-hematite altered rock (?sediment)

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Chlorite-sericite altered gneiss</u>		
Chlorite	43	Alteration
Sericite	50	Alteration
Opauques (?hematite)	5	Alteration
Leucoxene	2	Alteration
Apatite	Tr	Alteration
Zircon	Tr	Relict metamorphic
<u>Chlorite-sericite-hematite altered rock (?sediment)</u>		
Chlorite	59	Alteration
Sericite	20	Alteration
Opauques (?hematite)	20	Alteration
Apatite	1	Alteration
Zircon	Tr	Relict crystal fragments

In thin section, this sample displays a poorly preserved foliated altered gneissic texture in part of the sample, and a massive altered texture in the other portion.

Chlorite-sericite altered gneiss faintly retains a foliated medium-grained gneissic metamorphic texture, severely overprinted by massive pervasive alteration.

Sericite is abundant, occurring as a very fine-grained massive replacement mat throughout the rock. Local denser concentration of sericite in poorly-defined blocky sites suggests precursor crystals (?feldspar).

Chlorite is moderately abundant, also occurring as fine-grained massive replacement patches. No precursor crystal forms are preserved.

Opauques (probably mainly hematite) occur in significant amount as fine-grained granular to lath-like aggregates of opaque crystals. Local deep blood red colour in some thin grains suggests hematite.

Leucoxene occurs in minor amount as cryptocrystalline turbid granules concentrated in foliated lenticular to wispy patches with intergrown sericite. These appear to have been phyllosilicate flakes of metamorphic origin (probably biotite).

Apatite occurs in minor amount as ragged grains in small scattered aggregates. They appear to be of alteration origin, rather than relict metamorphic.

Zircon forms growth-zoned subhedral prisms, in places occurring within the leucoxene-sericite-altered phyllosilicate flake sites.

Chlorite-sericite-hematite altered rock (?sediment) is composed of a fine-grained massive replacement mat of very pale green pleochroic chlorite and colourless sericite. The two minerals tend to occur in patches. Scattered through the rock are small fine-grained opaque aggregates (probably mainly hematite).

Apatite occurs in trace amount as small ragged aggregates.

Zircon is sparsely scattered through the rock as subrounded crystals.

INTERPRETATION:

This sample has suffered severe pervasive replacement by the assemblage chlorite + sericite + opaques (?hematite) + minor apatite. Faint reservation of a foliated, medium-grained crystalline texture in portion of the sample suggests it formed as a medium- to high-grade gneissic regional metamorphic rock.

The nature of the other, more massive portion remains uncertain owing to almost complete destruction of primary minerals and textures. Only accessory subrounded zircon crystals are preserved. The alteration mineralogy and texture, including the preserved primary accessory zircon crystals, suggest it was similar to the basaltic tuffaceous rocks described elsewhere in this suite.

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REPORT TITLE	Petrographic Descriptions for Six Drill Core Rock Samples from Drill Holes SHRD004, SHRD010 and SHRD011 (Northern Territory)
REPORT #	2390
CLIENT	Afmeco Mining and Exploration Pty Ltd
ORDER NO.	03329
CONTACT	Mr Daniel Alonso

REPORT BY	Dr Douglas R. Mason
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SIGNED



for Mason Geoscience Pty. Ltd.

DATE	3 December 1997
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Petrographic Descriptions for Six Drill Core Rock Samples from Drill Holes SHRD004, SHRD010 and SHRD011 (Northern Territory)

SUMMARY

1. Rock Samples

- Six drill core rock samples from drill holes SHRD004, SHRD010 and SHRD011 have been studied using petrographic and mineragraphic methods.

2. Brief Results

- Rock names and mineralogy are summarised in TABLE 1.
- Veined, altered, mineralised quartz dolerite
 - Two samples of mineralised quartz dolerite are identified from drill hole SHRD004.
 - The primary rocks were quartz dolerite composed of early-formed pyroxene, plagioclase and Fe-Ti oxides (?ilmenite, ?magnetite), with interstitial late-formed quartz, K-feldspar and apatite. The relatively high abundance of quartz, together with the presence of micrographic interstitial intergrowths, suggest that the rocks formed by normal magmatic differentiation processes from quartz tholeiitic intrusive magma.
 - The rocks have suffered fracturing and invasion by low-temperature hydrothermal fluids. This resulted in selective pervasive alteration of the dolerite host rock, producing the assemblage sericite + chlorite + rutile/leucoxene. Open fractures were filled by vein assemblages of quartz ± minor chalcopyrite ± pyrite ± unknown (?uraninite). Selvedges of veins suffered slightly more intense replacement by chlorite + unknown (?uraninite) ± chalcopyrite ± pyrite, and the unknown phase suffered partial to complete metamict alteration to dull brown amorphous material.
 - In quartz dolerite of sample SHRD011 (154.5), a similar style of selective pervasive alteration has generated a slightly lower-grade assemblage of serpentine + sericite + leucoxene/rutile + pyrite + chalcopyrite. A thick zoned vein is filled from margins inwards by dense fibrous serpentine, intergrown serpentine + quartz, and inner quartz + carbonate (dolomite) + pyrite + chalcopyrite.
- Altered gneisses
 - Three samples from SHRD010 represent medium- to coarse-grained foliated granoblastic gneissic rocks, originally composed of feldspar, quartz, biotite and garnet with felsic laminae of quartz + feldspar. They appear to represent medium- to high-grade regional metamorphism of pelitic to quartzofeldspathic precursor rocks.
 - Selective pervasive hydrothermal alteration of the gneisses has generated illitic clays after feldspar at lower grades of alteration. At a slightly higher grade of alteration, sericite has replaced feldspar and chlorite has replaced garnet.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins***
SHRD004, 73.1	Quartz veined, sericite-quartz-chlorite-?uraninite altered quartz dolerite	Qtz,apa	?Qtz,ser,chl,opq(?urn),cpy,py	Qtz
SHRD004, 77.7	Quartz-sulphide veined, chlorite-sericite-?uraninite altered quartz dolerite	Qtz,apa	Chl,ser,leu,opq(?urn),cpy,py	Qtz,cpy,py,opq(?urn); Am
SHRD010, 256.0	Illite-altered quartzo-feldspathic biotite gneiss	?Zir	Pla,qtz,bio,Kf,apa,?zir; Ill	Qtz,pla,Kf; Serp
SHRD010, 259.4	Sericitised quartzo-feldspathic biotite-?garnet gneiss	-	Qtz,Kf; Ser,chl,leu/rut	Chl,opq
SHRD010, 260.5	Illite-altered quartzo-feldspathic biotite-garnet gneiss	-	Pla,qtz,bio,gar; Ill,ser,mus	-
SHRD011, 154.5	Quartz-serpentine veined, serpentine-sericite altered quartz dolerite	Qtz,Kf,bio,apa	Serp,ser,rut/leu,py,cpy	Qtz,serp,car(dol),py,cpy; Car(dol), py

NOTES:

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

** : Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations: Am = amorphous phase (metamict after ?uraninite); apa = apatite; bio = biotite; car = carbonate mineral; chl = chlorite; cpy = chalcopyrite; dol = dolomite; gar = garnet (probably almandine-rich); ill = illitic clay; Kf = K-feldspar; leu = leucoxene; mus = muscovite (coarse-grained K-mica); opq = undifferentiated opaques; pla = plagioclase; py = pyrite; qtz = quartz; rut = rutile; ser = sericite (fine-grained K-mica); serp = undifferentiated serpentine mineral; ?urn = uraninite (uncertain identification); zir = zircon.

1. INTRODUCTION

A collection of six drill core rock samples was received from Mr Daniel Alonso (Afmeco Mining and Exploration Pty Ltd, Darwin, Northern Territory) on 4 November 1997.

Particular requests were:

- i) To prepare a thin section and routine petrographic description (service PETRO 2) for four specified samples.
- ii) To prepare a polished thin section and combined petrographic and mineragraphic description (service PETRO 3) for two specified samples. Autoradiographs and photomicrographs should also be provided for these two specified samples.
- iii) To provide the results by the end of November if possible.

Preliminary petrographic results were provided by facsimile to Mr Alonso at the Darwin office of Afmeco Mining and Exploration on 28 November 1997. This report contains the full results of this study.

2. METHODS

The samples were examined in hand specimen, and section areas were marked on the samples in order to capture as many of the mineralogical and structural features as possible. Thin sections and polished thin sections were obtained from Pontifex & Associates Pty Ltd (Rose Park, South Australia), and autoradiographs were obtained from Amdel Limited (Thebarton, South Australia).

At Mason Geoscience Pty Ltd, conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions. Additional reflected light mineragraphic observations were included in a combined petrographic and mineragraphic description where a polished thin section was available.

Subsequent discussion with the client confirmed that photomicrographs and autoradiographs were required for samples SHRD004, 73.1 and SHRD004, 77.7. The colour photomicrographs were taken at Mason Geoscience and are presented in APPENDIX 1. The autoradiographs were obtained from Amdel Limited (Thebarton, South Australia) and are presented in APPENDIX 2.

3. PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages. Where a polished thin section was prepared, a combined petrographic and mineragraphic description is provided.

SAMPLE : SHRD010, 260.5

SECTION NO. : SHRD010, 260.5

HAND SPECIMEN : The drill core rock sample represents a gneissic rock composed of waxy yellowish cream felsic patches that are aligned in a darker grey matrix containing lustrous biotite flakes.

ROCK NAME : Illite-altered quartzo-feldspathic biotite-garnet gneiss

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase	28	Relict metamorphic
Quartz	30	Metamorphic
Biotite	10	Metamorphic
Garnet	2	Metamorphic
Phyllosilicate (?illitic clay)	30	Alteration (after plagioclase)
Muscovite	Tr	Alteration (after biotite)

In thin section, this sample displays a coarse-grained foliated granoblastic metamorphic texture, modified by low-intensity selective pervasive alteration.

Plagioclase was abundant, forming large anhedral grains ~3-5 mm long elongated in the trace of the foliation. All display polysynthetic twinning, but have suffered quite severe replacement by small randomly oriented phyllosilicate sheaves that appear to be illitic clay.

Quartz forms large anhedral grains ~1-3 mm long, generally aligned in the trace of the foliation. All display weak shadowy strain extinction.

Biotite occurs as well-crystallised plates ~0.4-2.0 mm long. They tend to be concentrated in foliae whose alignment contributes to definition of the foliation through the rock. Pleochroism in the biotite is bright red to pale yellow, suggesting a highly reduced composition (i.e. high $\text{Fe}^{2+}/(\text{Fe}^{2+} + \text{Fe}^{3+})$). Some biotite flakes contain thin sheaves or lenticles of muscovite alteration oriented along the biotite cleavage traces.

Garnet occurs in minor amount, but where it occurs it forms very large amoeboid grains up to ~5 mm in size. They enclose flakes of biotite and ragged quartz grains. The very pale buff pink colour of the garnet is consistent with an almandine-rich composition.

INTERPRETATION:

This sample represents a coarse-grained gneissic rock, which recrystallised under conditions of medium- to high-grade regional metamorphism. This generated the observed foliated granoblastic assemblage of plagioclase + quartz + biotite + garnet. All minerals and textures of the precursor rock have been destroyed, but a pelitic sedimentary rock is considered to be a likely precursor.

Low-grade alteration affected the rock, resulting in partial replacement of plagioclase by ?illitic clay, and incipient replacement of biotite by muscovite.

SAMPLE : SHRD011, 154.5

SECTION NO. : SHRD011, 154.5 (Polished thin section A: Mostly wall rock with vein displaying dull grey-green marginal material; Thin section B: Mostly zoned vein, with some wall rock)

HAND SPECIMEN : The drill core sample has captured a dark greenish brown altered rock, cut by a 2 cm-thick vein zoned from dull grey-green margins to central white lenses.

The section offcuts fail to react with dilute HCl, suggesting calcite is absent.

ROCK NAME : **Quartz-serpentine veined, serpentine-sericite altered quartz dolerite**

PETROGRAPHY AND MINERAGRAPHY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Serpentine-sericite altered quartz dolerite</u>		
Quartz	1	Igneous
K-feldspar	1	Igneous
Biotite	Tr	Igneous
Apatite	Tr	Igneous
Serpentine	80	Alteration
Sericite	15	Alteration
Rutile/leucoxene	2	Alteration
Pyrite	Tr	Alteration
Chalcopyrite	Tr	Alteration
<u>Quartz-serpentine veins</u>		
Quartz	53	Vein filling
Serpentine	45	Vein filling
Carbonate (dolomite)	2	Vein filling / late veinlet fillings
Pyrite	Tr	Vein filling / late microfracture fillings
Chalcopyrite	Tr	Vein filling

In thin section and polished thin section, this sample displays a partly-preserved massive ophitic doleritic igneous texture, modified by strong pervasive alteration and veining.

Serpentine-sericite altered quartz dolerite in places retains its primary massive ophitic doleritic igneous texture. Serpentine now occupies much of the rock, occurring in different forms and sites:

- i) Much occurs as fine-grained ragged flakes that occupy dense massive replacement mats. No primary texture is retained in these areas.
- ii) Some occurs as optically continuous replacements of large ferromagnesian grain sites up to ~3 mm in size that retain their primary ophitic texture. These clearly were pyroxene grains.

- iii) Some occurs as very fine-grained massive replacements of prismatic crystals ~1 mm long. These appear to have been plagioclase crystals, and some are enclosed in serpentinised pyroxene crystal sites.

Sericite is the other principal phase. It occurs as small ragged randomly-oriented flakes that form dense replacement aggregates, some in equant altered crystal sites (possibly precursor pyroxene), and some in altered prismatic crystal sites (probably plagioclase).

Clear angular quartz grains and associated small blocky to anhedral K-feldspar grains occur in small interstitial aggregates scattered through the rock. They clearly represent relict primary phases. Acicular accessory apatite crystals lace these interstitial felsic patches.

Biotite occurs in trace amount as small flakes located in interstitial areas. They are pleochroic from dark reddish brown to pale straw yellow.

TiO₂ phases occur as granular aggregates that have pseudomorphously replaced scattered precursor ragged angular grains ~0.5-1.5 mm in size. Small stumpy rutile crystals form dense aggregates, possibly after ?ilmenite, and dense cryptocrystalline ?leucoxene forms associated ragged alteration patches that may have formed by replacement of ?magnetite. No primary Fe-Ti phases are preserved.

Pyrite is rare, forming tiny equant crystals sparsely and irregularly scattered through the rock. Chalcopyrite occurs as rare small angular grains, locally concentrated in rutile-altered Fe-Ti crystal sites.

Quartz-serpentine veins are dominated by quartz and serpentine. Very pale green non-pleochroic serpentine (confirmed by length-slow orientation of fibres) is abundant in margins of the thick vein, where it forms dense aggregates of subradiating fibres. Inwards, the fibrous serpentine becomes intergrown with poorly-formed feathery quartz grains. Central parts of the veins are occupied mainly by larger anhedral quartz grains, intergrown with ragged carbonate grains (dolomite) and a trace of pyrite as small amoeboid aggregates and cubic crystals. Chalcopyrite is rare, forming tiny angular grains in vein quartz.

Thin veinlets of cross-fibre serpentine project from the serpentine-rich vein into altered wall rock. Locally, similar thin veinlets of carbonate (dolomite) cut the thin serpentine-rich veinlets. Uncommon very thin discontinuous microveinlets of pyrite locally cut the earlier serpentine-quartz vein.

INTERPRETATION:

The mineralogy and textures of this sample are interpreted in the following sequence of events (from earliest to latest):

1. Emplacement of dolerite.

Basic magma of quartz-tholeiitic magmatic affinity was emplaced as an intrusive body. It crystallised to the massive coarse-grained ophitic doleritic assemblage of pyroxene, plagioclase, minor quartz, K-feldspar, biotite, Fe-Ti oxides, and apatite.

2. Fracturing, veining and alteration.

The rock body suffered fracturing and invasion by hydrothermal fluids of relatively low temperature. Wall rock suffered pervasive replacement by serpentine + sericite + minor rutile/leucoxene + trace pyrite + chalcopyrite. Veins were filled by serpentine-quartz assemblages in the following paragenesis:

- i) Early serpentine. Early thin serpentine veinlets cutting wall rock probably formed at this time, and serpentine forms early deposits on vein walls.

- ii) Serpentine + feathery quartz. Intergrown serpentine and feathery quartz grains formed a band that overgrew the serpentine wall deposits.
- iii) Quartz + carbonate (dolomite) + sulphides (pyrite, chalcopyrite). Late thin carbonate veinlets and very thin pyrite microveinlets formed at this time.

APPENDIX 1: PHOTOMICROGRAPHS

A selection of colour photomicrographs is provided in the following pages for samples SHRD004, 73.1 and SHRD004, 77.7. They illustrate aspects of the primary rock, alteration and mineralisation in these samples.

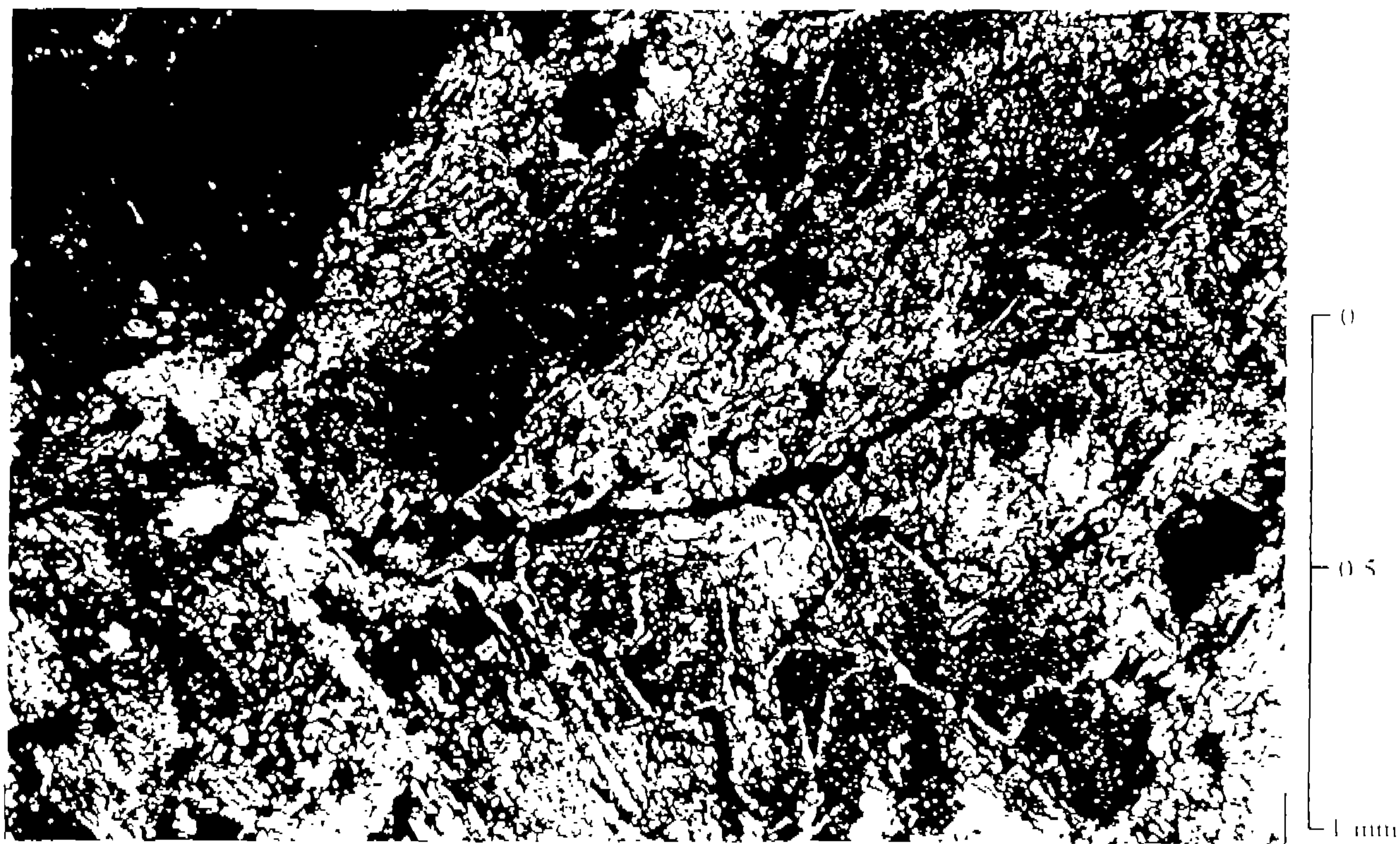


PLATE 1: SAMPLE SHRD004-731 (Transmitted light, crossed polarisers, x5, Frame 5)

A large plate of pyroxene (now replaced by optically continuous sericite, orange red) subophitically encloses elongated prismatic crystals (plagioclase, centre, now replaced by massive fine grained sericite mats). Fine grained chlorite (dull grey, lower right) fills ragged replacement patches.



PLATE 2: SAMPLE SHRD004-731 (Transmitted light, crossed polarisers, x5, Frame 0)

Primary interstitial quartz (white to grey, centre right) is preserved, but all other mineral have been replaced by sericite (yellow red colours), chlorite (dull grey, fine grained patches), and leucoxene (murky dark brown to black aggregate, centre).

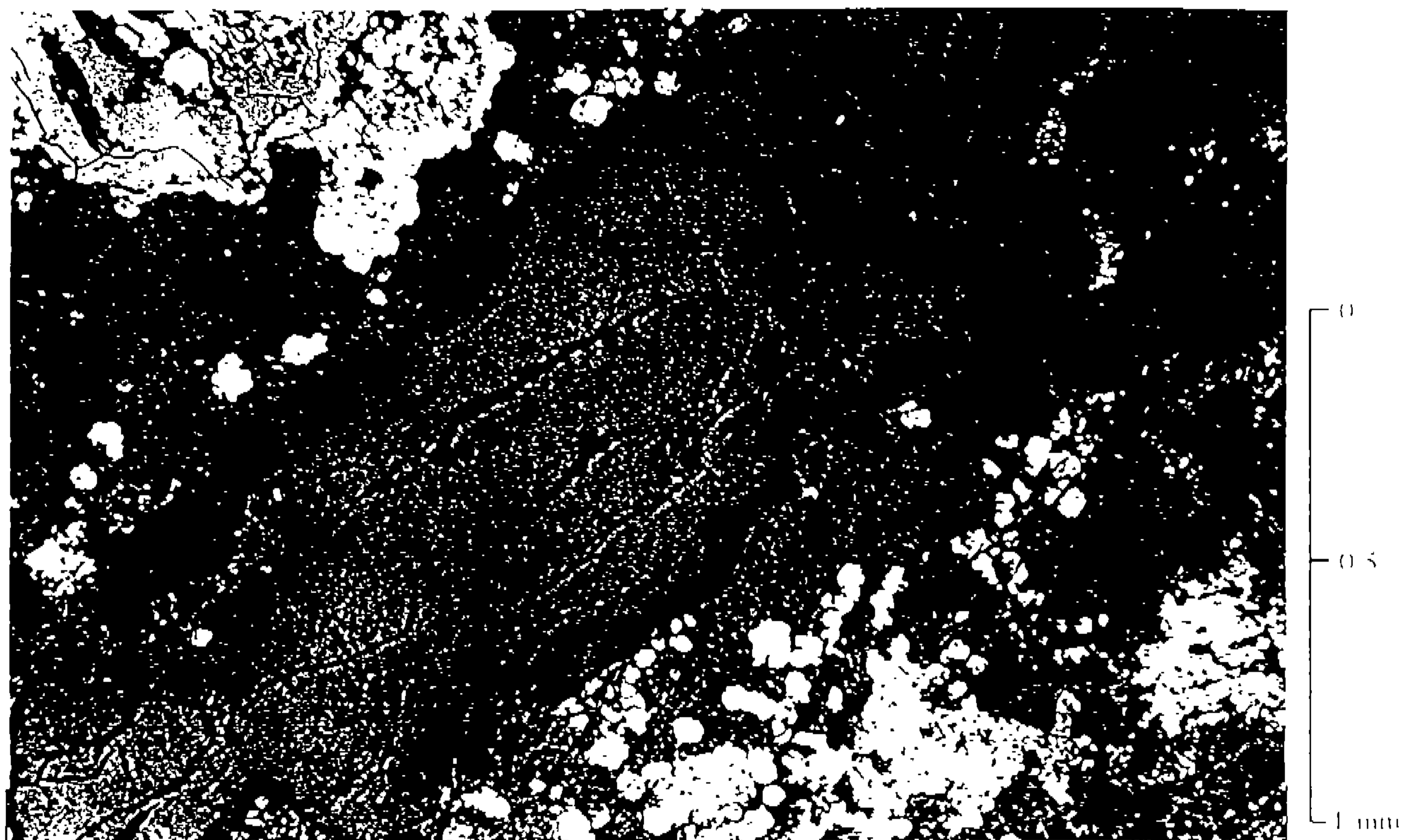


PLATE 3 SAMPLE SHR004-731 (Reflected plane polarised light x5 Frame 1)

Unidentified mineral (uraninite - pale grey - lower right, top left) occurs as small cubic crystals and ragged aggregates concentrated in the chloritic selvage of quartz rich veins, one of which is oriented NE-SW. Note minor sulphide (bright yellow colour - lower far right - top far right) in the Uraninite.

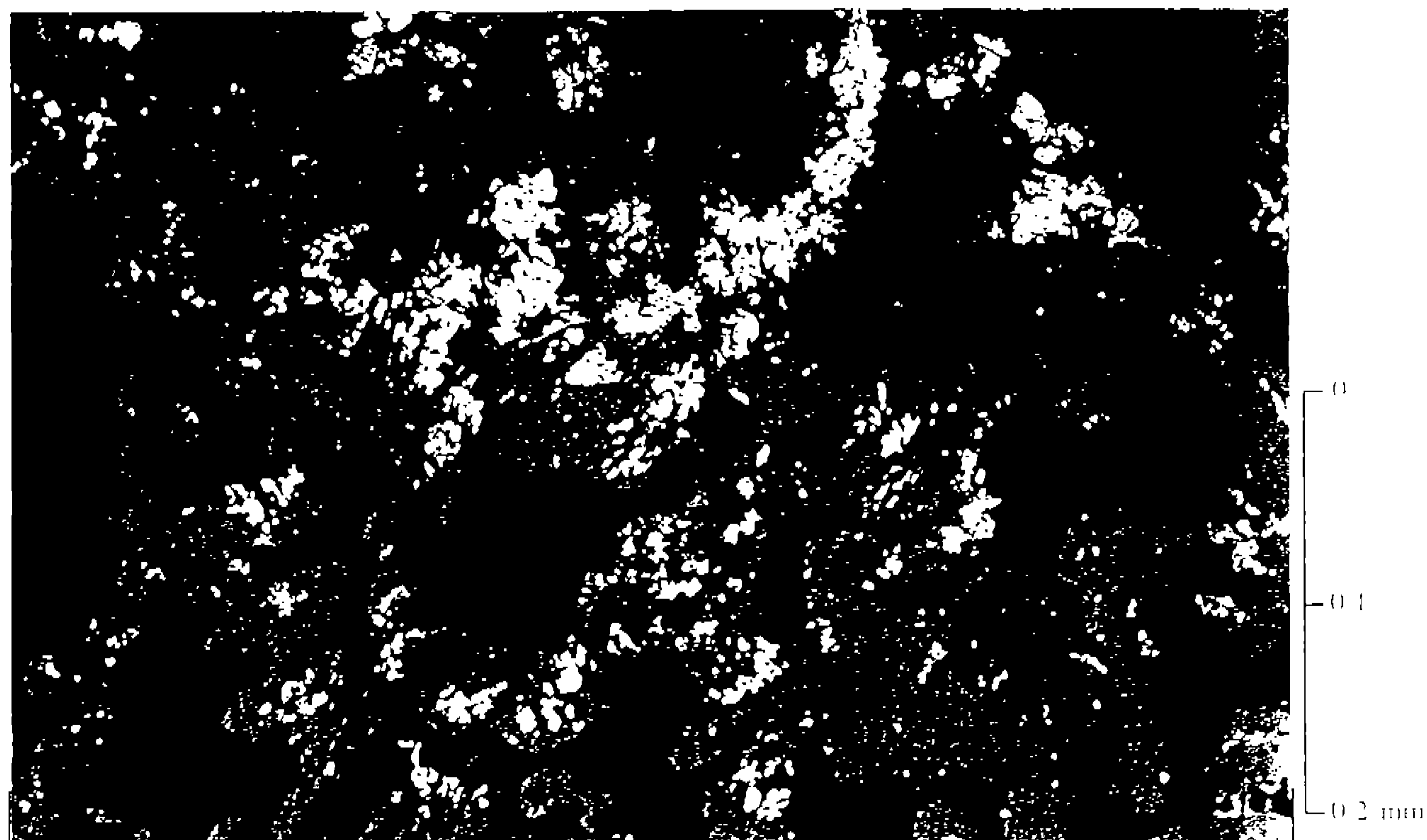


PLATE 4 SHR004-731 (Reflected plane polarised light x20 Frame 4)

Fine grained sulphides (chalcopyrite - pale yellow - pyrite - white) are intimately intergrown with small cubic crystals of unidentified mineral (uraninite - medium grey). This view lies within the chloritic selvage of a quartz vein.

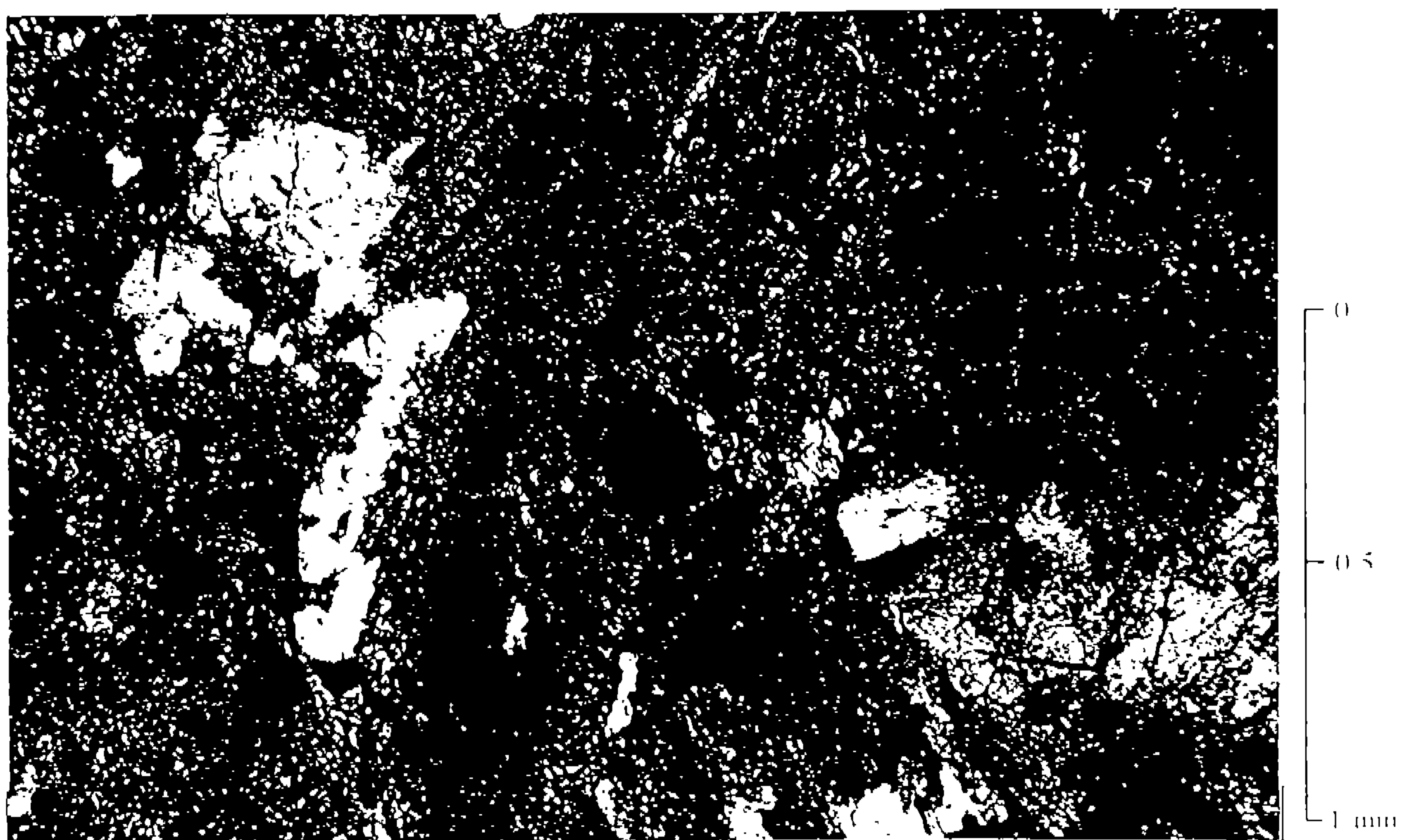


PLATE 5: SAMPLE SHRD004-77-7 (Transmitted light, crossed polariser, x5, Frame 6)

Relict primary interstitial quartz grains (white to yellow, upper left, lower right) are preserved, but all other minerals in the quartz dolerite have been replaced by dense massive fine-grained mats of sericite (yellow colour) and chlorite (dull grey colour).

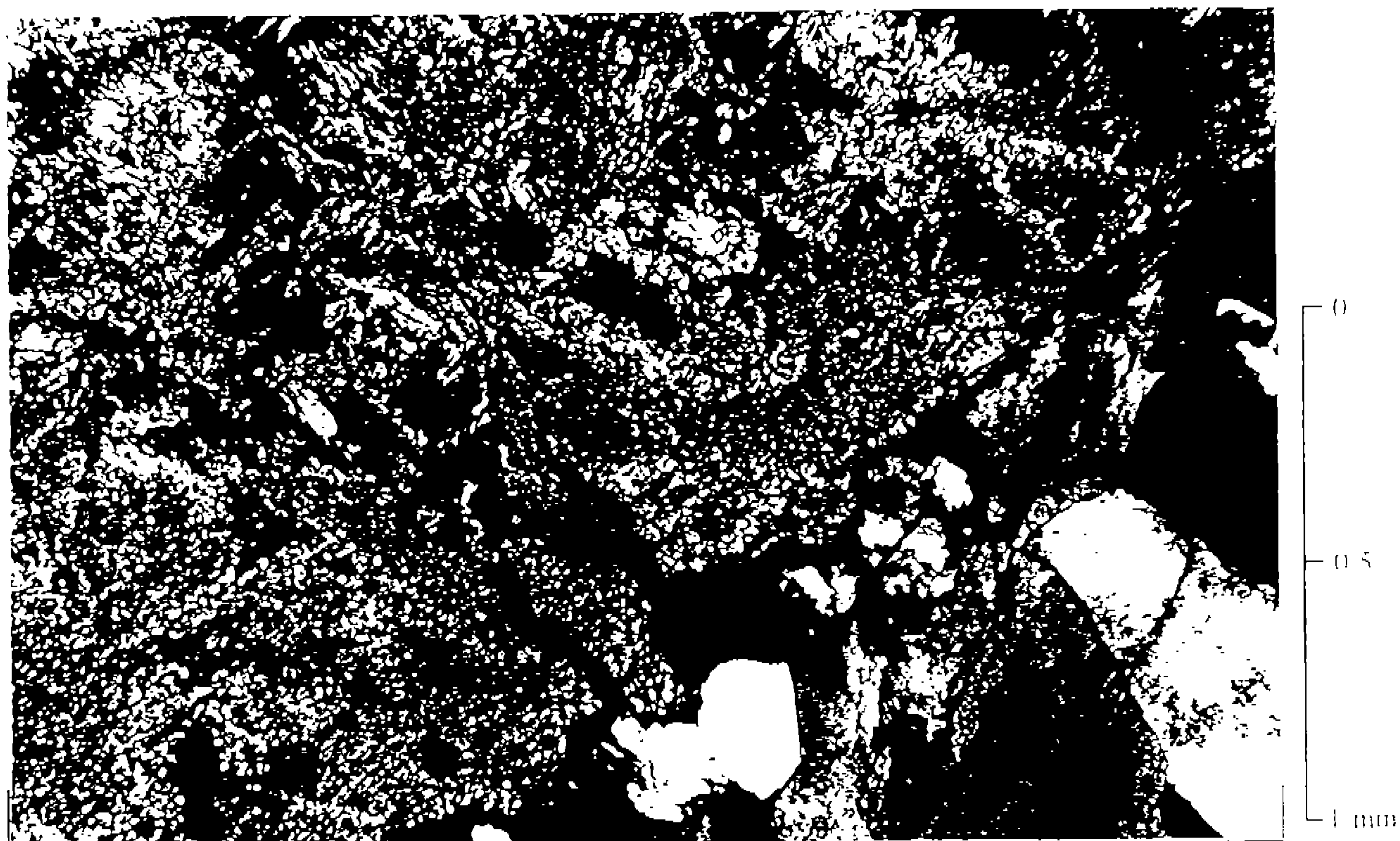


PLATE 6: SAMPLE SHRD004-77-7 (Transmitted light, crossed polariser, x5, Frame 7)

Doleritic wall rock (left) has suffered intense pervasive replacement by sericite (yellow-orange-blue) in the sledge of a quartz-rich vein (lower right).

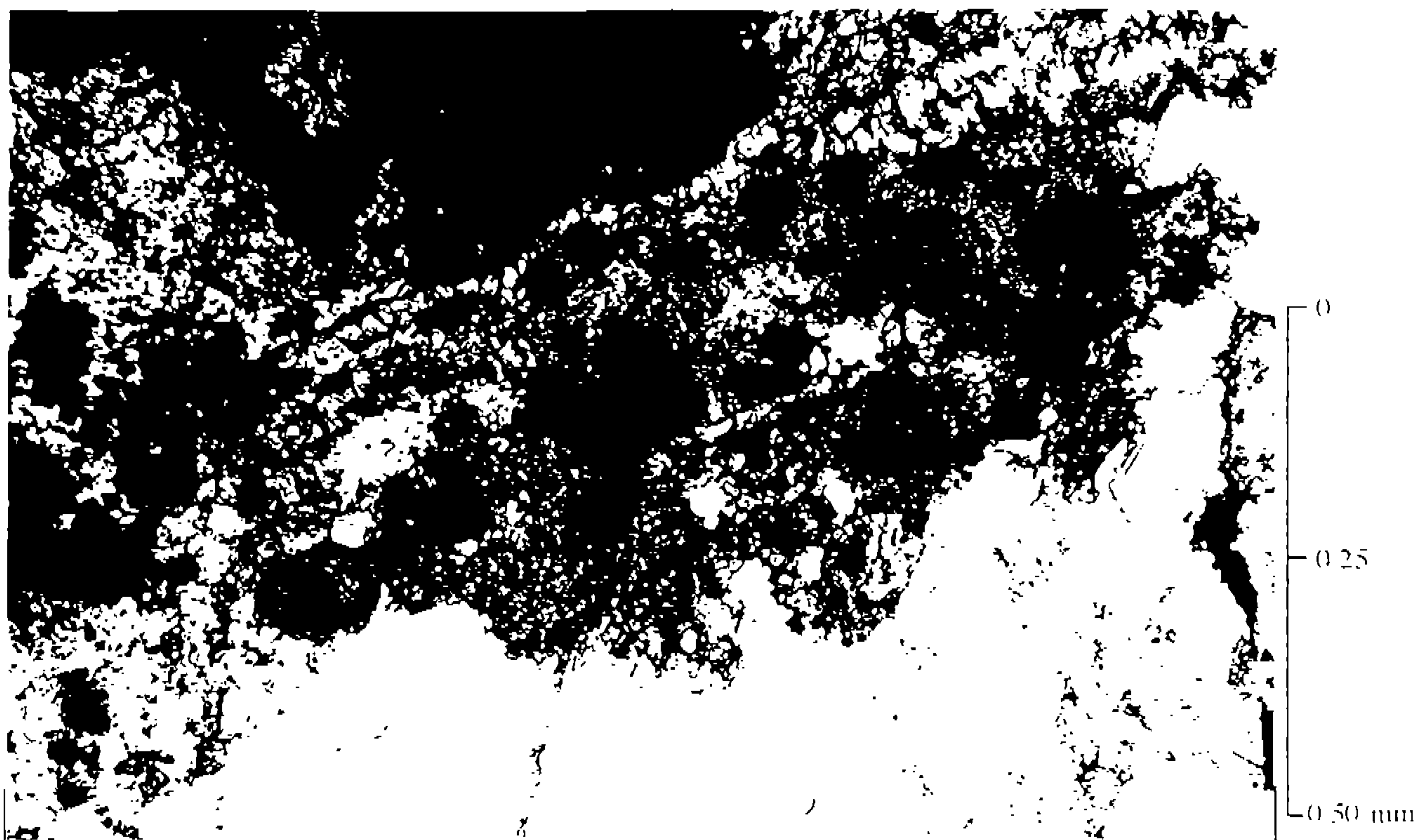


PLATE 7 SAMPLE SHRD004, 77.7 (Transmitted plane polarised light, $\times 10$, Frame 9)

Small cubic crystals of unknown mineral (pyraminite, black) are accompanied by metamict material (dull brown patches) within the chloritic selvage (dull green) of a quartz rich vein (lower right)

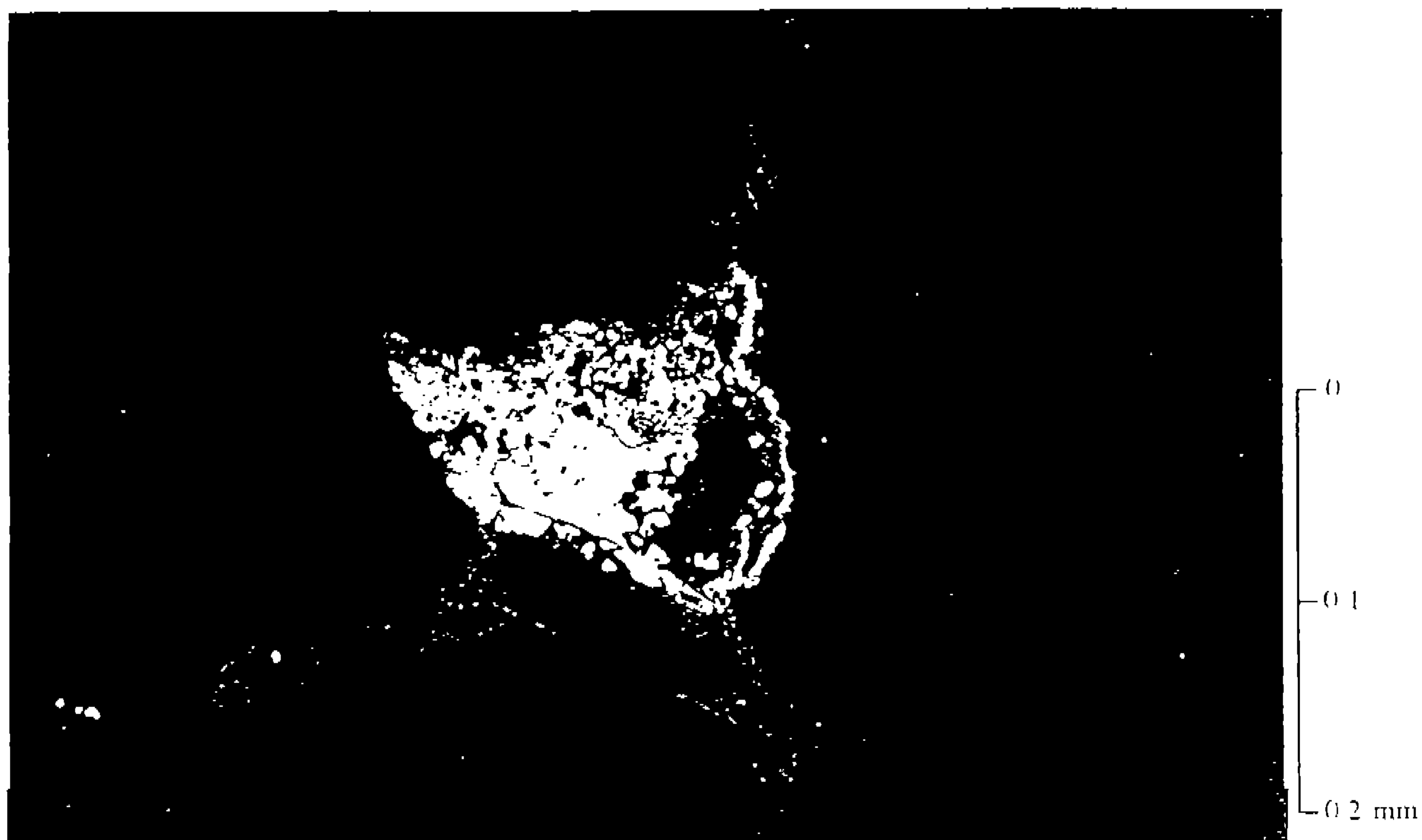
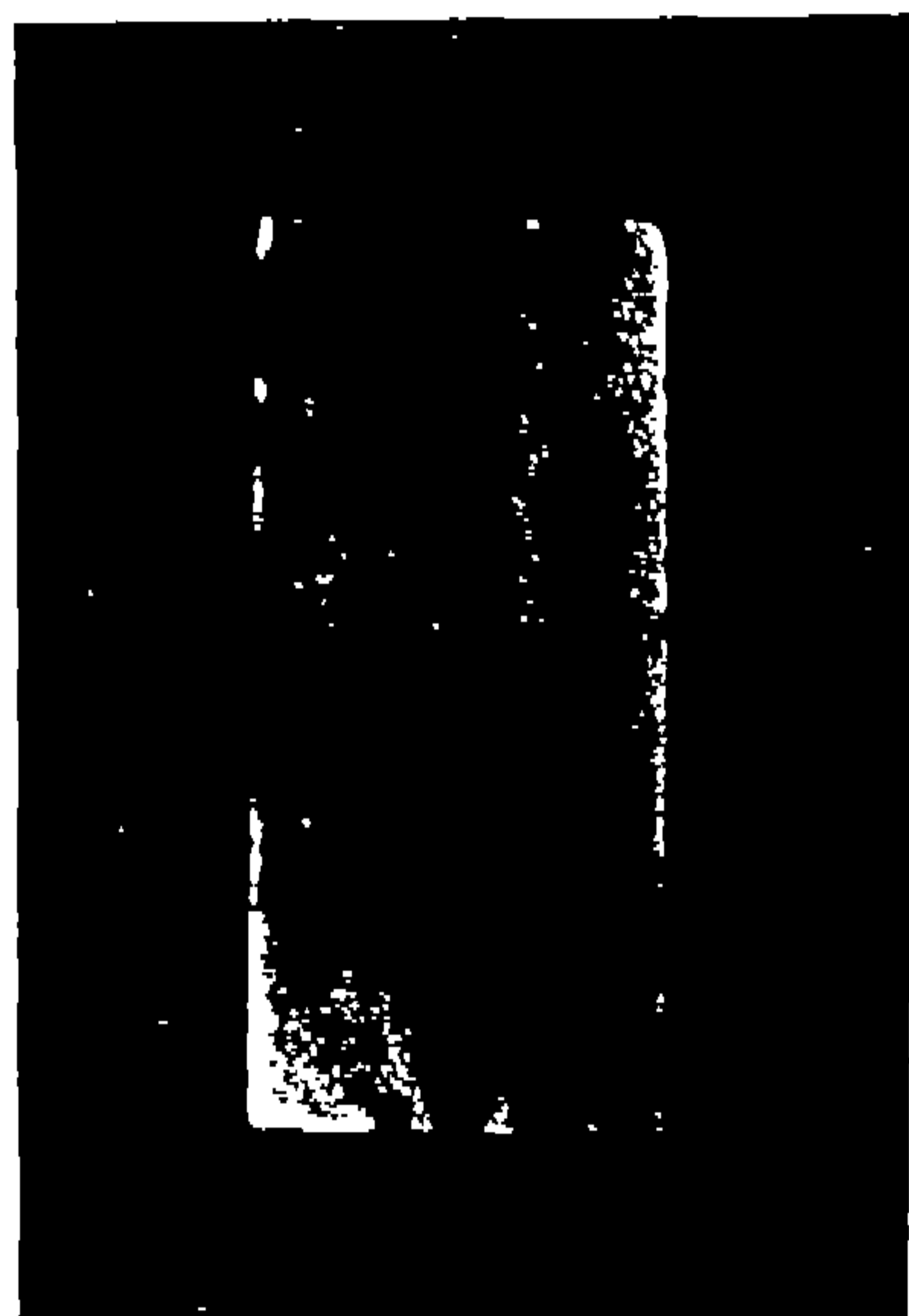


PLATE 8 SAMPLE SHRD004, 77.7 (Reflected plane polarised light, $\times 20$, Frame 10)

This view shows a small ragged grain of unknown mineral (pyraminite, grey) within a quartz vein (surrounding dark grey grains). Note the presence of fine grained ragged intergrowths of pyrite within the unknown grey mineral

APPENDIX 2: AUTORADIOGRAPHS

Two autoradiographs were obtained from Amdel Limited (Thebarton, South Australia) from section offcuts of samples SHRD004, 73.1 and SHRD004 77.7. The results are provided below. Note a stronger response is evident in SHRD004, 73.1.

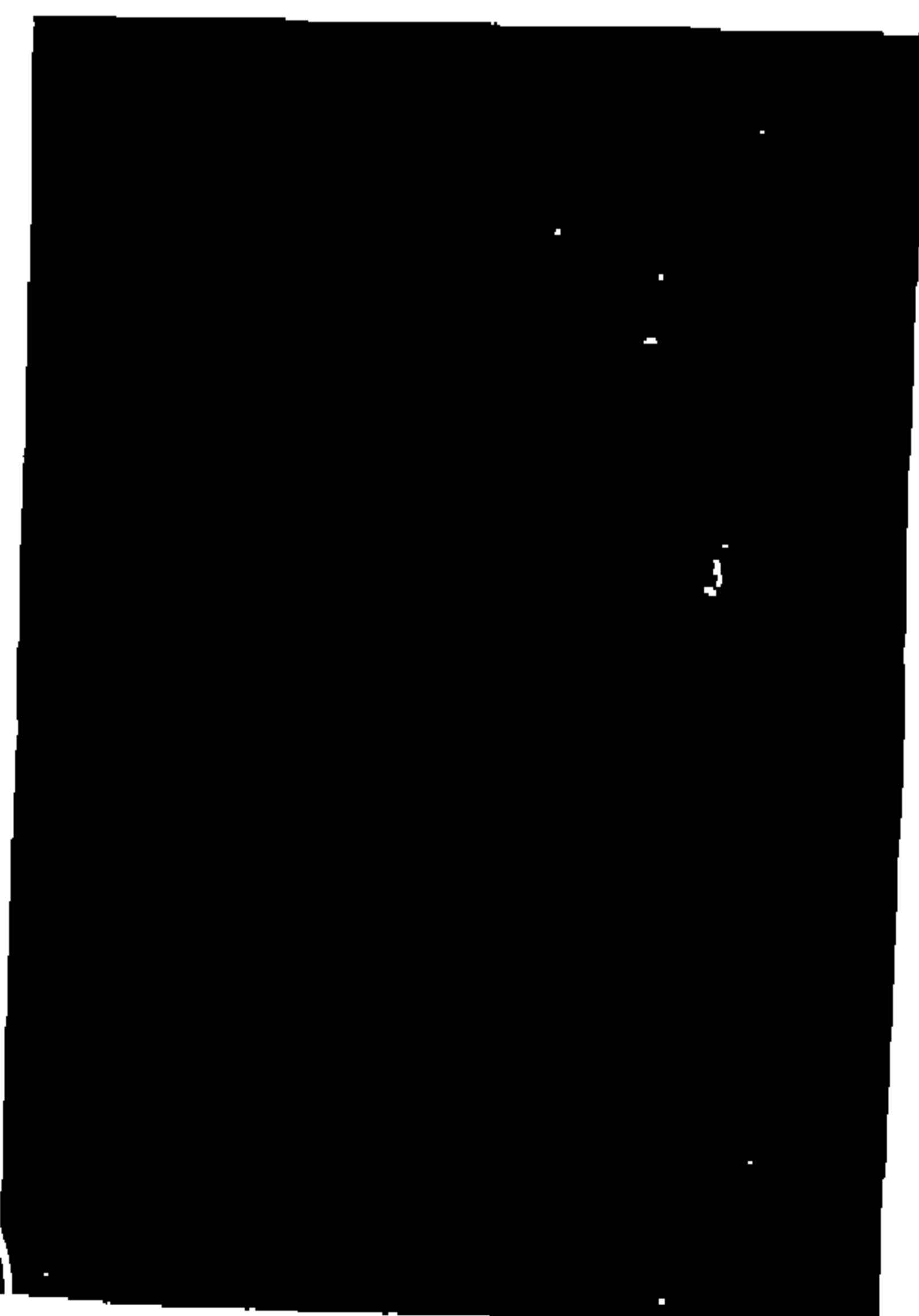


Sample SHRD004, 73.1



Sample SHRD004, 77.7

*Original
autoradiograph*



*Original
autoradiograph*



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REPORT TITLE	Petrographic Descriptions and X-ray Diffraction Studies for Ten Drill Core Rock Samples, Drill Hole SHD012 (Arnhem Land, NT)
REPORT #	2396
CLIENT	AFmeco Mining and EXploration Pty Ltd
ORDER NO.	03339
CONTACT	Mr Daniel Alonso

REPORT BY	Dr Douglas R. Mason
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SIGNED

for Mason Geoscience Pty. Ltd.

DATE	16 December 1997
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Petrographic Descriptions and X-ray Diffraction Studies for Ten Drill Core Rock Samples, Drill Hole SHD012 (Arnhem Land, NT)

SUMMARY

1. Rock Samples

- Ten rock samples from drill hole SHD012 have been studied using petrographic, mineragraphic and X-ray diffraction methods.

2. Brief Results

- Rock names and mineralogy are summarised in TABLE 1.
- Primary rock types are inferred from the principal metamorphic mineralogy and textures of the rock. They included pelitic sedimentary rocks, basic rocks of calc-silicate sedimentary origin, and basaltic tuffaceous sedimentary rocks.
- Regional metamorphism
 - Regional metamorphic assemblages are identified from relict metamorphic minerals and preserved metamorphic textures.
 - Pelitic sedimentary rocks recrystallised to foliated medium- to coarse-grained granoblastic assemblages of micas (mainly biotite, possibly muscovite), garnet, quartz, sillimanite, feldspar, graphite, and zircon.
 - Basic calc-silicate sedimentary rocks recrystallised to assemblages of hornblende, plagioclase, quartz, and biotite. Pyroxene may have formed in some rocks, but has been replaced by actinolite.
 - Metamorphic grade has been obscured by alteration (see below), but a grade in the middle to upper amphibolite facies is inferred from the relict metamorphic mineral assemblages (brown-green hornblende in calc-silicate meta-sediment; sillimanite + garnet in pelitic meta-sediment) and from the presence of coarse-grained thin to thick metamorphic segregation bands in some samples.
 - Most of the samples display foliated granoblastic assemblages consistent with recrystallisation of the precursor rock under the influence of a directed regional stress regime. Mylonitisation (i.e. physical disruption with or without annealing) is not recognised, but one sample displays a significant degree of ductile deformation such that garnet porphyroblasts have suffered elongation to aspect ratios of ~3:1.
 - Basaltic tuffaceous sedimentary rocks do not appear to have suffered the regional metamorphic event, and therefore are inferred to be much younger than the regionally metamorphosed sedimentary rock sequence.
- Hydrothermal alteration
 - All samples display moderate to severe selective pervasive hydrothermal alteration.
 - Basaltic tuffaceous rocks have suffered almost complete replacement to massive assemblages of chlorite + hematite + trace calcite + apatite. A trace of relict clastic zircon is preserved in some of these samples.

- The gneissic meta-sediments have suffered moderately severe alteration to assemblages of sericite, chlorite, illitic clay, quartz, pyrite and chalcopyrite.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins
SHD012, 242.6m	Chlorite-hematite altered basaltic breccia	-	Chl,opq(hem),apa	-
SHD012, 201.4m	Chlorite-hematite altered basaltic tuff	Zir	Chl,opq(hem),cal,rut	-
SHD012, 206.2m	Chlorite-hematite rock (altered basaltic tuff?)	Zir	Chl,opq(hem),apa,rut	-
SHD012, 223.0m	Chlorite-sericite altered intermediate gneiss	-	Qtz,apa,zir; Ser,chl,leu,opq	-
SHD012, 233.4m	Illite-sericite-chlorite altered gneiss (layered meta-pelite)	-	Qtz,bio,grp,zir; Ill,chl,ser,qtz,rut,py	-
SHD012, 235.3m	Sericite-chlorite altered ?garnet-sillimanite gneiss (meta-pelite)	-	Qtz,grp,bio,sill,zir; Ser,chl,rut,py	-
SHD012, 242.6m	Sericite-chlorite-pyrite altered mica-sillimanite-graphite gneiss (meta-pelite)	-	Qtz,grp,sill; Ser,chl,qtz,py,cpy	-
SHD012, 254.7m	Sericite-chlorite altered, deformed mica-garnet-sillimanite gneiss (meta-pelite)	-	Qtz,sill,opq; Qtz; Ser,chl,rut	-
SHD012, 296.0m	Illite-altered hornblende-plagioclase-quartz gneiss (para-amphibolite)	-	Hbl,qtz,pla; Act; Ill	Cal

NOTES:

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

** : Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations:

Apa = apatite; bio = biotite; cal = calcite; chl = chlorite; cpy = chalcopyrite; grp = graphite; hbl = hornblende; hem = hematite; ill = illitic clay; leu = leucoxene; opq = undifferentiated opaque minerals; pla = plagioclase; py = pyrite; qtz = quartz; rut = rutile; ser = sericite (fine-grained white mica); sill = sillimanite; zir = zircon.

1. INTRODUCTION

A batch of ten drill core rock samples was received from Mr Daniel Alonso (AFmeco Mining and EXploration Pty Ltd, Winnellie, Northern Territory) on 18 November 1997.

It was indicated that all samples originate from drill hole SHD012. Field notes were provided by the client regarding the nature of the samples. Particular requests were:

- i) To provide a thin section and routine petrographic description, or polished thin section and combined petrographic and mineragraphic description, as specified for each sample.
- ii) To respond to the particular queries for each sample.
- iii) To return the reports, sample remnants and thin sections to the Darwin office of AFMEX.

The Invoice for this work was requested by the client on 14 December 1997, and it was provided by facsimile to the Darwin office of AFMEX on that date. Preliminary XRD results were also provided on that date. This report contains the full results of this work.

2. METHODS

The drill core rock samples were examined in hand specimen and marked for section preparation. Thin sections and polished thin sections (as requested) were obtained from an external commercial laboratory (Amdel Limited, Thebarton, South Australia). Mineral identifications by X-ray diffraction (XRD) methods were also obtained from Amdel Limited, and the full report is provided as APPENDIX 1.

At Mason Geoscience Pty Ltd, conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions. Additional reflected light mineragraphic observations were included in a combined petrographic and mineragraphic description where a polished thin section was available.

3. PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages. Where a polished thin section was prepared, a combined petrographic and mineragraphic description is provided.

SAMPLE : SHD012, 190.9m

SECTION NO. : SHD012, 190.9 (C69410)

HAND SPECIMEN : The drill core rock sample represents a coarse fragmental rock composed of angular green and reddish brown rock fragments of variable size (up to ~3 cm), closely packed in a fine-grained dark green matrix.

ROCK NAME : Chlorite-hematite altered basaltic breccia

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	53	Alteration (after lithic fragments)
Opauques (mainly ?hematite)	7	Alteration (after lithic fragments)
Ti-phase (?leucoxene)	Tr	Alteration (after lithic fragments)
Chlorite	25	Alteration (after matrix)
Opauques (mainly ?hematite)	15	Alteration (after matrix)
Apatite	Tr	Alteration (after matrix)

In thin section, this sample displays a well-preserved coarse fragmental texture of clastic sedimentary origin, modified by strong pervasive alteration.

Chlorite dominates the rock, and occurs in two sites:

- i) Much occurs as fine-grained (microcrystalline to cryptocrystalline) dense pleochroic green massive replacements of angular lithic fragments. A small amount of the chlorite occurs as fillings in small spheroidal structures (vesicles).
- ii) A lesser amount occurs as slightly coarser-grained massive replacements of matrix areas.

Opauques represent the other principal components of the rock. Like the chlorite, they occur in two sites:

- i) A moderate amount occurs as tiny equant microgranular aggregates sprinkled through the chlorite-altered lithic fragments. Locally, these opaques define intricate 'finger-print'-like microstructures of devitrification origin, and some occur as fillings in vesicles.
- ii) Most of the opaques occur in the matrix areas, where they form elongate blades intergrown in aggregates.

The blade-like forms of the opaque crystals and their deep red colour in thin margins suggests they are mainly hematite.

Apatite occurs in trace amount as small stumpy subhedral grains ~0.1 mm in size, concentrated in limited areas of the matrix.

INTERPRETATION:

This sample represents a basaltic sedimentary breccia, which formed by rapid accumulation of aphyric glassy basaltic rock fragments. A near-vent site of deposition is suggested by the unsorted, non-layered, angular nature of the basaltic fragments.

Pervasive alteration of the rock generated the present mineral assemblage of chlorite + opaques (hematite) + trace apatite. The alteration was complete, leaving no primary materials in the rock, but primary lithic clast shapes were well-preserved.

Client query: *Sedimentary breccia?*

Response: Yes, a sedimentary origin is inferred for this coarse, unsorted fragmental rock. There is no textural support for a tectonic (e.g. fault breccia) origin.

SAMPLE : SHD012, 201.4m
SECTION NO. : SHD012, 201.4 (C69411)
HAND SPECIMEN : The drill core rock sample represents a fine-grained massive dark green rock, with indistinct dark reddish brown ferruginous alteration patches.
ROCK NAME : Chlorite-hematite altered basaltic tuff
PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	70	Alteration
Opagues (mainly ?hematite)	30	Alteration
Calcite	Tr	Alteration
?Rutile	Tr	Alteration
Zircon	Tr	Clastic crystals

[NOTE: XRD has identified chlorite and hematite.]

In thin section, this sample displays a poorly-preserved sorted clastic texture, modified by strong pervasive alteration.

Chlorite dominates the rock, occurring as tiny randomly oriented flakes that form a dense mat throughout the rock. In many places, the angular outlines of precursor fragments ~0.2-1.0 mm in size (most ~0.2-0.4 mm) are evident. No precursor minerals or textures are preserved in the fragments, so their origin remains enigmatic, but they are probably of basaltic lithic origin as supported by the relict devitrification textures in similarly altered fragments in the previous sample (SHD012, 190.9m).

Opagues are moderately abundant. They tend to be concentrated in small aggregates in the matrix, and therefore aid in definition of the lithic fragments. Although distributed throughout the rock, the opaque material is concentrated in a diffuse tortuous band ~1 cm thick. XRD has confirmed identification of the opagues as hematite.

Tiny microgranular accessory aggregates of a Ti-mineral (probably rutile) are sparsely distributed through the rock.

A small amount of calcite occurs as granular small aggregates sparsely and irregularly scattered through the dark hematite-rich diffuse band in the rock.

Zircon occurs in trace amount as subrounded stumpy crystals ~0.2-0.4 mm in size. Their size, shape and distribution suggest they represent primary clastic crystals.

INTERPRETATION:

This sample is interpreted to represent a basaltic lithic tuff. It was originally composed of abundant small angular fragments of aphyric glassy basalt. The limited size range suggests a moderate degree of reworking of the volcanogenic tuffaceous material. Accessory zircon was deposited with the basaltic materials, presumably as a relictate clastic contribution from a nearby acid crystalline terrain.

Pervasive alteration has affected the rock, generating the presently observed assemblage of chlorite + opaques (mainly hematite) + trace calcite.

Client query: Origin?

Response: A reworked basaltic tuffaceous origin is inferred. Alteration is intense, obscuring most of the primary features of the rock, but enough of the primary microtexture is preserved to allow identification as a basaltic tuff.

SAMPLE : SHD012, 206.2m

SECTION NO. : SHD012, 206.2 (C69412)

HAND SPECIMEN : The drill core sample represents a fine-grained, massive (non-foliated), non-layered dark green rock.

ROCK NAME : Chlorite-hematite rock (altered basaltic tuff?)

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	89	Alteration
Opagues (mainly ?hematite)	10	Alteration
Apatite	Tr	Alteration
Rutile	Tr	Alteration
Zircon	Tr	Clastic crystals

[NOTE: XRD has identified chlorite and hematite.]

In thin section, this sample displays a massive pervasive replacement texture, with only very faint preservation of possible primary clastic texture.

Chlorite dominates the rock. It occurs as small, randomly oriented flakes ~0.1-0.2 mm long that form a massive replacement mat throughout the rock. Pleochroism from green to colourless confirms an Fe-rich chlorite composition, and length-slow optical orientation of the flakes confirms identification of chlorite rather than superficially similar serpentine.

Opagues occur in moderate amount as fine-grained ragged aggregates scattered through the rock. Locally they are concentrated in angular patches ~0.4 mm in size that may represent altered lithic fragments, and elsewhere the opagues tend to outline possible precursor lithic fragments of similar size. The blood red colour of thin small grains suggests hematite is the principal opaque phase (confirmed by XRD).

Apatite occurs in trace amount as small equant colourless crystals sparsely scattered through the rock. Some display the perfect hexagonal basal section of this phase.

Rutile occurs in trace amount as tiny microgranular aggregates with typical deep yellow colour and strong birefringence. They are very sparsely and irregularly scattered through the rock.

Zircon is uncommon, occurring as small subrounded crystals ~0.1-0.2 mm in size. Although small in size, the optical properties of the phase are apparent: colourless, very high relief, no cleavage, microcracks, very high birefringence, and extinction parallel to the preserved prism faces.

INTERPRETATION:

This sample is considered to represent a basaltic tuffaceous sediment, originally composed of small angular aphyric glassy basalt fragments, with minor clastic zircon crystals contributed from an acid crystalline terrain. Pervasive intense alteration of the rock resulted in complete replacement by the assemblage chlorite + opagues (mainly hematite) + trace apatite + rutile.

SAMPLE : SHD012, 223.0m

SECTION NO. : SHD012, 223.0 (C69413)

HAND SPECIMEN : The drill core sample represents a medium-grained, strongly foliated crystalline rock that has been altered to a dull waxy green colour. Minor laminae rich in translucent grey quartz contribute to definition of the primary structure in the gneissic precursor rock.

ROCK NAME : Chlorite-sericite altered intermediate gneiss

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	20	Metamorphic
Apatite	Tr	Metamorphic
Zircon	Tr	Metamorphic
Sericite	59	Alteration
Chlorite	20	Alteration
Leucoxene	Tr	Alteration
Opauques (?hematite)	<1	Alteration

In thin section, this sample displays a well-preserved medium-grained foliated granoblastic metamorphic texture with gneissic mineral lamination.

Quartz is moderately abundant. It occurs mainly as small anhedral unstrained grains ~0.2-0.4 mm in size, distributed non-uniformly through the rock. They were in textural equilibrium with large grains (see sericite and chlorite below). Some quartz occurs as similar but larger grains up to ~2 mm in size, concentrated in laminae which contributed to the structure through the rock.

Sericite is abundant, occurring as very fine-grained fibrous replacements of precursor anhedral grains ~0.5-1.0 mm in size that were distributed throughout the rock. In some grains, the preserved intersecting cleavage traces of precursor amphibole can be distinguished, suggesting that hornblende was an important precursor mineral in the rock.

Chlorite occurs in significant amount, and occurs in different sites:

- i) Some occurs as pleochroic green replacements of strongly cleaved precursor flakes (biotite) whose strong preferred orientation contributed to definition of the foliation through the rock.
- ii) A similar amount occurs as fine-grained ragged replacement patches scattered through the rock. There is no clear indication of the nature of the precursor phase/s of this alteration chlorite.

Leucoxene occurs in trace amount as tiny turbid microcrystalline aggregates sprinkled through some altered grain sites (especially those that were biotite and hornblende).

Opauques (probably mainly hematite) occur in minor amount as small ragged aggregates commonly in the altered biotite flake sites.

Apatite occurs in trace amount as small euhedral crystals located within metamorphic quartz grains.

Zircon is rare, forming small euhedral stumpy prisms of apparent relict metamorphic origin.

INTERPRETATION:

This sample represents a gneissic metamorphic rock, originally composed of quartz, hornblende, biotite and accessory zircon. Other phases may have been present, but have been obscured by strong selective pervasive alteration which caused complete replacement to the assemblage of sericite + chlorite + trace opaques (?hematite) + leucoxene. Hornblende was replaced by sericite, and biotite by chlorite. Metamorphic quartz and zircon survived the alteration event.

The nature of the precursor rock has been obscured by the effects of alteration. It appears to have been a gneissic metamorphic rock of intermediate bulk composition, composed of hornblende, quartz, biotite and possibly other phases.

Client query: Altered amphibolite?

Response: The rock is unlikely to have been an amphibolite *sensu stricto*, because it appears to contain too much quartz and biotite. The rock did, however, contain a significant amount of amphibole.

SAMPLE : SHD012, 233.4m

SECTION NO. : SHD012, 233.4 (C69414)

HAND SPECIMEN : The drill core sample represents a layered gneissic rock in which layers several centimetres thick are defined by grain size and mineralogical variations. A moderately strong foliation lies subparallel to the layering. The rock displays a waxy drab green colour suggestive of pervasive alteration.

ROCK NAME : Illite-sericite-chlorite altered gneiss (layered meta-pelite)

PETROGRAPHY AND MINERAGRAPHY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol.%</u>	<u>Origin</u>
Quartz	30	Metamorphic
Zircon	Tr	Metamorphic
Biotite	Tr	Relict metamorphic
Graphite	Tr	?Relict metamorphic
Phyllosilicate (illitic clay?)	30	Alteration
Phyllosilicate (sericite)	10	Alteration
Chlorite	25	Alteration
Quartz	5	Alteration (after ?garnet)
Pyrite	Tr	Alteration
Rutile	Tr	Alteration

In polished thin section, this sample displays a foliated granoblastic metamorphic texture with mineralogical and grain size layering, modified by strong selective pervasive alteration.

Quartz is moderately abundant, and occurs in two forms:

- i) Most occurs as small anhedral grains ~0.1-0.2 mm that are uniformly distributed through the principal medium-grained layers that dominate the rock. It clearly represents metamorphic quartz.
- ii) Some quartz occurs as large anhedral grains ~1-2 mm in size, concentrated in the coarser-grained layer in the rock. This represents metamorphic quartz.
- iii) A modest amount of quartz occurs as small ragged grains that have pseudomorphously replaced amoeboid poikiloblastic grains of metamorphic origin up to ~2 mm in size. These grains have forms appropriate to garnet, but none is preserved.

Biotite occurs in trace amount as small well-crystallised flakes, pleochroic in reddish browns, enclosed within the large grains in the coarse-grained layer.

Graphite is uncommon, occurring as small but well-crystallised flakes within a single lamina within the coarse-grained layer. The graphite appears to have been texturally part of the metamorphic assemblage.

Zircon is rare, forming small subhedral stumpy crystals in the coarse-grained layer.

Two phyllosilicate phases are identified:

- i) Much occurs as tiny randomly oriented flecks concentrated in anhedral grain sites in the principal thick layers of the rock. This phyllosilicate phase appears to be an illitic clay: it is colourless but with a slight brownish tinge, and displays low birefringence. The clays appear to have completely replaced precursor feldspar of unknown type.
- ii) A significant amount of phyllosilicate occurs as fibrous, optically continuous replacements of coarse precursor foliated phyllosilicate plates (biotite) located in the coarse-grained layer. Small rutile crystals are sprinkled through these sericite-altered biotite flakes.

Chlorite occurs mostly as replacements of small aligned biotite flakes located in the principal layers of the rock. A smaller amount of chlorite occurs as fine-grained dense replacement mats in the coarser-grained layer.

Pyrite is rare, occurring as tiny equant grains located at the margin of quartz grains.

INTERPRETATION:

This sample represents a layered granoblastic metamorphic rock of medium to high metamorphic grade. It was composed of thicker, medium-grained layers of feldspar + quartz + biotite + garnet, and coarse-grained layers composed of biotite + quartz + trace graphite + zircon. A layered pelitic sedimentary precursor rock is inferred.

The metamorphic rock has suffered strong selective pervasive alteration to the assemblage illitic clay + chlorite + sericite + quartz + trace rutile. Feldspar was completely replaced by illitic clay, biotite was completely replaced by chlorite or by sericite, and garnet by quartz. Metamorphic quartz survived the alteration event, as well as traces of metamorphic biotite, graphite, and zircon.

Client query: Graphite? Protomylonite?

Response: Yes, a small amount of graphite is present in the coarser-grained layer, where it is considered to represent a relict metamorphic (not alteration) phase. The graphite is considered to represent recrystallised primary carbonaceous sedimentary material.

The rock is not considered to be of strong dynamic deformational (protomylonitic) origin because of particular petrographic observations:

- i) There are no fragmentation textures, with or without subsequent metamorphic annealing.
- ii) There are no ductile elongation textures evident, although a strong foliation was defined throughout the rock by aligned metamorphic phyllosilicate flakes.

SAMPLE : SHD012, 235.3m

SECTION NO. : SHD012, 235.3 (C69415)

HAND SPECIMEN : The drill core sample represents a strongly foliated, drab green, phyllosilicate-rich rock in which a coarser-grained felsic band lies subparallel to foliation.

ROCK NAME : Sericite-chlorite altered ?garnet-sillimanite gneiss (meta-pelite)

PETROGRAPHY AND MINERAGRAPY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	20	Metamorphic
Graphite	<1	Relict metamorphic
Biotite	Tr	Relict metamorphic
Sillimanite	Tr	Relict metamorphic (inclus. in quartz)
Zircon	Tr	Metamorphic
Sericite	73	Alteration
Chlorite	5	Alteration
Rutile	Tr	Alteration
Pyrite	Tr	Alteration

In polished thin section, this sample displays a strongly foliated metamorphic texture, locally poikiloblastic and with mineralogical banding, modified by strong selective pervasive alteration.

Quartz is moderately abundant, occurring as anhedral equant unstrained grains ~0.4-1.0 mm in size. It is restricted to a single thick felsic band.

Graphite occurs in minor amount as small but well-crystallised flakes up to ~0.4 mm long. They are sparsely distributed throughout the rock, but are most abundant in the strongly foliated phyllosilicate-rich portions of the rock. The graphite displays the characteristic optical features of this phase: opaque in transmitted light; bireflectant in browns to greys, and strongly anisotropic from brown to dark grey under reflected light.

Biotite is rare, occurring as small discrete pleochroic flakes enclosed within single quartz grains. Biotite was much more abundant in the precursor rock.

Sericite is abundant, and occurs in different sites:

- i) Most occurs as optically continuous replacements of precursor large phyllosilicate flakes (biotite). These flakes were aligned in a strong foliation subparallel to mineralogical layering, and their identification as biotite is supported by the presence of tiny rutile granules sprinkled throughout the sericite-altered large biotite flakes. The rutile represents the Ti contained in the precursor biotite flakes.
- ii) Some occurs as very fine-grained replacements of acicular to prismatic crystals up to ~2 mm long, aligned in the trace of the foliation and commonly located within the coarse-grained quartz-rich band. These acicular crystals display forms appropriate to sillimanite. Tiny acicular fresh crystals, most likely sillimanite, are preserved within single large quartz grains. It is also likely that some fibrolitic sillimanite occurs in

moderate amount within the phyllosilicate-rich bands, where it forms fibrous thin laminae in shear planes that cut the rock sub-parallel to the foliation. The identification of the fibrolitic sillimanite is difficult and remains uncertain, owing to its close similarity to finely foliated sericite in the vicinity.

- iii) A small amount of sericite occurs as fine-grained dense replacement mats that have pseudomorphed ragged grains of unknown origin. A trace of sericite occurs as fine-grained dense replacements along microcracks that cut altered ?garnet grain sites (see chlorite next).

Chlorite occurs in moderate amount as fine-grained pleochroic pale green fillings in kernels between sericite-filled microcracks in altered ?garnet grain sites. The ?garnet formed large anhedral poikiloblastic grains up to ~6 mm in size, in places aligned in the trace of the foliation.

Zircon is uncommon, forming small equant subhedral crystals in the phyllosilicate-rich bands.

Pyrite is very rare, occurring as tiny ragged grains scattered through the rock.

INTERPRETATION:

This sample is inferred to represent a pelitic sedimentary rock that suffered medium to high grade regional metamorphism. This generated the strongly foliated, mineralogically layered assemblage of biotite + quartz + sillimanite + garnet + minor graphite + zircon. Other minerals may have been present but may have been destroyed by the subsequent strong selective pervasive alteration event, which generated the assemblage sericite + chlorite + minor rutile + pyrite. During this event:

- i) Metamorphic biotite was replaced by sericite + trace rutile. A trace of biotite survived as inclusions in metamorphic quartz.
- ii) Metamorphic garnet was replaced by chlorite + sericite. No garnet survived.
- iii) Well-crystallised metamorphic sillimanite was replaced by sericite, but tiny acicular sillimanite crystals survived as inclusions in quartz. It is possible that some fibrolitic sillimanite also survived, but this remains very difficult to distinguish from finely foliated sericite.

Client query: Pelitic gneiss. Graphite? Protomylonite?

Response: Yes, the rock has appropriate metamorphic mineralogy for a pelitic sedimentary primary rock. A small amount of graphite formed during the medium to high grade regional metamorphic event, most likely by recrystallisation of primary carbonaceous material in the sedimentary precursor rock. There is no clear evidence that the rock has suffered mylonitic deformation, but biotite has locally accepted higher strain in thin strongly foliated laminae (incipient shear planes) within the trace of the foliation.

SAMPLE : SHD012, 242.6m

SECTION NO. : SHD012, 242.6 (C69416)

HAND SPECIMEN : The drill core sample represents a strongly foliated gneissic metamorphic rock with a drab greenish grey altered appearance. Large pale cream altered poikiloblastic grains are sparsely scattered through the rock, and local large patches of lustrous sulphide (pyrite) also are present.

ROCK NAME : Sericite-chlorite-pyrite altered mica-sillimanite-graphite gneiss (meta-pelite)

PETROGRAPHY AND MINERAGRAPHY:

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	25	Metamorphic
Graphite	3	Metamorphic
Rutile	Tr	Metamorphic
Sillimanite	Tr	Relict metamorphic
Sericite	45	Alteration
Chlorite	20	Alteration
Quartz	5	Alteration
Pyrite	1	Alteration
Chalcopryite	Tr	Alteration

In polished thin section, this sample displays a strongly foliated, relict porphyroblastic metamorphic texture, modified by strong selective pervasive alteration.

Sericite is moderately abundant, and occurs in different sites:

- i) Much occurs as fine-grained foliated sheaves that have pseudomorphously replaced large precursor biotite flakes ~1 mm long. No biotite is preserved, but identification of the Ti-bearing precursor phyllosilicate is supported by the common presence of tiny rutile granules sprinkled through the flake sites.
- ii) Some occurs as fine-grained dense replacements of large poikiloblastic grains several millimetres in size. These may have been feldspar grains, as inferred from the tendency for the sericite to be located in aligned (but not foliated) patches with quartz in a texture which appears to have mimicked cleavage in the precursor phase.

Chlorite is moderately abundant, occurring as pseudomorphous replacements of well-formed foliated biotite flakes, and as fine-grained dense massive replacements of an unknown precursor phase which formed large anhedral grains.

Sillimanite is identified as tiny acicular crystals that are enclosed in anhedral quartz grains. Identification as sillimanite is confirmed by their acicular crystal forms, moderate to high relief, low to moderate birefringence, and parallel extinction. More fibrolitic sillimanite may occur in minor amount as fibrolitic sheets within the phyllosilicate-rich bands of the rock, but identification is very difficult in these fibrous sericite-rich areas.

Pyrite occurs as a large ragged patch composed of anhedral small pyrite grains intergrown with quartz.

Chalcopyrite is rare, forming tiny ragged grains scattered through the rock.

INTERPRETATION:

This sample represents a pelitic sedimentary rock which suffered medium to high grade regional metamorphism, generating the strongly foliated porphyroblastic assemblage of biotite + quartz + sillimanite + graphite. Other phases may have been present but their identification is now impossible, owing to strong selective pervasive alteration which generated sericite + chlorite + pyrite + quartz + rutile + chalcopyrite.

Client query: *Muscovite biotite quartz graphite gneiss?*

Response: Yes, the pelitic sedimentary precursor recrystallised to metamorphic minerals expected for that type of bulk composition. Metamorphic muscovite has not been identified. It normally survives the type of alteration event that this rock has suffered; it has not been identified, so it may not have formed in the metamorphic event. Graphite formed in significant amount as part of the metamorphic assemblage, presumably from carbonaceous material in the primary sediment. Sillimanite formed as part of the metamorphic assemblage, and a large porphyroblast-forming phase (cream in hand specimen) has suffered complete replacement by sericite + quartz but remains unidentified; it may have been feldspar.

SAMPLE : SHD012, 254.7m

SECTION NO. : SHD012, 254.7 (C69417)

HAND SPECIMEN : The drill core sample represents a waxy dark yellowish green rock with strong metamorphic foliation. Small dark grey lenses are elongated within the trace of the foliation.

ROCK NAME : Sericite-chlorite altered, deformed mica-garnet-sillimanite gneiss (meta-pelite)

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	12	Metamorphic (annealed)
?Sillimanite (fibrolitic)	5	Metamorphic
Sericite	62	Alteration
Chlorite	20	Alteration
Rutile	Tr	Alteration
Opaques (?graphite)	Tr	?Relict metamorphic / ?alteration

In thin section, this sample displays a strongly foliated metamorphic texture with ductile deformation of porphyroblasts and annealing of elongated quartz grains, modified by a severe alteration overprint.

Sericite is abundant, occurring in different forms:

- i) Most occurs as fibrous and optically continuous replacements of strongly foliated phyllosilicate flakes (probably mainly biotite, as supported by the presence of tiny rutile crystals sprinkled through the altered flakes).
- ii) Some occurs as tiny randomly oriented flecks that form dense replacement patches throughout the rock. The precursor is indeterminate: it may have been feldspar, or possibly cordierite.
- iii) Some occurs as fine-grained fillings in microcracks that cut large altered porphyroblastic grains.

Quartz occurs in moderate amount as anhedral grains ~0.1-0.4 mm long. Most are elongated in the trace of the foliation, apparently in response to deformation, and some of these elongated grains and aggregates display sutured annealed textures that have destroyed strain in the grains. Fine-grained granoblastic quartz mosaics of recrystallised nature also occur in the pressure shadows of some elongated chlorite-altered porphyroblastic crystals (altered garnet, see chlorite below).

Fibrolitic sillimanite is tentatively identified as fine fibrous sheaves aligned in the trace of the foliation. Distinction between this phase and fine-grained sericite is difficult.

Chlorite occurs in moderate abundance as fine-grained fillings in kernels between sericite-filled microcracks within large porphyroblastic grains. The porphyroblasts most likely were garnet grains (none is preserved) which suffered ductile elongation in the trace of the foliation, displaying aspect ratios ~3:1. Uncommon less-deformed grain sites display aspect ratios ~1:1, which approximate original grain shapes.

Opaques occur in trace amount as small elongate grains ~0.2 mm long, aligned in the trace of the foliation. They may be graphite.

INTERPRETATION:

This sample represents a pelitic sedimentary rock that suffered regional metamorphism of medium to high grade, generating the foliated porphyroblastic assemblage of mica (biotite, ?muscovite) + quartz + garnet + sillimanite + opaques (?graphite). Garnet formed as equant grains ~1-2 mm in size.

The rock body suffered high strain during the metamorphic event, which resulted in ductile deformation of the garnet porphyroblasts. It is also likely that a significant amount of strain (perhaps most of the strain) was taken up by the strongly foliated phyllosilicate flakes. Originally equant metamorphic quartz grains suffered elongation, and subsequent annealing.

At a later time, the rock body was invaded by low-temperature hydrothermal fluids, which caused selective pervasive alteration to the assemblage sericite + chlorite + trace rutile.

Client query: *Sillimanite garnet schist (protomylonite?)*

Response: Yes, the pelitic primary sedimentary rock recrystallised to an assemblage containing sillimanite and garnet. Subsequent ductile deformation caused elongation of the garnet porphyroblasts, producing aspect ratios ~3:1. More strain may have been accepted by the phyllosilicates. However, there is no evidence that the rock actually suffered mylonitic disruption (i.e. physical disruption into brittle fragments). Certainly, mylonitisation may be followed by annealing of the brittle deformation texture, but there is no indication that the garnet porphyroblasts, for example, have suffered disruption: on the contrary, they display only ductile deformation in the trace of the foliation.

SAMPLE : SHD012, 296.0m

SECTION NO. : SHD012, 296.0 (C69418)

HAND SPECIMEN : The drill core sample represents a dark greenish grey crystalline rock with strong foliation. Pink felsic bands and laminae from millimetre to centimetre thickness lie subparallel to the foliation, but locally are discordant.

ROCK NAME : Illite-altered hornblende-plagioclase-quartz gneiss
(para-amphibolite)

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Hornblende	38	Metamorphic
Plagioclase	5	Relict metamorphic
Actinolite	3	Metamorphic (after ?pyroxene)
Quartz	20	Metamorphic
Illitic clay	34	Alteration (after plagioclase)
Calcite	Tr	Fracture fillings

In thin section, this sample displays a lineated granoblastic metamorphic texture with grain size banding, modified by weak selective illitic alteration of plagioclase.

Hornblende is abundant, occurring as anhedral grains ~0.4-1.0 mm in size. Their preferred orientation contributes to the structure through the rock. Grain size variation defines banding. The hornblende is pleochroic from brownish green to pale olive, suggesting a genuine hornblende composition (i.e. elevated Al and Ti composition).

A small amount of paler green pleochroic amphibole (actinolitic) occurs as optically continuous large anhedral grains up to ~2 mm in size in the coarse-grained band. These grains appear to represent retrogression of precursor pyroxene grains (possibly diopsidic).

Plagioclase was abundant, occurring as small equant anhedral grains ~0.2-0.4 mm in size in the finer-grained bands, and larger anhedral grains up to ~2 mm in size in the coarser band. Most of the plagioclase has suffered replacement by fine feathery patches of randomly oriented illitic clay, but twinned relict plagioclase is preserved in some grain sites.

Quartz occurs in significant amount. It forms minor small anhedral grains in the finer-grained hornblende-rich band, and larger more abundant grains in the felsic band.

Calcite occurs in minor amount as fillings in thin fractures subparallel to mineralogical banding.

INTERPRETATION:

This sample represents a basic precursor rock of presumed calc-silicate sedimentary origin. It suffered recrystallisation in response to medium to high grade regional metamorphism, generating the lineated granoblastic assemblage of hornblende + plagioclase + quartz. Some clinopyroxene (?diopsidic) may have formed in this assemblage, but was replaced by optically continuous actinolite.

At a later time, weak selective alteration of plagioclase by illitic clay occurred, and minor thin fractures were filled by calcite.

APPENDIX 1: X-RAY DIFFRACTION STUDY

Three samples were submitted to Amdel Limited (Thebarton, South Australia) for mineral identification by X-ray diffraction methods. The full results are provided in the following report.