

APPENDIX VI-3

PETROGRAPHY OF THIN AND POLISHED SECTIONS

BY CRAIG LEITCH, 1998

Vancouver Petrographics

THIN SECTIONS EXAMINED

Yukon-Tanana Terrane - Finalyson Lake area

Fyre Lake

JH96-62	photo	JH97-57
JH96-65	photo	JH97-59
JH96-KCFV		JH97-60
JH96-KZSILL		JH97-67
JH96-DGA	photo	JH97-70
JH96-DGB		JH97-75
JH96-DGC	photo	JH97-77

Kudz Ze Kayah JH96-KZKJ photo x 2

Wolverine

JH96-FZ2		JH96-FZQFP	photo
JH96-FZ5	photo	JH96-WZ1	photo
JH96-FZ6		JH96-WZ2	photo
JH96-FZ7		JH96-WZ6	photo
JH96-FZ8		JH96-WOLV4	photo
JH96-FZ11			

Pak

JH97-160	JH97-184
JH97-185	JH97-188
JH97-191	

Argus

JH96-57B	photo	DDHARG96-04-107.0m
DDHARG96-03-86.9m	photo	DDHARG96-05-145.3m
DDHARG96-03-91.4m		DDHARG96-07-119.7m

League JH96-28 photo

Mink Mink photo

Money

JH96-70A	photo	JH97-120	
JH96-70B		JH97-123	
JH96-71A	photo x 2	JH97-124B	photo
JH96-71C		JH97-125	
JH96-71D		JH97-141	photo

Yukon-Tanana Terrane – Dawson area

Matson Creek

DDHMA92-01-12.60m	photo	DDHMA92-01-109.4m	photo
DDHMA92-01-24.00m	photo	DDHMA92-01-195.3m	photo
DDHMA92-01-40.96m		DDHMA92-02-76.6m	photo
DDHMA92-01-67.66m		DDHMA92-03-80.3m	photo
DDHMA92-01-81.00m		JH96-40	
DDHMA92-01-82.55m	photo	JH96-42	
DDHMA92-01-84.42m	photo		

?Yukon-Tanana Terrane – other

Big Top (Iron Creek)

JH97-64A	photo	97R-254	photo
JH97-65	photo	97R-256	
JH97-105	photo	97R-258	
JH97-123		97R-261	
97R-249		97R-264	
97R-250			

North American margin - Pelly-Cassiar Platform

MM

MMDDH73-02-206'	photo	MMDDH77-03-825'	photo
MMDDH73-02-345'	photo	MMDDH77-03-830'	photo
MMDDH74-02-840.5'	photo	MMDDH77-03-867.5'	photo
MMDDH74-02-864.5'	photo	MMDDH77-03-978'	
MMDDH76-02-410'	photo	MMDDH77-03-1072'	photo x 2
MMDDH76-02-423'	photo	MMDDH96-01-600'	photo
MMDDH76-02-448'	photo	MMDDH96-01-682.5'	
MMDDH76-07-644'	photo	MMDDH96-01-691'	photo
MMDDH76-07-655'		MMDDH96-01-722'	photo x 2
MMDDH76-07-726'	photo x 2	MMDDH96-01-876'	
MMDDH77-01-933'	photo x 2	MMDDH96-01-982'	
MMDDH77-03-788'	photo		

Chzerpnough (Fire)

JH96-2A	photo	JH96-10A	
JH96-2C	photo	JH96-10B	photo
JH96-5F	photo	JH96-12C	
JH96-6A		JH96-13A	
JH96-7A		JH96-15A	

Dan

JH97-3A	JH97-55	photo
JH97-54		

North American margin – Selwyn Basin

Marg

DDHMARG96-48-13.5m		DDHMARG96-48-310.05m	photo
DDHMARG96-48-17.93m	photo	DDHMARG96-48-312.65m	
DDHMARG96-48-55.75m	photo	DDHMARG96-48-325.35m	photo
DDHMARG96-48-85.65m		DDHMARG96-48-325.80m	photo
DDHMARG96-48-89.54m		DDHMARG96-48-338.92m	
DDHMARG96-48-92.0m		DDHMARG96-48-341.28m	
DDHMARG96-48-130.15m		DDHMARG96-48-353.15m	photo
DDHMARG96-48-209.43m	photo	DDHMARG96-48-360.75m	
DDHMARG96-48-210.6m		DDHMARG96-48-361.49m	photo
DDHMARG96-48-270.0m		DDHMARG96-48-364.95m	
DDHMARG96-48-301.0m		DDHMARG96-48-376.0m	
DDHMARG96-48-301.23m	photo	DDHMARG96-48-401.32m	
DDHMARG96-48-303.2m	photo	DDHMARG96-48-413.40m	
DDHMARG96-48-306.27m	photo		
DDHMARG96-48-307.76m			
DDHMARG96-49-235.30m	photo	DDHMARG96-49-262.48m	
DDHMARG96-49-237.28m		DDHMARG96-49-268.72m	
DDHMARG96-49-238.50m	photo	DDHMARG96-49-270.00m	
DDHMARG96-49-238.65m		DDHMARG96-49-273.10m	

DDHMARG96-49-239.83m		DDHMARG96-49-274.60m	photo
DDHMARG96-49-242.05m	photo x 2	DDHMARG96-49-276.20m	photo x 2
DDHMARG96-49-254.45m		DDHMARG96-49-277.32m	photo
DDHMARG96-49-258.90m	photo x 2	DDHMARG96-49-277.80m	photo
		DDHMARG96-49-280.20m	
DDHMARG96-56-255.25m	photo	DDHMARG96-56-265.33m	photo
DDHMARG96-56-256.67m		DDHMARG96-56-265.96m	photo
DDHMARG96-56-257.30m		DDHMARG96-56-268.88m	photo
DDHMARG96-56-257.80m	photo	DDHMARG96-56-271.85m	photo
DDHMARG96-56-258.75m	photo	DDHMARG96-56-282.82m	photo
<i>Primo</i>		Primo photo	

PETROGRAPHIC REPORT ON 194 SAMPLES FROM VOLCANIC-ASSOCIATED MASSIVE SULFIDE DEPOSITS IN YUKON

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SUMMARY:

Deposits and prospects included in this study are as follows (see Hunt, 1998 and references therein): Argus, Chzernpough, Dan, Fyre Lake, Iron Creek, Kudz Ze Kayah, League, Marg, Matson Creek, Mink, MM, Money, Pak, Primo, and Wolverine; there are also some samples from NTS map-areas 105G/7 and 105G/1. All the samples and their corresponding thin or polished thin sections were described except those from the Fyre Lake deposit. For this deposit, a commentary on a photomicrograph atlas (Van Randen, 1998) was supplemented by a brief examination of the thin sections.

The level of metamorphism and deformation is a fairly constant factor in the samples from all these deposits. The mineral assemblages appear to be typically greenschist, mainly quartz-sericite-chlorite-biotite-carbonate-rare garnet (in places possibly manganiferous and therefore indicating only lower to middle greenschist; elsewhere, possibly upper greenschist). Amphibole is present in places, but typically in metabasalt, gabbro/diabase or ?ultramafic, or as tremolite-actinolite in calc-silicate altered rocks, or minor secondary tremolite-actinolite after pyroxene, and so may not indicate approach to amphibolite facies. Foliation is generally moderately to strongly developed; crenulation and kink banding are common, as are metamorphic quartz/carbonate "sweats".

Samples from the main deposits (Marg, Matson Creek, MM, Money, Fyre Lake) are mainly focussed on the massive sulfides. The least metamorphosed/deformed appear to be the Marg and Money, in which relict layered, collomorphic banded, radiating cockscomb, and possible framboidal textures are erratically preserved, suggesting primary deposition of sulfides on the seafloor (c.f. the origins proposed for similar textures described in Leitch, 1981, 1990). In the other main deposits (Matson Creek, MM, Fyre Lake) rare relict circular structures or fine-grained aggregates of iron sulfides and base-metal sulfides suggest the possible former presence of similar primary features, but this is speculative. The prominent sulfide textures seen throughout are mainly indicative of the order of ease of recrystallization of sulfides (galena easiest, followed by chalcopyrite, pyrrhotite, sphalerite, and finally the hard minerals such as pyrite, arsenopyrite and magnetite), as outlined by authors such as Vokes (1971).

The bulk of the samples from the other, more minor prospects are of wallrock for rock type identification purposes, or of weaker mineralization. In some, the level of metamorphism and deformation is such as to veil or obscure the primary lithology; even distinctions between possible felsic meta-volcanics and siliceous meta-sediments become difficult to establish. Part of the reason for this is the difficulty of distinguishing untwinned plagioclase of about oligoclase composition from quartz due to lack of relief difference. Most of the sulfide textures, particularly for the softer sulfides (in particular galena, chalcopyrite and to a lesser extent sphalerite) are typical of recrystallization and remobilization rather than of primary features.

For each deposit examined, individual summaries, followed by detailed descriptions and photomicrographs, are given in the body of the report following.

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FINLAYSON LAKE DISTRICT

FYRE LAKE DEPOSIT

Several deposits, including the Fyre Lake, Money, Wolverine, and Ice, are located in the Finlayson Lake area north of the Tintina Fault, near the Kudz Ze Kayah deposit. Restoration of 450 km of right-lateral slip on the Tintina Fault would place these deposits northeast of Dawson City and put their host rocks contiguous with other rocks of the Yukon-Tanana Terrane from south of the Tintina Fault (Hunt, 1998). The Fyre Lake deposit is located on the east side of Fire Lake, 45 km south-southeast of the Kudz Ze Kayah and about the same distance southwest of the Wolverine and Money deposits. Host rocks at Fyre Lake are chlorite and chlorite-actinolite-quartz schist, probably after mafic to intermediate volcanics (flows and tuffs), near the contact with overlying carbonaceous phyllite, probably after fine-grained sedimentary rocks (Blanchflower et al., 1997, in Hunt, 1998). At the Fyre Lake deposit, the Kona Zone contains two parallel zones of Cu-Co-Au mineralization, the East and West Kona with strike lengths in excess of 900 m and 1500 m respectively, average thicknesses of 8-12 m and 9-40 m respectively, and widths of 100-125 m. Mineralization comprises massive pyrite with lesser pyrrhotite and chalcopyrite overlying banded sulfides in the upper horizon of the East Kona, similar massive pyrite with lesser pyrrhotite, chalcopyrite and sphalerite locally surrounding lenses of massive magnetite in the lower horizon of the East Kona, and pyrite, magnetite, and chalcopyrite with lesser pyrrhotite in a siliceous matrix at the West Kona; mineralization averages 1.5-2.0% Cu, 0.1-0.14% Co and 0.5-1.0 g/t Au over reported drill intersections (W. Roberts, pers. comm. 1997, in Hunt, 1998).

Samples from the Fyre Lake deposit were examined and photographed in detail by Van Randen (1998). The comments that follow are from examination of the photo album produced. In general, where "replacement" features are described, I do not see strong evidence for timing of the various phases, and would prefer to call them all roughly coeval. Examples in 96-33 20.15m include sericite after chlorite (part of this "sericite" is likely fine-grained, limonite-stained carbonate), or pyrrhotite after chalcopyrite, chalcopyrite after sphalerite, etc. At the grade of metamorphism and deformation of these samples, it is my feeling that any such relationships, if demonstrable, are more likely to represent remobilization textures than primary features. Relict primary features such as circular structures, colloform banding, framboids etc. (best seen and photographed in the Marg deposit samples) are the only reliable features worthy of searching for; only vague suggestions of these features survive in the Fyre Lake samples. Very fine-grained pyrite and interstitial chalcopyrite/sphalerite intergrowths such as those photographed from 96-33 21.38m could represent primary intergrowths of these minerals (compare with photomicrographs in Leitch, 1981; note that this section appears to be missing from the collection, and so could not be examined). Possible relict colloform, atoll and radiating cockscomb textures occur in 96-33 73.1m (not photographed). The photomicrographs are in general excellent (with the reservations about replacement features noted above) and are well organized and beautifully displayed.

In sample 96-33 71.48m, the "unidentified striated mineral" is pyrite; this is a common feature for euhedral pyrite on faces that are actually below the plane of the section. Similarly, the "black alteration rims" on pyrite are merely areas of pyrite below the surface of the section (therefore non-reflective; see also 72.9m; see also "alteration rims" around magnetite in 96-34 24.1m). At least some of another "unidentified" mineral indicated to be possibly replacing or pseudomorphing pyrite is likely carbonate (definitely present in the section, and not mentioned by Jo in the photomicrograph captions). In 96-33 72.5m, the presence of chalcopyrite in fractures cutting both pyrite and sphalerite is likely a reflection of relative ease of recrystallization of chalcopyrite relative to the harder minerals pyrite and sphalerite (e.g., Vokes, 1971). Black "veinlets" cutting pyrite are likely merely fractures in the section, filled with epoxy; note that sericite veinlets commonly also contain carbonate surrounding the sericite, and that sericite "embayments" into sulfides are likely features typical of remobilization rather than primary features. Atoll textures of pyrite in the

matrix of chalcopyrite, pyrrhotite and sphalerite may be present in this sample (these sulfides are commonly partly remobilized into fractures in the more brittle pyrite; rare, likely secondary, pyrite veinlets cut pyrrhotite). Note that a good deal of the recrystallization of pyrite and pyrrhotite from original fine-grained aggregates (relics of which may be present in 96-33 72.9m; see photomicrographs) could be during ongoing hydrothermal activity at the time of sulfide deposition (c.f. Leitch, 1981). A portion of the mineral labeled ?sericite in 96-33 73.1 is actually carbonate (likely ferroan); carbonate (with chlorite, sericite) is also found replacing garnets, which are distinctly green and have sieve texture due to inclusions of pyrite, ?magnetite and sphalerite; sphalerite in this sample appears to be Fe-rich and zoned (more Fe-rich at the rims).

DDH 96-34 17.6m contains magnetite porphyroblasts that are cut by narrow fractures of carbonate (likely ferroan; brown in hand sample, no reaction to cold dilute HCl even when powdered) and contain rounded inclusions (not likely quartz) that are currently pseudomorphed by extremely fine-grained ?chlorite. Similarly, porphyroblastic ?garnet is replaced or in places pseudomorphed by carbonate and chlorite. In other layers, an unidentified (high positive relief, low birefringence) mineral forms subhedral but intensely fractured porphyroblasts up to 1.5 mm long that rarely contain striking green ?garnet (as in 96-33 73.1) inclusions. The "fine-grained sericite" shown at margins of mica (muscovite) crystals is actually mostly ferroan carbonate. In this sample, it is likely that the elongate clots of fine-grained pyrite (and the "light grey opaque ?alteration mineral" are actually mixtures of pyrite and marcasite, and are secondary after former pyrrhotite; typical "bird's-eye" textures characteristic of such secondary replacements are present in places.

Massive pyritic sulfides in 96-34 20.85m (sample not examined or photographed by Sebert) have the appearance of mostly recrystallized fine-grained aggregates, and contain irregular chalcopyrite (in places with rounded, ?relict colloform structures) and pyrrhotite plus minor red-brown (Fe-rich) sphalerite and pale green garnet. In 96-34 24.1m, the mineral identified as fine-grained mica is likely "hydrobiotite" (ferriferous, hydrous, secondary biotite), intergrown with chlorite replacing a garnet (garnets are pale green in this sample also; they contain pyrite and chalcopyrite but no other "unidentified" opaques). I would not tend to agree that the rounded boundaries between pyrrhotite and chalcopyrite in this sample indicate replacement of the latter by the former, or that embayments of pyrrhotite and sphalerite into chalcopyrite indicate replacement; they could easily be merely recrystallization textures. In 96-34 26.65m, mineralogy is as described in the photo captions (quartz, chlorite, pyrite, magnetite, chalcopyrite, with carbonate occurring interstitial to quartz and as limonite-stained veinlets cutting the rock). Rare pyrrhotite is present, and trace sphalerite is red-brown (moderate to high Fe content).

Massive, coarse-grained pyritic sulfides alternate with fine-grained magnetite-rich layers in 96-34 71.8m. Fine-grained skeletons of pyrite and chalcopyrite mainly rim carbonate (likely ferroan). Dark "haloes" surrounding magnetite are merely areas of magnetite (opaque) that are not polished, i.e. lie below the surface of the section. The striated mineral (also out of plane of section) is likely pyrite that is intergrown with chalcopyrite. No relict primary textures are preserved in this strongly recrystallized sample. Sample 96-34 72.3 is mainly composed of semi-massive, fine-grained, laminated to foliated magnetite-quartz-amphibole+epidote (not sericite; bright green pleochroism, oblique extinction for amphibole and pale yellow pleochroism for epidote) with minor pyrite and chalcopyrite. Carbonate in veinlets is mainly calcite (reacts strongly to HCl). The veinlets also contain epidote in places in addition to carbonate and quartz (see photo 16A). The presence of these minerals (amphibole and epidote) may suggest a ?mafic precursor rock, or an approach to higher (amphibolite) grade metamorphism, or both. Two sections for 96-34 73.45 are strikingly different: in A, coarse porphyroblastic magnetite is contained within a strongly foliated quartz-chlorite-carbonate matrix (not mica; likely ferroan: trace reaction to cold dilute HCl). Magnetite is partly oxidized to hematite (seen as reddish blush in hand specimen and as fine, 10-30 micron grains with higher reflectivity in reflected light, e.g. photos 2,4, and 5), and there are rare large (to 6 mm) euhedral, pale pink (not seen in hand specimen, but could be ?manganiferous) garnets, altered to carbonate along abundant fine fractures. Minor pyrite and chalcopyrite are associated with magnetite. In section B, coarse, mainly euhedral, rarely zoned pyrite crystals and minor interstitial chalcopyrite and carbonate (?ferroan; no reaction to cold dilute HCl) are set in a matrix composed mainly of strained quartz.

Thin sections from 96-33 include the following. At 25.8m, a strongly foliated, commonly kink banded chlorite matrix contains coarse porphyroblastic ?plagioclase crystals to 2.5 mm (relief slightly below quartz suggests oligoclase), commonly with quartz in pressure shadows around the margins. There is minor alteration of feldspar to carbonate and sericite, and narrow foliation-parallel fractures in the chlorite are also filled by ?ferroan carbonate (no reaction to cold dilute HCl in hand specimen). The same carbonate pseudomorphs former ?mafic crystals with euhedral outlines up to 1.25 mm long; minor magnetite and pyrite are present in some layers. A ?feldspar porphyritic intermediate rock is suggested, cut by a 1 cm thick

quartz-minor chlorite layer-parallel vein that may be a ?metamorphic sweat. At 29.2m, a strongly foliated quartz-chlorite-pyrite-magnetite-minor ferroan carbonate schist, also containing subhedral feldspar crystals to 1.5 mm that are partly altered to carbonate-sericite and with relief close to that of quartz, plus ?relict mafic crystals up to 1 mm long altered to carbonate and ferri-ferrous biotite, is cut by carbonate veinlets up to 1 mm thick (calcite; react to HCl). A feldspar-mafic mineral porphyritic ?intermediate volcanic is a possible precursor. The section from 47.6m consists of a foliated, crenulated matrix of fibrous, pale green amphibole and chlorite plus lesser ?quartz or feldspar that hosts 2-3 mm diameter, subhedral, dark greenish brown porphyroblasts of biotite. Except for the ?quartz content (partly in metamorphic "sweats") this sample could have been a mafic rock originally (?quartz gabbro or basalt). The section from 57.87m is similar (finely fibrous, foliated amphibolite composed mainly of needle-like pale ?actinolite <0.5 mm long with interstitial quartz and plagioclase to 0.15 mm and, in places, flakey chlorite, greenish brown biotite, and muscovite plus traces of carbonate. Scattered euhedral opaques are magnetite to 1 mm in diameter. Amphibole, biotite and ?Mg-chlorite could signal an approach to ?amphibolite facies metamorphism of a mafic rock such as basalt or gabbro/diorite. The isoclinally folded, fine-grained, amphibole-?plagioclase rock with foliae of greenish brown biotite-muscovite-Mg chlorite-quartz-?ilmenite, from 59.25m, also contains scattered magnetite euhedra and could have had a similar protolith. The sample from 70.5m is composed largely of the same Mg-chlorite, but with alternating foliae of ferroan carbonate (no reaction to cold dilute HCl) +/- sphene, and quartz-?plagioclase; coarse white "sweats" or "blows" of quartz are present, but magnetite is absent. Again, metamorphism of a mafic ?volcanic rock is indicated. The slide from 74.95m also consists of alternating foliae of chlorite (?more Fe-rich) and quartz plus minor carbonate (calcite; reacts strongly to HCl), sphene and ?"hydrobiotite", hosting magnetite euhedra to 3.5 mm diameter. The sample from 76.6m again consists of fibrous amphibole to 0.5 mm in a matrix of finer ?plagioclase and quartz, with wispy streaks and foliae of greenish biotite and minor opaques including euhedral magnetite to 0.25 mm.

Only those samples not described in Van Randen (1998) are examined in detail in this report (these include JH 96-62 and 65 from Fyre Lake; JH 96-DGA,B,C from the Dub Grid, and JH 96-KCFZ,SILL from Kona Grid). Sample 96-62 is a quartz-chlorite-relict ?plagioclase-epidote-garnet+rutile-apatite schist that appears to represent an intermediate to mafic volcanic (fractures contain calcite-pyrite-pyrrhotite); 96-65 is a chlorite-amphibole rock that appears to represent a metamorphosed ?ultramafic rock. Samples from the Dub grid appear to include variably K-feldspar, quartz and plagioclase phyrlic, meta-biotite quartz latite or rhyodacite to intermediate volcanic (DGA, DGC respectively), altered to epidote, chlorite, sericite and limonite, and quartz-sericite-chlorite (after biotite) +/-carbonate, opaque, rutile, zircon, apatite schist (possibly after ?siliceous sediment; DGB). Samples from the Kona grid include KCFV and SILL, that are plagioclase phyrlic, meta-felsic (dacitic) volcanic and ?high-level intrusive respectively, composed of plagioclase, quartz, sericite, chloritized biotite, limonite and ?rutile.

Other samples from sheet 105G/07 and 105G/01 are, respectively, JH97-57, 59 and 60 (all meta-gabbro/diabase composed of amphibole-quartz-plagioclase-accessory opaques-epidote-biotite/chlorite-sericite-sphene) and JH97-67, 70, 75 and 77 (meta-felsic volcanics composed of quartz-plagioclase-?Kfeldspar-biotite/chlorite-sericite+carbonate, epidote, and variable accessory sphene, rutile, limonite, pyrite except for 97-70 which is a meta-gabbro like samples 97-57, 59 and 60).

Fyre Lake **JH 96-62**: QUARTZ-CHLORITE-BIOTITE-?RELICT PLAGIOCLASE-EPIDOTE-GARNET SCHIST AFTER ?INTERMEDIATE-MAFIC VOLCANIC; MINOR CARBONATE-SULFIDES

Described as a siliceous layer in chlorite schist; offcut is light grey, fine-grained, foliated, harder than steel, with minor sulfides (pyrite, magnetic pyrrhotite, chalcopyrite) along wispy laminae. Trace reaction to HCl along fractures and some laminae; modal mineralogy in thin section is approximately:

Quartz	40%
Chlorite	20%
Biotite	10%
Relict feldspar (?plagioclase)	10%
Epidote	2-3%
Opaque (?mainly sulfides)	2-3%
Carbonate (?mainly calcite)	2-3%
Garnet	1-2%
Rutile	<1%
Apatite	<1%

Alternating laminae mainly <2 mm thick are either quartz-rich or chlorite-biotite-epidote-garnet rich, with the micaceous minerals commonly concentrated in wispy foliae <0.5 mm thick. Quartz forms mainly sub- to anhedral crystals generally elongated and aligned along the foliation defined by the micas, up to 0.5 mm long. There is no clear indication, either by twinning or by relief difference, of feldspar mixed with the quartz. Chlorite and biotite form subhedral flakes to about 0.5 mm and appear to be inversely proportional, i.e. chlorite is after biotite; in places, lens-shaped aggregates up to 1.5 mm long of the two minerals appear to be after former mafic crystals. Biotite is medium brown and chlorite has optical properties (green pleochroism, length-slow anomalous blue birefringence) indicative of moderate to high Fe content (Fe:Fe+Mg, or F/M, ratio near 0.5-0.6). In certain layers, epidote is common as euhedra up to 0.35 mm long, mainly lacking strong pleochroism (moderate Fe content); also in these layers, the biotite is green (ferriferous) and garnet forms subhedral fractured porphyroblasts up to 1.25 mm in size, commonly associated with the opaques (euhedral pyrite to 0.7 mm, in places containing carbonate to 0.3 mm). Minor feldspar, likely plagioclase as subhedra to 0.5 mm, appear to be remnants of alteration by epidote. Most of the carbonate, likely calcite, forms fine (<0.1 mm) subhedra along cross-cutting and layer-parallel fractures. Traces of rutile (minute crystals <10 microns) occur in chlorite, in places associated with apatite euhedra to 50 microns.

Fyre Lake JH96-65: AMPHIBOLE (?TREMOLITE-ACTINOLITE) AND MAGNESIAN CHLORITE ROCK AFTER ?ULTRAMAFIC ROCK

Offcut shows a dark green, fine-grained, altered metamorphic rock with moderate foliation, non-magnetic, minor reaction to HCl. The thin section consists mainly of fibrous, eu- to subhedral amphibole (50%, up to 1.5 mm long) in a matrix of chlorite (50%, subhedral bent flakes mainly <0.5 mm in diameter). Traces of fine-grained (<15 micron) opaques in amphibole could be rutile. Both amphibole and chlorite are very pale green to colourless, implying a low Fe content; optical characteristics (length-fast, first-order birefringence) suggest the chlorite is magnesian (F/M perhaps 0.3-0.4); amphibole may be tremolite-actinolite. The mineralogy suggests derivation from a mafic or more likely ultramafic rock.

Fyre Lake JH 96-DGA: KSPAR-QUARTZ PORPHYRITIC, META-?QUARTZ LATITE/RHYODACITE
Dub Grid; offcut shows a pale brownish to greenish grey, siliceous (harder than steel) rock with a weakly developed foliation, non-magnetic, no reaction to cold dilute HCl. In thin section, the slide consists of scattered, deformed relict quartz and feldspar phenocrysts in a fine-grained matrix of quartz-feldspar-chlorite-biotite-epidote-sphene. The relict phenocrysts are mainly <1 mm in diameter, and mainly K-feldspar (?microcline; grid twinning and negative relief compared to quartz), with subhedral, scalloped outlines. Possible relict quartz phenocrysts of similar size and outline are composed of granular aggregates of sutured, undulose extinguishing, sub-grains mostly <0.2 mm in diameter. In the matrix, sub- to euhedral epidote mostly <0.15 mm in diameter has no pleochroism, indicating low Fe content; chlorite and biotite form subhedral flakes mostly <50 microns in diameter, with chlorite possibly replacing biotite. Most of the fine-grained (<0.1 mm) anhedral feldspar in the matrix has relief similar to that of quartz, suggesting it may be plagioclase possibly near oligoclase in composition. Thus the protolith may have been a quartz-Kspar porphyritic volcanic or high-level intrusive of about quartz latite in composition. Minor opaques appear to be mostly red-brown limonite (hematite-goethite), possibly in part after pyrite.

Fyre Lake JH96-DGB: ?PLAGIOCLASE-QUARTZ-SERICITE-BIOTITE/CHLORITE-CARBONATE+/- OPAQUE, RUTILE SCHIST AFTER ?FELSIC VOLCANIC ROCK

Pale grey-green to brownish, foliated enough that relict textures are almost completely obscured in hand specimen. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, it consists of fine-grained, sutured, anhedral interlocking plagioclase and minor quartz, and wispy micaceous (sericite and biotite) laminae. Plagioclase and quartz crystals are commonly elongated parallel to foliation by about 2:1, up to 0.15 mm long, in places mixed with traces of very fine-grained (10-20 micron) carbonate and/or sericite that could represent the sites of former feldspar. Plagioclase is not directly detected by either twinning or relief difference against quartz; however, the hand specimen looks more plagioclase-rich than quartz-rich, and if plagioclase of oligoclase composition was present, it would not be easy to detect optically. Minor K-feldspar is distinguished by negative relief compared to quartz (fine-grained subhedra to 50 microns). Sericite and biotite form subhedral flakes mostly <0.35 mm in diameter; biotite is commonly greenish-brown, or partly altered to chlorite (in places mixed with minor carbonate subhedra to 0.1 mm). Minor apatite forms rounded crystals up to 0.15 mm in diameter, and there are traces of opaque (partly

limonite, subhedra to 50 microns), rutile (15 microns), zircon (20 microns). I interpret this as a quartz-sericite-biotite-minor carbonate-opaque-rutile-apatite schist, possibly but not necessarily derived by metamorphism of a felsic volcanic rock (less likely a siliceous sedimentary rock).

Fyre Lake **JH96-DGC**: FOLIATED PLAGIOCLASE-?QUARTZ-?KSPAR PHYRIC, EPIDOTE-CHLORITE-SERICITE-RICH ?META-INTERMEDIATE VOLCANIC

Pale greenish-grey, foliated but vaguely porphyritic rock of ?felsic-intermediate appearance. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the slide is composed mostly of ?fragments or disrupted phenocrysts of plagioclase, ?quartz and possibly ?K-feldspar up to 0.9 mm in diameter set in a fine-grained (mainly <0.1 mm), foliated matrix of the same minerals plus abundant epidote, sericite, chlorite and minor rutile; in places traces of biotite remain. Plagioclase is rarely vaguely twinned and has relief ?above quartz, indicating ?andesine composition; possible Kspar appears to have negative relief. However, these tentative identifications require etching and staining to confirm them. Epidote forms rounded subhedra to 0.25 mm lacking pleochroism (Fe-poor); chlorite is length-slow, with anomalous birefringence and strong pleochroism indicating relatively Fe-rich composition (F/M perhaps 0.5-0.6). Sericite flakes are an- to subhedral, up to 0.25 mm in diameter; biotite is mainly <15 microns, pale brown in colour. Rutile crystals are sub- to euhedral, up to 60 microns in size. Rare apatite euhedra to 50 microns, together with the abundant rutile and mafic minerals (epidote, chlorite) suggest an intermediate volcanic protolith.

Fyre Lake **JH96-KCFV**: METAMORPHOSD, PLAGIOCLASE PHYRIC, FELSIC VOLCANIC (PLAGIOCLASE-QUARTZ-SERICITE-CHLORITE-BIOTITE-LIMONITE)

Kona grid at Fyre Lake, possible ?felsic volcanic; hand sample is a buff-white, stained by minor limonite, with a vaguely disrupted porphyritic texture. The rock is not magnetic and shows no reaction to cold dilute HCl; modal mineralogy in thin section is approximately;

Plagioclase (?albitic)	60-65%
Quartz (groundmass only)	?20%
Sericite	10%
Chlorite, biotite	5%
Opaque (limonite, ?rutile)	1-2%

This slide consists mainly of rounded relict plagioclase phenocrysts in a fine-grained matrix of quartz and plagioclase with minor sericite and chlorite; minor patches of limonite could be after former sulfides. Plagioclase phenocrysts are up to 1 mm in diameter, commonly but not always vaguely twinned, with relief apparently negative compared to quartz in the groundmass (?albite-oligoclase composition), and with minor flecking by sericite. Quartz phenocrysts are not definitely identifiable. In the groundmass, which averages about 0.1 mm in diameter, an- to subhedral crystals of plagioclase and lesser quartz and sericite make up the bulk of the rock; in places, minor greenish-brown chlorite or chloritized biotite of similar size is present, commonly closely associated with fine (<10 micron) opaques that could be limonite and/or rutile. The protolith for this metamorphosed rock does appear to have been a plagioclase porphyritic felsic volcanic, possibly of ?dacitic composition (no K-feldspar visible).

Fyre Lake **JH96-KZSILL**: FOLIATED, META- FELSIC VOLCANIC OR SILL (COMPOSED OF PLAGIOCLASE, QUARTZ, SERICITE, CHLORITIZED BIOTITE, LIMONITE)

Kona grid, possible ?felsic sill; hand sample is grey-white and foliated enough so that relict porphyritic textures are only vaguely visible. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the slide is composed mainly of plagioclase and lesser quartz, sericite and chloritized biotite (much like the previous slide, but lacking the distinctive porphyritic texture). Possible relics of dismembered former plagioclase phenocrysts are <0.5 mm in diameter and rarely twinned; relief slightly negative compared to quartz suggests a composition near albite-oligoclase. The matrix is strongly foliated, composed mainly of <0.1 mm subhedral plagioclase and quartz; former more abundant plagioclase is commonly partly altered to fine (<15 micron) sericite. Sericite and chloritized biotite flakes also mainly <0.1 mm in diameter are common, probably representing the sites of former mafic minerals. Chlorite is length-slow and weakly pleochroic, suggesting F/M near 0.5. Opaques are mainly limonite, possibly after former ?sulfide. Lens- to layer-like segregations of quartz (subhedra to 0.2 mm) are up to 0.5 mm thick and sub-parallel to oblique to foliation.

Fyre Lake **JH97-57**: META-GABBRO/DIABASE (AMPHIBOLE-QUARTZ-PLAGIOCLASE-EPIDOTE-ACCESSORY SPHENE/OPAQUES)

From the SE corner of NTS 105G/07, possible mafic metavolcanic; hand sample is dark green, fine-grained, with a distinctly diabasic or gabbroic appearance, cut by crenulated limonite-stained quartz veins. The rock is not magnetic and shows no reaction to cold dilute HCl, and no stain for K-feldspar in the etched slab. In thin section, the slide is made up of about 60% amphibole, 20% quartz, and 10% relict plagioclase, 10% epidote, plus <1% accessory sphene, opaques and limonite/hematite. Amphibole forms mainly euhedral crystals rarely up to 0.5 mm long, with interstices filled by a clear mineral that appears to be mostly quartz (subhedra mainly <0.15 mm in diameter) but could include some plagioclase. Relict plagioclase (rarely twinned; altered to clay-sericite, no relief against quartz) is recognized only in the quartz veinlets (<1.5 mm thick, also containing subhedral epidote to 0.75 mm mainly lacking yellow pleochroism and therefore of low Fe content). However, epidote in the body of the rock has distinct pleochroism. The rock could have likely been a fine gabbro or diabase.

Fyre Lake **JH97-59**: META-GABBRO (AMPHIBOLE-PLAGIOCLASE-QUARTZ-ACCESSORY OPAQUES, BIOTITE/CHLORITE, SERICITE)

Described as meta gabbro/diabase; hand sample is similar to 97-57 (non-magnetic, no reaction to HCl) but coarser-grained. The mineralogy is similar to 97-57 but amphibole is less abundant (45%) and quartz and plagioclase more abundant (very difficult to reliably separate them since there is no appreciable difference and the plagioclase is not always twinned or lightly altered to clay-sericite). Lack of relief against quartz suggests an oligoclase composition for plagioclase. Subhedral amphibole crystals up to 1 mm in size form aggregates up to 2.5 mm in diameter, in places with associated opaques and partly chloritized biotite (subhedra mostly less than 0.1 mm in diameter). The outlines of sub- to euhedral relict plagioclase crystals up to 1.5 mm in diameter are visible, with a granulated appearance (recrystallization to fine plagioclase, overprinted by quartz and in places sericite).

Fyre Lake **JH97-60**: META-GABBRO/DIABASE (AMPHIBOLE-PLAGIOCLASE-QUARTZ-ACCESSORY BIOTITE-OPAQUES-CLAY/SERICITE)

Similar to JH97-57 and 59, perhaps in between in terms of grain size; non-magnetic, no reaction to cold dilute HCl. Somewhat more foliated, with fibrous to subhedral amphibole (60%) up to 0.75 mm long aligned in the plane of foliation, separated by irregular layers of plagioclase (25-30%, subhedra to 0.5 mm, slightly altered to clay-sericite, in places twinned and with slight relief difference against 10% quartz which forms sub- to anhedral to 0.5 mm that are relatively clear). Accessory opaques (<1%) are mainly <0.1 mm in diameter; biotite (1-2%) forms pale brown flakes up to 0.2 mm diameter. Likely also a meta-gabbro/diabase.

Fyre Lake **JH97-67**: CHLORITE-SERICITE-EPIDOTE ALTERED, QUARTZ-PLAGIOCLASE VEINED, META-FELSIC TO INTERMEDIATE VOLCANIC

From the NW corner of 105G/01, described as ?metavolcanic; hand sample is greenish to brownish grey (chlorite and biotite respectively) and cut by a stockwork of quartz veins. The rock is not magnetic but shows trace reaction to cold dilute HCl; in thin section, it is composed mainly of quartz, relict plagioclase, sericite, biotite, chlorite, and accessory opaques and sphene. Quartz and plagioclase occur both in fine sub- to anhedral (<0.2 mm in diameter) in the body of the rock, and in larger crystals in the veins (up to 1.5 mm diameter). Plagioclase relief is negative compared to quartz, suggesting a composition of albite-oligoclase; there is moderate alteration to fine sericite and epidote. Original proportions may have been about 40% quartz and 30% plagioclase, or may have been changed by metamorphism (addition of quartz "sweats"). Biotite forms sub- to euhedral pale brown flakes up to 1.5 mm in diameter, in places altered to pale green chlorite with length-fast, green anomalous birefringence suggesting F/M around 0.4-0.5. Depending on how much of the quartz is primary and how much due to metamorphism, this sample could have been a felsic to intermediate volcanic.

Fyre Lake **JH97-70**: META-GABBRO/DIABASE (AMPHIBOLE-PLAGIOCLASE-QUARTZ-ACCESSORY ?MAGNETITE-?ILMENITE; MINOR CLAY/SERICITE)

Described as chlorite schist; hand sample is dark green and foliated, magnetic but with no reaction to cold dilute HCl. In thin section, the slide is composed mainly of subhedral to bladed amphibole up to 2 mm long with interstitial fine-grained subhedra of plagioclase (mostly <0.25 mm in diameter) and lesser quartz (sub- to anhedral crystals to 0.5 mm commonly concentrated along <1 mm thick ?metamorphic

"sweats"). Relief of the plagioclase against quartz is difficult to determine due to abundant fine clay/sericite alteration in the feldspar. Abundant accessory opaques to 0.7 mm may include magnetite and ?ilmenite. This sample likely represents a meta-gabbro or diabase, very similar to the samples from 105G/07.

Fyre Lake **JH97-75**: META-FELSIC VOLCANIC (QUARTZ-?PLAGIOCLASE-?KFELDSPAR-SERICITE-CARBONATE-PYRITE)

Described as ?meta-rhyolite; hand sample is strongly foliated, pale buff-white; non-magnetic but reacts to cold dilute HCl. There is no etched/stained slab to test for K-feldspar; in thin section, the rock consists of laminae up to about 1 mm thick that are composed of alternating quartz-rich, ?feldspar-rich, and sericite-carbonate rich assemblages. The quartz-rich are coarsest, composed of sub- to anhedral to 0.2 mm long (flattening approximately 2:1) that may be mixed with partly sericite-carbonate altered ?relict plagioclase that have negligible relief difference against quartz. In the ?feldspar-rich layers, very fine crystals mainly <25 microns long, also flattened in the plane of foliation, have negative relief compared to quartz that suggest ?K-feldspar; minor sericite and carbonate (mostly calcite) are also present, mainly <0.1 mm and 50 microns respectively. In places, larger relict ?K-feldspar crystals are euhedral, up to 0.4 mm in diameter, suggesting a possible former porphyritic rock that could have been of ?felsic to intermediate composition (relict mafic minerals are not apparent, but could have been altered to carbonate). Opaques are mainly subhedral pyrite to 0.5 mm, and very fine-grained (10-20 micron) ?rutile and/or limonite. The original composition may not have been as felsic as rhyolite.

Fyre Lake **JH97-77**: META-FELSIC VOLCANIC (QUARTZ-?PLAGIOCLASE-?KFELDSPAR-SERICITE-BIOTITE-CHLORITE-MINOR OPAQUES)

Foliated, fine-grained, grey-buff rock similar to 97-75 but with more biotite in the laminae; non-magnetic, no reaction to cold dilute HCl. In thin section, the slide consists of a fine-grained aggregate of quartz, feldspar (likely including K-feldspar; negative relief compared to quartz), and micas (sericite, pale brown biotite). Most ?plagioclase appears to be partly altered to fine-grained clay-sericite; biotite is partly altered to pale green chlorite in places, associated with traces of minute ?rutile and some limonite. The original composition is likely to have been similar to 97-75, possibly a felsic volcanic.

KUDZ ZE KAYAH (ABM) DEPOSIT

The ABM deposit on the Kudz Ze Kayah property is located in the Finlayson Lake district of the Yukon-Tanana Terrane, in the Pelly Mountains about 200 km northwest of Watson Lake (Hunt, 1998). The deposit, with a geological resource estimated at 13.3 Mt of 5.5% An, 1% Cu, 1.3% Pb, 125 g/t Ag and 1.2 g/t Au, is hosted in a thick complex of felsic metatuffs and sills or flows interlayered with minor mafic sills or flows, and metasedimentary rocks, that have undergone isoclinal folding; barium and base and precious metal zonation, plus the position of chloritic alteration above the deposit, suggest that it may in part been overturned (Schultze, 1996a, in Hunt, 1998). The deposit ranges from 2 to 39 m thick and includes magnetite laminated, wispy laminated and net textured chalcopyrite (Schultze, 1996b, in Hunt, 1998).

Kudz Ze Kayah **JH 96 KZK**: MASSIVE SULFIDES (PYRITE-SPHALERITE-MINOR MAGNETITE-GALENA-CHALCOPYRITE); QUARTZ-CARBONATE-MINOR MUSCOVITE GANGUE

Only one sample from this deposit was submitted, and it is a massive sulfide that is strongly magnetic and shows minor reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	65%
Sphalerite	15%
Quartz	10%
Carbonate (?mainly calcite)	5-7%
Magnetite	2-3%
Galena	1%
Muscovite (sericite)	<1%
Chalcopyrite	tr

The sample has a poorly defined foliation or lamination caused by alternating wispy layers mostly less than 1 mm thick that are alternately richer in pyrite, sphalerite or gangue minerals (mainly quartz and carbonate).

Pyrite forms sub- to euhedral cubic crystals mainly less than 1 mm in diameter. Sphalerite crystals are similar in size but in places aggregate to 2.5 mm, with deep red-brown colour indicating fairly high Fe content. Magnetite forms subhedral crystals mainly less than 0.5 mm in diameter, generally contained in sphalerite and difficult to distinguish from it due to closely similar reflectivity. Minor galena forms subhedral crystals to about 0.2 mm in diameter, closely associated with sphalerite and pyrite. Only traces of chalcopyrite (subhedra to 80 microns) were found in the section; Ag-bearing hosts such as tetrahedrite were searched for but not found.

Quartz forms mainly subhedral crystals <0.5 mm in diameter with relatively little undulose extinction. Carbonate, which may be mostly calcite to judge by the reaction in hand specimen, forms aggregates to 3 mm across of tightly interlocked subhedra to 0.5 mm in diameter. Muscovite forms scattered euhedral flakes up to 0.25 mm in diameter with very slight pale green pleochroism suggesting possible Fe content (phengite).

WOLVERINE DEPOSIT

The Wolverine deposit is located in the Pelly Mountains about 20 km east of Kudz Ze Kayah and 50 km north of the Fyre Lake deposit. The deposit is hosted by Devonian-Mississippian carbonaceous metasedimentary and metavolcanic rocks similar to those at Kudz Ze Kayah; massive sulfide mineralization is hosted by argillite or aphyric metarhyolite. The immediate footwall consists of graphitic phyllite and porphyritic felsic metavolcanic rocks; interlayered carbonaceous phyllite, felsic metavolcanic (including fragmental and tuffaceous units), and magnetite +/- barite iron formation marker form the hangingwall (Tucker et al., 1997, in Hunt, 1998). The mineralized zone is tabular, fine- to medium-grained, polymetallic and zoned, with sulfides displaying banded, clastic and replacement textures and a Mg-chlorite footwall alteration zone enveloping pyrite-chalcopyrite-pyrrhotite stringer mineralization. Gangue minerals include quartz, muscovite, calcite and dolomite-ankerite. Ore minerals, including galena and sphalerite, are interstitial to pyrite; argentian tetrahedrite, galena and electrum are reported to contain the silver (reserves in several zones total 5.3 Mt grading 1.8 g/t Au, 360 g/t Ag, 1.4% Cu, 1% Pb and 13% Zn (Tucker et al., 1997, in Hunt, 1998).

Samples examined from the Wolverine wall rocks (no massive sulfide samples) include **JH 96-FZ2** (two sections, one parallel and one perpendicular to the foliation), **FZ-5, 6, 7, 8, 10, 11** and **QFP** all from the Fisher Zone, plus **WZ1, 2, 6,** and **WOLV4**. Samples from the Fisher Zone include 1) mainly quartz-sericite or sericite-quartz (+/- carbon, limonite, rutile, jarosite, ?epidote, zircon) schists that could represent former ?felsic metavolcanics (FZ-2, 5, 7, likely silicified, veined and sericite altered in FZ-5), or less likely ?siliceous metasediments (FZ-6, 7); 2) quartz-pyrite (+/- limonite-stained clay/sericite, ?jarosite-bearing) ?exhalites or intensely silicified felsic metavolcanics (FZ-8, 11) and unusual, massive to laminated (WOLV4 and FZ-10, respectively) quartz-barite-magnetite-limonite, trace pyrite (+/- sericite, biotite, amphibole, plagioclase) rocks that could also represent meta-exhalites; 3) sericitized, ?silicified, coarse K-feldspar phyrlic, ?rhyolite porphyry (FZQFP). Samples from WZ are distinctly more mafic in composition, ranging from sericite-epidote-chlorite-sphene altered ?intermediate volcanic porphyry (cut by epidote-chlorite-minor ?sphalerite veins; WZ1) to a breccia of ?basaltic clasts (clinopyroxene-plagioclase-sphene, altered to sericite-chlorite-epidote-quartz; WZ2) and epidote-chlorite-actinolite-sphene altered ?gabbro or diorite (WZ6).

Wolverine fisher zone **JH96-FZ2**: SERICITE-QUARTZ+LIMONITE-JAROSITE-RUTILE SCHIST AFTER ?FELSIC FRAGMENTAL VOLCANIC

Two distinctly different appearing samples bear the same label; both are strongly foliated, but one is cut parallel to the foliation and the other is cut perpendicular to it. The field description, quartz-eye phyrlic "phyllite" appears to be apt; the rock is not magnetic and shows no significant reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Sericite	60%
Quartz	35-40%
Limonite	1-2%
?Jarosite (?after pyrite)	1-2%
Rutile	<1%
?Epidote, zircon	<1%

Both slides consist of lens-like to laminae-shaped concentrations of fine-grained quartz in a matrix of strongly foliated sericite, with scattered limonite that may be after pyrite. Quartz-rich lenses up to 7 mm long are composed of an- to subhedral interlocking crystals mainly <0.1 mm in diameter, and minor sericite. No plagioclase can be identified by twinning or relief difference against quartz, although it is suspected on the basis of white colouration in parts of the offcut slab. Sericite forms laminae up to 3 mm thick composed of scaly flakes mostly <50 microns in diameter, containing concentrations of limonite as pseudomorphs up to 0.1 mm in diameter, in places with cubic outlines that suggest former ?pyrite. Both opaque ?goethite and yellow ?jarosite are common, in places mixed with minute crystals of ?rutile (difficult to distinguish from limonite). Rare subhedra to 75 microns of ?epidote and zircon are also scattered in the sericitic portions of the rock. The protolith for this rock is not obvious; it could have been a ?felsic, fragmental volcanic.

Wolverine fisher zone **JH96-FZ5**: QUARTZ-SERICITE SCHIST (POSSIBLY SILICIFIED, VEINED, SERICITE ALTERED, METAMORPHOSED ?RHYOLITE)

Grey, very fine-grained, siliceous to sericitic rock (possible metarhyolite from field description), non-magnetic, trace reaction only to cold dilute HCl. In thin section, the bulk of the slide consists of very fine-grained to fine-grained quartz and sericite. Minor opaques are probably mostly limonite (?after pyrite) and rutile. No feldspar is distinguishable on the basis of relief difference against quartz. However, any former feldspar in the rock could have been entirely converted to sericite by either hydrothermal alteration or metamorphism or both. Quartz crystals are mainly an- to subhedral, and almost all <0.1 mm in diameter, especially in narrow ?stringers or "sweats" up to 0.35 mm thick; in the matrix, quartz crystals are mainly <35 microns in diameter. Sericite flakes are subhedral and generally <0.2 mm in diameter, concentrated in wispy lens- or laminar-shaped areas that could represent former ?fiamme, deformed fragments, or sheared-out phenocrysts. In short, this sample could easily represent a strongly silicified, veined, sericitized, metamorphosed rhyolite, but there is no definitive petrographic evidence to prove it.

Wolverine fisher zone **JH96-FZ6**: SERICITE-QUARTZ-?CARBON SCHIST CONTAINING ?FRAGMENTS OF QUARTZ-PLAGIOCLASE-SERICITE ?METAVOLCANIC AND LIMONITE PSEUDOMORPHS

Described as carbonaceous phyllite with ?metarhyolite fragments (hand sample consists of coarse black sericite-rich rock hosting irregular-shaped, <1.5 cm siliceous ?fragments and rusty brown <2 mm ?limonite pseudomorphs after either pyrite or carbonate. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the sample is composed mainly of quartz and sericite, with lesser limonite. However, in certain areas of the siliceous fragments, relict plagioclase is distinguishable by polysynthetic twinning (subhedra <0.1 mm in diameter, partly altered to fine clay-sericite flakes of <10 microns diameter). This is supportive evidence for the proposed origin for FZ5, in which complete sericitization may have destroyed all former feldspar. Surrounding sericite (muscovite)- rich areas are composed of subhedral flakes up to 0.5 mm in diameter, generally strongly foliated and in places containing myriads of sub-microscopic (<1 micron) opaque particles that could be carbon, but cannot be positively identified. Quartz crystals are mainly sub- to anhedral and up to 0.15 mm in diameter. The limonitic relics commonly contain minor fine-grained quartz and have subhedral outlines up to 2 mm in diameter that are suggestive of either ferroan carbonate or iron sulfides (or possibly both). The field designation for this sample (?metarhyolite fragments in carbonaceous phyllite) appears appropriate.

Wolverine fisher zone **JH96-FZ7**: ?META-FELSIC VOLCANIC OR SILICEOUS SEDIMENT, COMPOSED OF QUARTZ-SERICITE-LIMONITE-?CARBON

Described as "black metarhyolite"; hand sample is dark grey, very fine-grained, and siliceous or cherty (harder than steel). The rock is not magnetic and shows only trace reaction to cold dilute HCl; modal mineralogy in thin section is approximately quartz 90%, sericite 10%, opaques (?carbon, limonite, rutile) 1% or less. As in other samples of the "metarhyolite" (FZ2/5), feldspar is not obvious by either twinning or relief difference against quartz. Most of the sample consists of <0.1 mm, an- to subhedral, interlocking quartz crystals with a slight tendency to elongation/flattening (length:width ratios up to 2.5:1) and some variation in grain size suggesting former ?stringers or veinlets up to 0.35 mm thick, although these could also represent metamorphic ?sweats. Sericite forms sub- to euhedral flakes mostly <50 microns in diameter, scattered throughout the rock but commonly concentrated in thin (<0.1 mm thick) wispy foliae, with concentrations of ultra-fine opaques (<10 micron, could be ?carbon), coarser subhedral opaques to 50 microns that could be ?sulfide, minor limonite and ?hydrobiotite. The mineralogy is permissive for either a meta-felsic volcanic that has been significantly silicified/sericitized, or a siliceous to cherty sediment.

Wolverine fisher zone **JH96-FZ8**: QUARTZ-?CLAY/SERICITE-RELICT PYRITE ROCK, POSSIBLY AFTER FORMER ?EXHALITE OR FELSIC VOLCANIC

Described as "quartz-pyrite"; hand sample is pale yellow-brown limonite stained, strongly disrupted, almost brecciated in appearance with angular ?fragments of quartz or siliceous rock up to almost 1 cm in diameter, some containing coarse cubic pyrite pseudomorphs, in a matrix of foliated, crenulated sericite-rich rock. The rock is not magnetic and shows only trace reaction to cold dilute HCl. In polished thin section, the quartz-rich fragments are composed of interlocking sub- to anhedral, commonly bladed or plumose crystals up to 1.6 mm in length (could be due to ?pressure shadows that formed around the pyrite). The intervening ?clay-sericite (virtually zero birefringence) is so strongly stained by yellowish limonite (?jarosite) that it is almost opaque. Areas of finer-grained quartz contain swarms of needle-like ?clay-sericite-limonite pseudomorphs that could be after former ?amphibole crystals up to 0.35 mm long. Although not visible in thin section, the slight reaction to HCl in hand sample suggests traces of calcitic carbonate are likely present in the relict pyrite casts. It is hard to be sure of the protolith for this intensely phyllic altered and deformed rock, but it could have been a siliceous exhalite or a strongly altered felsic volcanic.

Wolverine fisher zone **JH96-FZ11**: QUARTZ-RELICT PYRITE-?AMPHIBOLE OR SERICITE ROCK SIMILAR TO FZ-8, OR MORE STRONGLY SILICIFIED

Also described as quartz-pyrite; white, siliceous rock contains significant cubic casts that are likely after former pyrite crystals. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, strongly deformed quartz occurs as granulated, sutured, tightly interlocking crystals up to 1.2 mm in diameter with undulose extinction and strong fracturing. In places, wispy deformed foliae composed of needle-like ?clay-sericite-limonite pseudomorphs with near-zero birefringence or semi-opaque character, are similar to those in FZ-8, and possibly represent ?amphibole or sericite. The cubic pseudomorphs after ?pyrite are entirely plucked out (now filled only by epoxy).

Wolverine fisher zone **JH96-FZQFP**: SERICITIZED, SILICIFIED KSPAR PORPHYRY (?RHYOLITIC)

Pale grey, very siliceous rock containing large white feldspar crystals or shards up to 1 cm in diameter (partly sericite altered), and pale greenish patches (?sericite altered plagioclase and/or mafic crystals) in an aphanitic matrix. The rock is not magnetic and shows only trace reaction to cold dilute HCl. In thin section the phenocrysts have negative relief compared to quartz, display only simple twinning, and have microperthitic texture and small, -2V suggesting K-feldspar. Sericite appears to have replaced virtually all the ?plagioclase that was originally present in the rock, both as separate crystals mixed with K-feldspar, and the perthitic inclusions in the K-feldspar. Most of the Kspar appears unaffected by the sericitic alteration. In places secondary quartz rims or replaces the Kspar along fractures. The matrix consists of fine-grained (<0.1 mm) interlocking subhedral laths of alkali feldspar, likely mostly Kspar but possibly including some plagioclase, and minor subhedral quartz (mainly <75 microns). There is also a fairly well-developed network of hairline sericite-quartz fractures, likely representing hydrothermal alteration. Minor fine-grained (<15 micron) opaques found along these fractures are likely mostly rutile, but could include some limonite (traces of yellow ?jarosite and subhedral ?zircon to 65 microns are also present).

Plate 1

a) Fyre Lake **JH 96-62**: Porphyroblasts of garnet and ?pyrite in layered chlorite-quartz-epidote-green biotite-relict ?plagioclase schist (?metamorphosed intermediate volcanic). Transmitted light, uncrossed polars, field of view 2.5 mm wide.

b) Fyre Lake **JH 96-65**: Bladed amphibole (?tremolite-actinolite) in matrix of magnesian chlorite, meta-?ultramafic rock. Transmitted light, crossed polars, field of view 2.5 mm wide.

c) Fyre Lake **JH 96-DGA**: Relict microcline (slightly grid twinned) and quartz (sub-grained) ?phenocrysts in matrix of fine-grained quartz, ?plagioclase, chlorite, biotite, epidote; ?meta-quartz latite. Transmitted light, crossed polars, field of view 2.5 mm wide.

d) Fyre Lake **JH96-DGC**: Relict plagioclase phenocrysts in foliated fine-grained matrix of epidote-plagioclase-?quartz-chlorite-sericite-rutile, meta-intermediate volcanic (transmitted light, crossed polars, field of view 2.5 mm wide)

e) Kudz Ze Kayah **JH 97-Kudz Ze Kayah**: Euhedral pyrite (pyrite) in matrix of sphalerite (sphalerite) and magnetite (mt), minor galena (gn). Reflected light, uncrossed polars, field of view 1.9 mm wide.

f) Kudz Ze Kayah **JH 97-Kudz Ze Kayah**: Same area as above, but in transmitted light, uncrossed polars, 2.5 mm wide field of view, to show deep red-brown colour of Fe-rich sphalerite, quartz and carbonate gangue.

g) Wolverine **JH96-FZ5**: Stringers of coarser-grained quartz cutting matrix of fine-grained quartz and lensey sericite concentrations (?silicified, sericite altered ?metarhyolite). Transmitted light, crossed polars, field of view 2.5 mm wide.

h) Wolverine **JH96-FZQFP**: K-feldspar and sericitized ?plagioclase phenocrysts, secondary quartz and fine-grained feathery alkali feldspar matrix in ?rhyolitic porphyry. Transmitted light, crossed polars, field of view 2.5 mm wide.

Wolverine **JH96-WZ1**: INTENSELY SERICITE-EPIDOTE-CHLORITE-SPHENE ALTERED ?INTER-MEDIATE VOLCANIC PORPHYRY; TRACE ?SPHALERITE IN EPIDOTE-CHLORITE VEINS

Porphyritic rock, with bright green rhombic- to irregular-shaped ?relict phenocrysts up to 1.5 cm long set in a pale green-buff, aphanitic, scratchable matrix; traces of limonite-stained ?carbonate occur along hairline fractures (trace magnetic, trace reaction to HCl). Modal mineralogy in thin section is approximately:

Sericite	65%
Epidote	20%
Chlorite	10%
Sphene	3-5%
Limonite	<1%
Sphalerite (?)	tr

The relict phenocrysts are pseudomorphed by a mixture of sericite, epidote, and minor chlorite; they could have been either feldspar or a mafic mineral, but vaguely defined relict twinning suggests they were likely plagioclase. Sericite forms subhedral flakes mostly less than 35 microns in diameter; epidote forms sub- to euhedral crystals up to (rarely) 1 mm in diameter, with absence of pleochroism suggesting a low Fe content. The coarser epidote is mixed with chlorite booklets up to 0.25 mm in diameter and is associated with minor ?sphalerite (red-brown, moderate Fe content); these aggregates might more likely represent former mafic phenocrysts, or alteration along a veinlet. Chlorite forms subhedral flakes to 50 microns with very pale green colour, no pleochroism and length-fast birefringence suggesting moderately Mg-rich composition (F/M perhaps 0.4). In the matrix, sericite, epidote, abundant sphene and minor chlorite are intimately intergrown as subhedral crystals mostly <0.1 mm (commonly <30 microns) in diameter. Chlorite is so pale green that it is difficult to estimate its modal abundance with confidence. The fine felted texture is suggestive of a possible former trachytic groundmass of microlitic feldspar, or it could be merely the result of alignment of sericite flakes. The abundance of sphene and epidote suggests a former ?intermediate volcanic porphyry.

Wolverine **JH96-WZ2**: BRECCIA OF BASALTIC CLASTS (CLINOPYROXENE-PLAGIOCLASE ALTERED TO SERICITE-CHLORITE-SPHENE) IN COMMINUTED MATRIX OF THE SAME

Breccia, composed of angular clasts up to 1 cm in size supported by a fine-grained, buff-green matrix with minor limonitic fractures. The rock is not magnetic and shows only trace reaction to cold dilute HCl. In thin section, the clasts are composed of variably altered, variegated textured, mostly mafic (?basaltic) volcanics, and the matrix appears to consist of the same minerals as in the clasts, but more comminuted (mainly <0.1 mm in diameter). In the clasts, phenocrysts or interlocking euhedral crystals of pale brownish ?acmitic clinopyroxene up to about 0.5 mm long are common, with extinction angle near 40-45 degrees. In some clasts, they are set in a matrix of interlocking plagioclase feldspar laths (likely calcic; eu- to subhedral outlines up to 0.5 mm long). However, in most cases they have been altered to a very fine-grained (<10 micron) mixture of sericite and chlorite. A brownish-green chlorite is common as alteration product of the pyroxene or less commonly in relict ?amygdules; it forms subhedral flakes to 50 microns that are length-slow and probably Fe-rich. Minor bright green amphibole (probably also Fe-rich, actinolitic), minor epidote and quartz replace pyroxene in places. Sphene is common throughout, forming subhedra to 50 microns both as microphenocrysts/aggregates and in the groundmass of the clasts; this suggests a mafic to intermediate rock. The matrix is commonly almost semi-opaque due to the abundance of sphene and ?pyroxene, and limonite commonly along fractures.

Wolverine **JH96-WZ6**: EPIDOTE-CHLORITE-ACTINOLITE-SPHENE ALTERED ?GABBRO/DIORITE

Green-grey, porphyritic mafic volcanic containing about 20% dark green-black altered ?mafic crystals and abundant yellow-green ?epidote-altered plagioclase in an ?aphanitic matrix. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Plagioclase	30%
Clinopyroxene	20%
Epidote	20%
Chlorite	15%
Amphibole (secondary, actinolitic)	10%
Sphene	3%
Clay-sericite	2%

In thin section, this actually appears to be a crystalline rock, mainly composed of euhedral crystals of altered clinopyroxene and plagioclase up to 3 mm in diameter, plus chloritic relics up to 2 mm in diameter after

some former mafic mineral (such as ?orthopyroxene or ?olivine). Clinopyroxene is mainly colourless with extinction angle near 45 degrees, and is mostly partly altered along fractures and margins to pale green chlorite (sub- to euhedral flakes to 0.1 mm, F/M likely near 0.5), epidote (sub/euhedral crystals to 0.5 mm, yellow pleochroism indicating moderate Fe content), and fibrous pale green (?actinolitic) amphibole to 0.35 mm. It is intergrown with skeletal brown sphene euhedra up to 0.5 mm. Plagioclase crystals are altered to clay-sericite (flakes up to 15 microns) and epidote (subhedra to 0.5 mm). This sample likely represents a propylitic (epidote-chlorite-actinolite-sphene-clay/sericite) altered or greenschist facies metamorphosed pyroxene gabbro or diorite.

Wolverine *JH96-WOLV4*: UNUSUAL MAGNETITE-QUARTZ-SERICITE-AMPHIBOLE-BIOTITE-?BARITE PLAGIOCLASE-PYRITE AND QUARTZ-?BARITE-AMPHIBOLE-LIMONITE-BIOTITE ROCK

This sample consists about half semi-massive magnetite/minor pyrite, and half white to pale greenish siliceous rock; there is no reaction to cold dilute HCl. In thin section, the magnetite-rich portion consists of euhedral, 0.5-1 mm magnetite crystals and rare pyrite euhedra up to 1.5 mm in diameter, in a matrix of quartz, sericite, amphibole, biotite (major pale green and minor dark brown), plagioclase, and a high-relief, low to moderate birefringence mineral that could be ?barite or zoisite (Fe-poor epidote), all jumbled together with the appearance of detrital grains that have been derived by erosion of a suite of fairly mafic rocks. By contrast, the pale portion of the sample consists mainly of subhedral quartz up to about 0.15 mm diameter with significant amounts of the unidentified high-relief mineral (to semi-massive, subhedra to 0.25 mm, interference figure suggests small positive 2V, moderately developed cleavages at right angles, length-slow, all suggestive of ?barite, but this is speculative in absence of any geochemistry to support such an identification). A fibrous, length-slow mineral (needles to 0.15 mm long) could be ?amphibole; minor pale green and brown biotite are present, as in the other half of the rock, and areas of opaque to deep red-brown ?limonite may mark the sites of oxidation of former ?sulfide minerals. This is an unusual rock, particularly if it does contain barite as proposed; it could be from a mineralized horizon. Note that JH96-FZ10 from the Fisher zone is described as barite-magnetite rock; in polished thin section, this finely laminated, fine-grained (mainly <0.25 mm) rock contains about 20% barite and 15% magnetite, minor goethite, green biotite, hydrobiotite and rare pyrite, mixed with 65% quartz. Barite layers up to 0.5 cm thick are present in what is likely a metamorphosed exhalative rock.

PAK PROPERTY

A group of samples (**JH 97-184, 185, 188, 191**) is described as coming from the PAK locality. They are all siliceous, felsic ?volcanic to ?high-level intrusive rocks that may have been about dacite in composition, ranging from quartz-feldspar-?biotite phyrlic (160) to ?feldspar phyrlic (184) to finely laminated (185) to plagioclase phyrlic in a phaneritic quartz-plagioclase-calcite-biotite groundmass (188; Cretaceous dyke) to intensely silicified ?metavolcanic (or ??siliceous metasediment) in 191.

Pak *JH 97-160*: PHYLLIC (SERICITE-QUARTZ-PYRITE-RUTILE) ALTERED, QUARTZ-PLAGIOCLASE-?BIOTITE PHYRIC, ?DACITIC HIGH-LEVEL PORPHYRY

Pale grey-green, siliceous (mainly harder than steel) quartz-probably feldspar porphyritic felsic rock; non-magnetic, no reaction to cold dilute HCl. In thin section, the rock is composed of about 10-15% 1-3 mm sub- to euhedral quartz, 15-20% 1-2 mm sub- to euhedral relict plagioclase, and scattered (<5%) pyrite cubes up to 1.5 mm in diameter, in a very fine-grained (25-35 micron) groundmass of quartz and interstitial sericite (likely after feldspar). Traces of rutile mixed with coarser flakes of sericite (muscovite) up to 0.2 mm in diameter suggest the presence of former ?biotite. Thus the suggestion is of an original quartz-plagioclase-?biotite phyrlic rock, either high-level intrusive or extrusive, of possible ?dacitic composition and possibly weakly to moderately phyllic (sericite-quartz-pyrite-rutile) altered.

Pak *JH 97-184*: FOLIATED, DEFORMED ?FELDSPAR PORPHYRITIC ?DACITIC VOLCANIC (QUARTZ-FELDSPAR-SERICITE SCHIST)

Foliated, buff-white to greenish, probably felsic metavolcanic rock (relict nodular feldspar texture between wispy foliae of greenish sericite); not magnetic, no reaction to cold dilute HCl. In thin section, the rock is composed of alternating laminae rich in coarse sericite (muscovite) as sub- to euhedral flakes up to 1 mm in diameter, or rich in 0.1-0.2 mm sub- to anhedral quartz and feldspar (relief distinctly negative

compared to quartz, could be either albite, although untwinned, or Kspar; etching and staining tests required to distinguish between these possibilities). Rare aggregates of feldspar up to 0.75 mm in diameter suggest the possible former presence of feldspar phenocrysts in a felsic, possibly dacitic, volcanic rock prior to deformation. Traces of limonite and rutile occur in the sericitic layers, but there are no suggestions of former sulfides.

Pak JH 97-185: LAMINATED QUARTZ-FELDSPAR-SERICITE-LIMONITE-RUTILE ROCK, POSSIBLY ORIGINALLY FELSIC VOLCANIC ROCK

White to buff, fine-grained, finely laminated and faintly limonite stained, siliceous (harder than steel), felsic-looking metavolcanic rock; not magnetic, no reaction to cold dilute HCl. In thin section, the rock is composed mainly of fine-grained (<0.1 mm) granular, sub- to anhedral quartz and somewhat lesser, interstitial, feldspar distinguished by negative relief compared to quartz. Feldspar crystals are untwinned and could be either albite or Kspar. The greenish cast to the rock is caused by minor flakes of euhedral sericite, mostly <0.1 mm in diameter. There are traces of limonite and rutile. The finely laminated structure of the rock is caused by slight variations in grain size and quartz/feldspar ratio of the <0.25 mm thick layers, due either to original flow banding, metamorphic foliation, or both.

Pak JH 97-188: MILDLY CALCITE-SERICITE-CHLORITE-QUARTZ ALTERED, HIGH-LEVEL BIOTITE DACITE OR GRANODIORITE INTRUSIVE

Grey-white, finely "salt-and-pepper" textured, Cretaceous high-level intrusive rock; non-magnetic, but reacts to cold dilute HCl. In thin section, the slide consists of intergrown feldspar and quartz with lesser carbonate, biotite and opaques. The feldspar is twinned, with extinction angle up to about 15 degrees and relief distinctly negative compared to quartz indicating albite composition; it forms subhedral to rounded crystals up to 1.8 mm in diameter, in a finer-grained but phaneritic matrix of quartz, plagioclase, carbonate and minor biotite mostly <0.2 mm in diameter (quartz locally up to 0.5 mm; carbonate, likely mostly calcite, to 0.5 mm). Biotite is dark brown to blackish, partly altered to dark green chlorite, and associated with minor alteration of plagioclase to very fine sericite and carbonate. Opaques are likely mostly limonite after pyrite, forming aggregates up to 1 mm long along fractures associated with carbonate and sericite. The original rock was likely a hypabyssal intrusive of possible biotite dacite composition.

Pak JH 97-191: SILICIFIED HIGH-LEVEL INTRUSIVE LIKE 97-188, METAVOLCANIC, OR SILICEOUS METASEDIMENT (QUARTZ-SERICITE+BIOTITE, PYRITE/LIMONITE)

Similar in appearance to 188 (grey-white, siliceous, granular texture possibly obscured by deformation); weakly magnetic, but no reaction to cold dilute HCl. However, in thin section it appears to consist entirely of granular, sub- to euhedral quartz crystals up to about 0.5 mm in diameter, with minor interstitial sericite (subhedral flakes to 0.25 mm diameter) and traces of opaque (mostly sulfide such as pyrite, partly oxidized to limonite). Feldspar is not detectable either by twinning or relief difference, but the presence of pale brownish, washed-out biotite suggests a possible link to the previous sample. It is possible that this represents a silicified version of 97-188 or a silicified felsic metavolcanic rock, or that it is a siliceous metasediment.

ARGUS PROPERTY

The six samples in this suite include three of meta-gabbro or more mafic rock (**DDH ARG 96-03 86.9m** and **91.4m**, and **96-07 119.7m**), two of metamorphosed volcanic wacke or felsic volcanic (**DDH ARG 96-04 107.0m**, **96-05 145.3m**) and one of tuffaceous wacke (**JH 96-57b**). The meta-gabbro samples are composed of plagioclase-carbonate-chlorite-sericite-sphene/rutile + magnetite-apatite, or aggregates of dolomitic carbonate-rutile/sphene and secondary quartz that may represent former plagioclase, in a matrix of chlorite-rutile and quartz. The meta-volcanic wacke or felsic volcanics are composed of quartz-carbonate-sericite-variable plagioclase-chlorite-minor rutile; the tuffaceous wacke is similar, and consists of quartz-plagioclase-sericite-minor chlorite and significant limonite after pyrite. The latter is the only "mineralized" sample of the suite (the only one to contain significant, partly oxidized, sulfide). It is not clear whether the abundant quartz in the latter samples represents former phenocrysts or shards in a volcanic rock, or detrital quartz in a sedimentary (epiclastic) rock. In any case, there is no

obvious connection of any samples to base-metal massive sulfide mineralization. Individual descriptions of the samples follow, followed by photomicrographs to illustrate major mineral and textures.

Argus **JH96-57b**: ?TUFFACEOUS WACKE/SANDSTONE (QUARTZ, PLAGIOCLASE CRYSTALS IN MATRIX OF QUARTZ-SERICITE-PLAGIOCLASE-OXIDIZED PYRITE-CHLORITE)

Described as sandstone?; hand specimen is pale green-grey, siliceous, with a texture suggestive of a sheared quartz-feldspar porphyry. The rock is not magnetic but shows minor reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	50%
Plagioclase (?albitized)	35%
Sericite	10%
Opaque (mostly limonite; after pyrite)	3-5%
Chlorite	1%

In thin section, this sample does in fact consist of sheared, rounded crystals of quartz and plagioclase in a somewhat foliated matrix of the same minerals plus sericite and minor opaques (mostly limonite, in places surrounding and replacing cores of relict pyrite). There is only minor chlorite. Proportions of quartz and plagioclase are difficult to estimate due to general lack of twinning in plagioclase and low relief difference between the two minerals, or separation by micaceous minerals. Extinction on 010 up to 13 degrees and negative relief of some plagioclase suggests a composition near oligoclase-albite (possibly secondary, i.e. albitized). Minor alteration to sericite is common in plagioclase. Sericite in the matrix forms subhedral flakes up to about 0.25 mm in diameter that define the foliation. Rare chlorite is pleochroic in pale green and length-fast, suggesting moderately Fe-rich composition (Fe/Fe+Mg, or F/M, ratio possibly near ?0.5).

Quartz and plagioclase crystals are up to 2 mm in diameter and could represent former phenocrysts in a volcanic porphyry, except that quartz appears to be more abundant than would be expected in such a rock. Possibly the sample represents a tuff or epiclastic rock derived from an eroding volcanic terrane (tuffaceous wacke/sandstone).

Argus **DDH ARG 96-03 86.9m**: ?METAGABBRO (PLAGIOCLASE-CARBONATE-CHLORITE-SERICITE-SPHENE/RUTILE-MAGNETITE-APATITE)

Dark green, medium-grained granular rock, mostly softer than steel and containing scattered large (to 4 mm) porphyroblasts of ?magnetite. There is moderate reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Plagioclase (could include some quartz)	40%
Carbonate (?mainly calcite)	30%
Chlorite	20%
Sericite	5-7%
Sphene/rutile, ?ilmenite	2-3%
Opaque (?mainly magnetite)	1-2%
Apatite	<1%

This sample consists mainly of a granular mosaic of plagioclase, flakey chlorite and sericite, hosting abundant porphyroblastic carbonate and scattered large crystals of magnetite. Fine opaques include both wispy foliae of sphene/rutile, and clusters of ?ilmenite/sphene with eu- to subhedral outlines suggestive of skeletal replacements of ?former mafic crystals up to 1.5 mm in diameter.

Plagioclase forms small interlocking sub- to anhedral crystals (<0.2 mm in diameter) that are only rarely twinned, making distinction from possible quartz difficult (no relief difference with untwinned crystals is apparent). Thus quartz may be present but is not detectable or quantifiable, and is included with the estimate for plagioclase. Chlorite tends to occur interstitially to plagioclase, but sericite (muscovite) grows into and across plagioclase. Chlorite forms subhedral flakes mainly <0.1 mm in diameter, with optical character (bright yellow to green pleochroism, length-fast weakly anomalous green birefringence) suggesting moderately Fe-rich composition, F/M perhaps 0.5-0.6). Sphene and ?rutile form tiny crystals mainly <35 microns in size, generally associated with the chlorite. Sericite flakes are euhedral, up to 0.3 mm in diameter, and also pale green (possibly Fe-rich, i.e. phengite). Carbonate clusters up to 1 mm in diameter are mostly irregular in outline; they could represent former ?mafic crystals. Small euhedra of apatite to 0.15 mm occur associated with chlorite.

The overall impression is of a metamorphosed mafic rock such as ?gabbro (abundance of chlorite, carbonate, plagioclase, sphene/rutile, magnetite, ?ilmenite, apatite).

Argus **DDH ARG96-03 91.4m**: METAMORPHOSED ?GABBRO OR MORE MAFIC ROCK (CHLORITE-CARBONATE-QUARTZ-RUTILE)

Fine ?feldspar phyric volcanic or hypabyssal porphyry with dark green matrix, very slightly magnetic and showing minor (slow) reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Chlorite	45%
Carbonate (?dolomitic)	35%
Quartz (?largely secondary)	15%
Rutile, ?minor sphene	5%

In thin section, the white ?feldspar relics are subhedral in outline, up to 2 mm in size, and are pseudomorphed by coarse porphyroblastic carbonate crystals or aggregates up to 2.5 mm in diameter, mixed with variable amounts of quartz (aggregates of subhedral <0.25 mm crystals). Carbonate contains abundant wispy trails of semi-opaque inclusions, especially in the cores and mostly <10 microns in size, that may be rutile and/or ?sphene; these are not usual for relict plagioclase, and together with the ?dolomitic character of the carbonate, introduce the possibility that the phenocrysts were originally mafic crystals, not plagioclase. The matrix between these relict crystals consists mainly of chlorite (subhedral flakes to 0.15 mm diameter with optical properties similar to those described for ARG 96-03 86.9 m), and lesser needle-shaped yellow-brown euhedral rutile (to 0.2 mm long) that impart the yellow colour to the matrix in hand specimen.

This sample is very rich in TiO₂ and as such may be a metamorphosed ?gabbro or possibly more mafic (?ultramafic) rock; metamorphism has possibly remobilized TiO₂ into former ?plagioclase sites. Quartz may be largely secondary.

Argus **DDH ARG 96-04 107.0m**: METAMORPHOSED ?VOLCANIC WACKE OR ?FELSIC VOLCANIC (QUARTZ-CARBONATE-SERICITE-PLAGIOCLASE-CHLORITE-MINOR RUTILE)

Pale grey-white, siliceous (harder than steel) rock with foliae of greenish ?chlorite-sericite. There is essentially no magnetism and no reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	50%
Carbonate (?dolomitic)	20%
Sericite	15%
Plagioclase (?albitic)	10%
Chlorite	3-5%
Rutile	1%

This section consists mainly of areas of quartz and lesser carbonate, plagioclase and sericite, separated by wispy irregular foliae of sericite and minor rutile, or fracture-controlled chlorite. In the former, quartz forms irregular aggregates to about 1 mm diameter composed of anhedral crystals mostly <0.5 mm in size, characterized by abundant minute fluid inclusions that impart a milky appearance to the quartz. Carbonate occurs as highly irregularly-shaped ?porphyroblastic (small inclusions of quartz are common) aggregates up to 1.5 mm across composed of subhedral crystals to 0.75 mm size, possibly mainly ?dolomitic in composition. Scattered sub- to anhedral plagioclase crystals are up to 0.5 mm in diameter, distinguished by twinning and negative relief compared to quartz (indicating albitic composition).

Sericite forms subhedral flakes to about 0.2 mm in diameter containing wispy semi-opaque foliae that in places can be resolved as minute (<15 micron) euhedral crystals of ?rutile. Chlorite forms fine subhedral flakes <15 microns in diameter (length-fast, no pleochroism; likely more Mg-rich than higher in this DDH, with F/M possibly 0.4), mainly confined to fracture networks that are <1 mm thick.

Due to the metamorphism, it is difficult to be sure what this sample represents; it could have been a felsic volcanic or a volcanic-derived sediment. The abundance of quartz and apparent paucity of plagioclase makes me suspect the latter.

Argus **DDH ARG 96-05 145.3**: METAMORPHOSED ?VOLCANIC WACKE OR ?FELSIC VOLCANIC (QUARTZ-SERICITE-CARBONATE-CHLORITE-PLAGIOCLASE-MINOR OPAQUE-RUTILE)

Pale grey-green, fine- to medium-grained quartz-sericite schist with bluish-grey ?quartz eyes, minor pyrite and cut by stringers of quartz-minor carbonate (react to cold dilute HCl. Rock is non-magnetic; modal mineralogy in thin section is approximately:

Quartz	60%
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Sericite	15%
Chlorite (2 varieties)	10%
Carbonate (?mainly calcite)	10%
Plagioclase	3-5%
Opaque (pyrite, ?carbon)	<1%
Rutile, rare ?sphene	<1%

This section consists essentially of scattered (about 10-20%) quartz "eyes" in a matrix of finer quartz, sericite, chlorite, and carbonate. The "eyes" are up to 3.5 mm in maximum dimension, rounded to subrounded in shape, and consist of either aggregates of interlocking quartz anhedral up to 1 mm in size, or less commonly single subhedral crystals to 1.5 mm size. It is not clear whether they are relict shards or phenocrysts from a volcanic rock (in part recrystallized due to deformation and metamorphism), or detrital quartz grains/aggregates. The matrix consists of anhedral to subhedral, interlocking quartz crystals mainly less than 0.15 mm in diameter, with irregularly-shaped patches up to 1 mm across (?relict mafic crystals), composed of chlorite, carbonate, and sericite. Chlorite forms subhedral flakes up to 0.1 mm in diameter that are pale yellow-green, non-pleochroic, and have length-slow, weakly anomalous birefringence indicating median composition with F/M near 0.5. Rare plagioclase (twinned, relief close to that of quartz) is mixed with the chlorite as subhedra to 0.25 mm. Sericite forms subhedral flakes to 0.5 mm diameter, commonly intimately interleaved with the chlorite; carbonate forms irregular aggregates to 0.5 mm. Minute opaques (1-5 microns) are associated with sericite; rarely, euhedral needles of rutile to 15 microns and scattered crystals of ?sphene to 50 microns are seen, but the bulk of the fine opaques cannot be resolved optically. They may be ?carbon; rare coarser pyrite crystals are up to 0.3 mm in size.

The rock is cut by scattered veinlets composed of carbonate (mainly calcite, subhedra to 1 mm long) and very fine-grained chlorite similar to that in veinlets in DDH ARG 96-04 107.0m. This sample appears to be somewhat similar to 96-04 107.0 in composition (quartz-rich, minor plagioclase, chlorite-carbonate-sericite aggregates). Again, it could represent a former ?felsic-intermediate volcanic, or a volcanic wacke.

Argus **DDH ARG-96-07 119.7m**: METAMORPHOSED ?GABBRO OR MORE MAFIC ROCK (CARBONATE-CHLORITE-QUARTZ-RUTILE)

Grey-white, siliceous (harder than steel) rock somewhat similar to 96-03 91.4m (white to buff-coloured relict crystals that look to be after ?plagioclase feldspar, but react slowly to cold dilute HCl. The rock is very weakly magnetic in some areas. Modal mineralogy in thin section is approximately:

Carbonate (?dolomitic)	50%
Chlorite	25%
Quartz (?largely secondary)	20-25%
Rutile, trace ?sphene	2-3%

In this sample, as in 96-03 91.4m, relict ?feldspar sites have irregular to subhedral outlines up to 2.5 mm in maximum dimension and are replaced by cores of carbonate (subhedral crystals to 2 mm diameter) and rims of fine-grained quartz (subhedral crystals to 0.35 mm). Interstitial areas are composed of aggregates of fine flakey chlorite (subhedra to 0.1 mm, near-zero to length-fast birefringence, virtually non-coloured and non-pleochroic, suggesting median composition near F/M of 0.4-0.5). Abundant rutile is contained in the chlorite, forming euhedral yellow-brown needles up to 0.2 mm long, and as finer crystals mainly <15 microns in size in the carbonate, accompanied by minor ?sphene to 25 microns in diameter.

As in 96-03 91.4m, what appear to be relict plagioclase feldspar laths are replaced by cores of ?dolomitic carbonate, containing significant TiO₂ minerals, and rims of ?secondary quartz, in a matrix of chlorite-rutile and quartz. This sample may also represent a meta-gabbro or, less likely, a ?more mafic rock.

LEAGUE PROPERTY

League **JH 96-28**: ?K-FELDSPAR, MINOR ?QUARTZ PHYRIC HYPABYSSAL ?RHYOLITE PORPHYRY, PARTLY SILICIFIED AND SERICITE-CARBONATE ALTERED

Hand sample consists of large (to almost 1 cm) white feldspar phenocrysts in a pale green, siliceous (harder than steel) fine-grained matrix stained by minor black ?Mn-oxides. The rock is not magnetic and shows only minor reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Alkali feldspar (?Kspar and ?plagioclase)	60%
Quartz	30%

Sericite	5-7%
Opaque (limonite, ?rutile)	1-2%
Carbonate (?mainly calcite)	1-2%
Apatite	<1%

The large feldspar phenocrysts in this sample are mainly euhedral in outline but with features suggestive of resorption; they appear to be ?K-feldspar based on appearance, negative biaxial interference figure, and relief negative compared to quartz. However, confirmation of this identification would require staining of the offcut. Some phenocrysts are altered to fine sericite and acicular prisms of apatite (up to 0.2 mm long).

The groundmass or matrix is composed of very fine-grained, tightly interlocking, subhedral crystals of alkali feldspar and somewhat lesser quartz, both mostly <50 microns in diameter. It is not certain whether this alkali feldspar is mostly albite, mostly K-feldspar, or both; staining tests would be required to resolve this uncertainty, but for the present, lack of relief difference of matrix feldspar against phenocrysts suggests both may be K-feldspar. Sericite is abundant, forming fine subhedral flakes to about 75 microns that cause the pale greenish colour in the matrix in hand specimen.

Clots of quartz, or less commonly quartz and carbonate, with rounded outlines up to 1 mm in diameter could represent former ?quartz phenocrysts, amygdules, or possibly alteration. The latter interpretation is partly supported by the presence of irregular veinlets of quartz and carbonate that cut the feldspar phenocrysts and the presence of opaques along similar quartz-carbonate-sericite fractures/veinlets. Opaques are mostly subhedral in outline, up to 0.3 mm in diameter, and could represent partly oxidized sulfides and in places ?rutile (very dark to almost opaque; possibly Fe-rich).

The composition of this ?K-feldspar-?minor quartz porphyry could be rhyolitic; it appears to have undergone significant alteration to quartz, sericite, carbonate, rutile and possibly minor sulfide.

MINK PROPERTY

Mink property AMPHIBOLE-PLAGIOCLASE GABBRO (ACCESSORY ?ILMENO-MAGNETITE) ALTERED TO QUARTZ-CARBONATE-EPIDOTE-CHLORITE-SPHENE-RUTILE

Hand sample is a dark green, fine to medium grained, mafic plutonic rock of about gabbro composition. The rock is slightly magnetic and reacts to cold dilute HCl; modal mineralogy in thin section is approximately:

Amphibole	40%
Plagioclase (oligoclase)	30%
Quartz (secondary)	15%
Carbonate (mainly calcite)	5%
Epidote	5%
Sphene/rutile	3-5%
Chlorite	1-2%
Opaque (?ilmenite, magnetite)	tr

This is a mafic rock, composed mainly of subhedral amphibole crystals and interstitial, mostly altered plagioclase, and characterized by large, unusually abundant relict TiO₂ crystals (now mostly sphene). Amphibole crystals are ragged to partly fibrous (replaced by secondary amphibole and in places chlorite and carbonate), up to 3 mm in length. Pale green to olive-green pleochroism suggests a hornblende or actinolitic hornblende composition. Chlorite flakes are sub- to euhedral and up to 0.25 mm in diameter, with optical characteristics (pale green pleochroism, length-fast, weakly anomalous birefringence) indicating moderate F/M ratio near ?0.5. Carbonate forms subhedral crystals up to 1 mm in diameter, likely mostly calcite to judge by the reaction in hand specimen. The texture is ophitic, with slightly smaller, interstitial plagioclase relict crystals having subhedral to ragged (altered) outlines up to 1.5 mm in diameter. Plagioclase in places displays twinning with extinction Y⁰¹⁰ of 10 degrees; this, with relief close to that of quartz, indicates a composition near An₂₅, oligoclase. Most crystals are extensively replaced by fine-grained (20-50 micron) subhedral quartz that tends to spread out from narrow hairline fractures, and also to clots of tiny (20-40 micron) epidote crystals and 10-20 micron chlorite flakes, plus in places ragged subhedra of carbonate.

The titania relics, possibly originally ilmenite or ilmeno-magnetite, have euhedral outlines up to 2 mm long and are now composed of fine-grained (20 micron) aggregates of sphene, with traces of similar-sized rutile and minor opaque (?ilmenite) at the cores.

Plate 2

a) Wolverine **JH96-WZ1**: Possible veinlet of epidote-chlorite-minor ?sphalerite (black) cutting sericitized ?plagioclase phenocryst in fine-grained, altered matrix of sericite, epidote, chlorite and sphene. Transmitted light, crossed polars, field of view 2.5 mm wide.

b) Wolverine **JH96-WZ2**: Clasts of clinopyroxene-plagioclase ?basalt and chlorite-epidote-quartz altered volcanic, in comminuted matrix of altered plagioclase and pyroxene plus sphene, and limonite along fractures. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

c) Wolverine **JH967-WZ6**: Crystals of clinopyroxene (cpx) and plagioclase (pl) altered to epidote (ep), chlorite (ch) and amphibole (ac); skeletal sphene crystals, in altered gabbro or diorite. Transmitted light, crossed polars, field of view 2.5 mm wide. **Plate 13**

d) Wolverine **JH96-WOLV4**: Semi-massive ?barite (cleavages), magnetite (euhedral opaque), limonite (anhedral opaque), minor pale green biotite (bright colours), minor quartz. Transmitted light, crossed polars, field of view 2.5 mm wide.

e) Argus **JH 96-57b**: Quartz (quartz) and plagioclase (pl) crystals, clots of oxidized pyrite (black) in matrix of quartz and sericite (bright colours). Transmitted light, crossed polars, 2.5 mm wide field of view.

f) Argus **DDH ARG 96-03 86.9m**: Relict ?mafic crystal outlined by skeletal opaques and carbonate (cb) plus rutile (ru); white is plagioclase, green is chlorite. Transmitted light, uncrossed polars, 2.5 mm field of view.

g) League **JH 96-28**: ?Rhyolite porphyry from League prospect, showing partly resorbed ?K-feldspar and recrystallized ?quartz phenocrysts in a matrix of fine-grained quartz and ?K-feldspar plus secondary sericite. Transmitted light, crossed polars, field of view 2.5 mm wide.

h) **MINK-1**: Ragged, carbonate-chlorite altered amphibole (am), quartz-epidote altered plagioclase, sphene-rutile altered ?ilmeno-magnetite in gabbro; transmitted light, crossed polars, field of view 2.5 mm.

MONEY PROPERTY

The Money prospect lies 5 km east of the Wolverine deposit in the Campbell Range belt; host rocks consist of a thick sequence of pillowed and pillow breccia basalts intercalated with mudstone and chert (Hunt, 1998), typical of a Besshi-type VMS deposit setting. Mineralization, consisting of a tabular massive sulfide layer defined for 50 m on strike, 130 m down dip and 1 m thick, is located within a sequence of mafic flows and breccia and is marked by maroon oxidized fine-grained sediments. The metals present include Cu with lesser Zn, Au and Ag (Baknes, 1997; in Hunt, 1998), again typical of a Besshi-type deposit.

Petrography of the 11 samples examined indicate a suite of mafic, likely basaltic volcanics (**JH97-123, 124B, 132, 141; JH96-70b, 71c**), and volcanic wackes likely derived from similar mafic volcanic and quartz-bearing terrane (**JH97-120, 125**). Possibly pillowed (meta-) basalts in 123, 124B and 132 are composed of amphibole, chlorite, epidote, plagioclase, calcite, and sphene/rutile; possible pillow breccias in 70b, 71c have "quenched" textures but similar mineralogy (clasts composed of fine fibrous amphibole and lesser sphene in matrix of calcite-chlorite/biotite-epidote-sericite-sphene/rutile); a possible feeder dyke/sill in 141 has a diabasic texture of plagioclase laths in a matrix of clinopyroxene altered to amphibole-chlorite-epidote-sphene. Possible volcanic wackes (120, 125) consist of small (<0.5 mm) clasts of quartz, lesser plagioclase, and lithic material in a comminuted matrix of chlorite, quartz, sericite and opaques.

Altered equivalents **JH96-70A** and **71d** appear to be ?mafic volcanics (possibly tectonically interleaved with siltstone in 70A) that have been strongly (70A) to intensely (71d) silicified and partly pyritized. In spite of the felsic appearance, especially in 71d, the abundance of relict rutile/sphene suggests derivation from a mafic volcanic precursor; stringery distribution of pyrite and rare sphalerite suggests these samples could come from a stockwork or feeder zone to the massive sulfides (pyrite-quartz-minor chalcopyrite) that are sampled in **JH96-71A**.

Thus the observed petrography is entirely consistent with classification of the Money prospect as a Besshi-type volcanogenic massive sulfide deposit.

Money **JH96-71A**: MASSIVE PYRITE-MINOR CHALCOPYRITE IN QUARTZ GANGUE (FAINTLY LAYERED, RARE ?REMNANT ATOLL AND "RADIAL BOMB" PRIMARY TEXTURES)

Fine-grained, semi-massive pyritic sulfides with faintly layered aspect caused by variations in concentration of sulfides. The hand specimen (offcut slab) is siliceous (harder than steel), non-magnetic, and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	60%
Quartz	35%
Chalcopyrite	5%

Pyrite is concentrated in crude layers up to about 1 cm thick alternating with pyrite-poor, quartz-rich layers of similar thickness. Most pyrite crystals are sub- to euhedral cubes less than about 1 mm in diameter. Chalcopyrite is common, although not abundant, mostly forming irregular-shaped masses up to 2 mm across that loosely infill spaces between pyrite crystals, or smaller subhedra that fill cracks or atolls in pyrite. Apart from rare curvilinear (?remnant colloform) and scattered atoll and/or "radial-bomb" (Leitch, 1990) texture, little remains of any primary textures. It is likely that ongoing hydrothermal recrystallization at the time of mineralization (e.g., Leitch, 1981), and subsequent metamorphism, has destroyed most of the primary textures.

Gangue is mainly quartz, forming sub- to anhedral, tightly interlocking crystals to 0.45 mm, or commonly bladed lamellar crystals to 0.6 mm long in pressure shadows near and between the coarser pyrite crystals. However, there are also patches of very fine-grained (<40 micron) quartz and similar-sized to 0.1 mm pyrite, and in places the quartz appears to be distributed along short discontinuous veins less than 1 mm thick, sub-parallel to the layering (these are likely to be ?metamorphic sweats).

Money **JH96-70A**: ?TECTONICALLY INTERLEAVED ALTERED BASALT (CHLORITE-PYRITE-QUARTZ-SPHENE) AND SILICIFIED SILTSTONE (QUARTZ-PYRITE-SPHALERITE)

Siliceous, white, and pale green, soft (chloritic) rock containing minor wispy/lensey pyrite, partly oxidized to reddish-brown limonite along fractures. The rock is not magnetic and shows no reaction to cold dilute HCl. Mineralogy in polished thin section is approximately:

Quartz (?largely secondary)	70%
Chlorite	20%
Pyrite	7-10%

Sphene	1-2%
Sphalerite	<1%

Siliceous portions of the slide are composed almost entirely of quartz (variations in texture and apparent relief appear to be caused by varying abundances of micron-sized fluid inclusions; no feldspar can definitely be identified by relief difference against quartz). Textures of the quartz vary from fine-grained granular or sucrosic (mainly <25 microns) to subhedra up to 0.5 mm controlled along highly irregular veinlets or patchy clots, to bladed lamellar up to 0.25 mm long in pressure shadows around pyrite crystals. Most of the quartz appears to be secondary. Minor chlorite (flakes to 0.1 mm) and sphene (aggregates with euhedral outlines up to 0.1 mm diameter) occur in the siliceous portions of the slide, generally associated with pyrite.

In the chloritic portions of the slide, chlorite forming subhedral flakes mostly <0.1 mm in diameter is mixed with lesser quartz, pyrite, and significant sphene plus minor limonite. Sphene aggregates are generally more elongated and wispy than those in the siliceous portion of the rock, suggesting deformation has been concentrated in these softer parts. The abundance of chlorite and sphene in these parts suggests a fairly mafic precursor rock; siliceous parts could represent either silicified volcanics or interbedded or tectonically interleaved slivers of sedimentary rock such as siltstone.

In the siliceous portions, pyrite mostly occurs as disseminated cubic crystals up to 0.85 mm in diameter; rare sphalerite forms subhedral masses up to 0.75 mm in diameter with pale yellow colour indicating a low Fe content. Clots of pyrite up to 3 mm long occur in quartz veins. In the chloritic portions, pyrite is cubic but finer-grained (mostly less than 0.1 mm). Chalcopyrite is not obvious in the section.

Money JH96-71d: INTENSELY SILICIFIED, STRINGERY QUARTZ-PYRITE-MINOR ?CLAY-RUTILE ?MAFIC VOLCANIC ROCK

Described as quartz-pyrite breccia in field notes; offcut slab shows a white, siliceous rock (harder than steel) containing minor disseminated pyrite, and vuggy/limonitic portions where pyrite has been leached out. The rock is not magnetic and shows no reaction to cold dilute HCl. Mineralogy in polished thin section is dominated by quartz (largely secondary, veinlet-controlled subhedra up to 3 mm long). Lesser pyrite forms cubic crystals up to about 1 mm in diameter, mainly concentrated along the veinlets where it is associated with patches up to 1 mm across of ?clay (minute flakes mainly <15 microns in diameter with near zero birefringence, negative relief compared to quartz). Minor rutile forms subhedral crystals to 30 microns (aggregates to 0.1 mm), suggesting that this sample could have been derived by intense silicification of a ?mafic volcanic rock, such as would be expected in the footwall stringer zone of a massive sulfide deposit.

Money JH96-70B: ?PILLOW BRECCIA (AMPHIBOLE-SPHENE RICH CLASTS IN MATRIX OF CALCITE-CHLORITE-BIOTITE-EPIDOTE-SERICITE-RUTILE)

Pale green, brecciated rock (siliceous clasts are mainly harder than steel; soft matrix reacts strongly to cold dilute HCl). The rock is very slightly magnetic. In thin section, the clasts are dominated by a very fine-grained mineralogy that appears to be ?amphibole (needle-like fibrous crystals mainly < 20 microns long) and ?sphene (rounded subhedra to 10 microns); there may be minor ?epidote and ?quartz. A vaguely discernible relict structure consists of ovoid areas <0.5 mm in size defined at their rims by ?sphene; they possibly suggest a fine-grained, ?quenched pillow basalt precursor to this metamorphosed rock. The matrix, composed of subhedral calcite to 0.5 mm, chlorite to 1 mm containing traces of rutile to 20 microns and in places after pale brown ?biotite, epidote to 0.5 mm, and sericite to 25 microns, could be much later in origin (post-peak deformation), although it could have originally derived from a pillow breccia.

Money JH96-71c: AS FOR 70b

There are two sections of this sample with different textures, one essentially similar to JH96-70B (fine-grained amphibole-?sphene rich clasts in a coarser-grained matrix of calcite, chlorite/biotite, epidote, sericite and sphene/rutile), and the other containing abundant smaller, epidote-rich clasts in a matrix of chlorite, calcite, and abundant sphene/rutile. The mineralogy and textures suggest similar ?basalt pillow breccias.

Money JH97-120, 125: FINE-GRAINED QUARTZ-RICH "GRIT" OR MAFIC VOLCANIC WACKE

Described as volcanic breccia; offcut shows a mainly homogeneous, dark greenish grey, fine-grained rock with a "grit" or sedimentary rock appearance; portions of the offcut are pale buff-grey, possibly due to ?oxidation and weathering. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the sample is composed mainly of detrital quartz and lithic clasts <0.5 mm in size in a matrix of

comminuted quartz, sericite, chlorite and opaques almost all <50 microns in diameter. Lithic clasts include common lenticular ?mafic rock composed of sericite and chlorite, and lesser black ?argillite chips composed of minute opaques and ?quartz, plus included fragments of chlorite-sericite rich rock. Modal mineralogy in thin section is approximately:

Quartz	60%
Sericite	20%
Chlorite	10%
Opaque (?rutile/sphene, ?carbon)	10%

The mineralogy suggests derivation from erosion of a mafic volcanic and quartz-rich clastic sediment pile, but I would prefer to call this sample a volcanic wacke or "grit" rather than volcanic breccia. Note that sample 125, described in the field as ?sandstone, is very similar in texture and mineralogy (but contains some plagioclase feldspar clasts in addition to quartz).

Money **JH97-123**: ?ALBITE-CHLORITE-EPIDOTE-CALCITE-SPHENE/RUTILE ALTERED, ?METABASALT

Described as phyllite; offcut slab is fine-grained and green, somewhat resembling a fine-grained basalt. The rock is very slightly magnetic and shows minor reaction to cold dilute HCl. In thin section, the mineralogy and texture indicate a fine-grained mafic volcanic rock:

Plagioclase	45%
Chlorite	30%
Epidote	10%
Carbonate (?mainly calcite)	10%
Sphene/rutile	3-5%
Quartz (?)	1%
Opaques (pyrite, goethite)	<1%

In this sample, crystals or aggregates of carbonate, epidote, and plagioclase likely represent the relics of former small phenocrysts that are set in an altered matrix of plagioclase, chlorite and fine-grained sphene/rutile. Carbonate, likely mostly calcite, forms subhedral crystals up to 0.5 mm diameter; epidote forms subhedral crystals to 0.3 mm, in places mixed with carbonate and likely marking the sites of former mafic crystals. Plagioclase is less well defined except in narrow (<0.2 mm thick) veinlets, in which twinning is clearly evident with extinction on 010 up to 13 degrees, in subhedral crystals mainly <0.1 mm in diameter. Other minerals in the veins include epidote, chlorite and traces of hematite. There are a few suggestions of larger (to 3 mm) pseudomorphs of sub- to euhedral plagioclase phenocrysts, but throughout most of the rock, plagioclase forms such small (<50 micron), sub- to anhedral, untwinned crystals that it is difficult to be sure of their identity. However, lack of relief difference against the twinned crystals in the veins, and abundance of mafic minerals and sphene/rutile, suggest that quartz is mainly absent (rare clots and aggregates of subhedral to 0.1 mm) and that this sample represents a fine-grained basalt that has undergone propylitic alteration or greenschist metamorphism to a ?albite-chlorite-epidote-calcite-sphene/rutile assemblage. Rare euhedral pyrite crystals to 1.5 mm are partly to largely oxidized to goethitic limonite.

Money **JH97-124B**: AMPHIBOLE-EPIDOTE-CHLORITE-PLAGIOCLASE-SPHENE ROCK (MAFIC METAVOLCANIC) CONTAINING ?RELICT AMYGDULES OF EPIDOTE-HEMATITE

Described as hematitic chert in pillowed mafic volcanic; offcut slab shows a dark green and yellow green (chlorite-epidote rich) fine-grained, partly foliated mafic rock containing small rounded red (hematitic) nodules < 3 mm in diameter. The rock shows only trace magnetism and minor reaction to cold dilute HCl.

Modal mineralogy in thin section is approximately:

Amphibole (?tremolite-actinolite)	40%
Epidote (Fe-rich)	20%
Plagioclase	20%
Chlorite	15%
Sphene	3%
Carbonate (calcite)	1-2%
Opaque (hematite)	<1%

In thin section, the rock is composed of a fine-grained intergrowth of amphibole, chlorite, plagioclase and lesser sphene, hosting crystals and aggregates of epidote and minor carbonate, and cut by narrow veinlets (likely metamorphic "sweats", up to 0.5 mm thick) of plagioclase-chlorite-epidote-carbonate (calcite). The

nodules are composed of epidote containing minute inclusions of hematite, and lesser chlorite, calcite and plagioclase. Amphibole forms subhedral to fibrous laths up to 0.5 mm long with very pale green pleochroism and small extinction angle (?tremolite-actinolite). Plagioclase crystals are interstitial to amphibole and mainly subhedral, less than 0.1 mm in length; they display rare vaguely defined twinning. Chlorite forms sub- to euhedral flakes up to 0.35 mm in diameter with optical characteristics (pale pleochroism, mainly length-fast, weakly anomalous birefringence) suggestive of moderate Fe content (F/M about ?0.5). Fine-grained sphene (mainly subhedral, <15 microns in diameter; aggregates to 0.1 mm) is abundant in the matrix. Epidote crystals are subhedral, up to 0.35 mm in diameter (to 0.7 mm in the nodules); they have strong yellow pleochroism indicating high Fe content, and contain minute (<5 micron) particles of hematite. Carbonate crystals in the mostly subhedral <0.25 mm in diameter.

This sample is clearly derived by metamorphism of a mafic volcanic rock (abundant amphibole, chlorite, epidote, plagioclase, TiO₂ in the form of sphene); hematite appears to be mostly confined to what may have been epidote-chlorite-calcite-plagioclase ?amygdules. JH97-132 is described as pillow breccia; offcut is pale green, very fine-grained, and similar to parts of 124B. In thin section, it is composed of the same minerals (scattered euhedral epidote crystals to 0.15 mm in a matrix of fibrous, very pale green amphibole to 0.25 mm long, with minute sphene, and interstitial plagioclase and ?chlorite.

Money **JH97-141**: DIABASIC (PLAGIOCLASE IN AMPHIBOLE-CHLORITE-EPIDOTE ALTERED CLINOPYROXENE; MINOR SPHENE, RARE OXIDIZED PYRITE

Described as pillowed volcanic with epidote alteration; however, the rock is significantly coarser than the other pillowed samples (JH97-123, 124B, 132), rather more like a diabase (could have been a ?feeder dyke or a ?sill). The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, it is composed of slender laths of plagioclase up to almost 2 mm in length in a matrix of interstitial chlorite, sphene and scattered epidote crystals; rare oxidized pyrite cubes are up to 2.5 mm diameter. In places the chlorite is seen to be after partly amphibolitized clinopyroxene relics up to 0.5 mm in diameter. Thus the petrography confirms that this likely was a typical diabasic-textured rock of basaltic composition; narrow veinlets of plagioclase are likely metamorphic in origin.

Plate 3

a) Money **JH96-70A**: Interlayered (?tectonically interleaved) chlorite-pyrite-quartz-sphene ?relict mafic rock and siliceous ?siltstone, MONEY prospect. Transmitted light, crossed polars, 2.5 mm field of view.

b) Money **JH96-71A**: Two views of massive sulfide textures from the MONEY prospect (subhedral pyrite surrounded and infilled by chalcopyrite masses; rare poorly preserved atoll or ?radial-bomb textures). Reflected light, uncrossed polars, field of view 2 mm wide.

c) Money **JH97-124B**: Nodules of epidote (ep) containing minute hematite particles) and chlorite (ch) in a fine-grained, foliated matrix of amphibole, chlorite, plagioclase, epidote, and sphene (transmitted light, uncrossed polars, field of view 2.5 mm).

d) Money **JH97-141**: Diabasic-textured ?dyke or sill of basaltic composition (laths of plagioclase enmeshed in relict clinopyroxene, cpx, altered to amphibole, chlorite, epidote, sphene and cut by narrow veinlet of plagioclase). Transmitted light, crossed polars, field 2.5 mm wide.

DAWSON AREA

MATSON CREEK PROPERTY

The Matson Creek prospect is located approximately 100 km southwest of Dawson City near the border with Alaska, in the Klondike Schist (Johnston and Mortensen, 1994, in Hunt, 1998). Mineralization exposed at surface is restricted to boxwork-textured gossanous fragments with coincident Pb-Zn-Cu geochemical anomalies that suggest underlying sulfide mineralization (Haverslew, 1978, in Hunt, 1998). The petrographic samples examined come mainly from **DDH MA92-01** (one sample each from **DDHMA92-02** and **DDHMA92-03**; two surface samples), and consist primarily of quartz-sericite+plagioclase-carbonate-biotite/phlogopite-chlorite schists, with accessory pyrite-rutile/sphene-apatite. Although metamorphosed to greenschist facies and mostly strongly deformed and foliated, relict textures/minerals in about half of the samples examined suggest most samples were derived from volcanic precursors, possibly ranging from felsic through intermediate to rarely mafic; siliceous sediments could also have been present.

In detail, the samples from DDHMA92-01 can be classified as follows: variably ?plagioclase phyric, ?felsic (?dacitic) to intermediate volcanics, including DDHMA92-01 12.6-12.7, 40.96-41.05, 67.66, 82.55, 84.42, composed of albite or oligoclase commonly as rounded to subhedral aggregates up to 3 mm in diameter, in a foliated matrix of quartz, plagioclase, sericite, carbonate and variable biotite/phlogopite or chlorite. In one of these samples (84.42) there also appear to be relict quartz phenocrysts of up to similar size as the feldspar phenocrysts, suggesting a quartz-feldspar porphyry. Well-developed quartz-feldspar porphyry textures are evident in the surface samples JH 96-40 and 42, likely intrusive ?dacite in the former; the latter is more strongly tectonized and metamorphosed, but contains significant microcline and may have been ?rhyodacitic. In the ?intermediate volcanics (DDHMA92-01 24.0-24.15, 81.0, 109.4, 195.3, pale greenish brown biotite or ?phlogopite is more prominent; in the sample from 109.4, the abundance and coarse crystalline nature of sphene in particular and to a lesser extent pyrite, and minor apatite, suggest a mafic to intermediate precursor. The presence of only minor or trace amounts of plagioclase in the samples from DDHMA92-02 (76.6) and DDHMA92-03 (80.3) suggest these could be derived from ?siliceous sediment or less likely felsic volcanic precursors. Carbonate throughout these samples varies from ferroan (?Fe-calcite, or ankeritic) to calcite. K-feldspar appears to be largely absent from the drill core samples examined except possibly DDHMA92-01 40.96-41.05 (however, staining tests of offcuts were not performed to confirm this).

Mineralization apart from pyrite was seen in only one sample (DDHMA92-03 80.3), which contained ?veins or "sweats" of quartz-ferroan carbonate-biotite with minor sphalerite and galena. Detailed descriptions of individual samples and photomicrographs follow.

Matson Creek **DDHMA92-01 12.6-12.7: FOLIATED ?PLAGIOCLASE PORPHYRITIC ?DACITIC VOLCANIC**

Offcut shows a spotty-textured, somewhat foliated rock with an appearance of a deformed porphyritic volcanic or high-level intrusive rock. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Plagioclase (albitic)	35-40%
Sericite	25%
Quartz	25%
Carbonate (ferroan)	10%
Opaque (pyrite)	1-2%
Limonite	<1%
Rutile	<1%

This slide consists mainly of scattered (20-30%) rounded and in places disrupted crystals of plagioclase in a foliated matrix of finer-grained (mainly <0.5 mm) sub- to anhedral plagioclase, quartz and sericite plus lesser carbonate. Sericitic laminae alternate with laminae richer in plagioclase or quartz; rarely carbonate-rich laminae are present, probably the buff-coloured areas in hand specimen. The carbonate is likely ferroan dolomite (ankerite) to judge by the lack of reaction in hand specimen. Minor opaques, mostly cubic pyrite crystals <0.3 mm in diameter and stains of limonite emanating from them plus traces of euhedral rutile to 35 microns, are scattered along sericitic and carbonate-rich laminae. K-feldspar is not definitely detected due to lack of a stained offcut; no phase with negative relief compared to (generally twinned) albite is seen in thin section. Relict plagioclase ?phenocrysts form sub- to euhedral crystals up to 2 mm long with negative relief

compared to quartz and extinction Y^{010} up to 16 degrees indicating albitic composition (An₅). The crystals include significant quartz and carbonate and are altered to traces of sericite. It is possible that the scattered carbonate aggregates, and part of the sericite, represent former ?mafic mineral crystals in a porphyritic volcanic rock possibly originally of ?dacitic composition.

Matson Creek DDHMA92-01 24.0-24.15: QUARTZ-SERICITE-BIOTITE-CARBONATE-PYRITE SCHIST

Grey to black, laminated and foliated rock, also with sheared out buff-coloured ?plagioclase relicts in the plane of foliation. The rock is not magnetic but shows minor reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	40-45%
Sericite	30%
Biotite	15%
Carbonate (partly calcite)	10%
Opaque (pyrite)	3%
Limonite	<1%
Rutile, zircon	tr

Quartz crystals are generally subhedral, polygonal and <0.5 mm in diameter; micaceous laminae contain subhedral flakes of sericite (muscovite) and pale greenish-brown biotite up to 1 mm in diameter. Carbonate forms subhedral crystals rarely over 0.7 mm, mainly in quartz-rich laminae, where elongated aggregates up to 2 mm long occur, in places associated with cubic opaques (pyrite) up to 1 mm in size and minor traces of limonite emanating from the pyrite. Traces of rutile occur as euhedra to 15 microns, mainly in quartz; rare ?zircon to is up to 0.1 mm. Feldspar is not apparent (either by twinning or by relief difference) in the thin section, in spite of the buff-coloured areas in the offcut. Thus this sample can only be described as a quartz-sericite-biotite-carbonate-minor pyrite schist, of uncertain parentage; however, the presence of significant biotite suggests that it could have been derived from a somewhat more mafic rock than 92-01 12.6-12.7.

Matson Creek DDHMA92-01 40.96-41.05: QUARTZ-SERICITE-FELDSPAR SCHIST AFTER ?VOLCANIC

Buff-coloured, laminated and foliated felsic-looking rock with scattered white ?feldspar relicts. The rock is not magnetic and shows no reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	50%
Sericite	30%
Feldspar (?plagioclase, ?Kspar)	20%
Opaques (oxidized pyrite)	<1%
Limonite (after pyrite)	<1%
Rutile, zircon	<1%

In thin section, the only ?plagioclase present appears to be restricted to fine-grained, lens-shaped patches up to 2 mm long in which it forms subhedra mainly <0.1 mm in diameter with rare twinning and negative relief compared to the more dominant quartz (subhedra up to 0.25 mm). By comparison to 92-01 12.6-12.7, it is possible that these aggregates could represent former ?plagioclase phenocrysts that have been almost entirely replaced by secondary quartz, indicating a former felsic ?volcanic rock. However, there is also a possibility that K-feldspar is present, since some distinctly twinned eu- to subhedral crystals to 0.6 mm have no relief difference against quartz (presence of Kspar should be confirmed by staining of the offcut slab). Thus it is possible more plagioclase exists than is estimated in the mode above. Most sericite forms subhedral to bent or crenulated flakes <0.5 mm in diameter; note the lack of carbonate in this sample. Opaques include minor oxidized pyrite cubes up to 0.4 mm in diameter, mostly partly altered to limonite; traces of rutile form stubby euhedra to 0.1 mm.

Matson Creek DDHMA92-01 67.66: QUARTZ-SERICITE-PLAGIOCLASE-CHLORITE-CARBONATE-PYRITE-SPHENE-RUTILE SCHIST AFTER ?FELSIC-INTERMEDIATE PORPHYRITIC VOLCANIC

Pale grey-green, strongly foliated, quartz-sericite-minor chlorite +pyrite schist. The rock is not magnetic but shows minor reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	40%
Sericite	30%
Feldspar (plagioclase)	20%
Chlorite	3-5%

Carbonate (partly calcite)	3-5%
Opaque (?pyrite)	1-2%
Sphene, rutile	<1%

It is very difficult to discern between quartz and plagioclase in this specimen, due to general lack of relief difference between the two; only where the feldspar is twinned can the distinction be made. The composition is therefore likely in the oligoclase range; minor alteration to carbonate is present. Crystals of both quartz and plagioclase are subhedral to elongate (flattened parallel to plane of foliation) and mainly less than 1 mm in diameter, although in places both occur as larger, subrounded ?relict phenocrysts up to ?3.5 mm in length. Granular quartz and ?lesser plagioclase of about 0.3 mm diameter form layers mainly less than 0.5 mm thick that alternate with foliae of similar thickness composed of sericite and minor chlorite, sphene and opaque. Sericite and chlorite form euhedral flakes to 0.35 mm; chlorite is length-fast, with first-order birefringence (likely magnesian, F/M perhaps 0.4). Pockets of chlorite and porphyroblastic carbonate up to 0.5 mm in size could represent the sites of former ?mafic minerals. Sphene subhedra are <0.1 mm, and cubic pyrite <0.4 mm. It is possible that this sample represents a former felsic-intermediate volcanic or porphyry, metamorphosed to greenschist facies.

Matson Creek DDHMA92-01 81.0: QUARTZ-SERICITE-PLAGIOCLASE-BIOTITE-CARBONATE-PYRITE-RUTILE SCHIST (AFTER FORMER ?INTERMEDIATE PORPHYRITIC VOLCANIC)

Grey-green, foliated rock with common buff-white spots of TiO₂ mineral (likely rutile) and minor pyrite; not magnetic, no reaction to cold dilute HCl. In thin section, it is similar to 92-01 67.66 but contains pale greenish brown biotite in place of chlorite (euhedral flakes to 0.5 mm), intermixed with the sericitic foliae, and clots up to 3 mm across of carbonate (likely dolomite/ankerite, subhedra to 1 mm diameter). Scattered subhedral crystals of plagioclase up to 1.25 mm in diameter, and quartz up to 2.5 mm, suggest the presence of former ?phenocrysts of these minerals. Slight negative relief of the feldspar suggests a composition near oligoclase-albite. Opaque, including cubic pyrite to 0.4 mm and rutile, is sparsely disseminated. Rutile is very dark brown, forming clusters up to 0.5 mm across of minute (<25 micron) crystals. The mineralogy and texture is suggestive of a former ?inter-mediate, porphyritic volcanic rock metamorphosed to greenschist facies.

Matson Creek DDHMA92-01 82.55: QUARTZ-SERICITE-PLAGIOCLASE+LIMONITE SCHIST AFTER ?FELSIC VOLCANIC

White to buff-orange (limonite-stained) quartz-sericite schist; non-magnetic, no reaction to cold dilute HCl. The slide consists of alternating layers, about 1-2 mm thick, of quartz-feldspar rich and sericite-rich rock. Quartz (50-60% of the rock) forms subhedral interlocking crystals mainly <0.5 mm long (elongated in the plane of foliation). Plagioclase feldspar crystals (10-20%), possibly relict ?phenocrysts, are subhedral and <1 mm in diameter, generally twinned (extinction on 010 up to 10 degrees and with negative relief compared to quartz, suggesting a composition near An₁₀₋₁₅, sodic oligoclase). Sericite (20-30%) forms sub- to euhedral flakes up to 0.5 mm in diameter. Minor pale yellow-brown to red-brown limonite is found as stains along foliation in the sericitic portions of the rock, and as pseudomorphs after ?pyrite crystals up to 0.2 mm in diameter. As at 81 m, this appears to have been a ?felsic rock (note lack of chlorite and carbonate) that has undergone greenschist facies metamorphism.

Matson Creek DDHMA92-01 84.42: META-FELDSPAR/QUARTZ PORPHYRY (OLIGOCLASE-QUARTZ-SERICITE-?PHLOGOPITE-CARBONATE-PYRIET-RUTILE)

White to pale greenish, apparently metamorphosed plagioclase-rich rock with sericite-minor pyrite matrix; could have been a feldspar porphyry prior to metamorphism. The rock is not magnetic and shows only trace reaction to cold dilute HCl. This sample is mostly composed of plagioclase feldspar (55%), forming subhedral interlocking crystals mainly <1 mm in size but commonly aggregating to 3 mm lens-shaped areas that likely represent the sites of former feldspar ?phenocrysts; lesser similar areas of quartz (single subhedral crystals to 4 mm) could also be ?phenocrysts. These areas are set in a matrix of finer plagioclase (mostly <0.3 mm, anhedral, untwinned, distinguished from quartz by slightly negative relief suggesting a composition of ?oligoclase), lesser quartz (20%), sericite (15%) and minor pale brown biotite or ?phlogopite (5%, 0.5 mm) and carbonate (3%, <0.2 mm). Aggregates of pyrite (1-2%, opaque cubes to 0.3 mm) and rutile (<1%, needles to 50 microns, enmeshed in carbonate) are common in the sericitic layers. The composition and texture suggests a former feldspar-quartz porphyry, possibly of volcanic or intrusive origin.

Matson Creek **DDHMA92-01 109.4**: SERICITE-QUARTZ-CHLORITE-BIOTITE/PHLOGOPITE-CARBONATE-PYRITE-SPHENE+APATITE SCHIST AFTER ?INTERMEDIATE-MAFIC ROCK

Green-grey, foliated rock with common zones of cubic pyrite, cut by 1 cm thick white quartz-minor buff carbonate layer-parallel ?vein. The rock is not magnetic but shows minor reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Sericite	40%
Quartz	25%
Chlorite	10%
Biotite/phlogopite	10%
Carbonate	10%
Pyrite	3%
Sphene	1-2%
Apatite	<1%

This sample consists of interleaved sericite-chlorite-biotite rich and quartz-feldspar rich foliae, each about 1-2 mm in thickness; abundant pyrite and sphene, and traces of apatite, are concentrated in the sericitic foliae. and suggest derivation from an intermediate to mafic rock. Quartz and feldspar are difficult to tell apart due to lack of twinning in the latter, and lack of relief difference between the two; however, quartz appears to greatly predominate. Sericite forms subhedral to bent flakes mostly <0.25 mm in diameter, commonly mixed with chlorite (<0.1 mm, length-fast, likely magnesian). There are scattered aggregates of pale greenish-brown biotite/phlogopite (subhedral flakes to 0.3 mm), pyrite (cubic crystals to 0.5 mm, aggregating to 1.5 mm), sphene (euhedra to 1 mm) and rare apatite (euhedra to 0.2 mm). The vein consists of quartz (interlocking anhedral to 0.75 mm), carbonate (calcite/?dolomite, subhedral porphyroblastic aggregates to 3 mm), and minor sericite, biotite/phlogopite and pyrite (sphene is remobilized into very fine-grained aggregates of 20 micron crystals). The "vein" could be due to metamorphic recrystallization-remobilization.

Matson Creek **DDHMA92-01 195.3**: SERICITE-QUARTZ-BIOTITE-CARBONATE+RUTILE, APATITE SCHIST AFTER ?FELSIC-INTERMEDIATE ROCK

Dark grey-green, moderately foliated quartz-sericite-chlorite schist with lenses to 1 cm long of carbonate (react slowly to cold dilute HCl); rock is not magnetic. The thin section shows a rock somewhat similar to that from 109.4, composed mainly of alternating laminae <1 mm thick of sericite(45%)-biotite(10%)-minor carbonate(10%) and quartz(35%)-rich material; no plagioclase feldspar is clearly distinguishable. However, chlorite appears to be absent, and the abundant sphene and pyrite of 109.4 are absent. Carbonate in places has very strong relief change on rotation, and could include both calcite and ?ferroan dolomite (ankerite) as subhedra to 0.2 mm diameter. Layer-parallel lensey segregations of quartz with more abundant carbonate and minor biotite are scattered in the slide. Biotite forms sub- to dark greenish brown euhedral flakes up to almost 1 mm in diameter; sericite forms finer flakes <0.2 mm in diameter, commonly crenulated or kink banded and in places mixed with very fine (25 micron) sericite. Rare <30 micron apatite crystals occur in quartz, but the absence of sphene is unusual given the abundance of biotite and sericite. It is possible that minute rutile crystals (needle-like, to 15 microns) occur in carbonate; the precursor may have been a felsic-intermediate rock.

Matson Creek **DDHMA92-02 76.6**: QUARTZ-SERICITE-CARBONATE-PLAGIOCLASE-PYRITE-RUTILE SCHIST

Pale grey-white to greenish schist that is non-magnetic and shows only trace reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	45%
Sericite	40%
Carbonate (partly calcite)	10%
Plagioclase (?)	3%
Opaque (pyrite)	1-2%
Rutile, sphene	<1%

This slide consists of alternating laminae of quartz-carbonate and sericite-rich rock on a 0.5 to 1 mm scale. Quartz forms subhedral interlocking crystals mostly <0.5 mm in diameter, with common triple junctions between the crystals indicating some annealing. As far as I can tell, plagioclase is very minor (<0.2 mm an- to subhedral crystals, distinguished only by negative relief compared to quartz). Carbonate forms common

porphyroblastic aggregates up to 1.5 mm in diameter or vein-like segregations, composed of subhedral crystals to 1 mm size, possibly both calcite and ?dolomite, including minor sphene. Sericite flakes are finely foliated and crenulated, mainly <0.2 mm in diameter. Pyrite forms cubic crystals up to 0.5 mm, aggregating to 1 mm; rutile occurs as aggregates to 0.25 mm long composed of fine euhedra to 25 microns. The precursor to this metamorphic rock is not obvious; it could have been a siliceous sediment or a felsic volcanic.

Matson Creek **DDHMA92-03 80.3**: QUARTZ-FERROAN CARBONATE-SERICITE-PYRITE/GALENA/SPHALERITE MINOR BIOTITE SCHIST

Variegated, brown-buff, grey, and greenish siliceous schistose rock containing patches of dark grey quartz and coarse cubic pyrite. The rock is not magnetic but shows minor reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz	40%
Carbonate (?calcite and ankerite)	30%
Sericite	25%
Pyrite, galena, sphalerite	2-3%
Biotite	1-2%
Limonite	1%

This slide consists of alternating, irregular laminae mostly <1 mm thick composed of quartz-carbonate or sericite rich rock; rarely there is significant biotite, generally in the coarser quartz-sulfide ?veins or metamorphic "sweats". Quartz crystals are generally sub- to anhedral and elongated in the plane of foliation with length:width ratios around 2 or 3:1, and maximum dimension up to 1.5 mm long. No plagioclase is discernible by either twinning or relief difference against quartz. Carbonate forms subhedral crystals up to 2.5 mm diameter with generally high relief and strong limonite stains along fractures and margins, suggesting ?ferroan dolomite (ankerite) as well as calcite. Sericite flakes are bent to subhedral and mainly <0.25 mm in diameter; biotite flakes are subhedral, dark greenish brown, and mainly <1 mm in diameter. Sulfides include pyrite (subhedra to 1 mm), galena (euhedra to 0.5 mm) and sphalerite (yellow-brown, moderate Fe content subhedra to 0.75 mm), closely associated with coarse carbonate subhedra/euhedra to 1.25 mm. Absence of plagioclase and chlorite, but abundance of carbonate, make this rock difficult to propose a precursor for, but it could represent carbonate altered ?felsic volcanic or siliceous sedimentary rock.

Matson Creek **JH 96-40**: PROPYLITIC (EPIDOTE-SERICITE-CHLORITE) ALTERED ?INTRUSIVE QUARTZ-FELDSPAR PORPHYRY

Pale buff-greenish, coarse-grained, somewhat disrupted ?quartz-feldspar porphyry. The rock is not magnetic and shows only trace reaction to cold dilute HCl. Modal mineralogy in thin section is:

Quartz	40%
Plagioclase (albitic, altered)	35%
Epidote	15%
Sericite	5%
Biotite, chlorite	3%
Sphene, rutile	1-2%
Carbonate, trace opaque	<1%

This slide consists mainly of subhedral, <2 mm quartz and eu- to subhedral, <1 mm plagioclase with minor interstitial epidote, sericite, chlorite, sphene and accessory opaques. Quartz crystals are strained (undulose extinction) and fractured, and include both large (?pheno-crystic) and small (groundmass) crystals. Most plagioclase is partly altered to minute (5-30 micron) crystals of epidote, which imparts the green colour in hand specimen, as well as minor sericite. Negative relief of plagioclase against quartz suggests an albitic composition. Former mafic sites are represented by aggregates (to 1.5 mm) of coarser subhedral epidote, flakes of biotite or chlorite (after biotite) up to 0.5 mm diameter, and aggregates up to 0.35 mm across of sphene cored by fine-grained rutile; opaques are rare (euhedral ?hexagons seen in the offcut). Epidote has strong yellow pleochroism indicative of high Fe content; green pleochroism, length-slow weakly anomalous birefringence of chlorite indicates a moderate F/M, perhaps 0.5. This sample appears to be a moderately propylitic (epidote-sericite-chlorite) altered quartz-feldspar porphyry, likely intrusive.

Matson Creek **JH 96-42**: FOLIATED META-RHYODACITE (QUARTZ-FELDSPAR PORPHYRY)

Buff-coloured, strongly sheared and flattened, possible quartz-feldspar porphyry somewhat similar to 96-40. The rock is not magnetic and shows only trace reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	30%
Sericite	25%
Plagioclase (?albitic)	20%
K-feldspar (microcline)	20%
Limonite (?jarosite)	1-2%
Opaque	<1%
Carbonate (calcite)	<1%

This slide consists of alternating laminae, approximately 1-2 mm thick, composed of quartz-feldspar rich or sericite-rich rock, hosting rounded augen-like aggregates or relict ?phenocrysts of feldspar and less commonly, quartz. Both plagioclase and K-feldspar are identifiable by their polysynthetic and "grid" twinning, respectively, and their refractive indices (both lower than quartz, with that of the microcline Kspar lower than plagioclase, which may be albitic. Quartz crystals are mainly subhedral and <0.5 mm in diameter, except for strained and fractured ?relict phenocrysts up to 1.5 mm in diameter. Feldspar aggregates in places have sub- to euhedral outlines up to 1.5 mm in size, in places with rims of microcline on cores of plagioclase. Sericite forms eu- to subhedral flakes up to 0.75 mm diameter (more properly termed muscovite) that are concentrated in wispy foliae that define the foliation. Minor limonite and trace opaque and carbonate may be after former ?pyrite. This also appears to have been a quartz-feldspar porphyry, although likely of somewhat more felsic (rhyodacite) composition than the ?dacite of 96-40.

Plate 4

a) Matson Creek **DDHMA92-01 12.6-12.7**: Relict plagioclase ?phenocryst, partly altered to carbonate, quartz and trace sericite, in matrix of quartz, plagioclase and sericite (transmitted light, crossed polars, field of view 2.5 mm).

b) Matson Creek **DDHMA92-01 24.0-24.15**: Biotite crystal with carbonate (?calcite) in matrix of quartz and sericite, scattered pyrite (opaque). Transmitted light, uncrossed polars, field of view 2.5 mm wide.

c) Matson Creek **DDHMA92-01 82.55**: Plagioclase ?phenocryst (twinned) in layered matrix of quartz-sericite. Transmitted light, crossed polars, field of view 2.5 mm wide.

d) Matson Creek **DDHMA92-01 84.42**: Relict quartz ?phenocryst, in matrix of finer plagioclase-sericite-quartz-minor carbonate-pyrite-rutile. Transmitted light, crossed polars, field of view 2.5 mm wide.

e) Matson Creek **DDHMA92-01 109.4**: Blastic sphene (bright colours, high relief) and pyrite (opaque) in matrix of sericite-quartz-plagioclase-chlorite; meta-?intermediate rock. Transmitted light, crossed polars, 2.5 mm wide.

f) Matson Creek **DDHMA92-01 195.3**: Alternating laminae of sericite-biotite+carbonate rich and quartz rich rock in schist derived from ?felsic-intermediate rock. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

g) Matson Creek **DDHMA92-02 76.6**: Porphyroblastic carbonate (note cloudy core containing minor sphene) in quartz lamina; minor pyrite (opaque), rutile (ru) in sericitic laminae. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

h) Matson Creek **DDHMA92-03 80.3**: Pyrite, galena (both opaque), sphalerite (yellow-brown), ferroan carbonate (cb), sericite(ser), and biotite (brownish) in quartz ?vein. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

BIG TOP

There are 11 samples from the Big Top (Iron Creek) prospect. Most samples (**JH 97-64A, 249, 250, 264, 97R 254 and 97R 261**; possibly **123**, and ?tuffaceous or epiclastic equivalents in **256 and 258**) appear to be ?metadacite (composed mainly of quartz and ?albitic alkali feldspar, with lesser variable amounts of carbonate, biotite, sericite, chlorite, sphene, and sulfides that appear to include both pyrite and ?sphalerite (although polished surfaces are not available for examination). Oxidation of sulfides, particularly pyrite, to limonite is common. The association of pyrite, sphene, and sphalerite, along laminae or in clots in JH 97-64A, and along cross-cutting fracture networks in 264, appears to be the strongest mineralization present in the samples of this suite.

Other samples include biotite-calcite-pyrite-chlorite-epidote-apatite-rutile altered ?diorite (**JH 97-65**) and epidote altered hornblendite (possibly after ultramafic; sample **105**).

Big Top **JH 97-64A**: ?METADACITE (QUARTZ-ALBITE-CALCITE-SERICITE-BIOTITE) WITH MINOR PYRITE-SPHALERITE-?SPHENE-APATITE

Described as metarhyolite or quartzite?; hand sample is white to grey, strongly foliated and laminated, fine-grained, siliceous (harder than steel), and non-magnetic. The rock shows moderate to strong reaction to HCl; modal mineralogy in thin section is approximately:

Quartz	50%
Alkali feldspar (?albitic)	30%
Carbonate (?mainly calcite)	10%
Sericite	3%
Opaque (?pyrite)	3%
Biotite	2%
Sphalerite	1%
Sphene	<1%
Apatite	tr

This sample consists of laminae up to 2 mm thick of quartz-rich and alkali-feldspar rich rock, interleaved by foliae that contain minor sulfides (mainly pyrite, minor sphalerite), biotite and ?sphene. Quartz-rich laminae predominate, and are composed of sub- to anhedral, interlocking crystals of quartz up to 0.35 mm in diameter with minor interstitial alkali feldspar to 0.1 mm and variable amounts of carbonate and sericite (muscovite) as subhedra to 0.2 mm diameter, plus scattered opaques to 0.75 mm, pale brown biotite flakes to 0.25 mm (partly interleaved by sericite), aggregates of ?sphene up to 0.35 mm, and traces of sphalerite subhedra to 0.15 mm and euhedral apatite to 50 microns. The identification of sphene is questioned due to the dark green pleochroism of the individual, <50 micron subhedral crystals in these aggregates; sphene is not normally so deeply coloured. In the absence of a polished surface, the identification of sphalerite is tentative, but bright red-brown colour (implying Fe-rich composition) and isotropic character strongly suggest that it is sphalerite. There appears to be an association between pyrite, sphalerite, ?sphene, biotite and apatite.

Feldspathic laminae are generally narrower, composed of interlocking sub- to anhedral laths mainly <50 microns long with minor quartz sericite, carbonate and opaques (mainly ?pyrite). Negative relief of feldspar compared to quartz suggests a sodic (?albitic) composition. Although strongly metamorphosed and deformed, the make-up of this sample (quartz, albite, minor biotite, sericite, sphene, and sulfides) seems more indicative of a dacite than a quartzite.

Big Top **JH 97-65**: BIOTITE-CALCITE-PYRITE-CHLORITE-EPIDOTE-APATITE-RUTILE ALTERED ?DIORITE

Hand sample is a fine- to medium-grained, mafic to intermediate plutonic rock with abundant fine disseminated pyrite; it is not magnetic but reacts moderately to cold dilute HCl. Modal mineralogy in thin section is approximately:

Plagioclase (?albite or oligoclase-andesine)	65%
Biotite (secondary)	15%
Carbonate (calcite)	15%
Opaque (pyrite)	2-3%
Chlorite	1%
Epidote	1%

Apatite	<1%
Rutile	<1%

This sample consists mostly of plagioclase and interstitial mafic minerals now altered to biotite, carbonate, pyrite, chlorite, and epidote. Plagioclase forms subhedral to euhedral tablets up to 2 mm in diameter with extinction on 010 up to 15 degrees indicating either albite or oligoclase-andesine composition (there appears to be no quartz in the slide to compare refractive indices with and thus decide between these two alternatives). However, the association with secondary minerals such as calcite, chlorite and epidote makes the albitic composition likely. It is also not clear what the original mafic minerals were, since they are now thoroughly replaced by fine shreddy dark greenish (?secondary) biotite as subhedral flakes to 0.15 mm diameter, carbonate (likely mostly calcite as subhedral crystals to 0.2 mm), epidote (subhedral to 0.2 mm) and in places chlorite (pale green, subhedral, length-fast, Fe-poor flakes to 0.25 mm that replace biotite and are associated with pyrite and rutile). Pyrite forms sub- to euhedral crystals and aggregates up to 1.5 mm in size; rutile forms clusters of minute (<20 micron) dark brown to semi-opaque crystals generally in the chlorite or biotite flakes. Apatite is unusually abundant, forming small prismatic euhedra to 0.15 mm long associated with altered mafic sites. Lack of quartz, abundance of intermediate plagioclase and altered mafic minerals suggests a protolith for this biotite-calcite-pyrite-chlorite-epidote-rutile-apatite altered rock of about diorite.

Big Top 105: ?ULTRAMAFIC (HORNBLENDITE), COMPOSED OF AMPHIBOLE-MINOR EPIDOTE-?MAGNETITE-PYRITE-APATITE-CHLORITE

Black, fine-grained, mafic rock that is harder than steel and magnetic, but shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Amphibole (primary, ?hornblende)	90%
(secondary, ?actinolite)	3%
Epidote	3%
Opaque (?magnetite, pyrite, ?ilmenite)	3%
Apatite	<1%
Chlorite	<1%

This is a very mafic, likely ultramafic rock (hornblende) composed almost entirely of amphibole with minor interstitial epidote and scattered opaques, cut by planar zones of recrystallized and secondary amphibole. Primary amphibole (itself likely after former ?pyroxene) forms a fine granular mosaic of euhedral to subhedral crystals mainly less than 0.25 mm in diameter, with olive green pleochroism suggesting ?hornblende. Near the planar zones of secondary amphibole, the ?hornblende is recrystallized to coarser subhedral up to 1 mm in length. Secondary amphibole at the center of the zone forms ragged, fibrous crystals to 0.25 mm with pale green pleochroism indicating actinolitic composition; it appears to replace ?clinopyroxene, traces of which remain as subhedral to rounded crystals up to 0.35 mm in diameter. The secondary amphibole is associated with subhedral crystals of epidote and ?zoisite up to 0.1 mm in diameter, plus accessory apatite as euhedral prisms up to 0.1 mm long. These same minerals (epidote-group, apatite) are also found throughout the slide as small crystals interstitial to the ?hornblende. Opaque minerals include subhedral aggregates to 1 mm across of both ?magnetite and pyrite, commonly surrounded by epidote minerals and minor chlorite. Traces of limonite are found around pyrite. There are also fine vermiform inclusions of opaque (?magnetite, ilmenite, less than 20 microns in diameter) in hornblende crystals.

Big Top 123: ?SPHERULITIC FELSIC VOLCANIC (EXTREMELY FINE-GRAINED, OXIDIZED)

Strongly limonite-stained, buff-brown, fine-grained rock with a ?spherulitic texture that is mostly softer than steel, non-magnetic, and shows no reaction to cold dilute HCl. In thin section, the slide is so limonite-stained and so fine-grained (average about 10 microns; rarely to 20 microns) and therefore the crystals are so piled on top of each other in the 30 micron thick section, that identification is very difficult. Low birefringence suggests that it is mostly either quartz or alkali feldspar; softness in hand specimen argues against significant quartz, so my guess would be mostly alkali feldspar, possibly clay-sericite altered, possibly ?chlorite, and abundant limonite, suggesting a former ?felsic volcanic, but this is highly speculative. Aggregates of limonite up to 0.25 mm in diameter could represent former ?pyrite crystals or aggregates.

Big Top 249: ?FELSIC, POSSIBLY DACITIC, TUFFACEOUS VOLCANIC (PLAGIOCLASE-CHLORITIZED AMPHIBOLE-QUARTZ-LIMONITE-RUTILE)

Hand specimen is a bleached white, fine-grained ?porphyritic rock, partly harder than steel, and strongly oxidized (limonite stained on the outer rind). It is not magnetic and shows no reaction to cold dilute HCl. In thin section, it is a leucocratic rock, composed mainly of alkali feldspar (twinned, likely mostly sodic plagioclase as subhedra up to 0.5 mm diameter) and lesser, partly chloritized amphibole (ragged subhedra to 0.5 mm that lack colour and are likely tremolitic). Chlorite forms subhedral flakes to 0.25 mm diameter with optical characteristics (no colour or pleochroism, near-zero to length-fast birefringence) indicating Fe-poor composition (F/M near ?0.4). Traces of rutile are associated with the chlorite as fine euhedra to 25 microns long. Limonite staining is common in the mafic minerals; some of it may be derived by oxidation of former ?pyrite up to 0.25 mm in diameter. Minor quartz is present as irregular subhedra to 0.15 mm, detectable in places by relief difference against plagioclase; however, most of the untwinned, fine-grained material appears to be plagioclase. Etching and staining of the block would be necessary to help resolve this question; for the moment, I would classify it as a ?tuffaceous felsic volcanic, possibly dacitic in composition.

Big Top 250: STRONGLY FOLIATED, METAMORPHOSED, PYRITIZED ?TUFFACEOUS FELSIC VOLCANIC (PLAGIOCLASE, QUARTZ, BIOTITE, CHLORITE, LIMONITE)

Hand specimen is a dark grey-brown, fine-grained, strongly foliated rock with abundant pyrite in wispy concentrations along foliae and in fractures perpendicular to it. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the rock is made up of very fine-grained (mostly <35 microns) ?plagioclase, quartz, and partly chloritized biotite; coarser ?metamorphic "sweats" up to 0.2 mm thick contain quartz (confirmed by uniaxial positive interference figure) as subhedra to 0.2 mm. Biotite forms fine (<0.25 mm) ragged to subhedral red-brown flakes, in places (especially near pyrite) partly chloritized (length-fast, Fe-poor chlorite). Pyrite forms aggregates of small subhedral crystals to 0.1 mm in diameter. Slightly coarser ?quartz and plagioclase aggregates throughout the rock suggest it may have been tuffaceous (although the strong deformation evident in the foliation could have dismembered a ?porphyritic rock). The degree of deformation and metamorphism even make it difficult to say if the rock was originally volcanic or sedimentary (?epiclastic).

Big Top 256/258: ?FELSIC (DACITIC) TUFFACEOUS OR EPICLASTIC ROCK (PLAGIOCLASE-QUARTZ-BIOTITE/MINOR CHLORITE-?CARBONACEOUS MATTER)

Hand specimens for both these samples are fine-grained, black and siliceous (harder than steel), non-magnetic and show no reaction to cold dilute HCl. In thin section, the rock is finely laminated, strongly foliated and crenulated, and consists mainly of scattered relict quartz and plagioclase ?phenocrysts or shards, up to about 0.75 mm in size, in a fine-grained (mostly <25 micron) matrix of quartz, feldspar, and biotite plus abundant, but volumetrically minor, dust-like (<1-2 micron) opaques that may be ?carbonaceous matter. Biotite forms sub- to euhedral medium brown flakes up to 0.1 mm in diameter in aggregates up to 0.2 mm across that may represent former ?mafic shards, or where next to quartz "sweats" that form sub-parallel laminae up to 0.3 mm thick composed of subhedra to 0.15 mm (in these locations, part of the biotite is converted to chlorite). Plagioclase and quartz ?phenocrysts or shards or aggregates are subhedral to sheared and recrystallized in character; they could represent shards in an originally tuffaceous rock, or clasts in a fine epiclastic rock. Predominance of plagioclase, possibly about ?oligoclase in composition (extinction on 010 to 11 degrees, no significant relief against quartz) and lack of K-feldspar suggest the rock may have been dacitic. In 258, the overall grain size is finer (mainly <15 microns), but quartz and biotite is coarser in the "sweats", and in places is accompanied by epidote, amphibole, chlorite and opaques as subhedral aggregates to 0.75 mm size that include pyrite and limonite after ?pyrite.

Big Top 264: ?METADACITE (QUARTZ-PLAGIOCLASE-CHLORITIZED BIOTITE-SERICITE) WITH PYRITE-MINOR ?SPHALERITE-?SPHENE

Hand specimen is grey-white, fine-grained, siliceous (harder than steel), non-magnetic and non-reactive to cold dilute HCl, cut by hairline fractures with partially oxidized sulfides (mainly pyrite but may include minor sphalerite). Modal mineralogy in thin section is approximately:

Quartz (partly secondary)	60%
Alkali feldspar (?plagioclase)	25%
Opaque (?mainly pyrite)	5%
Chlorite	3%
Sericite	2%

Limonite	2%
Relict biotite	1%
Sphalerite	<1%
Opaque (?carbonaceous matter)	<1%
Sphene	<1%
Carbonate	<1%

This slide consists of a granular mosaic of relatively coarse-grained quartz in areas up to 0.5 cm across that are separated from each other by narrower areas of finer-grained alkali feldspar. Clots, blebs and fracture-controlled areas of opaques are up to 0.5 mm in diameter and are commonly associated with subhedral flakes of pale brown biotite to 0.35 mm, or similar-sized aggregates of chlorite and sericite as subhedral flakes to 0.3 and 0.15 mm respectively, that have likely replaced biotite. Quartz crystals are mainly <0.5 mm and have strongly undulose extinction and sutured boundaries due to strain. The finer alkali feldspar forms sub- to anhedral crystals mostly <50 microns in size with negative relief compared to quartz suggesting albite-oligoclase composition, in places associated with traces of finer (25 micron) sericite. Pyrite forms mainly eu- to subhedral crystals and fine-grained aggregates that are interstitial to the silicate minerals; the latter are commonly oxidized to limonite, and are associated in places with dust-like intergranular opaques that could be ?carbonaceous matter. Sphalerite (?) is difficult to distinguish from limonite, but in places away from oxidized pyrite, subhedral crystals to 0.15 mm that are also bright red-brown but appear to be isotropic, may be sphalerite. They are loosely associated with aggregates up to 0.5 mm composed of green-brown subhedral ?sphene crystals to 50 microns diameter. This association is similar to that in JH 97-64A (pyrite, ?sphalerite, sphene, chloritized biotite); the host rock could have originally been similar (?dacite) but has undergone strong metamorphism/deformation.

Big Top 97R 254: ?METADACITE (FINE-GRAINED QUARTZ-ALKALI FELDSPAR CUT BY SEAMS AND CLOTS OF SECONDARY AMPHIBOLE AND OXIDIZED PYRITE)

Cherty-looking, siliceous, very fine-grained, white to grey (where fresh, with pyrite) to limonite stained (where oxidized). The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the rock appears to be composed of very fine-grained ?quartz or alkali feldspar, mostly forming interlocking subhedral to anhedral crystals <25 microns in diameter. Poorly defined relief differences between the crystals, which are commonly piled on top of each other in the 30 micron thickness of the section, suggest both quartz and ?albitic alkali feldspar may be present, but this is difficult to be sure of except in zones of recrystallization where crystal size reaches 0.1 mm. The original composition could have been that of a ?dacite.

Clots of pyrite, composed of sub- to euhedral crystals to 0.25 mm diameter, are closely associated with small subhedral to fibrous crystals of pale coloured (?tremolitic) amphibole mostly <0.15 mm long (except in cross-cutting fractures, where amphibole crystals are up to 1 mm long). Pyrite is extensively oxidized to limonite in many places.

Big Top 97R 261: QUARTZ-BIOTITE/CHLORITE-PLAGIOCLASE-MINOR OPAQUE SCHIST (POSSIBLY METADACITE)

Dark grey, finely laminated, fine-grained rock, mainly harder than steel. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, it is mainly a quartz-biotite-minor ?plagioclase schist, with very minor accessory opaques. Laminae are defined by slightly coarser (to 0.15 mm) quartz-rich and finer (to 75 micron) biotite-rich layers, each mostly less than 0.5 mm thick. Foliation is mostly defined by parallel alignment of the medium brown biotite flakes, which also show strong crenulation cleavage, and partly by elongation of quartz crystals which display length:width ratios up to 3:1. Plagioclase crystals are very difficult to pick out with certainty, but are indicated by rare twinning, or by slight cloudiness or slightly negative relief compared to quartz. These characteristics plus extinction on 010 up to about 10 degrees indicate a composition near An₂₅ (oligoclase). It is not possible to be sure of the identity of the opaques, which are mainly subhedral to tabular, <0.1 mm in size, and associated with chloritization of biotite; they could be ?ilmenite. Chlorite has optical properties (pale green colour, no pleochroism, length-fast non-anomalous birefringence) indicative of low to moderate Fe content (F/M perhaps 0.4).

Plate 5

a) Big Top **JH 97-64A**: Quartz and alkali feldspar-rich lamina in ?metarhyolite, with pyrite (black)-sphene (dark green), biotite (bi), sphalerite (sl), calcite (ca) and apatite (ap); transmitted light, uncrossed polars, 1.0 mm wide field of view.

b) Big Top **JH 97-65**: Diorite, showing mosaic of plagioclase (twinned) with interstitial mafic minerals altered to biotite (bi), calcite (ca), epidote (ep), pyrite (opaque) and chlorite (ch). Transmitted light, crossed polars, field of view 2.5 mm wide.

c) Big Top **105**: ?Ultramafic (metamorphosed to hornblendite): olive-green, granular amphibole with accessory magnetite (black) and interstitial epidote-minor chlorite. Transmitted light, uncrossed polars, 2.5 mm wide.

d) Big Top **97R 254**: Amphibole (secondary, ?tremolitic) associated with partially oxidized pyrite, cutting partly recrystallized fine-grained quartz and alkali feldspar in ?metadacite; transmitted light, crossed polars, 2.5 mm wide field of view.

PELLEY-CASSIAR PLATFORM

MM PROPERTY

The MM prospect is one of a group of Zn-Pb-Ba occurrences (see also the Chzernpough) associated with Mississippian volcanic rocks in the Pelly-Cassiar Platform, southwest of the Tintina fault next to the Finlayson Lake area (Hunt, 1998). The volcanic rocks are of felsic to intermediate composition, about 200 m thick, overlain and underlain by carbonaceous pelitic sediments that may belong to a unit of Devonian-Mississippian shales (Morin, 1977, in Hunt, 1998). The volcanic rocks are primarily submarine lapilli tuffs and breccias, capped by tuffaceous and argillaceous chert and intruded by high-level comagmatic syenite or trachyte domes and stocks (Mortensen and Godwin, 1982, in Hunt, 1998). Sulfide mineralization occurs as narrow lenses (less than 3 m thick) in the middle and upper parts of the volcanic sequence, composed of pyrite-pyrrhotite and lesser galena-sphalerite-chalcopryite and quartz, or massive, poorly banded sucrosic barite and pyrite with minor disseminated sphalerite and galena; the underlying trachyte is strongly fractured and veined by quartz-chlorite-pyrite-chalcopryite stringers that may represent a vent zone (Mortensen and Godwin, 1982, in Hunt, 1998).

Samples examined come from many of the older drill holes (73-02, 74-02, 76-02, 76-07, 77-01, 77-03) as well as from the recent drill holes (96-01). There may be some confusion in labeling these samples, as some are labeled in meters and others in feet; in the following discussion and in the descriptions and photomicrographs, I have ordered the samples as if all were in feet (i.e. by absolute numerical value). In hole 73-02, both samples (206 and 345) are quartz-sericite schist, the latter with possible relict ?K-feldspar suggesting it could be derived from a protolith of syenite or trachyte, whereas the former could have been a ?siliceous sediment (or ?silicified volcanic). Possible ?stringers of quartz-pyrrhotite/pyrite-ilmenite-epidote-biotite-calcite+sphalerite-rutile-tourmaline are found in both samples. Neither this hole or hole 74-02 occurs on the section A-B provided, but the geology plan provided indicates that 74-02 was collared about 1000 feet south of the section line in the area of 76-07 in Kechika Group sediments. Two samples from hole 74-02 from 840.5 and 864.5 vary from quartz-sericite-biotite-carbonate schist with semi-massive to crudely layered pyrrhotite/pyrite-sphalerite-galena+chalcopryite-barite. Metamorphism in these and most other samples of the suite appears to have destroyed any traces of primary texture in the sulfides and host gangue minerals.

In hole 76-02 located near 74-02 but drilled in the opposite direction, all the samples (410, 423, 448) appear to be from a mineralized horizon which ranges from massive pyrite+sphalerite-galena in a matrix of quartz-calcite-sericite-minor fluorite and ?barite to massive or semi-massive barite-pyrite+sphalerite-galena, magnetite with muscovite/phengite/chlorite-calcite-epidote (mineralization ?stringery, with ?fluorite, in 448). Protoliths of host rocks are not observable.

In hole 76-07 (644, 655), massive to semi-massive pyrite contains minor sphalerite, galena, and magnetite+chalcopryite in a matrix of quartz-calcite-tremolite-muscovite/biotite/phengite+Kspar; sericitized possible relict ?phenocrysts in 644 may suggest feldspar crystals in a felsic or intermediate rock. The sample from 726 may represent clotty or ?stringery mineralization (?Kspar-carbonate-amphibole-epidote-pyrite-?plagioclase veins containing significant magnetite and minor sphalerite and ?allanite (REE-bearing epidote), also possibly after an ?intermediate rock.

One sample from hole 77-01 (933) appears to represent semi-massive sphalerite-pyrite-magnetite+galena-chalcopryite in a matrix of quartz-amphibole-green (?phengitic) mica-epidote-carbonate-?fluorite, from an interval that assayed 3% Zn, 0.3% Pb, 0.1% Cu, and 0.2 oz/ton Ag over 20 feet. Samples from 788 and 825/825.5 in hole 77-03, 200 meters to the west, appear to be laminated disseminated pyrite/pyrrhotite-sphalerite+magnetite-galena-chalcopryite in a matrix of quartz-biotite/chlorite-sericite-epidote-calcite; as in 76-07, possible relict ?phenocrysts are seen at 788. The sample from 830 is massive pyrite-sphalerite-pyrrhotite-galena-chalcopryite in a matrix of quartz-biotite/chlorite-sericite-epidote and fluorite. Deeper in this hole, samples from 867.5, 978 and 1072 are composed of somewhat foliated quartz-biotite or sericite-ferroan carbonate/calcite-chlorite/hydrobiotite schists with minor pyrite-pyrrhotite-rutile-?apatite-?barite, possibly after former ?intermediate volcanic rocks, cut by quartz veins (?stringer zone in 1072) or metamorphic "sweats" (867.5).

In the recently drilled 96-01 (from the same site as 77-03 but drilled along section to the northeast), samples from 600 and 876 may represent altered, metamorphosed ?intermediate volcanics (now composed of quartz-amphibole and quartz-sericite-epidote-biotite/chlorite-garnet +rutile-sphalerite-galena-?pyrite

schists). There appear to be relict ?fragments (quartz-sericite-biotite-garnet-pyrite-sphalerite-galena) in 876. The samples from 682.5, 691, and 722 are semi-massive pyrite-sphalerite+magnetite-galena in a matrix of quartz-sericite-epidote-biotite/chlorite/phengite+garnet, rutile, tourmaline, amphibole, calcite and fluorite. The sample from 982 is distinctly different from the rest, composed of extremely fine-grained (20 micron) quartz and interstitial ?Kspar-carbonate-sericite, with clotty or stringery quartz-sericite-calcite-biotite/chlorite-pyrite; it could represent a ?chert or possibly ?exhalite horizon.

MM 73-02 206': QUARTZ-SERICITE SCHIST CUT BY IRREGULAR ?STRINGERS OF QUARTZ-BIOTITE-EPIDOTE-PYRRHOTITE-ILMENITE/RUTILE-CALCITE

Grey-green, fine-grained, altered rock containing wispy, vaguely defined laminae rich in strongly magnetic sulfides (mostly pyrrhotite). There are traces of reaction to cold dilute HCl; modal mineralogy in polished thin section is approximately:

Quartz	45%
Sericite	40%
Pyrrhotite, trace pyrite	10%
Biotite	2-3%
Ilmenite, minor rutile	1-2%
Epidote	1%
Carbonate (?calcite)	<1%

This sample consists mainly of crenulated, foliated laminae (<0.25 mm thick) of quartz and sericite that appear to be crosscut by ?stringers of sulfide-coarser quartz-sericite (muscovite) and minor biotite (partially chloritized), epidote and carbonate. Most quartz crystals are subhedral and <0.2 mm in diameter except in the ?stringers, where they reach 0.5 mm in size. Sericite forms bent subhedra mainly <0.25 mm in size. In the ?stringers, biotite is pale reddish-brown, subhedral, and up to 0.35 mm in diameter; where chloritized, minor rutile is developed. Epidote forms subhedral to irregular crystals up to 0.5 mm, commonly containing minute flakes of biotite and confined to margins of the former ?stringers; carbonate, likely mostly calcite, forms subhedra to 0.35 mm intergrown with sulfides. No feldspar is clearly distinguishable either by twinning or relief difference, suggesting the precursor is not likely to have been igneous (volcanic); it could have been a siliceous clastic rock.

Vaguely defined, irregular stringers of pyrrhotite (aggregates to a few mm across composed of sub- to euhedral crystals to 0.5 mm) are in places associated with significant, coarse (to 0.5 mm) euhedral ilmenite crystals. Finer ilmenite aggregates, in places containing sub- to euhedral crystals of rutile to 25 microns, are also found in the intervening gangue layers. Pyrrhotite shows traces of alteration to lamellar pyrite/marcasite and tiny (<50 micron thick) veinlets of pyrite. However, no base-metal sulfides are seen.

MM 73-02 345': QUARTZ-SERICITE-RELICT K-FELDSPAR SCHIST CUT BY ?STRINGERS OF QUARTZ-PYRRHOTITE/PYRITE-CARBONATE-MINOR SPHALERITE-TOURMALINE

Folded, crenulated, laminated pale grey-green siliceous schist containing irregular ?stringers of quartz and sulfide. Most of the slide is similar to that from 206 m, and consists of a granular mosaic of fine-grained quartz and sericite plus minor pyrrhotite, carbonate and sphalerite, cut by deformed stringers of quartz containing pyrite and narrow fractures of carbonate. Quartz crystals are strongly deformed and contain trails of inclusions parallel to the foliation or crenulation in adjacent sericite, suggesting syn-kinematic quartz growth. Areas of very fine (10-20 micron) sericite, plus minor carbonate, have the appearance of replacing former ?feldspar which may have formed 15-20% of the rock, as subhedra to 0.2 mm (in places aggregates to 1.5 mm of relict ?Kspar, have distinct negative relief compared to quartz), suggesting a possible igneous (trachyte/syenite) precursor. In the stringers, pyrite forms subhedra up to 0.5 mm in diameter, associated with traces of sphalerite (to 0.15 mm and containing inclusions of pyrrhotite to 0.1 mm; minor tourmaline forms pale greenish-brown (schorl-dravite) euhedra to 0.7 mm. In the wallrock, pyrrhotite forms subhedral aggregates to 1 mm across that are in places associated with (?altered to) pyrite as cubic crystals to 0.2 mm, or red-brown (Fe-rich) sphalerite aggregates up to 0.6 mm across.

MM 74-02 840.5': QUARTZ-SERICITE-BIOTITE-CARBONATE-EPIDOTE SCHIST; SEMI-MASSIVE PYRRHOTITE-SPHALERITE-GALENA IN QUARTZ-BIOTITE-CARBONATE

Foliated dark grey-green rock and semi-massive magnetic sulfides; the rock reacts to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Quartz	25%
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Sericite	20%
Carbonate	15%
Pyrrhotite, minor pyrite	15%
Biotite	10%
Sphalerite	10%
Epidote	2-3%
Galena	1-2%
Rutile	<1%

This slide consists mainly of foliated quartz, sericite and biotite plus minor epidote and traces of rutile, again with relict textures suggesting that at least part of the sericite and biotite (especially the fine-grained flakes) have replaced former feldspar and ?mafic minerals in a possible igneous rock. Quartz is clotty where closely associated with sulfides, forming aggregates up to 1.5 mm across composed of subhedral to 0.6 mm. Sericite and very pale greenish-brown biotite flakes are sub- to euhedral, up to 0.3 mm in diameter except where replacing former ?feldspar and/or mafic minerals that may have been subhedral, up to 0.25 mm in size. Some layers contain fine (<0.1 mm) anhedral carbonate interstitial to quartz. Sub- to euhedral crystals of epidote are mainly <0.2 mm in diameter.

In the sulfide-rich portion of the slide, pyrrhotite (subhedral to 0.35 mm, aggregating to 2 mm) is mixed with sphalerite (red-brown, relatively Fe-rich subhedral mainly <0.2 mm) in a matrix of alternating layers of very pale brownish to greenish biotite and sericite (subhedral flakes to 0.35 mm; radiation damage around inclusions of ?REE-bearing epidote), carbonate (likely mostly calcite, subhedral to 0.6 mm that poikilitically enclose sulfides), and quartz (subhedral to 0.5 mm). Minor galena is included in sphalerite as subhedral to 0.5 mm.

MM 74-02 864.5': CRUDELY LAYERED PYRITE-SPHALERITE+GALENA-CHALCOPYRITE AND QUARTZ-CARBONATE-BARITE-CHLORITE/BIOTITE/SERICITE

Semi-massive pyritic sulfides interleaved with a 1 cm thick layer of quartz-carbonate-pyrrhotite (magnetic, trace reaction to cold dilute HCl). The semi-massive sulfide layers (up to 2 cm thick) consist mainly of eu- to subhedral cubic pyrite up to 0.5 mm in diameter, with interstitial sphalerite (subhedral, to 0.2 mm, red-brown colour indicating moderately high Fe content) and in places minor chalcopyrite (irregular-shaped masses up to 1 mm across, commonly intergrown with sphalerite near the margins of the gangue-rich layer) and galena (subhedral to 0.15 mm). The sulfides are intergrown with barite (ragged subhedral crystals to 2 mm long), quartz (sub- to anhedral, to 0.25 mm), carbonate (subhedral to 0.5 mm) and minor chlorite (subhedral flakes to 0.1 mm, especially immediately adjacent to sulfides). All gangue minerals show signs of deformation (sub-grain development, sutured grain boundaries). Barite contains abundant fine <30 micron) inclusions of sphalerite/pyrite. In the central, gangue-rich layer, minor sulfides include pyrite, sphalerite, minor pyrrhotite (subhedral to 0.25 mm) and traces of fine-grained chalcopyrite and galena. Gangues include quartz (sub/anhedral crystals to 0.5 mm), carbonate (calcite and ?dolomite, subhedral to 0.3 mm), barite (elongate, bladed subhedral up to 2 mm long) and minor pale greenish-brown chlorite (patches to 0.35 mm of minute <20 micron flakes, commonly closely associated with the sulfides) and sericite (subhedral flakes to 0.2 mm).

MM 76-02 410': MASSIVE PYRITE-MINOR SPHALERITE-GALENA IN GANGUE OF QUARTZ-SERICITE-CARBONATE-?FLUORITE

Massive, pyritic sulfides with a nodular, faintly laminated appearance. The rock is not magnetic but shows minor reaction to cold dilute HCl. Modal mineralogy in polished thin section is roughly:

Pyrite	65%
Quartz	25%
Sericite (muscovite)	3%
Carbonate (?mainly calcite)	3%
?Fluorite	2%
Sphalerite	1-2%
Galena	<1%

This sample consists of an aggregate of mostly eu- to subhedral pyrite crystals <1.5 mm in diameter, in places surrounded by minor sphalerite, in a matrix of quartz with minor sericite, carbonate and ?fluorite. Pyrite crystals in places have elongate shapes suggestive of formation after ?pyrrhotite; the granular character of most pyrite causes the apparently "nodular" texture of the sample. Sphalerite forms subhedral

to 0.1 mm with pale colour indicating low Fe content, in contrast to other sphalerites from this deposit (red-brown, moderate Fe content). Traces of galena (subhedra <0.1 mm) are intergrown with the sphalerite, or included in pyrite. The interstitial matrix to the sulfides is quartz-rich (commonly with bladed or lamellar texture caused by pressure shadows near the pyrite crystals). However, in places there are subhedral flakes of fairly coarse (to 0.25 mm) sericite or muscovite, subhedra of carbonate (calcite), and minor amounts of an isotropic mineral with strong negative relief, possibly fluorite, as subhedral crystals <0.25 mm in diameter. There could be minor ?barite (only a few crystals; could be a near-basal section of carbonate).

MM 76-02 423': MASSIVE ?BARITE-PYRITE-MINOR CARBONATE-SERICITE-SPHALERITE MAGNETITE AND GALENA

Buff-grey, fine-grained altered rock (mostly softer than steel) with heavy disseminated pyrite and minor pale brownish ?sphalerite. The rock is weakly magnetic and shows minor reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Barite	55%
Pyrite	35%
Carbonate (?mainly calcite)	5%
Sericite	2%
Sphalerite	2%
Magnetite	<1%
Galena	<1%
Chalcopyrite	tr

This sample consists of semi-massive pyrite (disseminated cubic crystals up to 0.5 mm in diameter) and minor magnetite (rounded subhedra to 0.5 mm), with interstitial sphalerite (subhedra mostly <0.2 mm) and galena (subhedra to 0.15 mm). Traces of chalcopyrite (<10 microns in diameter) also occur included in the magnetite. Gangues consist mainly of granular subhedral crystals to 0.5 mm of ?barite, commonly showing minor cleavage (length-slow; ?small positive 2V). Apart from the cleavage, and apparent high relief compared to epoxy, it looks like quartz! but I believe it is mostly barite. Carbonate forms irregular to subhedral crystals up to 0.25 mm diameter, locally aggregating to 1 mm; minor sericite forms subhedral flakes to 0.15 mm diameter.

MM 76-02 448': CRENULATED BARITE-MUSCOVITE/PHLOGOPITE/CHLORITE-CARBONATE-EPIDOTE; STRINGERS BARITE-PYRITE-PYRRHOTITE-SPHALERITE-GALENA-?FLUORITE

Fairly coarse-grained, siliceous, grey, sulfide-rich altered rock, strongly magnetic, reacts to HCl; modal mineralogy in polished thin section is approximately:

Barite	50%
Muscovite/phlogopite	25%
Pyrite	5%
Pyrrhotite	5%
Sphalerite	5%
Carbonate (calcite)	5%
Chlorite (after "phlogopite")	2-3%
Epidote	1%
?Fluorite	1%
Galena, chalcopyrite	<1%

This sample consists of stringery pyrite-pyrrhotite-sphalerite with coarse barite and lesser muscovite, in a finer-grained, foliated, crenulated matrix of barite and sericite plus lesser sulfides. In the coarse-grained ?stringer zones, up to 1 cm thick, barite forms sub- to euhedral crystals up to 6 mm in diameter, commonly with inclusions of carbonate and sericite and in places recrystallized to granular aggregates of smaller, rounded sub-domains (all less than about 0.15 mm in size). In the margins of some of the ?stringer zones, there are minor amounts of carbonate (subhedra to 0.4 mm) associated in places with an isotropic, negative relief mineral that could be ?fluorite (anhedra interstitial to barite, <0.2 mm in size). Pyrite, pyrrhotite and sphalerite form sub- to euhedral crystals up to 1.2 mm in diameter, in aggregates up to 1 cm or so across that are commonly intergrown with pale mica (muscovite or bleached-out biotite/phlogopite) as sub- to euhedral flakes up to 0.25 mm in diameter. Rare galena forms subhedra to 0.5 mm intergrown with sphalerite; traces of chalcopyrite occur separately, in barite. In places the biotite/phlogopite is altered to chlorite (green, pleochroic, F/M perhaps 0.5) and minor epidote (subhedra to 0.15 mm). In the matrix, grain

size is generally 0.1-0.2 mm, although there are foliated, crenulated zones of 50 micron grain size, possibly reflecting a deformed early structure such as bedding.

MM 76-07 644': MASSIVE PYRITE/?MARCASITE+SPHALERITE-GALENA; INCLUSIONS OF ?K-FELDSPAR, QUARTZ, CARBONATE-?TREMOLITE-SERICITE/BIOTITE

Massive, pyritic sulfides, weakly magnetic, intense reaction to cold dilute HCl. The slide consists essentially of massive pyrite with interstitial gangue minerals (carbonate, a pale amphibole that may be tremolite, sericite/pale green biotite, ?K-feldspar, quartz).

Pyrite occurs as granular aggregates of mainly <0.25 mm, subhedral crystals; faint but distinct anisotropism in many crystals suggests possible ?marcasite. Interstitial sphalerite is minor, mainly <0.25 mm in diameter, and red-brown in colour, indicating moderate Fe content. Rare galena forms subhedra to 0.25 mm, also interstitial to pyrite and mainly in the quartz- and feldspar rich portion of the sample. There may be a trace of magnetite present (difficult to distinguish from sphalerite) to explain the magnetism in hand specimen.

Feldspar forms large (up to 2 mm diameter) rounded subhedral crystals that have distinct negative relief compared to quartz inclusions, and minor perthitic structure, suggesting they are likely K-feldspar (optic angle is large and negative, twinning is simple Carlsbad). Quartz forms irregular aggregates of anhedral crystals mainly <0.35 mm in diameter (rarely, square euhedra to 0.75 mm). Both quartz and feldspar could have originated as phenocrysts in a felsic rock that has been subsequently mainly replaced by sulfides and secondary silicates/carbonates. Carbonate, commonly massive, forms tightly interlocking, mainly anhedral crystals up to 0.35 mm in diameter, commonly intergrown with either bladed ?tremolite (extinction angle to 13 degrees) up to 0.25 mm long, or sub- to euhedral sericite (muscovite) flakes up to 0.75 mm in diameter. In places the mica has pale greenish or brownish pleochroism, suggesting it may be phlogopitic or derived by sericitization of a biotite.

MM 76-07 655': SEMI-MASSIVE PYRITE-SPHALERITE-MAGNETITE+GALENA/DISSEMINATED PYRRHOTITE IN CARBONATE-MUSCOVITE-PHENGITIC MICA MATRIX

Offcut shows half semi-massive pyritic sulfides, half grey and white altered rock with disseminated sulfides. The rock is strongly magnetic and reacts to cold dilute HCl. In polished thin section, the sulfide-rich portion is composed mainly of sub- to euhedral pyrite crystals up to 1 mm in diameter (rare inclusions of galena to 40 microns) in a matrix of carbonate (likely mostly calcite; subhedra optically continuous for up to 1 mm, with strong undulose extinction indicating deformation). Minor sphalerite (red-brown, moderate Fe content) forms sub- to euhedral crystals up to 0.2 mm in size, generally adjacent to pyrite and in places associated with clusters of radiating very pale green (?phengitic) mica flakes to 0.5 mm diameter. Muscovite, confined to certain layers, forms subhedral flakes up to 0.25 mm diameter, in places with cores of pale brown ?bleached biotite or phlogopite. The rest of the slide is composed principally of muscovite and a green (ferriferous) mica as sub- to euhedral flakes up to 0.5 mm, clots of euhedral sieve-textured (porphyroblastic) pyrite crystals, and fine (<0.2 mm) disseminated pyrrhotite in a matrix of carbonate (similar to that in the pyritic portion). In both parts, skeletal sieve-textured clumps of magnetite up to 2 mm across (mixed with traces of sphalerite) are common.

Plate 6

a) MM **DDHMM73-02 206'**: Possible stringer of pyrrhotite(po)-ilmenite(il) in quartz-minor biotite-epidote-calcite (reflected light, uncrossed polars, field of view 2.0 mm wide).

b) MM **DDHMM77-02 345'**: Aggregate of sphalerite (sl) and pyrrhotite (po) in quartz-carbonate stringer, in quartz-sericite schist (reflected light, uncrossed polars, field of view 2.0 mm wide).

c) MM **DDHMM74-02 840.5'**: Pyrrhotite(opaque)-sphalerite (red-brown) in matrix of quartz(clear)-biotite(pale brown)-epidote(high relief); more intense colour in biotite caused by radiation damage around RED-bearing epidote (transmitted light, uncrossed polars, field of view 2.5 mm wide).

d) MM **DDHMM74-02 864.5'**: Typical sulfides at the border of the gangue-rich layer (composed of quartz, carbonate, barite, chlorite): cubic pyrite, shapeless mass of chalcopyrite intergrown with subhedral sphalerite; reflected light, uncrossed polars, field of view 2 mm wide.

e) MM **DDHMM76-02 410'**: Cubic pyrite, minor interstitial sphalerite (sl) and rare galena (gn) in gangues of quartz(qz)-carbonate(ca)-?fluorite(fl) and muscovite (ms) or sericite (reflected light, uncrossed polars, field of view 1.6 mm wide).

f) MM **DDHMM76-02 423'**: Euhedral pyrite, subhedral magnetite with inclusions of and interstitial sphalerite and galena; matrix of barite, minor sericite and carbonate (reflected light, uncrossed polars, field of view 1.6 mm wide).

g) MM **DDHMM76-02 438'**: Coarse euhedral and finer, subhedral barite, muscovite or bleached biotite/phlogopite, and carbonate, and pyrite-pyrrhotite (opaque) plus sphalerite (red-brown). Transmitted light, uncrossed polars, field of view 2.5 mm wide.

h) MM **DDHMM76-07 644'**: Granoblastic pyrite or ?marcasite, minor interstitial sphalerite and rare galena, in gangues of quartz, carbonate, tremolite, sericite (reflected light, uncrossed polars, field of view 1.9 mm).

**MM 76-07 726': CLOTTY/STRINGERY ?KSPAR-CARBONATE-AMPHIBOLE-EPIDOTE-PYRITE-
?PLAGIOCLASE-MAGNETITE-SPHALERITE-?ALLANITE ALTERED ?INTERMEDIATE ROCK**

Similar in appearance to 655', but sulfides more irregularly distributed (?clots along possible deformed stringers) and there is a white ?vein. The rock is strongly magnetic and reacts strongly to cold dilute HCl. In polished thin section, pyrite forms mainly subhedral crystals up to 2 mm in diameter (containing rare rounded inclusions to 50 microns of pyrrhotite and galena), in clumps or ?veinlets up to 1 cm across or 0.5 cm thick respectively, in places associated with porphyroblastic magnetite up to 3 mm in length and minor euhedral sphalerite (red-brown, moderate Fe content) up to 1 mm in diameter. The matrix consists of ?K-feldspar (low birefringence, ?negative relief compared to the ?plagioclase in the vein, moderate negative 2V) as rounded, granular crystals mostly <1 mm in diameter intergrown with carbonate, epidote, amphibole and green biotite, and partly altered to fine carbonate and sericite. Carbonate forms sub- to anhedral crystals up to 0.65 mm in diameter, likely mostly calcite; epidote forms sub- to euhedral crystals up to 0.7 mm size with deep yellow pleochroism indicating high Fe content. Amphibole forms deep green pleochroic subhedral to fibrous crystals up to 0.3 mm long with small extinction angle (possibly actinolite). In some places there are wispy, elongate concentrations of deep red-brown, pleochroic ?allanite as sub- to euhedral crystals up to 0.25 mm in size with fine-grained magnetite, ?sphene/rutile and minor pyrite all mostly <20 microns in diameter. The white vein seen in hand specimen consists of subhedral, twinned crystals to 1.5 mm that are cloudy, higher in birefringence, and have positive relief compared to the ?K-feldspar of the matrix, suggesting plagioclase possibly of ?andesine composition (extinction on 010 up to 23 degrees). I do not have a high degree of confidence in some of the identifications (particularly the ?feldspars) in this sample; however, it appears to be somewhat unusual (containing ?allanite, epidote and amphibole), possibly derived from an intermediate rock.

**MM 77-01 933': SEMI-MASSIVE SPHALERITE-PYRITE-MAGNETITE-GALENA IN QUARTZ-AMPHIBOLE-
MICA-EPIDOTE-CARBONATE-?FLUORITE-PLAGIOCLASE GANGUE**

Vaguely laminated, deformed, pale buff-greenish and pale red-brown (sphalerite-rich) rock; scattered clots of pyrite. The rock is magnetic and shows minor reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Quartz	40%
Sphalerite	25%
Amphibole	15%
Epidote	5%
Pyrite	5%
Green mica	3%
Carbonate (?mainly calcite)	3%
?Fluorite	1%
Magnetite	1%
Galena	1%
Plagioclase	<1%
Chalcopyrite	<1%

This slide consists of layers up to 2.5 cm thick of semi-massive sulfides (mainly sphalerite, lesser pyrite, pyrrhotite; trace chalcopyrite) in a gangue of quartz, amphibole, pale green mica, epidote, carbonate, and ?fluorite. Pyrite occurs as mainly subhedral crystals up to 1.2 mm in size. Sphalerite is yellow, indicating low to moderate Fe content; it forms masses up to 0.5 cm across of subhedra to 0.25 mm, in places (along certain layers) intergrown with magnetite subhedra to 0.5 mm across. Minor galena forms anhedral to 0.25 mm; in certain laminae, chalcopyrite forms anhedral skeletal crystals to 0.1 mm, mixed with sphalerite. Quartz forms subhedral polygonal crystals up to 0.5 mm diameter with triple junctions indicating some annealing; carbonate forms irregular crystals up to 0.2 mm, likely mostly calcite. The micaceous mineral occurs as subhedral crystals to 0.3 mm in diameter; it could be a phengitic (Fe-rich) muscovite to judge by its colour, although in places it is green enough to be possibly Fe-rich biotite. Amphibole forms subhedral to ragged crystals up to 0.25 mm long with olive-green to sea-green pleochroism and small extinction angle; it could be hornblende or actinolite. Epidote has only pale yellow pleochroism, indicating low Fe content, forming skeletal crystals <0.2 mm in size commonly contained within amphibole, or ragged ?relics up to 0.75 mm long. An isotropic mineral with strong negative relief that forms anhedral masses mostly <0.25 mm in size, closely associated with carbonate and sphalerite, could be fluorite; rare polysynthetic twinned plagioclase is subhedral, <0.1 mm.

MM 77-03 788': LAMINATED QUARTZ-BIOTITE-SERICITE-EPIDOTE-CALCITE (QUARTZ ?PHENOCRYSTS, DISSEMINATED PYRITE-PYRRHOTITE-MAGNETITE+SPHALERITE)

Dark grey, siliceous, vaguely laminated/foliated rock with abundant disseminated sulfides; magnetic, reacts to cold dilute HCl. Sulfides include both widespread pyrrhotite (mainly small clots <0.5 mm in diameter composed of subhedra to 0.2 mm) and magnetite (subhedra to 0.15 mm; rare sphalerite to 50 microns) as well as local concentrations of pyrite (coarser, subhedral cubic crystals to 0.75 mm, in places including or associated with minor magnetite subhedra to 0.15 mm and red-brown (moderate Fe content) sphalerite subhedra to 0.3 mm. In places fine-grained aggregates of pyrrhotite and magnetite are ?replaced at the core by the coarse pyrite crystals which contain inclusions of pyrrhotite and magnetite. The gangue is composed of subhedral quartz (<0.5 mm but commonly in aggregates with rounded outlines up to 1.5 mm in diameter, possibly representing former ?quartz phenocrysts), in a fine-grained matrix of pale brown biotite, sericite, quartz, and clotty epidote and lesser carbonate. Micas form mainly shreddy flakes <0.15 mm in diameter (mainly <50 microns for sericite that could be replacing former feldspar); in places the pale biotite forms flakes to 0.5 mm in the pyrite-rich aggregates that are up to almost 1 cm in diameter. Epidote forms sub- to euhedral crystals up to 0.25 mm in size but commonly in aggregates (with sulfides/magnetite) to 0.75 mm that suggest the presence of former ?mafic mineral crystals; faint yellow pleochroism indicates moderate Fe content.

MM 77-03 825': LAMINATED QUARTZ-BIOTITE/CHLORITE-EPIDOTE-CALCITE AND PYRITE-SPHALERITE-PYRRHOTITE+GALENA-CHALCOPYRITE

Two samples from 825 and 825.5m appear to be very similar to each other and to the sample from 788m; only the one from 825m will be described. The hand samples are dark grey to brownish, laminated on a mm to cm scale, and somewhat foliated. Some laminae are enriched in coarse pyrite and others in pale red-brown sphalerite, pyrrhotite and galena, or sphalerite and minor chalcopyrite, suggesting primary compositional layering. Coarse-grained pyrite is euhedral, up to 1 mm; pyrrhotite forms subhedral skeletal crystals to 0.6 mm; sphalerite forms masses up to 1.5 mm across containing minor galena to 0.5 mm or chalcopyrite to 0.6 mm (minor chalcopyrite "disease"). The sample consists of alternating layers of finer and coarser quartz-mica-sulfides, separated by foliated mica-rich (minor epidote) laminae. Quartz crystals are generally subhedral polygonal, up to 0.5 mm in diameter although in finer-grained laminae the average grain size is mainly <0.1 mm. Biotite is pale brown to greenish (subhedral flakes to 0.3 mm, in places partly replaced by chlorite as subhedral flakes to 0.2 mm with optical characteristics indicating moderate Fe:Fe+Mg (F/M) ratio near ?0.5). Epidote forms sub- to euhedral crystals to 0.25 mm with little pleochroism indicating low Fe content.

MM 77-03 830': MASSIVE PYRITE-SPHALERITE-PYRRHOTITE-GALENA-CHALCOPYRITE IN QUARTZ-BIOTITE-CHLORITE-SERICITE-EPIDOTE; AUGEN OF FLUORITE

Massive to semi-massive, strongly magnetic sulfides containing large (0.7 cm) apparently zoned crystal or ?augen of a clear to pale greenish mineral (fluorite in thin section). The rock does not react to cold dilute HCl. In polished thin section, the sample is made up of about 25% pyrite (coarse sub- to euhedral up to 1.2 mm in diameter), surrounded by about 25% sphalerite (dark red-brown moderately Fe-rich sub- to euhedral crystals up to 1 mm in diameter), concentrated in layers up to 1.5 cm thick where it is associated with pyrrhotite (5%, subhedra mainly <0.5 mm in size) and wispy laminae enriched in galena (2-3%, subhedra to 0.75 mm); in certain ?layers, and in gangue-rich layers, there are concentrations of chalcopyrite (1-2%, sub- to anhedral crystals up to 0.85 mm in diameter). Gangues consist of quartz (30%, rounded subhedra to 0.6 mm diameter, in places aggregating to rounded 3 mm patches) and interstitial patches of biotite-chlorite-sericite-epidote (<10%, mostly as subhedral crystals <0.25 mm in diameter) that could be after former ?mafic and/or feldspar minerals; in places there is minor ?fluorite (2-3%, anisotropic, negative-relief subhedra to 0.5 mm). The rock appears to be strongly fractured, with mobilization of the mafic minerals in between the (granulated) quartz. Chlorite intergrown with sphalerite forms euhedral flakes to 0.2 mm that have optical properties (pale green pleochroism, anomalous blue length-slow birefringence) indicative of moderate Fe content (F/M perhaps 0.5-0.6).

MM 77-03 867.5': QUARTZ-BIOTITE-SERICITE SCHIST, DISSEMINATED PYRRHOTITE-PYRITE-MAGNETITE+CHALCOPYRITE-SPHALERITE, CUT BY QUARTZ ?VEIN

Dark grey, siliceous, fine-grained altered rock with layer of white ?quartz and minor disseminated sulfides; magnetic, minor reaction to cold dilute HCl. The bulk of the slide is composed of sub- to euhedral, polygonal quartz up to about 0.5 mm in diameter, with patchily distributed fine sericite and biotite that appear to be secondary, possibly after former feldspar and mafic minerals respectively with sub- to anhedral, strongly deformed outlines mostly <1 mm in size. Most sericite is present as shreddy flakes <25 microns in diameter; biotite is pale brown and forms subhedral flakes up to 0.15 mm diameter, in places partly chloritized at the margins. Biotite-rich laminae are marked by pleochroic haloes around concentrations of very fine (10-20 micron) ?allanite or REE-bearing epidote. Fine (mainly <0.1; rarely to 0.25, aggregating to 1.5 mm) crystals of pyrrhotite and magnetite, are disseminated, in places ?replaced by cubic pyrite. Sphalerite is rare, mainly <50 microns in size, with red-brown colour indicating moderate Fe content; traces of chalcopyrite (subhedral to 50 microns) are included in pyrrhotite aggregates. The protolith may have been a felsic to intermediate rock that has undergone greenschist facies metamorphism. The quartz ?vein contains strained subhedral quartz up to 1.5 mm in diameter, with minor interstitial sericite, carbonate, and ?fluorite all less than 0.2 mm in diameter; minor chalcopyrite, pyrite and magnetite are associated with high-relief, brownish ?rutile and chlorite (after biotite).

MM 77-03 978': QUARTZ-SERICITE-CARBONATE (FERROAN/CALCITE)-HYDROBIOTITE-PYRITE-PYRRHOTITE-RUTILE-APATITE SCHIST AFTER ?INTERMEDIATE VOLCANIC

Pale grey-green, fine-grained, siliceous schist with disseminated pyrite and minor ?sphalerite imparting a reddish colouration; slightly magnetic, trace reaction to cold dilute HCl. In polished thin section, this sample consists mainly of layers/laminae from 1 to 6 mm thick that are alternately richer in quartz or sericite; the bulk of the sulfide occurs in the quartz-rich layers. Sulfides include both pyrite and pyrrhotite as eu- to subhedral crystals up to 0.5 mm in diameter, locally aggregating to several mm. The reddish colouration appears to be due to limonite (staining in Fe-carbonate crystals which surround the iron sulfides), not to sphalerite. Quartz crystals are mainly subhedral polygonal and rarely up to 0.5 mm in diameter; undulose extinction is minor, and they appear to have been somewhat annealed since deformation. Sericite flakes are subhedral, rarely to 0.5 mm diameter; in places, patchy aggregates of finer (<0.1 mm) sericite flakes suggest the former presence of ?feldspar crystals with irregular outlines up to almost 3 mm in diameter. In places, these aggregates contain minor pale brownish biotite or "hydrobiotite" as ragged flakes to 0.1 mm (mostly lacking pleochroism), associated with minor brownish (?ferroan) carbonate mainly <50 microns in diameter, and aggregates or rarely single subhedral crystals of rutile up to 0.15 mm in diameter, suggesting the presence of former ?mafic crystals. There are also ragged anhedral of clear carbonate (?calcite) up to 0.15 mm in diameter, and rare occurrences of an isotropic mineral with strong negative relief, tentatively identified as ?fluorite. Scattered subhedral of ?apatite, <0.1 mm in diameter, reinforce the suggestion that the protolith for this quartz-sericite-pyrite-pyrrhotite-carbonate +hydrobiotite schist could have been an intermediate volcanic.

Plate 7

a) MM **DDHMM76-07 726'**: Coarse porphyroblastic pyrite and magnetite (reflected light, uncrossed polars, 2 mm wide) in matrix of ?K-feldspar, epidote (yellow), amphibole (?actinolite, green) and carbonate (see photo f).

b) MM **DDHMM76-07 726'**: Coarse porphyroblastic pyrite and magnetite (see photo g) in matrix of ?K-feldspar, epidote (yellow), amphibole (?actinolite, green) and carbonate (photo, transmitted light, uncrossed polars, field of view 2.5 mm wide).

c) MM **DDHMM77-01 933'**: Magnetite (mt, containing chalcopyrite) and pyrite (py) in semi-massive sphalerite (sl)-minor galena (gn) in reflected light, uncrossed polars, 2 mm wide; gangues (see photo c) include quartz, amphibole, epidote, carbonate, ?fluorite.

d) MM **DDHMM77-01 933'**: Gangue to sulphides in photo b include quartz, amphibole, epidote, carbonate, ?fluorite (transmitted light, uncrossed polars, 2.5 mm wide).

e) MM **DDHMM77-03 788'**: Fine-grained aggregates of magnetite and pyrrhotite ?replaced at the core by coarser pyrite containing inclusions of pyrrhotite and magnetite; hosted in quartz-sericite-biotite-epidote-carbonate (reflected light, uncrossed polars, field of view 1.9 mm).

f) MM **DDHMM77-03 825'**: Euhedral pyrite, red-brown sphalerite in biotite-chlorite-epidote rich laminae, quartz-rich matrix. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

g) MM **DDHMM77-03 830'**: Euhedral pyrite, pyrrhotite in matrix of sphalerite-galena; minor chalcopyrite rimming pyrrhotite. Gangues mostly muscovite, quartz and fluorite (reflected light, uncrossed polars, field of view 1.9 mm wide).

h) MM **DDHMM77-03 867.5'**: Possible ?feldspar and mafic mineral relict crystals (altered to sericite and biotite-opaques respectively) in matrix of quartz-minor sericite. Transmitted light, crossed polars, field of view 2.5 mm wide.

MM 77-03 1072': MUSCOVITE-QUARTZ-?CLAY/CHLORITE-HYDROBIOTITE-CARBONATE-EPIDOTE-PYRITE-PYRRHOTITE-RUTILE ALTERED/STRINGERED ?INTERMEDIATE ROCK

Grey-green, fine-grained altered rock (mostly softer than steel) with disseminated/stringery iron sulfides; magnetic, reacts to HCl. Modal mineralogy in polished thin section is approximately:

Muscovite	50%
Quartz	15%
?Clay-chlorite, ?hydrobiotite	10%
Carbonate (?mainly calcite)	10%
Pyrite	5%
Pyrrhotite	3%
Epidote, ?zoisite	3%
Chlorite	3%
Rutile	<1%
?Barite	<1%

This sample consists mainly of muscovite (coarse, sub- to euhedral, in places bent and broken flakes of sericite up to 1 mm in diameter) that are closely associated with the sulfides in what appear to be coarser-grained, irregular ?stringers up to about 2 mm thick cutting a finer-grained aggregate of muscovite (0.15 mm) and minor carbonate (?calcite subhedra to 0.1 mm) in a matrix of very fine-grained (10-15 micron) ?clay-chlorite or in places brownish ?hydrobiotite. The ?clay-chlorite flakes are subhedral, very pale brownish in colour and lack any pleochroism; relief appears to be negative compared to quartz. Other minerals in the ?stringers include epidote (and crystals with no pleochroism, low birefringence suggesting ?zoisite) as subhedral crystals to 0.35 mm, and colourless chlorite (length-fast, first-order birefringence suggests magnesian composition, F/M near ?0.4) as subhedral flakes to 0.2 mm, and quartz (subhedra to 1 mm diameter, with undulose extinction indicating strain). Rarely, sub- to euhedral crystals of ?barite up to 1 mm in size surround sulfides. The rock is cut by later, more planar, carbonate (?calcite) veins up to about 1 mm thick. Pyrite forms subhedral crystals to about 0.5 mm diameter, largely ?replacing pyrrhotite, remnants of which form subhedra up to 0.35 mm in size. Significant amounts of rutile (subhedral very dark brown to almost opaque, ?Fe-rich crystals up to 0.15 mm in diameter) are present, suggesting a mafic to intermediate protolith. No base-metal sulfides are seen. This is an unusual rock, possibly reflecting a strongly muscovite-quartz-hydrobiotite-epidote-chlorite-iron sulfide altered ?intermediate or mafic volcanic from a stringer zone underlying the deposit.

MM 96-01 600': QUARTZ-AMPHIBOLE AND QUARTZ-SERICITE-EPIDOTE-BIOTITE-CHLORITE-GARNET, +SPHALERITE-GALENA-?PYRITE, ALTERED ?INTERMEDIATE ROCK

Dark green to black rock with irregular white ?quartz clots and scattered reddish ?garnets; trace magnetism and reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	35%
Amphibole	20%
Sericite	20%
Epidote	10%
Biotite	5%
Chlorite	5%
Garnet	2-3%

Sphalerite, ?pyrite, galena, rutile 2-3%

One half of this slide consists of alternating layers, up to 0.5 cm thick, that are either composed of sericite, biotite (variably chloritized), epidote, garnet, sphalerite, and opaques, or are quartz-rich (with minor amounts of the minerals found in the other layers). Quartz forms subhedral crystals up to about 0.5 mm in diameter, mainly lacking undulose extinction and displaying mild annealing textures. Sericite and biotite occur as sub- to anhedral flakes mainly <0.15 mm in diameter; biotite ranges from medium brown to greenish brown to chloritized (pale green, pleochroic, length-slow anomalous blue birefringence), the latter with minor rutile. Epidote forms large irregular crystals up to 1.2 mm in size that may be ?porphyroblastic, or may represent replacements of former ?feldspar or mafic crystals. Red-brown sphalerite (subhedra to 0.2 mm) are closely associated with epidote and chlorite, plus minor opaques that likely include galena and pyrite or pyrrhotite. Garnet forms subhedral to rounded crystals or aggregates up to 2.5 mm diameter, with faint reddish colour where thickest; they are more likely to be Fe-rich than Mn-rich. Sieve texture due to inclusions of epidote and chlorite suggests syn-kinematic growth.

The other half of the slide contains abundant dark green amphibole (?actinolitic hornblende; sub- to euhedral crystals to 0.25 mm long) in crude, irregular, deformed layers up to 4 mm thick alternating with similar poorly defined layers rich in sericite and epidote, and containing variable quartz and minor biotite (in places chloritized); minor red-brown sphalerite and opaques (?galena, pyrite) are associated with epidote and chlorite, or are found in the amphibole. This may have been an intermediate to ?mafic rock that has been strongly altered and metamorphosed; mineralization is fairly minor.

MM 96-01 682.5': MASSIVE PYRITE-SPHALERITE IN QUARTZ-SERICITE+BIOTITE-GARNET-EPIDOTE-CARBONATE-RUTILE GANGUE

Massive, pyritic sulfides with vaguely layered texture (minor sphalerite-rich layers up to 1 cm thick, disrupted biotite-enriched layers to 2 mm). White areas are siliceous (harder than steel); rock is not magnetic and shows only trace reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	35%
Quartz	30%
Sericite (muscovite)	20%
Sphalerite	5%
Biotite	5%
?Garnet	2-3%
Epidote	1-2%
Carbonate, rutile	<1% each

This slide consists of one half relatively fine-grained (<0.5 mm) semi-massive pyrite, sphalerite, quartz, sericite, and minor epidote; the other half is coarser-grained (to 1 mm) and clotty in texture, composed of quartz, pyrite, muscovite, biotite, and garnet with traces of carbonate. In the former, pyrite is mostly euhedral and sphalerite is generally subhedral and <0.25 mm, interstitial to or surrounding pyrite; galena, if present, is not obvious. In the latter, pyrite is subhedral and porphyroblastic; quartz and muscovite or biotite form subhedral crystals in alternating crude laminae a few mm thick, with traces of euhedral 10-20 micron rutile common in the sericite. Much of the biotite appears to be remnant, partly altered to muscovite; carbonate is intergrown with the margins of pyrite crystals. Epidote and garnet form subhedral, sieve-textured crystals or intergrowths, the latter in places as elongated aggregates parallel to the layering and foliation suggesting former garnet-rich laminae. Pale colour of the garnet (pink in hand specimen) suggests it could be Mn-rich, and therefore of interest to exploration in indicating possible exhalative origin (see, for example, description of "coticles" at Sullivan, in Jiang et al., 1998, and references by Slack therein).

MM 96-01 691': SEMI-MASSIVE SULFIDES (SERICITE-QUARTZ-PYRITE+SPHALERITE-GALENA-TOURMALINE-RUTILE-FLUORITE ROCK)

Semi-massive, pyritic sulfides (non-magnetic, no reaction to cold dilute HCl). Modal mineralogy in thin section is approximately:

Sericite	35%
Quartz	30%
Pyrite	30%
Sphalerite	2-3%
Tourmaline (schorlitic)	1%
Galena	<1%
Rutile	<1%
Fluorite	<1%
Biotite	tr

This is a poorly foliated quartz-sericite-pyrite-rutile schist with minor red-brown sphalerite, and in certain layers, minor green tourmaline, isotropic ?fluorite, and traces of pale brown biotite. Quartz mostly forms subhedral, polygonal (somewhat annealed) crystals <0.5 mm in diameter. Sericite forms subhedral flakes mainly <0.3 mm in diameter and randomly oriented except in certain narrow foliae <0.25 mm thick where they are sub-parallel and contain traces of minute (<15 micron) rutile crystals. Pyrite forms subhedra up to about 1 mm in diameter, closely associated with fringing Fe-rich subhedral sphalerite to 0.2 mm and minor sub- to euhedral galena to 0.15 mm. Tourmaline forms euhedra to 0.5 mm long, likely schorlitic in composition, intergrown with pyrite and sphalerite. Rare fluorite forms subhedral crystals to 0.1 mm, associated with sulfides in quartz; biotite flakes are <50 microns in diameter.

**MM 96-01 722': SEMI-MASSIVE PYRITE-SPHALERITE-MAGNETITE-GALENA IN MATRIX OF QUARTZ-
?PHENGITIC MICA-AMPHIBOLE-FLUORITE**

Vaguely folded, disrupted, semi-massive sulfides (pyrite-sphalerite-galena) in pale grey to black gangues. The rock is strongly magnetic and reacts strongly to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	20%
Quartz	20%
Muscovite (?phengitic)	20%
Carbonate (calcite)	15%
Sphalerite	15%
Magnetite	3-5%
Galena	2-3%
Amphibole (tremolite-actinolite)	1-2%
Fluorite	1-2%

This sample consists of a coarse-grained, clotty intergrowth of pyrite (subhedral to 2 mm), sphalerite (subhedral to 1.5 mm), magnetite (sieve-textured subhedral to 2 mm) and minor galena (subhedral to 1 mm) in a matrix of quartz (subhedral to 1.25 mm), green mica (?Fe-rich, rounded subhedral books/flakes to 0.35 mm), carbonate (likely mostly calcite, subhedral to 0.3 mm) and minor pale green amphibole (fibrous, <0.2 mm ?tremolite-actinolite). Quartz in places contains rounded inclusions of fluorite, and elsewhere rounded fluorite subhedra are intergrown with silicates. The dark colour in hand specimen is probably caused by the green mica and amphibole; pale coloured areas are rich in quartz and carbonate. Protolith is hard to guess at in this strongly altered and recrystallized rock, but could have been an intermediate volcanic rock to judge by the mineralogy.

**MM 96-01 876': SERICITE-QUARTZ-EPIDOTE-RUTILE SCHIST AFTER ?INTERMEDIATE ROCK
(?FRAGMENTS CONTAINING PYRITE-BIOTITE+SPHALERITE-GALENA-GARNET)**

Grey to pale greenish, partly siliceous (harder than steel), sericite-rich schist with clots of pyrite and relict ?fragments containing red-brown sphalerite and minor steel galena. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Sericite	45%
Quartz	40%
Pyrite	5%
Biotite, minor chlorite	3-5%
Epidote	2-3%
Rutile	1-2%
Sphalerite	1%
Garnet	1%
Galena	<1%

This slide consists mainly of somewhat foliated, commonly disrupted, crenulated sericite-quartz laminae mainly less than 0.5 cm thick, alternating with quartz-rich, coarser grained layers. In the former, sericite and quartz form subhedra mostly <0.2 mm in diameter; in the latter, quartz subhedra are up to 0.5 mm in diameter. Concentrations of fine (10-20 micron) euhedral rutile crystals mark the foliation planes in the former; in places the rutile is also found as inclusions in porphyroblastic epidote crystals up to 0.3 mm long. Swirls of pale brown biotite (subhedral flakes to 0.4 mm, in places chloritized to 0.1 mm flakes with first-order length-fast birefringence and no colour indicating F/M <0.4) occur in the quartz-rich "sweats", commonly associated with the sulfides (cubic pyrite up to 0.75 mm; traces of deep red-brown, Fe-rich sphalerite to 0.1 mm, and rare galena to 50 microns). Rarely, there are subhedral <1 mm garnet crystals (sieved by inclusions of sericite, quartz, and biotite) associated with the sulfides. In places, remnant textures (patches of sericite or quartz) suggest the possible former presence of phenocrysts in an ?intermediate and possibly fragmental volcanic rock.

MM 96-01 982': EXTREMELY FINE-GRAINED ?CHERT WITH PATCHES OF SECONDARY QUARTZ-SERICITE-CALCITE-BIOTITE/CHLORITE AND PYRITE

Pale grey-greenish, very fine-grained, siliceous, (cherty-looking) rock with traces of sulfide. The sulfides are magnetic; the rock shows only trace reaction to cold dilute HCl. In thin section, it consists almost entirely of a very fine-grained granular mosaic of quartz (80%, 10-20 microns) with interstitial ?K-feldspar (10%), carbonate (likely calcite, 2-3%) and sericite (1-2%). Scattered opaques up to 40 microns in diameter may include ?pyrite and ?rutile. In places, areas of ?secondary quartz, possibly representing deformed ?stringers up to 3 mm thick, contain more abundant opaques (?pyrite, rutile) associated with sericite, carbonate, and traces of biotite (partly altered to chlorite). In these zones, quartz crystals are subhedral and interlocking, up to 0.45 mm in diameter; sericite flakes are subhedral, up to 0.2 mm, pyrite (1-2%) forms cubic eu- to subhedral crystals to 0.5 mm, and biotite/chlorite (<1%) is subhedral, to 0.1 mm.

Plate 8

a) MM **DDHMM77-03 1072'**: Remnants of pyrrhotite (po) in pyrite (py), in matrix of coarse subhedral muscovite (ms) flakes (reflected light, uncrossed polars, field of view 1.6 mm wide).

b) MM **DDHMM77-03 1072'**: Coarse muscovite (ms), epidote (ep) associated with sulfides (black) in ?stringer cutting fine-grained mosaic of sericite, quartz, and ?clay-chlorite. Transmitted light, crossed polars, field of view 2.5 mm wide.

c) MM **DDHMM96-01 600'**: Porphyroblastic garnet, inclusions of chlorite, in matrix of quartz/sericite-chlorite-biotite-epidote+deep red-brown sphalerite-galena-?pyrite. Transmitted light, uncrossed polars, 2.5 mm wide.

d) MM **DDHMM96-01 691'**: Green to blue, euhedral, schorlitic tourmaline crystals in pyrite-sphalerite+galena aggregate; matrix of quartz and sericite, trace rutile. Transmitted light, uncrossed polars, 2.5 mm wide.

e) MM **DDHMM96-01 722'**: Euhedral pyrite, pale-coloured (low Fe) sphalerite, in matrix of quartz (containing fluorite), green (?phengitic) mica, minor carbonate, tremolite-actinolite. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

f) MM **DDHMM96-01 722'**: Euhedral pyrite, skeletal magnetite, low-Fe sphalerite, and galena in matrix of quartz, carbonate, green mica, amphibole and fluorite (see above). Reflected light, uncrossed polars, field of view 2 mm wide).

CHZERPNOUGH (FIRE) PROPERTY

Thirteen samples are listed as being from the Chzerpnough prospect, which is in felsic volcanic breccias of Early Mississippian age (Mortensen, 1982, in Hunt, 1998) varying from tuff to coarse agglomerate. Sphalerite and galena mineralization are disseminated in lapilli tuff with a carbonate matrix; fluorite and sugary laminated barite plus large, multi-element geochemical anomalies also occur (up to 2.5% Pb, 11.7% Zn, 72.9 g/t Ag and 1.06 g/t Au; Hunt, 1998).

The samples examined are mainly felsic lapilli tuffs that range from medium-fine grained (subangular to subrounded clasts to 1.5 cm composed of variably altered alkali feldspar, quartz, sericite, carbonate: **JH 96-5F, 10a, 10B, 13A, 13B, 13C, 13D**) to fine grained (flattened shards mostly <0.5 cm in size composed of sericite with minor relict alkali feldspar: **JH 96-2C**, or replaced by carbonate: **JH 96-6A, 7A**). Two samples (**JH 96-2A and 12C**) appear to be non-fragmental but similar in composition (mainly alkali feldspar), and **JH 96-15A** appears to be a more mafic (?biotite-hornblende-pyroxene quartz diorite or diabase) dyke. Alkali feldspar in most of the felsic rocks could be partly K-feldspar and partly albite; staining tests would be required to separate these mostly very fine (<0.15 mm), subhedral laths with negative relief compared to quartz except where coarser crystals display twinning. Some clasts, notably in JH 96-13A, are quartz-feldspar phyrlic; others such as in JH 96-2C, may have originally consisted of plagioclase (now sericitized) and K-feldspar. Carbonate in these samples is likely mostly ankeritic or possibly in places sideritic: relief is commonly high, and only portions of the carbonate (with lower relief) react to cold dilute HCl. Pyrite is the only sulfide seen (no polished surfaces to examine), but there is significant barite in JH 96-5F and 13D, and JH 96-2A contains limonite that could be after other sulfides. Both pyrite and barite appear to be associated with quartz-sericite alteration of the matrix and clasts, especially in fractures that cut some of the clasts. This suggests that at least part of the mineralization is later than formation of the host rocks, i.e. epigenetic, although similar effects could be produced by remobilization of syngenetic mineralization during metamorphism and deformation. Detailed descriptions for some samples and abbreviated descriptions for the rest follow; significant textures are illustrated in photomicrographs following the descriptions.

Chzerpnough (Fire) **JH 96-2A**: FELSIC (?RHYOLITIC) VOLCANIC CUT BY QUARTZ-MINOR ALKALI FELDSPAR-CARBONATE-LIMONITE STRINGERS AND REPLACEMENTS

Fine-grained, pale greenish-buff, felsic-looking, siliceous rock (harder than steel) cut by numerous narrow quartz stringers and containing irregularly-shaped clots of red- to orange-brown limonite that may in part be after sulfides. The rock is not magnetic and shows no reaction to cold dilute HCl; Modal mineralogy in thin section is approximately:

Alkali feldspar (?K-feldspar or albite)	45%
Quartz (partly secondary, veinlets)	30%
Limonite	15%
Carbonate (?ankerite or siderite)	5-7%
Sericite	3%
Rutile	<1%

This slide consists mainly of very fine-grained alkali feldspar and quartz, cut by narrow stringers composed mainly of quartz and lesser alkali feldspar. There is little remnant primary texture except for scattered patches of alkali feldspar and quartz of slightly coarser grain size, with irregular to rounded outlines up to 2.5 mm long. These patches could represent former feldspar phenocrysts or shards; there are no clast boundaries obviously visible in the section to indicate a fragmental rock. Alkali feldspar, which may be K-feldspar (relief significantly negative compared to quartz; albite is also a possibility, but no stained offset to examine) forms lath-shaped subhedral crystals rarely over about 0.15 mm long. Quartz forms sub- to anhedral crystals up to 0.1 mm in diameter. In the matrix, both alkali feldspar and quartz are mainly finer-grained (<50 microns).

Patches of limonite up to 1 cm across have subhedral to rounded outlines, and consist of fine-grained aggregates or impregnations of the rock, in places containing or replacing significant carbonate as subhedra to 0.7 mm diameter (likely ankerite or siderite to judge by the lack of reaction in hand specimen and the Fe-staining) and in places associated with sericite as fine subhedral flakes to 50 microns. The limonitic patches may represent former aggregates of carbonate and sulfide; smaller limonite-carbonate aggregates are also found in the <1 mm thick quartz stringers, which consist of subhedral bladed quartz up to 3 mm long and minor alkali feldspar along the selvages as bladed subhedra up to 0.2 mm long.

The overall impression is of a felsic volcanic rock, possibly rhyolitic if the abundant alkali feldspar is actually K-feldspar, cut by abundant quartz-minor alkali feldspar-carbonate-limonite (?after sulfide) veins and replaced in places by areas of carbonate, limonite after sulfide and sericite.

Chzerpnough (Fire) **JH 96-2C**: INTENSELY SERICITIZED, FINE LAPILLI TUFF (RELICT ALKALI FELDSPAR, RUTILE, LIMONITE AFTER ?PYRITE)

Pale greenish ?tuffaceous rock with common flattened clasts of dark green, ?chloritic or pale green, ?sericitic character. The rock is partly softer than steel, non-magnetic, and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Sericite (largely after ?plagioclase)	70%
Alkali feldspar (?Kspar)	25%
Limonite (?after sulfide)	3-5%
Rutile	1-2%

This clearly was a fragmental rock, probably a lapilli tuff composed mainly of heterolithic clasts up to 0.6 cm in diameter that have been flattened, either by compaction during welding or later deformation, or both. Most clasts vary in proportion of sericite and relict feldspar; the dark green clasts in hand specimen are not obviously chloritic, but instead consist mainly of sericite. The alkali feldspar may be Kspar, to judge by the lack of alteration to sericite, and negative relief (compared to sericite; quartz is not definitely identifiable in this section). Most of the feldspar forms ragged subhedral laths < 0.15 mm long, and is clouded by minute (<1 micron) particles of hematite/clay. Sericite mostly forms fine subhedral flakes less than 25 microns in diameter, that appear in part to replace former ?plagioclase crystals mainly < 0.15 mm in diameter (possibly hydrothermal alteration rather than entirely due to metamorphism). The internal texture of the clasts is suggestive of a crowded porphyritic or tuffaceous, feldspar-rich rock of felsic (but quartz-poor) composition.

Scattered clots of limonite, mostly <0.1 mm in size, could be after sulfide (cubic outlines in some suggest former pyrite). In places limonite aggregates are up to 3 mm long (replacing an entire clast, raising the possibility of clasts of ?massive or semi-massive sulfide). Very fine-grained opaques (<5 microns in diameter) along wispy foliations, intimately mixed with sericite in places, are likely rutile. Chlorite does not seem to be present in this sample.

Chzerpnough (Fire) **JH 96-5F**: FELSIC (?DACITIC) FRAGMENTAL VOLCANIC (LAPILLI TUFF) WITH BARITE-SERICITE-PYRITE MATRIX, REPLACEMENT AND FRACTURES

Cherty-looking (grey, siliceous, mainly harder than steel) ?felsic fragmental volcanic rock (most clasts subrounded to subangular, <0.5 cm in diameter) with a clast-supported texture and fine pyrite-rich matrix. The rock is not magnetic and shows no reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Alkali feldspar (albite, ?K-feldspar)	50%
Barite	20%
Sericite	15%
Quartz	10%
Pyrite	5%

Most clasts in this sample consist of fine subhedral laths of alkali feldspar, mostly <0.25 mm long, with lesser quartz (subhedral, to 0.15 mm diameter), partly ?replaced by barite (subhedral to ragged crystals up to 1 mm in diameter) and pyrite (sub- to euhedral crystals up to 0.2 mm in diameter). Most feldspar appears to be albitic (twinned, negative relief compared to quartz) but K-feldspar could be present (need to stain the offcut to determine if this is so). It is difficult to separate replaced clasts from the matrix, which appears to consist of barite, pyrite and sericite (subhedral flakes to 75 microns in diameter), likely due to partial replacement of clasts adjacent to matrix. Sericite and barite, plus possibly pyrite, also occur on fractures that cross-cut some fragments, suggesting most mineralization is late (epigenetic) rather than syngenetic. However, this appearance could also be due to mobilization during metamorphism and deformation.

This sample appears to be similar in original composition to JH 96-2A (felsic, alkali feldspar-rich but quartz poor fragmental volcanic, possibly a dacitic lapilli tuff), but is more obviously mineralized (barite, pyrite). Sericite appears to be an alteration mineral rather than merely a metamorphic product, as in JH 96-2C.

Chzernpough (Fire) **JH 96-6A**: FELSIC LAPILLI TUFF (CARBONATE-QUARTZ-SERICITE-PYRITE ALTERED CLASTS IN INTENSELY SERICITIZED MATRIX, RELICT ?ALKALI FELDSPAR)

Hand specimen indicates a pale grey-green, siliceous, fine-grained and flattened lapilli tuff similar to JH 96-2C; limonite, partly replacing whole clasts that are up to 0.5 cm long, appears to be after pyrite (fine-grained disseminated pyrite is preserved in the body of the rock). Light-coloured clasts are carbonate-rich (composed of subhedra to 0.5 mm, but do not react to cold dilute HCl, and are likely ankerite or siderite; the carbonate is mixed with lesser but variable quartz, sericite and pyrite). Minor calcite, found along late fractures, does react to HCl. Other severely flattened ?fiamme or deformed lapilli are mostly sericite (subhedral flakes to 50 microns) with minor included euhedral laths of ?alkali feldspar (strong negative relief compared to sericite). The matrix is mainly sericite and lesser pyrite, minor quartz and/or alkali feldspar.

Chzernpough (Fire) **JH 96-7A**: INTENSELY CARBONATE-ALTERED ?FELSIC LAPILLI TUFF (?ANKERITE-SIDERITE-CALCITE-QUARTZ-SERICITE-PYRITE; RELICT ALKALI FELDSPAR)

Hand sample is a brown (strongly to moderately limonite-stained) fine tuffaceous rock that is not magnetic and reacts to cold dilute HCl only along fractures. The limonite is mostly after pyrite, some of which is preserved in the less limonitic portions. Clasts have vague and diffuse, subangular to subrounded outlines up to 4 mm in diameter. The clasts, and the matrix, are mainly composed of carbonate (subhedra up to about 0.5 mm in diameter, likely mostly ankerite and ?siderite to judge by lack of reaction in hand specimen) and minor quartz (subhedra to 0.1 mm) and alkali feldspar (feathery subhedra to 0.1 mm) plus sericite (subhedral flakes mostly <50 microns in diameter) plus pyrite (cubic euhedra to 0.15 mm diameter). Although this is a very carbonate-rich rock, similarities to JH 96-2C and JH 96-6A are indicated by the fine lapilli clasts, and replacement by carbonate.

Chzernpough (Fire) **JH 96-10a**: INTENSELY SERICITIZED-SILICIFIED-PYRITIZED (OXIDIZED TO LIMONITE), ?FELSIC FINE TO MEDIUM LAPILLI TUFF

This is a coarser lapilli tuff (rounded to subangular clasts up to 1.2 cm in diameter similar to those in JH 96-5F, scattered in a fine lapilli tuff similar to JH 96-2C, 6A, 7A). Like 2C and 6A, it is easily scratched by steel, and in thin section is composed mainly of very fine-grained (<20 micron) sericite and quartz in variable proportions, hosting small fragments composed mainly of quartz, pyrite, or ?alkali feldspar, or combinations of these three minerals. The hand specimen is not magnetic and shows no reaction to cold dilute HCl (no carbonate seen in thin section).

Chzernpough (Fire) **JH 96-10B**: INTENSELY CARBONATE-SERICITE ALTERED, FINE TO MEDIUM ?FELSIC LAPILLI TUFF (ANGULAR CLASTS, MORE MATRIX SUPPORTED; LITTLE PYRITE)

This is a fine to medium lapilli tuff in which the clasts (mostly <0.5 cm in diameter) are more angular than in the other samples in this suite, and matrix is more abundant (the rock is more matrix-supported). Clasts, which are buff-pink in colour, are mainly composed of carbonate with very strong relief (?siderite or ankerite) as subhedra mostly <0.15 mm in diameter. The matrix is principally sericite (fine subhedral flakes mostly <15 microns in diameter), in places with relict alkali feldspar (probably secondary, aggregates of subhedral crystals to 0.1 mm, minor secondary quartz as narrow veinlets, and scattered barite euhedra to 0.1 mm and traces limonite after ?pyrite to 0.15 mm).

Chzernpough (Fire) **JH 96-12C**: SERICITE-PYRITE-?ANKERITIC CARBONATE ALTERED FELSIC VOLCANIC (FINE-GRAINED ALKALI FELDSPAR)

Hand specimen is a fine-grained, grey, non-magnetic, siliceous (harder than steel), not obviously fragmental rock with wispy discontinuous foliae of buff-brown ?ankeritic carbonate (slow reaction to cold dilute HCl). In thin section, the rock is composed mainly of fine sub- to euhedral alkali feldspar laths mainly <0.15 mm long, partly altered to fine sericite (<5 microns) and possibly minor carbonate. Carbonate is mainly confined to the limonite-stained wispy foliae, forming sub- to euhedral crystals up to 75 microns in diameter that commonly coat pyrite. Disseminated pyrite is common as euhedral cubic crystals < 0.1 mm in diameter. Quartz, if present, is not detectable by relief difference against the feldspar, which is likely plagioclase but could be K-feldspar (no stained offcut). Even narrow veinlets, <0.35 mm thick, are composed of alkali feldspar rather than quartz (no relief difference).

Chzernpough (Fire) **JH 96-13A**: SERICITIZED FELSIC LAPILLI TUFF (CLASTS OF QUARTZ-ALKALI FELDSPAR PHYRIC ?DACITE OR RHYOLITE IN SERICITE MATRIX)

Hand specimen is a fragmental rock composed of grey, irregular-shaped to subangular, siliceous (harder than steel) clasts up to 1 cm in diameter in a pale yellowish, sericitic (softer than steel) matrix that contains rare pyrite. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, the clasts consist mainly of fine to very fine-grained alkali feldspar (subhedral laths mostly <0.1 mm in relict ?phenocrysts up to 1.5 mm across, or <20 microns in the matrix). Quartz occurs as both relict ?phenocrysts with subhedral to ragged (resorbed, altered, recrystallized) outlines mostly <0.5 mm in size, and as cross-cutting veinlets of secondary origin. Variable sericitization (fine subhedral flakes mostly <35 microns in diameter) affects the clasts. Thus the original composition of the rock appears to be rhyolitic or dacitic, depending on whether the alkali feldspar is plagioclase or K-feldspar (stained slab required to differentiate these). The matrix, which may be largely secondary, is composed of fine sericite, with minor wispy foliae of ?rutile or limonite (<5 micron diameter) and scattered pyrite as cubic crystals to 0.6 mm (rarely enclosed in bright green mica, possibly Fe-rich biotite as flakes to 0.25 mm).

Samples JH 96-13B and 13C are similar felsic lapilli tuffs, with sericitic matrix and sericite alteration; JH 96-13C is more similar to JH 96-5F, with a secondary silica-barite-sericite matrix that includes in addition a fine-grained yellow mineral that may be ?jarosite (5 micron rosettes with high relief and moderate birefringence that ?replace pyrite with cubic outlines up to 0.1 mm in diameter).

Chzernpough (Fire) **JH 96-15A**: FINE-GRAINED "DIABASE" DYKE (BIOTITE-?HORNBLende-?PYROXENE QUARTZ DIORITE), ALTERED TO CARBONATE-SERICITE-CHLORITE

This sample is noted as being from a dyke, and is dark grey-green and fine-grained, magnetic, and reacts strongly to HCl. In thin section, it consists of a network of small (mostly <0.25 mm long but up to 1 mm) euhedral plagioclase laths, altered to sericite, with interstitial quartz subhedra to 0.3 mm, hosting variably altered mafic relicts. The mafic minerals include biotite as eu- to subhedral pale brown flakes to 0.3 mm, partly altered to pale green length-slow chlorite at margins, and clusters of relict ?hornblende or pyroxene crystals to 1.5 mm that have been altered to fine-grained carbonate (subhedra to 50 microns) and olive-green chlorite (flakes mostly <15 microns) plus traces of rutile/sphene and euhedral opaque (?magnetite) and apatite, or to pale green chlorite flakes up to 0.25 mm in size. Coarser, euhedral carbonate crystals up to 0.5 mm are calcite, and are mixed in places with quartz; these could represent ?amygdules.

This probably was a mafic-intermediate hypabyssal intrusive such as biotite-?hornblende-?pyroxene quartz diorite, or "diabase".

Plate 9

a) Chzerpnough (Fire) **JH 96-2A**: Limonite-altered carbonate pseudomorph (cb) and limonite after ?sulfide (opaque) associated with quartz veining cutting fine matrix of alkali feldspar and quartz. Transmitted light, crossed polars, 2.5 mm field of view.

b) Chzerpnough (Fire) **JH 96-2C**: Mainly sericitic (ser), less commonly alkali feldspar-rich (Kf) or limonite-rich (opaque), tuffaceous clasts in fine felsic lapilli tuff. Transmitted light, crossed polars, 2.5 mm field of view.

c) Chzerpnough (Fire) **JH 96-5F**: Barite (white, ba), sericite, pyrite (black) replacement along edge of alkali feldspar-rich clast (twinned, plagioclase) and in matrix. Transmitted light, crossed polars, 2.5 mm field of view.

d) Chzerpnough (Fire) **JH 96-10B**: Carbonate (ankerite/siderite)-minor quartz clast in fine-grained sericite matrix, fine to medium ?felsic lapilli tuff; transmitted light, crossed polars, field of view 2.5 mm wide.

e) Dan **JH 97-55**: Alternating laminae of amphibole-rich (green), sericitized alkali feldspar (cloudy) and quartz-rich (clear) rock in calc-silicate hornfels. Transmitted light, uncrossed polars, field of view 2.5 mm.

DAN PROPERTY

There are three samples from the Dan prospect, briefly described in the field as meta-andesite (**JH 97-53A**), meta-rhyolite (**JH 97-54**), and banded actinolite/marble (hornfels: **JH 97-55**). However, in thin section all three samples show similar calc-silicate mineralogy (clinopyroxene variably altered to secondary, actinolitic amphibole, epidote, or chlorite; sericitized, ?albitic alkali feldspar; quartz that may be largely secondary or due to metamorphism; sphene or rutile; and minor opaques including ?magnetite and pyrite). The mineralogy suggests skarny alteration or calc-silicate hornfels, possibly of a mafic to intermediate protolith that could have been ?andesitic in composition. No significant mineralization was noted in any of the samples.

Dan **JH 97-53A**: CALC-SILICATE (ALKALI FELDSPAR-QUARTZ-CLINOPYROXENE, ALTERED TO SERICITE-AMPHIBOLE-EPIDOTE-TRACE CALCITE, RUTILE, PYRITE)

Hand sample is a variegated white and dark green, fine- to medium-grained rock that is not magnetic and shows only trace reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Alkali feldspar (?albite, ?Kspar)	35%
Quartz (?partly secondary)	30%
Clinopyroxene	10%
Sericite	10%
Amphibole (secondary)	5%
Epidote	5%
Carbonate	3%
Rutile	<1%
Opaque (pyrite)	<1%

This is a complex rock, which most likely justifies the name skarn or calc-silicate hornfels. It is composed of three main parts: clear granular areas, white foliated areas, and dark green areas. In thin section, these parts are, respectively, quartz-rich, alkali feldspar-rich, and pyroxene/amphibole-rich. The clear areas consist of subhedral, sucrosic quartz crystals mainly <0.2 mm in diameter, with interstitial, finer-grained (mainly <20 micron) alkali feldspar and ragged patches up to 1 mm across composed of clinopyroxene partly altered at rims to dark green secondary amphibole and along fractures to carbonate (?calcite). The white areas contain more alkali feldspar, which is mostly partly altered to very fine sericite (flakes <10 microns except less commonly up to 0.1 mm associated with cubic pyrite to 0.75 mm), and wispy foliae defined by concentrations of minute (<10 micron) dark brown to semi-opaque ?rutile crystals. There is minor quartz (subhedra to 50 microns). Green areas are always enclosed within quartz-rich areas, and where best developed take the appearance of mafic cores to quartz "veins" up to 1.5 cm thick. Quartz is coarse and subhedral, up to 1.5 mm in diameter, with strong undulose extinction and wispy fractures marked by trails of secondary fluid inclusions. Clinopyroxene forms subhedral to ragged crystals up to 0.5 mm in diameter, aggregating to 2 mm across and commonly strongly altered at the cores to epidote (subhedra to 0.7 mm with pale yellow pleochroism indicating moderate Fe content) and at rims to deep green (?Fe-rich actinolitic) amphibole. In places the mafic minerals are rimmed by aggregates of sub- to anhedral, 0.25 mm alkali feldspars that are strongly saussuritized (clouded by minute clay-sericite, epidote and amphibole) and are likely albitic plagioclase. The identity of the bulk of the alkali feldspar in the slide remains in doubt due to lack of a stained slab; it could include both Kspar and albite (relief is negative compared to quartz, but no twinning is seen).

Although certain aspects of the mineralogy (common rutile, mafic minerals, plagioclase) suggest that this sample could have been derived from an intermediate-mafic volcanic rock such as andesite, it is very difficult to place confidence in such a statement. It is possible that skarny, or calc-silicate, alteration was followed by metamorphism and deformation to produce the current mineralogy and texture.

Dan **JH 97-54**: CALC-SILICATE (ALKALI FELDSPAR-QUARTZ-CLINOPYROXENE, ALTERED TO AMPHIBOLE-SERICITE-TRACE CHLORITE, SPHENE, MAGNETITE)

This sample is partly oxidized along fractures to orange- and red-brown limonite, but where fresh is pale green and siliceous (harder than steel) and very fine-grained. The rock is weakly magnetic but shows no reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Sericitized alkali feldspar	30%
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Quartz (?partly secondary)	30%
Amphibole (secondary)	15%
Clinopyroxene	10%
Sericite	10%
Chlorite	2-3%
Opaque (limonite, ?magnetite)	1-2%
Sphene	1%

The bulk of this slide in the unoxidized portion consists of fine-grained, foliated aggregates of sericitized alkali feldspar (likely sodic plagioclase), quartz, and mafic minerals including clinopyroxene, amphibole and chlorite. Quartz and feldspar are difficult to distinguish in this sample (both form subhedral crystals mostly less than 50 microns in diameter) except where feldspar is clouded by minute particles of clay or more crystalline sericite (to 10 microns). Clinopyroxene forms subhedra generally less than 0.1 mm in diameter, in places altered to greenish amphibole as fibrous crystals of similar size or rarely chlorite as subhedral flakes to 50 microns. Abundant fine amphibole as sub- to anhedral crystals mainly less than 50 microns in size are possibly after former ?pyroxene. In places, patches or aggregates of mafic minerals up to 1 cm long are composed of euhedral clinopyroxene crystals to 1 mm long surrounded by pale green amphibole as fibrous crystals to 0.5 mm, in turn surrounded by quartz to 0.15 mm, similar to the calc-silicate patches seen in JH 97-53A.

Vague, poorly defined patches of feldspar and amphibole or pyroxene, with subhedral outlines up to about 1 mm long. could represent former ?feldspar and mafic phenocrysts; the ?matrix is richer in quartz, much of which could be secondary. However, the strongly developed foliation and/or shearing have largely destroyed the primary textures of the rock. Concentrations of fine-grained opaques (?likely mostly magnetite, subhedra to 50 microns) and TiO₂ minerals (mainly sphene, euhedra to 25 microns) suggest that the protolith to this altered, metamorphosed rock was more likely andesitic than rhyolitic.

Although described as meta-rhyolite, there are a lot of similarities between this sample and JH 97-53A (sericitized alkali feldspar, quartz, clinopyroxene altered to amphibole and chlorite, fine-grained TiO₂ minerals).

Dan **JH 97-55**: FOLIATED CALC-SILICATE (AMPHIBOLE-EPIDOTE-CHLORITE-SERICITE ALTERED ALKALI FELDSPAR-QUARTZ-SPHENE), POSSIBLY META-ANDESITE

Foliated, dark green and pale yellow-green, fine-grained rock that is harder than steel, weakly magnetic in places, and shows no reaction to cold dilute HCl. Mineralogy in this slide is similar to that of the preceding two samples, with dark green foliae up to 2 mm thick composed mainly of amphibole, and pale-coloured foliae up to 1 cm thick composed of alternating mm-scale layers of clear (quartz rich) and cloudy (sericitized alkali feldspar, chlorite, epidote, sphene) rich rock. As in the other two samples in this suite, amphibole (subhedral to fibrous crystals up to 0.35 mm long with yellow-green to sea-green pleochroism, likely Fe-rich actinolite) are surrounded by subhedral quartz to 0.15 mm diameter, with a recrystallized aspect. Minor epidote (subhedra to 0.1 mm) is mixed with the amphibole or cuts it in narrow stringers. The clear and cloudy laminae consist of varying proportions of quartz (subhedra mainly <35 microns), clay-sericitized ?sodic plagioclase of similar size, epidote (pale yellow sub- to anhedral <15 microns but aggregating along foliae to 0.15 mm), chlorite (subhedral flakes to 0.1 mm but aggregating to 0.25 mm with length-slow anomalous blue birefringence indicating moderately Fe-rich composition, probably after amphibole) and wispy foliae of sphene (subhedra mostly <15 microns). The concentrations of sphene, amphibole, epidote and chlorite suggest a fairly mafic protolith; quartz is likely secondary or related to metamorphism.

SELWYN BASIN

MARG DEPOSIT

The Marg deposit, with drill indicated reserves of 5.5 Mt averaging 1.76% Cu, 2.46% Pb, 4.60% An, 62.7 g/t Ag, and 1.0 g/t Au, lies within a sequence of intensely deformed Devonian to Mississippian carbonaceous, siliceous schists and quartz-muscovite schists (?felsic metavolcanic rocks) sandwiched between massive Mississippian Keno Hill Quartzite in the north-central Selwyn Basin (Turner and Abbott,

1990). The deposit includes four stacked, relatively continuous, tabular, massive sulphide horizons plus other smaller sulphide lenses; the horizons are subparallel, up to 23 m but averaging about 5 m thick, and have been traced along strike for 1500 m by drilling (Carne and Gish, 1996, in Hunt 1998). The sulphide bodies are dominated by up to 90% fine-grained pyrite but also contain quartz and ferroan carbonates, lesser sphalerite, chalcopyrite and galena, and minor tetrahedrite and arsenopyrite (Turner and Abbott, 1990).

Most of the samples examined come from a series of drill holes (**DDH 96-48, 49, and 56**) that cut the massive sulfide deposit and the enclosing host rocks. In 96-48, petrography of the enclosing host rocks roughly confirms the divisions made on the drill sections provided. Six sections from unit 3a (QMPH, or quartz-muscovite phyllite) above the mineralization, including 13.5, 17.93, 55.75, 85.65, 89.54 and 92 m, and two from below the mineralization logged as unit 1 (QZIT), including 376.0 and 413.40, are composed of quartz, sericite, ferroan carbonate, and in places lesser chlorite, with accessory tourmaline, pyrite, rutile, ?carbon, and minor limonite. Colour varies from buff-greenish to dark grey-black, probably depending on the amount of chlorite and ?carbon present. The presence of tourmaline in the samples from 376 and 413 m suggests a ?common provenance for units 1 and 3a. Four samples are from unit 2c (QGPH, or quartz-graphite phyllite), including 130.15, 209.43, 210.60 and 301.0 m; of these, only the first and last are black, ?carbon-rich phyllites composed mainly of sericite, quartz, ferroan carbonate, ?carbon and rutile. The sample from 209.43 is a quartz-ferroan carbonate-chlorite-pyrite-sericite breccia, and 210.60 is a carbonate-quartz-chlorite-sericite-rutile schist or phyllite. The samples from 270.0, 310.05, 312.65, 325.8, 338.92, 341.28, 360.75 and 401.32 m, all logged as unit 3a, QMPH, are unlike the samples from this unit from above and below the mineralized horizon in that they appear to lack the ?detrital tourmaline; they are composed of quartz-sericite-ferroan carbonate and variable proportions of chlorite, suggesting intermediate to mafic volcanics. Two samples from 310 and 313 m (just below a massive sulfide horizon) contain Mg-chlorite, suggesting intermediate to mafic volcanics and/or Mg-chlorite footwall alteration at this location; two samples from 325.8 and 338.92 m are sericite-rich, suggesting possible more felsic volcanics or exhalative rocks; and the samples from 341.28 and 360.75 m appear to contain minor ?carbon, suggesting possible tectonic interleaving with more "normal" host rocks of unit 2c (QGPH) from more distal to the deposit. Massive sulfides occurring in three separate horizons (samples from 301.23 to 309.02 m inclusive; 325.35 m; and 353.15 to 364.95 m inclusive) consist mainly of pyrite, with lesser chalcopyrite, sphalerite, galena, and in places significant tetrahedrite-tennantite and minor arsenopyrite; gangues include quartz, ferroan carbonate, and sericite. Note that tetrahedrite does not tend to occur with galena, but instead with chalcopyrite-rich assemblages. Layered textures in some samples, accompanied by and parallel to compositional layering (e.g., chalcopyrite-rich or sphalerite-carbonate rich layers up to 1 cm thick), are the only well-preserved ?primary textures; there are only traces of poorly preserved colloform or atoll textures.

In 96-49, the sampled section runs from just above to just below the mineralized section (235 to 280 m). The hangingwall sample at 235.3, and samples from intercalated host rocks at 242.05, 262.48, and 270.20/273.10 m, consist of quartz-sericite-ferroan carbonate-pyrite-minor sphalerite, trace rutile, +/- trace ?carbon, schists that could be after former intermediate-felsic volcanics (quartz-feldspar porphyry at 242.05) or in places ?exhalative horizons (e.g. 262.48). Massive sulfide samples are mainly fine-grained and pyritic, ranging from structureless (237.28, 273.10) to in places laminated or layered (238.5, 238.65, 239.83, 254.45, 258.90, 268.72, 280.2) and displaying remnants of relict collomorphic and rare ?framboidal texture (258.90, 276.20, 277.32, 277.80) that I have attempted to capture in photomicrographs (below, with detailed descriptions that follow). With the pyrite, there are significant proportions of chalcopyrite and sphalerite (generally colourless, low Fe) and lesser galena and tetrahedrite-tennantite, interstitial to or surrounding the pyrite; in places, layers contain scattered euhedral arsenopyrite crystals. Coarser-grained layers could be due to metamorphic recrystallization. Gangue minerals include quartz (commonly bladed where located in pressure shadows near pyrite), carbonate (likely mostly ferroan; dolomite and ankerite), and sericite.

In 96-56, almost all the samples are of massive sulfides with the exception of a possible ?exhalite horizon at 257.80, similar to that at 262.48 of DDH96-49, and the adjacent semi-massive sulfides at 257.30. The massive sulfides in this hole from horizons D1, C and B5 appear to be the richest in base-metal sulfides of the samples examined. They range from layered (cm scale; 255.25, 282.82) to laminated (mm scale; 256.67, 258.75, 265.33, 271.85) or less commonly ?clastic-textured (especially 265.96, 268.88; possibly 257.3), in which fragments, clasts or rounded "balls" of pyrite-?marcasite, mostly less than 0.5 cm in diameter (commonly <1.5 mm), are set in a matrix of finer-grained pyrite, chalcopyrite, sphalerite, and minor galena and tetrahedrite-tennantite. Remnants of relict ?collomorphic and atoll texture are common, and are illustrated in photomicrographs following the detailed descriptions below, along with less common features

such as relict ?radiating cockscomb texture (possibly after aggregates of former bladed ?marcasite crystals), possible framboidal textures, and other features commonly found in known or inferred sea-floor sulfides. Certain layers are enriched in sphalerite-arsenopyrite-galena and sericite, or chalcopyrite-tetrahedrite-galena and quartz-carbonate. Some intergrowths of pyrite and included base-metal sulfides are so fine-grained that some difficulty is to be expected in liberating and separating them.

Marg **DDH96-48 13.5m**: SILICEOUS SCHIST (FINE-GRAINED QUARTZ WITH WISPY LAMINATIONS OF LIMONITE-TOURMALINE-SERICITE-RARE PYRITE, ZIRCON)

This is a fine-grained, dark grey, finely laminated rock containing abundant disseminated fine buff-orange specks. The rock is not magnetic and shows no reaction to cold dilute HCl; in thin section, it is composed principally of fine-grained quartz and minor patches of limonite (the buff-orange mineral), with wispy discontinuous foliae defined by minor sericite and concentrations of microscopic opaques (?possibly carbonaceous matter, mainly <5 microns in diameter). Quartz forms tightly interlocking, anhedral to subhedral crystals with distinct elongation subparallel to the foliation (roughly 2:1 to 3:1 length:width ratios). Patches of limonite are mainly <0.2 mm in size, associated in places with tourmaline; rare pyrite cubes are up to 0.3 mm in diameter, partly oxidized to limonite at margins and along fractures. Tourmaline forms subhedral ?detrital crystals are pale to medium greenish-brown, implying a moderately high Fe:Fe+Mg ratio possibly near 0.7-0.8. Sericite flakes are mainly less than 75 microns in diameter. Rare zircon euhedra are up to 50 microns long. The quartz-rich mineralogy suggests that this sample likely represents the siliceous carbonaceous schist host rocks; I am not sure if the tourmaline is normal for this unit, or represents a local anomalous concentration associated with proximity to mineralization.

Marg **DDH96-48 17.93m**: QUARTZ-SERICITE-FERROAN CARBONATE SCHIST

Pale grey-green, fine-grained, siliceous rock with faint laminations and foliation defined by wispy concentrations of buff- and green-coloured material. The rock is not magnetic and shows no reaction to cold dilute HCl. Mineralogy in thin section is dominated by quartz, with the laminations defined by sericite and lesser carbonate (likely dolomitic or ankeritic to judge by the lack of reaction in hand specimen and buff colour). Quartz forms polyhedra mainly less than 0.1 mm in diameter without significant elongation or preferred orientation. Sericite flakes are mostly <0.3 mm in diameter, with sub-parallel orientation defining the foliation. Carbonate crystals are subhedral to ragged or skeletal in outline, and mostly <0.5 mm in diameter. This sample may belong to the quartz-sericite schist host rocks for the deposit (Turner and Abbott, 1990).

Marg **DDH96-48 55.75m**: QUARTZ-SERICITE-FERROAN CARBONATE-CHLORITE-?CARBON-MINOR PYRITE, TOURMALINE SCHIST

Similar to the sample from 17.93 m (quartz-sericite-ferroan carbonate schist) but with addition of significant intercalations of black ?carbonaceous matter, progressively increasing towards one end of the slide. The rock is not magnetic, but shows slow reaction to cold dilute HCl. Scattered large pyrite cubes are up to 1.75 mm in diameter. The fine-grained opaque matter is too fine to identify in thin section, but it may be carbonaceous; it occurs in contorted foliae up to 50 microns thick that are interleaved with sericite-rich layers and associated with layers rich in chlorite (subhedral flakes or books to 0.2 mm diameter, with pale green pleochroism and anomalous blue, length-slow birefringence indicating moderate F/M near ?0.5-0.6). Rare tourmaline is as described for 13.5 m; the rounded grains look detrital in origin.

Marg **DDH96-48 85.65m**: LAMINATED QUARTZ-SERICITE-FERROAN CARBONATE-CHLORITE-?RUTILE-MINOR PYRITE SCHIST AFTER ?MAFIC VOLCANIC

Finely laminated, foliated, fine-grained, green and buff-coloured schist with quartz veinlets or "sweats" up to 1 mm thick. The rock is not magnetic but shows minor reaction to cold dilute HCl. In thin section, the slide is made up of interlayered quartz and sericite laminations. In the quartz-rich layers, quartz crystals, mainly <0.1 mm in diameter, are subhedral and polygonal (common triple junctions indicate annealing since deformation); minor carbonate forms subhedra to 0.35 mm, locally associated with subhedral pyrite to 0.5 mm diameter, and rare chlorite occurs as subhedral flakes to 0.1 mm as wispy foliae in quartz laminations. Sericite flakes are mainly less than 0.25 mm in diameter, strongly aligned, and contain abundant minute (<5 microns long by <1 micron thick) inclusions of needle-like ?rutile. There may be significant proportions of chlorite intimately mixed with the sericite, but difficult to separate optically. If

this is correct, and rutile is a correct identification, it could indicate that the protolith was a mafic rather than felsic rock. Minor carbonate also occurs in the sericitic layers.

Marg **DDH96-48 89.54m**: QUARTZ-SERICITE-CHLORITE-FERROAN CARBONATE-RUTILE-PYRITE SCHIST, POSSIBLY AFTER ?INTERMEDIATE VOLCANIC PRECURSOR

Pale green, quartz-sericite-?chlorite schist with abundant "sweats" of white quartz. The rock is not magnetic but shows minor slow reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz (including sweats)	50%
Sericite	25%
Chlorite	20%
Carbonate	3-5%
Rutile	<1%
Opaque (pyrite, ?carbon)	<1%
Tourmaline	<1%

The composition of this sample is similar to that of the other quartz-sericite-chlorite-carbonate schists in this drill hole. Quartz layers up to 0.5 cm thick are made up of coarse interlocking anhedral crystals up to 3.5 mm long, with strong undulose extinction and sub-grain development indicating significant strain; finer-grained layers contain subhedral, polygonal crystals mostly <0.35 mm in diameter. Micaceous layers consist of masses of subhedral to slightly bent flakes of interleaved sericite and chlorite, mostly <0.5 mm in diameter. Chlorite displays optical characteristics (distinct green pleochroism, weakly anomalous blue length-slow birefringence) suggestive of moderate Fe content (F/M about ?0.5-0.6). Carbonate forms scattered sub- to euhedral porphyroblastic crystals up to 0.75 mm in diameter with strong change of relief on rotation (could include ?ankerite as well as calcite). Dark wispy foliae in the micaceous portions of the rock consist of concentrations of sub-microscopic ?carbon and ?rutile (mainly <5 microns), in places associated with rare rounded (?detrital), green (schorlitic) tourmaline crystals to 0.1 mm, scattered cubic pyrite to 0.5 mm, and clusters of rutile (subhedra to 25 microns diameter). The protolith for this metamorphic rock is not certain, but the abundance of chlorite and rutile probably suggest an intermediate rather than felsic precursor.

Marg **DDH96-48 92m**: QUARTZ-SERICITE-FERROAN CARBONATE-MINOR PYRITE-TOURMALINE-?CARBON-RUTILE-LIMONITE SCHIST

Interlaminated white to grey (siliceous) and black (?carbonaceous) layers mostly < 1 mm thick, probably isoclinally folded. The rock is not magnetic and shows only slow reaction to cold dilute HCl. In thin section, mineralogy is similar to that of the other schists in this hole: quartz, sericite, ferroan carbonate possibly including ankerite, limonite (partly after pyrite and partly after carbonate), and fine opaques that may include ?carbon, rutile, and limonite, concentrated in wispy foliae with which scattered crystals of green (schorlitic) tourmaline occur. Chlorite is not recognizable in this slide, but carbonate is more abundant than at 89.54m; the protolith could have been a sedimentary or volcanoclastic rock of intermediate composition.

Marg **DDH96-48 130.15m**: BLACK PHYLLITE: FOLIATED, KINKED, FINE-GRAINED SERICITE-OPAQUE (?CARBON, RUTILE)-MINOR QUARTZ-CARBONATE-PYRITE SCHIST

Black, fine-grained, foliated rock, mostly softer than steel. The rock is not magnetic and shows no reaction to cold dilute HCl. In thin section, it is composed almost entirely of very fine-grained, <20 μ m, strongly foliated, commonly kink banded sericite with abundant wispy foliae of submicroscopic opaques (both rounded and needle-like; could include ?carbon and ?rutile). Chlorite may be present but not resolved due to the fine-grained nature of the rock. Scattered quartz grains, mostly <50 microns in diameter, are subordinate. Ragged porphyroblasts of carbonate up to 0.5 mm in diameter may include subhedral cores of ?calcite with minor opaque (?pyrite) and sphalerite, both <50 microns in diameter, and rims of ?ferroan carbonate such as ankerite. Quartz segregations ("sweats") up to 0.5 cm thick contain abundant coarser quartz to 0.35 mm, and coarse eu- to subhedral pyrite up to 1.5 mm in diameter (aggregates to 4 mm). The protolith to this black phyllitic rock ("argillite") may have been a fine clastic rock such as siltstone.

Marg **DDH96-48 209.43m**: QUARTZ-FE CARBONATE-CHLORITE-PYRITE-SERICITE BRECCIA

Fine breccia composed of greenish black and lesser white angular fragments up to 3 mm and 1 cm respectively. The dark clasts contain fine pyrite; coarse cubic pyrite to 1.5 mm is also scattered throughout

the rock. The rock is not magnetic, but shows strong reaction to cold dilute HCl in the matrix. Modal mineralogy in thin section is approximately:

Quartz	40%
Carbonate (?mostly calcite)	40%
Chlorite	10%
Pyrite	5%
Sericite	3-5%
?Carbonaceous matter	1-2%

Dark clasts are mainly composed of carbonate (rims of low relief calcite and cores of dark, higher-relief ?ferroan carbonate that are full of minute opaque inclusions, likely including both pyrite to 15 microns that is visible in the offcut slab, and possibly ?carbonaceous matter, mostly <2 microns in diameter). Chlorite is found around the margins of some of these clasts, forming subhedral flakes to 0.15 mm with optical characteristics (very pale green pleochroism, near-zero to length-fast birefringence) indicating low to moderate Fe content (F/M perhaps 0.4-0.5). White clasts are mostly quartz, as elongate to bladed (pressure-shadow) crystals up to 0.7 mm, and minor carbonate. The matrix is composed of quartz (subhedral to 0.5 mm) and carbonate (mainly calcite, subhedral to 0.25 mm). Sericite occurs as scattered flakes to 0.35 mm in diameter, and pyrite as euhedra to 1.5 mm size.

Marg DDH96-48 210.60m: CARBONATE-QUARTZ-CHLORITE-SERICITE-RUTILE SCHIST

Interlayered buff and greenish grey (with buff "spots") schist that is mainly softer than steel and non-magnetic, but reacts slowly in the buff areas to cold dilute HCl. Modal mineralogy in thin section is approximately:

Carbonate (?calcite, ankerite)	40%
Quartz	20%
Chlorite	20%
Sericite	20%
Rutile, opaque	<1%

The buff-coloured portions of this sample are mainly composed of carbonate and lesser quartz; darker, greenish-grey portions are composed of chlorite, sericite, carbonate and minor quartz. Carbonate forms mainly subhedral crystals <0.5 mm in diameter, in places with differences in relief (lower relief rims surrounding core areas of higher relief) suggesting the possibility of calcite surrounding ferroan carbonate such as ?ankerite. Minor Fe-staining of the carbonate in places (minute particles to amorphous films of limonite) also suggests the presence of ferroan carbonate. Quartz mainly forms sub- to anhedral crystals to 0.2 mm diameter intergrown with the carbonate. Chlorite and sericite form sub- to euhedral flakes up to about 0.15 mm in diameter, with chlorite generally surrounding lesser sericite. Chlorite displays optical characteristics (pale green pleochroism, weakly to non-anomalous length-fast birefringence) suggestive of lower Fe content (F/M about ?0.4). Needle-like euhedral rutile to 25 microns is common, especially in chlorite and suggest an intermediate to mafic precursor rock; minor opaques (mostly <50 microns in diameter) occur in carbonate.

Marg DDH96-48 270.0m: QUARTZ-SERICITE-CHLORITE-FERROAN CARBONATE SCHIST

Strongly laminated, foliated, crenulated, isoclinally folded green-grey quartz-sericite-chlorite schist that is non-magnetic and shows little or no reaction to cold dilute HCl. It is composed of similar minerals to the sample at 210.0 m, but with different proportions:

Quartz	60%
Sericite	20%
Chlorite	10%
Carbonate (?dolomite, ankerite)	10%
Opaque (pyrite; trace rutile)	<1%

Laminae are mainly composed either of quartz (subhedral to 0.2 mm) or of sericite and lesser chlorite (flakes to 0.15 mm), the latter mixed in places with lesser carbonate (?dolomite, subhedral to 0.1 mm); chlorite contains traces of minute needle-like rutile to 10 microns. Coarser, porphyroblastic carbonate with euhedral outlines up to 1.5 mm in diameter has distinctive higher relief and contains minor opaques along fractures that may be limonite, suggesting a ferroan carbonate such as ankerite or possibly ?siderite. Chlorite has optical properties similar to that in the sample from 210.6 m. Scattered pyrite forms cubic crystals to 0.5 mm diameter.

Marg **DDH96-48 301.0m**: QUARTZ-?GRAPHITE-FERROAN CARBONATE-SERICITE SCHIST

Black to buff, finely laminated schist that looks very carbon-rich (lustrous flakes that may be possible graphite in layers up to 1 mm thick, alternating with quartz-rich layers). Minor carbonate in the quartz-rich layers reacts slowly to cold dilute HCl; it consists of ?ferroan carbonate cores clouded by minute inclusions of ?carbon, surrounded by clear rims that may be calcite or dolomite. Minor pyrite occurs in the ?graphitic layers; rare sericite is up to 0.5 mm.

Marg **DDH96-48 301.23m**: MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA; MINOR QUARTZ-SERICITE-?RUTILE GANGUE

Massive sulfides, mostly fine-grained pyrite with vaguely defined laminae up to 2 mm thick enriched in interstitial chalcopyrite or lesser galena and sphalerite. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	65%
Quartz	15%
Sericite	10%
Chalcopyrite	5%
Sphalerite	3-5%
Galena	1%
?Rutile	<1%

Pyrite occurs as scattered large subhedral crystals up to 1.5 mm in diameter, as well as smaller euhedral to subhedral cubic crystals that range from about 50 microns up to 0.3 mm in diameter. Chalcopyrite is mainly interstitial to pyrite, forming subhedral to rounded masses up to about 1 mm in diameter that include pyrite and sphalerite around the margins, and rarely galena. Sphalerite mostly occurs as subhedral crystals less than 0.1 mm in diameter, with yellow colour indicating low to moderate Fe content, clustered around or forming interstitial masses to pyrite. Most galena is intergrown with the sphalerite, forming wispy, anhedral (?remobilized) grains <0.4 mm in diameter.

Gangue minerals consist of subhedral to bladed quartz to 0.3 mm (the latter in pressure shadows near pyrite crystals), and subhedral flakes of sericite to 0.25 mm, generally weakly oriented parallel to the lamination/foliation. Needle-like inclusions in sericite, <2 microns thick by up to 10 microns long, could be ?rutile. Tetrahedrite and arsenopyrite were not seen during routine observation of the slide.

Marg **DDH96-48 303.2m**: MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE

Mainly finer-grained massive sulfides, composed mainly of pyrite with fine interstitial chalcopyrite, sphalerite and galena in places. The rock is not magnetic and shows no reaction to cold dilute HCl; modal mineralogy in polished thin section is approximately:

Pyrite	70%
Chalcopyrite	10%
Carbonate (?ankerite)	10%
Sphalerite	5-7%
Galena	1-2%
Tetrahedrite-tennantite	<1%

The fine-grained sulfides in this slide have features suggestive of, but not conclusive for, relict primary textures. Chalcopyrite is abundant in some parts of the slide, forming masses that fill the interstices between the eu- to subhedral, generally <0.5 mm pyrite crystals (this texture could be largely due to the greater ease of recrystallization of chalcopyrite compared to the more refractory pyrite). Sphalerite occurs as euhedral to subhedral crystals up to 0.2 mm in diameter, commonly aggregating to 0.5 mm masses interstitial to pyrite. Galena occurs as subhedral to irregular masses up to 1 mm across, associated with sphalerite and chalcopyrite interstitial to pyrite crystals. Tetrahedrite-tennantite occurs as subhedral crystals aggregating to 0.25 mm, associated with sphalerite and chalcopyrite interstitial to the massive pyrite. Arsenopyrite may be present (small rhomb-shaped crystals <50 microns in diameter) but is difficult to confirm at this grain size (identification depends on recognizing the sometimes faint anisotropism compared to pyrite). Gangue is principally carbonate, likely ferroan such as ?ankerite.

Marg **DDH96-48 306.27**: MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-TRACE GALENA IN GNGUE OF SERICITE-FERROAN CARBONATE-QUARTZ

Faintly layered, pyritic massive sulfides similar to 301.23 (common larger pyrite crystals in matrix of fine crystalline pyrite, gangues, minor chalcopyrite and sphalerite. The rock is not magnetic and shows no reaction to cold dilute HCl unless scratched; modal mineralogy in polished thin section is approximately:

Pyrite	70%
Sericite	20%
Carbonate (?ankerite)	3%
Chalcopyrite	2-3%
Quartz (secondary)	2-3%
Sphalerite	1-2%
Galena (?)	<1%

Pyrite occurs mainly as fine cubic crystals less than 0.5 mm in diameter embedded in a matrix of sericite (subhedral, partly aligned, flakes up to 0.15 mm diameter), or in certain layers, carbonate (subhedra to 0.3 mm) and lesser quartz (subhedra to 0.25 mm, commonly in pressure shadows where the crystals are bladed). Large pyrite crystals have sub- to euhedral outlines up to 2.5 mm in diameter. Chalcopyrite occurs as anhedral masses up to 2 mm in maximum dimension that are interstitial to (infill between) pyrite crystals, with sphalerite, which mostly occurs as sub- to euhedral, orange-brown (moderate Fe-content) crystals up to 0.25 mm diameter, commonly surrounding pyrite crystals. Traces of ?galena or a ?sulfosalt occur as irregular inclusions up to 20 microns in size, closely associated with chalcopyrite, in some pyrite crystals. The segregation of gangue minerals into distinct layers (sericite or ferroan carbonate-quartz) suggests primary layering; it is parallel to the observed layering and weak foliation defined by sericite. No primary textures appear to be preserved in the sulfide minerals.

Marg DDH96-48 307.76: SEMI-MASSIVE PYRITE-SPHALERITE-CHALCOPYRITE-GALENA IN MATRIX OF QUARTZ-FERROAN CARBONATE

Granular semi-massive sulfides (crystalline pyrite, minor chalco-pyrite, sphalerite) in a matrix of quartz and carbonate (reacts only when scratched: dolomite or ankerite). Modal mineralogy in polished thin section is approximately:

Pyrite	40%
Quartz	35%
Carbonate (?dolomite/ankerite)	15%
Sphalerite	3-5%
Chalcopyrite	3-5%
Galena	<1%

This sample consists of subhedral pyrite crystals up to 1 mm in diameter, in places associated with minor sphalerite (sub- to euhedral crystals to 0.2 mm diameter with yellow-brown colour indicating low to moderate Fe content) and chalcopyrite (subhedra up to 0.3 mm diameter), in a matrix of abundant quartz (sub- to euhedral crystals to 0.3 mm) and lesser carbonate (likely ankerite, subhedra to 0.35 mm). Part of the sphalerite is locked within pyrite as 10-30 micron inclusions. As in 96-48 306.27, ?primary compositional layering is vaguely preserved, with layers up to 2 mm thick enriched in sphalerite relative to pyrite (plus minor galena as irregular wispy aggregates to 0.25 mm, or locked in sphalerite as 20-40 micron inclusions), or carbonate relative to quartz. Only vague relics of circular features are preserved in the sulfides, suggesting possible original (primary) colloform textures.

Marg DDH96-48 309.02: MASSIVE PYRITE (?PARTLY AFTER MARCASITE)-CHALCOPYRITE-SPHALERITE IN GANGUE OF QUARTZ-FERROAN CARBONATE

Semi-massive sulfides, fine-grained pyritic in one half and coarser-grained, chalcopyrite-rich in the other half across a fairly sharply defined contact. The rock is not magnetic and shows no reaction to cold dilute HCl even when scratched (mainly siliceous). Modal mineralogy in polished thin section is approximately:

Pyrite	55%
Quartz	20%
Carbonate (?ankerite)	15%
Chalcopyrite	7-10%
Sphalerite, trace galena	1-2%

In the pyritic portion, pyrite forms mainly euhedral cubic crystals to 0.25 mm (but commonly aggregated to 1 mm clusters) set in a matrix that includes quartz (subhedral to bladed, to 0.2 mm) and carbonate (likely

ferroan, subhedra to 0.25 mm). Chalcopyrite and sphalerite are rare, mostly subhedra <0.1 mm in diameter. In the other half of the slide, pyrite forms subhedral crystals up to 2 mm in diameter with rounded outlines, in a matrix of chalcopyrite (irregular masses also up to 2 mm in size). The pyrite includes euhedral, in places bladed, crystals up to 0.5 mm long with slightly lower reflectance but no distinguishable anisotropism and therefore not likely marcasite; they could be the so-called "melnikovite pyrite", possibly after marcasite. Rare sphalerite (sub- to euhedra to 0.1 mm) has orange-brown colour indicating moderate Fe content; galena is very rare, <40 microns in diameter. Quartz and carbonate, both as subhedra to 0.3 mm, are more abundant than in the pyritic portion.

Marg DDH96-48 310.05: QUARTZ-CHLORITE-FERROAN CARBONATE-MINOR PYRITE-TRACE SPHALERITE-RUTILE-?ALLANITE SCHIST AFTER ?INTERMEDIATE VOLCANIC

Finely laminated, foliated green-grey schist with some laminae rich in buff-coloured carbonate that reacts slowly to cold dilute HCl, and rare laminae rich in finely crystalline pyrite. The slide is composed mainly of quartz (60%, subhedra to 0.2 mm) and chlorite (25%, subhedral flakes to 0.15 mm defining the foliation), lesser carbonate (10%, subhedral crystals of ?ankerite/ferroan calcite to 0.25 mm) and minor pyrite (<5%, subhedral cubes to 1 mm) plus trace sphalerite (subhedral aggregates to 0.6 mm; orange-brown colour indicates moderate Fe content). Chlorite displays optical characteristics (pale green, non-pleochroic, weakly to non-anomalous length-fast birefringence) suggestive of lower Fe content (F/M about ?0.4); dark pleochroic haloes are common around 25 micron inclusions of radioactive ?allanite or monazite, in places associated with euhedral rutile to 35 microns. Traces of sphalerite and rutile also occur included in carbonate.

Marg DDH96-48 312.65: QUARTZ-MAGNESIAN CHLORITE SCHIST (TRACE PYRITE-RUTILE-?ALLANITE) CUT BY QUARTZ-FERROAN CARBONATE-SERICITE VEIN

Grey, siliceous rock with wispy dark foliae cut by a white quartz-carbonate vein (minor reaction to cold dilute HCl; non-magnetic). The thin section indicates that the rock is composed mainly of fine-grained quartz (60%, subhedral polyhedra mainly <0.1 mm) and chlorite (30%, euhedral flakes to 0.15 mm) plus minor opaques (<1%, euhedral pyrite to 50 microns, clusters of ?rutile to 25 microns plus trace ?allanite or monazite to 25 microns with pleochroic haloes in chlorite). Chlorite optical characteristics (no pleochroism, first-order grey-white length-fast birefringence) suggests a magnesian composition (F/M about ?0.3-0.4). The vein (10%) consists of coarser quartz (interlocking anhedral to 0.5 mm), carbonate (?ferroan, subhedra to 0.5 mm) and sericite (euhedral flakes to 0.3 mm) in the vein and adjacent envelopes.

Marg DDH96-48 325.35: MASSIVE PYRITE-TETRAHEDRITE-ARSENOPYRITE-SPHALERITE WITH LENSES OF QUARTZ-CARBONATE-MINOR SERICITE

Massive fine-grained pyrite containing lensey inclusions of gangue up to 4 mm long (mainly siliceous; no reaction to cold dilute HCl). Modal mineralogy in polished thin section is approximately:

Pyrite	55%
Quartz	20%
Carbonate (?ankerite)	10%
Tetrahedrite	5%
?Arsenopyrite	5%
Sphalerite	2-3%
Sericite	1-2%

The lensey gangues are mainly quartz (subhedra to 0.5 mm) with lesser carbonate (subhedra to 0.2 mm, likely ferroan dolomite) and traces of sericite (subhedral flakes to 0.15 mm). Pyrite forms an- to subhedral masses up to about 1 mm in diameter that are mainly aggregates of fine (<0.1 mm; rarely to 0.25 mm) crystals, in places containing subhedral crystals of ?arsenopyrite to 0.15 mm. Tetrahedrite-tennantite (likely the latter, given the presence of arsenopyrite) is significant in this sample, forming aggregates up to 1.5 mm across as well as very fine subhedra (<25 microns) mixed with sphalerite, interstitial to pyrite. Sphalerite forms sub- to euhedral, pale coloured (low Fe) crystals mainly less than 0.1 mm in diameter, interstitial to pyrite.

Plate 10

a) Marg **DDH 96-48 17.93m**: Quartz-sericite-carbonate schist: transmitted light, crossed polars, field of view 2.5 mm wide.

b) Marg **DDH 96-48 55.65m**: Detail of sericite containing minute needle-like ?rutile, minor quartz grains (transmitted light, uncrossed polars, field of view 0.4 mm wide).

c) Marg **DDH 96-48 209.43m**: Clasts of quartz and carbonate (chlorite at rims); scattered pyrite crystals. Transmitted light, crossed polars, field of view 2.5 mm wide.

d) Marg **DDH96-48 301.23m**: Massive sulfides, showing cubic pyrite crystals embedded in a matrix of chalcopyrite (cp), sphalerite (sl), galena (gn) and minor gangues (quartz and sericite; black). Reflected light, uncrossed polars, field of view 2.0 mm wide.

e) Marg **DDH96-48 303.2m**: Detail of sulfides to show tetrahedrite-tennantite (grey-greenish; tt), sphalerite (darker grey; sl), chalcopyrite (cp) hosting eu- to subhedral pyrite (py). Reflected light, uncrossed polars, field of view 0.7 mm wide).

f) Marg **DDH96-48 306.27m**: Layered pyrite (opaque) and sphalerite (orange-brown), in matrix of ferroan carbonate (ank) and quartz (qz). Transmitted light, uncrossed polars, field of view 2.5 mm wide.

g) Marg **DDH96-48 310.05m**: Traces of radioactive ?allanite or monazite with pleochroic haloes, plus rutile and pyrite, included in chlorite (ch); alternate layers of quartz (qz) and ferroan carbonate (ank). Transmitted light, uncrossed polars, field of view 1.0 mm wide.

h) Marg **DDH96-48 325.35**: Coarse clot of tetrahedrite-tennantite in matrix of fine-grained pyrite, sphalerite, tetrahedrite-tennantite, quartz-carbonate (reflected light, uncrossed polars, field of view 2.0 mm wide).

Marg **DDH96-48 325.8**: SERICITE-QUARTZ-FERROAN CARBONATE-PYRITE+SPHALERITE SCHIST

Dark grey, pyritic, fine-grained, strongly laminated and foliated quartz-sericite schist (non-magnetic; minor reaction to cold dilute HCl). Modal mineralogy in thin section is approximately:

Sericite	70%
Quartz	20%
Carbonate (calcite, ?ankerite)	5%
Pyrite	3-5%
Sphalerite	<1%
Rutile	<1%

This sample consists essentially of intensely foliated, crenulated, kink-banded sericite, with quartz commonly confined to narrow (<1 mm thick) veinlets or clots, or less commonly mixed with the sericite (subhedral crystals mainly <0.15 mm in diameter). Carbonate forms scattered porphyroblastic subhedra up to almost 1 mm long in the matrix or in the veinlets or clots; cloudy, higher relief cores suggest the possibility of ankerite surrounded by calcite. Pyrite is common throughout, both as extremely fine and coarse cubic disseminated crystals (respectively, mainly <25 microns and up to 1 mm in diameter). Rare sphalerite aggregates are colourless (low Fe content), up to 0.3 mm in diameter. Needle-like ?rutile crystals are <20 microns long.

The sericite-rich composition suggests a ?felsic (feldspar-rich) or exhalite (clay-rich) precursor lithology.

Marg **DDH96-48 338.92**: QUARTZ-SERICITE-?CHLORITE-PYRITE-CARBONATE-RUTILE SCHIST

Grey-green, strongly folded, foliated quartz-sericite-minor pyrite-?chlorite-carbonate-rutile schist (non-magnetic, no reaction to cold dilute HCl). Textures (crenulation, kink banding) are similar to those of 325.8 although mineralogy is more quartz-rich; chlorite is difficult to recognize due to near-zero birefringence. The precursor may have been an ?intermediate volcanic rock, but abundant quartz "sweats" and remobilization obscure primary features.

Marg **DDH96-48 341.28**: QUARTZ-SERICITE-FERROAN CARBONATE-PYRITE-?CARBON SCHIST

Dark grey, strongly laminated and foliated quartz-sericite-carbonate-pyrite-?chlorite schist. In one portion of the sample, grey porphyroblasts up to 2.5 mm in diameter react slowly to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	55%
Sericite	20%
Carbonate (?ferroan)	20%
Opaque (pyrite, ?carbon)	5%
Rutile, zircon	<1%

Quartz-rich layers ("sweats") consist of jigsaw-like interlocking anhedral quartz (in places bladed, in pressure shadows), rarely up to 0.75 mm long (parallel to the foliation, defined by alignment of sericite flakes to 0.25 mm). Scattered subhedral quartz crystals could represent former ?quartz "eyes" or phenocrysts. Large porphyroblasts of carbonate are characterized by cores of ?ferroan carbonate (cloudy with amorphous ?limonite, ?carbon) and rims of calcite; they are probably metamorphic in origin rather than representing some former feldspar or mafic crystals. Some sericitic foliae contain abundant fine opaques, possibly carbon as particles <5 microns in diameter, as well as cubic pyrite aggregates up to 0.6 mm in diameter; other sericitic foliae contain sagenitic ?rutile needles mainly <1 micron thick and traces of euhedral zircon to 60 microns. Chlorite may be present, with zero birefringence, but is hard to confirm; the protolith may have been an intermediate volcanic, sediment or exhalite.

Marg **DDH96-48 353.15**: LAYERED MASSIVE CHALCOPYRITE-TETRAHEDRITE/TENNANTITE-SPHALERITE-GALENA, PYRITE-QUARTZ-FERROAN CARBONATE, QUARTZ-SERICITE

Contact between massive sulfides (pyrite, chalcopyrite, ?tetrahedrite, sphalerite, galena) and grey quartz-sericite schist. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	35%
Quartz	25%
Carbonate (?ankerite, siderite)	20%
Chalcopyrite	10%
Sericite	5%

Tetrahedrite	3%
Sphalerite	1-2%
Galena	<1%

The host rock consists of finely laminated quartz and ferroan carbonate interleaved by foliae of sericite and fine opaques (partly pyrite, some ?carbon). Both quartz and carbonate form elongate, almost rectangular crystals up to 1.5 mm long by 0.3 mm wide, oriented parallel to the foliation. The massive sulfides consist of layers, 1 cm thick, of chalcopyrite and major tetrahedrite-minor sphalerite, galena with coarse quartz and lesser carbonate (subhedra to 0.7 mm), followed by pyrite-chalcopyrite-quartz-carbonate-tetrahedrite-sphalerite-galena, quartz-carbonate-pyrite and finally quartz-sericite-Fe carbonate with an unusual "mottled" texture caused by concentrations of carbonate across the foliation. Arsenopyrite could be present (rhomb-shaped, weakly anisotropic crystals), but is difficult to separate from partly anisotropic pyrite. Compositional layering in the sulfides could indicate syngenetic sulfide deposition.

Marg **DDH96-48 360.75**: QUARTZ-SERICITE-FERROAN CARBONATE-PYRITE-?CARBON SCHIST
This sample is very similar to 341.28m; see that description for details.

Marg **DDH96-48 361.49**: MASSIVE FINE-GRAINED PYRITE-SPHALERITE-CARBONATE LAYERS IN PYRITE-CHALCOPYRITE-TETRAHEDRITE-SPHALERITE-GALENA-?ARSENOPYRITE

Massive, fine-grained pyrite with minor interstitial chalcopyrite and gangue minerals, parts of which react slowly to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	70%
Chalcopyrite	10%
Quartz	10%
Carbonate (?dolomitic)	5%
Sphalerite	2-3%
Tetrahedrite-tennantite	1-2%
Galena	<1%
Arsenopyrite	<1%

In detail, the massive sulfides of this sample are finely layered, with zones <1 cm thick of <30 micron cubic pyrite, sub/euhedral colourless (low Fe) sphalerite, and carbonate, alternating with layers >1 cm thick of coarser-grained (up to 0.7 mm) subhedral pyrite, interstitial chalcopyrite, quartz, tetrahedrite-tennantite, and minor sphalerite, carbonate, and galena. Rare ?arsenopyrite (distinctly white compared to pyrite; not distinctly anisotropic) forms rhomb-shaped crystals up to 0.1 mm in size. Although the presence of chalcopyrite in between pyrite crystals and in fractures likely indicates remobilization, the compositional layering suggests preserved primary features of ?syngenetic sulfides. Sample 361.77 is similar to 364.95 (see below).

Marg **DDH96-48 364.95**: LAMINATED PYRITE-QUARTZ-FERROAN CARBONATE-SPHALERITE-CHALCOPYRITE-TETRAHEDRITE/TENNANTITE-?ARSENOPYRITE-SERICITE-GALENA

Finely laminated, fine-grained, alternating layers of pyrite and quartz rich rock (not magnetic, but showing minor slow reaction to cold dilute HCl). Pyrite, making up about 50% of the rock, forms subhedral crystals up to about 1.2 mm in diameter, rarely associated chalcopyrite (1-2%) as irregular masses up to 0.8 mm in diameter. Quartz makes up about 30% of the rock, forming subhedra to 0.3 mm diameter; carbonate, possibly ferroan dolomite making up 10% of the rock, forms sub- to euhedral crystals to 0.2 mm. Minor arsenopyrite (1-2%; weakly anisotropic, but distinctly white compared to pyrite) forms aggregates to 0.4 mm in diameter of 0.1 mm subhedra; sphalerite (2-3%) forms colourless (low Fe) subhedra to 0.1 mm, in places associated with tetrahedrite-tennantite (1-2%) to 0.2 mm and rare galena (<1%, 0.1 mm). Minor sericite (1-2%) forms euhedral flakes to 0.2 mm diameter. Again, compositional layering implies ?syngenetic deposition of sulfides and ?exhalative gangue minerals.

Marg **DDH96-48 376.0**: QUARTZ-RICH (+SERICITE-CARBONATE-TOURMALINE) SCHIST

Dark grey, very fine-grained, siliceous rock with faint laminae and oblique veinlets of white quartz. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is roughly:

Quartz	90%
Sericite	5%
Carbonate (?ferroan dolomite)	1-2%

Opaque (pyrite, ?carbon)	1%
Tourmaline (?detrital), ?rutile, zircon	<1% each

The bulk of this rock is made up of fine-grained, subhedral quartz (<0.1 mm diameter) with minor wispy foliae of sericite (subhedral flakes to 0.2 mm), opaques (?pyrite and ?carbon to 100 microns and 5 microns respectively). Scattered ?detrital dark green (schorlitic) tourmaline crystals are rounded euhedra up to 0.15 mm long; rare zircon euhedra are up to 80 microns long. The protolith for this quartz-rich metamorphic rock could have been a siliceous clastic sediment.

Marg **DDH96-48 401.32**: QUARTZ-SERICITE-CHLORITE-FERROAN CARBONATE SCHIST

Fine-grained, laminated, foliated, pale green and buff-coloured schist (non-magnetic, minor reaction to cold dilute HCl). Modal mineralogy in thin section is approximately:

Quartz	60%
Sericite	20%
Chlorite	15%
Carbonate (?calcite, dolomite)	2-3%
Opaques (?mainly pyrite, ?carbon)	1-2%
Rutile	<1%
Relict ?garnet	<1%

This slide consists of alternating laminae of quartz- or sericite- or chlorite-rich rock, each mainly less than 2 mm thick. Quartz forms subhedral polyhedra mainly <0.1 mm in diameter; sericite forms either subhedral flakes to 0.3 mm or fine aggregates of 30 micron flakes that have subhedral to irregular outlines up to 0.1 mm long, likely indicating former plagioclase crystals. Chlorite forms euhedral pale green flakes up to 0.25 mm diameter with near-zero to weakly anomalous birefringence indicating F/M around 0.5; chloritic laminae contain euhedral pyrite to 0.25 mm, extremely fine ?carbon <5 microns in diameter, and sagenitic ?rutile needles mainly <1 micron thick. Carbonate forms subhedral to irregular aggregates to 0.5 mm size with cloudy, higher relief cores of ?ferroan dolomite and rims of ?calcite, some of which contain traces of relict ?garnet. It seems likely that this rock represents a strongly deformed and greenschist facies metamorphosed, former ?intermediate volcanic rock.

Marg **DDH96-48 413.40**: QUARTZ-CARBONATE-SERICITE SCHIST WITH MINOR PYRITE, ?CARBON, TOURMALINE, ZIRCON, RUTILE

Dark grey-green to black, finely foliated/laminated/folded rock that is non-magnetic but shows minor reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	60%
Carbonate (?calcite, dolomite)	20%
Sericite	15%
Opaque (pyrite, ?carbon)	3%
Tourmaline	<1%
Zircon	<1%
Rutile	<1%

This sample consists of alternating laminae of quartz-carbonate rich and sericite-?carbon+pyrite-tourmaline-zircon-rutile bearing rock that are generally highly contorted. In the former, quartz forms mainly fine subhedral polyhedra <0.1 mm in diameter; there is more quartz than can be accounted for by the limited reaction to HCl, suggesting there may be both calcite and dolomite or ankerite present (subhedra up to 0.15 mm, in aggregates to 0.5 mm across). In the latter, sericite forms subhedral or commonly bent flakes up to 0.25 mm in diameter that could be mixed in places with chlorite of zero or near-zero birefringence (not definitely identifiable, however). Wispy foliae of extremely fine opaque matter probably consist of <2 micron ?carbon and sagenitic rutile (<1 micron thick needles). Tourmaline, as scattered green (schorlitic) subhedral to rounded (?detrital) crystals up to 0.1 mm long, is common in the sericitic layers, and there are rare zircon crystals to 70 microns long. Pyrite forms coarse cubic euhedra up to 1 mm in diameter (rarely containing inclusions of orange-brown ?sphalerite to 50 microns), commonly associated with coarser quartz "sweats" and bladed quartz in pressure shadows.

Marg **DDH96-49 235.3**: QUARTZ-SERICITE-FERROAN CARBONATE-PYRITE-SPHALERITE SCHIST

White to grey, siliceous rock with black wispy foliae; non-magnetic, no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	75%
Sericite	15%
Carbonate (?ferroan)	7%
Opaque (pyrite)	1-2%
Sphalerite	<1%
Rutile (?)	<1%

This slide consists mainly of subhedral interlocking quartz crystals <0.2 mm in diameter, in places with minor carbonate (?dolomite or ankerite, subhedra to 0.5 mm) or pyrite-sphalerite (both subhedra to 0.5 mm, sphalerite commonly coating pyrite), and wispy foliae of sericite (flakes to 0.2 mm) containing concentrations of sub-microscopic opaques (?rutile needles <1 micron thick).

Marg **DDH96-49 237.28**: MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-ARSENOPYRITE CONTAINING QUARTZ-FERROAN CARBONATE-SERICITE INCLUSIONS

Massive, fine-grained pyritic sulfides with minor chalcopyrite concentrated near irregular-shaped inclusions of gangue. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	75%
Chalcopyrite	5%
Quartz	5%
Carbonate (ferroan)	5%
Sphalerite	5%
Sericite	1-2%
Galena	1-2%
Arsenopyrite	1-2%

This sample consists mainly of fine-grained (50 micron) pyrite, in places aggregated to subhedra <1 mm in diameter, or containing irregular-shaped aggregates of arsenopyrite to 1 mm size. Chalcopyrite, sphalerite and minor galena fill interstices between the pyrite crystals, forming irregular aggregates to 0.5 mm, euhedral crystals to 0.15 mm, and subhedral crystals to 0.2 mm respectively. Sphalerite is very pale coloured, probably due to a low Fe content. Although the fine-grained sulfides are suggestive of a syngenetic origin, there are no distinctive textures or structures (e.g. layering) preserved.

Marg **DDH96-49 238.5**: LAMINATED QUARTZ-SERICITE+FERROAN CARBONATE-?CARBON AND PYRITE/ARSENOPYRITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE ROCK

Laminated quartz-sericite-?chlorite or carbonaceous rock and pyrite rock, non-magnetic and non-reactive to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Quartz	40%
Pyrite	30%
Sericite	15%
Chalcopyrite	5%
Sphalerite	5%
Carbonate (?ferroan)	2-3%
Galena	1-2%
Tetrahedrite	1%
?Carbon	<1%

This slide consists largely of quartz and sericite laminations, with disseminated sulfides concentrated in quartz-rich layers. Sericitic laminae in places (especially right at the contact between silicate-rich and sulfide-rich rock) contain sub- to euhedral porphyroblasts up to 0.3 mm across of ferroan carbonate, and abundant microscopic opaques that have very low reflectivity, and could be carbon (not recrystallized sufficiently to be graphite). Pyrite (and lesser arsenopyrite; difficult to distinguish reliably except where adjacent, so the whiter colour of arsenopyrite at the core is clearly seen against the rimming pyrite) form mainly euhedral crystals up to 0.5 mm diameter that are commonly surrounded by euhedral sphalerite (to 0.15 mm; pale colour indicates low Fe content), chalcopyrite, minor galena and tetrahedrite to 0.15 mm.

Marg **DDH96-49 238.65**: LAYERED PYRITE-CHALCOPYRITE-ARSENOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE AND QUARTZ-FERROAN CARBONATE-SERICITE

Layered, laminated semi-massive sulfides (non-magnetic, no reaction to cold dilute HCl). Modal mineralogy in polished thin section is approximately:

Pyrite	40%
Quartz	30%
Arsenopyrite	10%
Sericite	5%
Sphalerite	5%
Chalcopyrite	5%
Carbonate (ferroan)	2-3%
Galena	1-2%
Tetrahedrite	1-2%

In most of the slide, fine-grained pyrite forms cubic euhedra mainly <0.5 mm in diameter that are distinguishable with difficulty from similarly sized, euhedral arsenopyrite (best seen with a hand lens in glancing incident light as whiter than pyrite). In some layers, there are above average concentrations of chalcopyrite and tetrahedrite, or, sphalerite and galena. In these layers, fine-grained pyrite has vague rounded ?collomorphic textures. Sphalerite is colourless to pale yellow, indicating a low Fe content.

Marg DDH96-49 239.83: LAYERED PYRITE-CHALCOPYRITE-FERROAN CARBONATE-QUARTZ AND FINER-GRAINED PYRITE-SERICITE-SPHALERITE-GALENA-TRACE ARSENOPYRITE

Fine-grained massive pyritic sulfides, with abundant interstitial chalcopyrite-sphalerite-minor galena and gangue minerals; not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	50%
Chalcopyrite	20%
Carbonate (ferroan)	10%
Sphalerite	5%
Quartz	5%
Sericite	5-7%
Galena	2-3%
Arsenopyrite	1%

Coarsely crystalline (to 1.5 mm) subhedral pyrite and finer euhedral pyrite crystals are set in a matrix of irregular chalcopyrite masses (up to 4 mm diameter), ferroan carbonate and quartz, in crudely defined layers up to several cm thick interspersed with fine-grained pyrite-sericite-sphalerite-galena-chalcopyrite, rare arsenopyrite layers < 1 cm thick. As in the previous sample, vestiges of former rounded balls (?relict collomorphic texture) are seen in pyrite-chalcopyrite aggregates, although mostly overprinted by later recrystallization.

Marg DDH96-49 242.05: QUARTZ-SERICITE-FERROAN CARBONATE-PYRITE-SPHALERITE-RUTILE SCHIST, POSSIBLY AFTER INTERMEDIATE/FELSIC VOLCANIC PORPHYRY

Grey to black, finely laminated, foliated siliceous rock with white to buff quartz-carbonate veins, and disseminated pyrite. Appears to come from Unit 2b, QMPH; slow reaction to cold dilute HCl when scratched. Modal mineralogy in thin section is approximately:

Quartz	55%
Sericite	35%
Carbonate (?dolomite/ankerite)	5%
Pyrite	3%
Sphalerite	1%
Rutile	<1%
?Carbon	<1%

This slide contains scattered crystals or aggregates of quartz (up to 2 mm diameter) and porphyroblastic carbonate of similar size, as well as a few irregular patches of sericite up to 1.5 mm across, in a fine-grained (mainly <0.1 mm) foliated matrix of quartz and sericite. The quartz aggregates have sub- to anhedral outlines, with overgrowth or recrystallization at the margins, and could possibly represent former ?phenocrysts. It is also possible that the porphyroblastic carbonate, and sericite patches, could represent the sites of former ?mafic and plagioclase crystals, respectively. Taken together with the presence of fine euhedral needles of rutile (to 40 microns long), these observations suggest the protolith for this metamorphic

rock could have been an intermediate or felsic volcanic. Carbonate crystals up to 1 mm in diameter have cloudy, high relief cores that could be ?ankerite, rimmed by clear carbonate. Pyrite forms cubic crystals up to 1 mm in size that are concentrated in quartz-carbonate veins and in places associated with lesser pale yellow (low Fe) sphalerite up to 0.5 mm in diameter. Sub-microscopic opaques in sericite could be trace ?carbon.

Plate 11

- a) Marg **DDH96-48 325.8**: Strongly foliated, crenulated, kink-banded sericite-quartz with clots of carbonate (cloudy, ?ferroan cores and calcite rims), minor cubic pyrite. Transmitted light, uncrossed polars, field of view 2.5 mm wide.
- b) Marg **DDH96-48 353.15**: Layered chalcopyrite-tetrahedrite/tennantite-sphalerite-galena, fine-grained pyrite, and quartz-ferroan carbonate (reflected light, uncrossed polars, field of view 2.0 mm wide).
- c) Marg **DDH96-48 361.49**: Layered massive pyrite-chalcopyrite+tetrahedrite/tennantite-sphalerite-galena containing cluster of ?arsenopyrite rhombs (reflected light, uncrossed polars, field of view 2.0 mm wide).
- d) Marg **DDH96-49 235.3**: Aggregates of pyrite and Fe-poor (colourless) sphalerite in quartz (qz), carbonate (ca) with wispy foliae of sericite (ser) and trace sagenitic ?rutile. Transmitted light, uncrossed polars, field of view 1.0 mm wide.
- e) Marg **DDH96-49 238.5**: Aggregate of euhedral rhomb-shaped ?arsenopyrite (as), subhedral tetrahedrite (tt), sphalerite (sl), and minor chalcopyrite (cp) and galena (gn) in quartz-minor sericite gangue (reflected light, uncrossed polars, field of view 0.7 mm wide).
- f) Marg **DDH96-49 238.65m**: Fine-grained, rounded aggregates of pyrite in a matrix of chalcopyrite-tetrahedrite-sphalerite-galena. Reflected light, uncrossed polars, field of view 2.0 mm wide.
- g) Marg **DDH96-49 242.05**: Possible quartz ?phenocryst in matrix of quartz and sericite with sweats of slightly coarser quartz and carbonate, minor pyrite (transmitted light, crossed polars, field of view 2.5 mm wide).
- h) Marg **DDH96-49 242.05**: Carbonate porphyroblast with cloudy ?ankerite core rimmed by clear ?dolomite, with pyrite and sphalerite in quartz-carbonate sweat. Transmitted light, uncrossed polars, field of view 2.5 mm wide.

Marg **DDH96-49 254.45/258.90**: LAMINATED PYRITE-CHALCOPYRITE-SPHALERITE-MINOR GALENA-TETRAHEDRITE (+COLLOMORPHIC TEXTURES) IN QUARTZ-CARBONATE GANGUE

Semi-massive, pyritic, laminated sulfides, from horizon C; non-magnetic, no reaction to cold dilute HCl. Modal mineralogy in polished thin section (258.90) is approximately:

Pyrite	50%
Quartz	40%
Carbonate (?ferroan)	5%
Chalcopyrite	2-3%
Sphalerite	2-3%
Tetrahedrite-tennantite	<1%
Galena	<1%

This sample consists of interlaminated pyrite-rich and quartz-lesser carbonate layers mainly less than 1 cm thick; some pyritic layers contain minor chalcopyrite and sphalerite. Pyrite is mostly very fine-grained (<50 micron cubic crystals, but commonly in aggregated up to 1 mm across); chalcopyrite occurs in anhedral masses up to 1 mm across. Sphalerite forms subhedral crystals up to 0.1 mm in size, commonly intergrown with the margins of pyrite and chalcopyrite (minor 0.1 mm inclusions of tetrahedrite in the latter); very pale yellow colour indicates a low Fe content. Pyrite, chalcopyrite, sphalerite and ?galena form rounded aggregates, in places with relict ?collomorphic textures. Quartz forms fine-grained aggregates (anhedral crystals mostly <0.2 mm except where bladed, in pressure shadows). Carbonate may include ankerite cores and dolomite rims, in aggregates up to 0.5 mm in diameter; note absence of sericite.

Marg **DDH96-49 262.48**: QUARTZ-SERICITE-FERROAN CARBONATE-PYRITE+RUTILE SCHIST

From QMPH unit 2b; very finely laminated, fine-grained siliceous schist that is not magnetic and does not react to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	65%
Sericite	25%
Ferroan carbonate	5%
Opaque (pyrite)	5%
Rutile	<1%

In this quartz-sericite schist, quartz forms sub- to anhedral crystals mainly <0.1 mm in diameter in layers up to 2.5 mm thick that alternate with wispy foliae rich in subhedral sericite <0.25 mm in diameter. There are also thicker, coarser-grained quartz-carbonate (both subhedral, up to 0.3 mm in diameter) layers or "sweats". Pyrite is disseminated throughout all layers, forming fine cubes to 0.1 mm in the sericite layers and to 0.3 mm in the "sweats"; rutile needles to 15 microns are common in the sericite. Little remains of the primary texture to indicate the protolith for this rock, but it could have been a felsic volcanic or ?exhalite.

Marg **DDH96-49 268.72**: LAYERED PYRITE-SPHALERITE-CHALCOPYRITE-?ARSENOPYRITE-TETRAHEDRITE-GALENA AND QUARTZ-FERROAN CARBONATE

From B5 horizon; semi-massive sulfides (non-magnetic, no reaction to cold dilute HCl). Modal mineralogy in polished thin section is:

Pyrite	60%
Quartz	20%
Carbonate (ferroan)	10%
Sphalerite	5%
Chalcopyrite	2-3%
Arsenopyrite (?)	1-2%
Tetrahedrite	<1%
Galena	<1%

This sample is pyrite-rich, with a faintly layered structure caused by 1-2 mm thick zones richer in gangue (quartz and carbonate, likely dolomite or ankerite, both as subhedra to 0.5 mm diameter). Pyrite occurs as subhedral crystals mainly <0.3 mm in diameter, intimately mixed with lesser sphalerite (subhedral pale yellow, low Fe crystals to 0.25 mm), minor chalcopyrite (irregular masses to 0.5 mm containing subhedral tetrahedrite to 0.5 mm) and rare galena (subhedra to 0.5 mm). Whitish colour in some of the sulfides suggest the presence (restricted to layers up to 1 mm thick) of ?arsenopyrite or ?marcasite. The fine-grained sulfides have vague collomorphic textures; sericite is absent.

Marg **DDH96-49 270.0:** QUARTZ-FERROAN CARBONATE-SERICITE-PYRITE-?CARBON SCHIST

From QGPH (Unit 2c); sample consists of finely interlaminated, fine-grained, white (quartz) and black (pyritic, ?carbon-rich) rock. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in thin section is approximately:

Quartz	55%
Carbonate (?ferroan)	20%
Sericite	10%
Pyrite	10%
?Carbon	5%

Quartz-rich laminae consist of sub- to anhedral, interlocking quartz crystals up to 0.5 mm in diameter and aggregates of ferroan carbonate (?ankerite and dolomite) with in places subhedral outlines up to 2 mm diameter (cores strongly clouded by sub-microscopic ?carbon particles; clear but high-relief rims, not likely calcite). The carbonate aggregates are likely porphyroblastic rather than pseudomorphic after former mafic crystals. Sericitic laminae contain most of the opaques in the sample, both finely crystalline pyrite (mainly <30 microns, but up to 0.5 mm) and possibly very fine (<10 micron) ?carbon particles. Sericite is strongly foliated, bent, and crenulated.

Marg **DDH96-49 273.1:** QUARTZ-FERROAN CARBONATE-SERICITE-PYRITE-?CARBON SCHIST IN CONTACT WITH MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE

Sample shows the contact between black, siliceous, folded, possibly carbon-rich sediments and fine-grained massive sulfides (pyrite, chalcopyrite, sphalerite). The wallrock is very similar to that described above for 270.0 m (laminated quartz, ferroan carbonate, sericite, pyrite, possible ?carbon). Massive sulfides consist of mainly fine-grained (<50 micron) pyrite, but commonly in aggregates with subhedral outlines up to 1 mm in diameter, with interstitial chalcopyrite (subhedral masses to 1 mm) and sphalerite (pale coloured, low Fe, subhedral to euhedral, to 0.2 mm) plus traces of tetrahedrite and galena to 0.1 mm; arsenopyrite may be present but is difficult to confirm. Gangue is mainly quartz (subhedral to bladed crystals to 0.35 mm) and lesser sericite, which is concentrated at the contact of sulfides and wallrock; carbonate appears to be absent from the sulfide portion). Rare collomorphic textures are preserved by inclusions of chalcopyrite and sphalerite, in cores of pyrite crystals.

Marg **DDH96-49 274.6:** MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE IN QUARTZ-SERICITE

Semi-massive sulfides (pyrite, chalcopyrite) in quartz-sericite gangues (in places with vague fragmental texture caused by wispy lensey sericite- or quartz-rich ?clasts up to 0.5 cm in size). The rock is not magnetic and shows no reaction to cold dilute HCl; in polished thin section it is composed of heavily disseminated to semi-massive sulfides (pyrite, chalcopyrite, sphalerite, minor galena and tetrahedrite; cannot be sure if arsenopyrite is present or not). Gangue minerals include quartz, ferroan carbonate, and sericite.

Marg **DDH96-49 276.2:** LAYERED MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-ARSENOPYRITE-TETRAHEDRITE AND QUARTZ-FERROAN CARBONATE/SERICITE

Massive to semi-massive, vaguely layered, fine-grained pyrite +/- chalcopyrite, sphalerite in siliceous gangue (no reaction to cold dilute HCl). The polished thin section shows layers up to 1.5 cm thick composed of aggregates (commonly 1 mm in diameter) of fine-grained (mainly <0.1 mm) pyrite, sphalerite and scattered, interstitial chalcopyrite (irregular masses to 1.5 mm, commonly intergrown with subhedral tetrahedrite to 0.5 mm) and lesser galena (to 0.2 mm). Sphalerite is colourless and mainly surrounds pyrite aggregates. Arsenopyrite occurs as sub- to euhedral, commonly rhombic shaped crystals up to 0.75 mm in size in certain layers. The sulfide-rich layers are separated by narrower laminae rich in quartz and carbonate (both subhedral, to 0.35 and 0.5 mm respectively except for bladed quartz in pressure shadows around pyrite); carbonate is likely dolomite or ferroan dolomite (ankerite) to judge by lack of reaction in the outcut. In some laminae, sericite is important with the quartz. There are also rare aggregates up to 0.5 mm across in certain laminae, composed of semi-isotropic ?garnet associated with (possibly replaced by) the carbonate. Both the ?garnet and the carbonate should be analyzed (by SEM or microprobe) for Mn content, an element commonly concentrated in these minerals in exhalative massive sulfides. Scattered remnants of collomorphic texture are found preserved in pyrite in aggregates with chalcopyrite, sphalerite and galena.

Marg **DDH96-49 277.32**: MASSIVE PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-ARSENOPYRITE TETRAHEDRITE (COLLOMORPHIC, LAYERED)/QUARTZ-FERROAN CARBONATE-SERICITE

Fine-grained, pyritic massive sulfides with certain layers (1 mm thick) enriched in arsenopyrite, chalcopyrite, galena, sphalerite and tetrahedrite. The rock is not magnetic and shows no reaction to cold dilute HCl; modal mineralogy in polished thin section is approximately:

Pyrite	60%
Chalcopyrite	10%
Quartz	10%
Carbonate (?ferroan)	10%
Sericite	2-3%
Sphalerite	2-3%
Galena	1-2%
Arsenopyrite	1-2%
Tetrahedrite	1-2%

Most of this slide consists of fine-grained (<0.1 mm) eu- to subhedral pyrite embedded in a matrix of abundant, interstitial chalcopyrite and lesser sphalerite plus minor tetrahedrite and galena. This is one of the richest samples in the suite from the Marg deposit, and might prove useful if the locus of the gold is to be sought. Sphalerite is colourless (low in Fe content). Gangues include quartz, sericite and carbonate, likely ferroan, as subhedral crystals mainly <0.25 mm in diameter. A faintly layered, in places collomorphic banded structure is evident on a large scale (layers about 1 mm thick). Coarser-grained layers contain essentially the same minerals plus arsenopyrite and more abundant galena and tetrahedrite; they may possibly have been recrystallized by metamorphism.

Sample 96-49 277.8 is very similar, composed of fine-grained, laminated pyrite-rich massive sulfides with interstitial chalcopyrite, sphalerite, tetrahedrite and minor galena. Some of the base-metal sulfides are so finely interlocked with vaguely collomorphically banded fine-grained pyrite (<20 microns) that recovery may be difficult. Gangues in coarser, ?recrystallized layers include quartz, ?ferroan carbonate, and sericite.

Marg **DDH96-49 280.2**: LAMINATED PYRITE-MINOR SPHALERITE-CHALCOPYRITE-GALENA-CARBON AND QUARTZ-SERICITE-FERROAN CARBONATE-RUTILE

Heavily disseminated pyrite to semi-massive sulfides from base of B3 horizon; vaguely defined, wispy to lensey ?fragments up to 1.5 cm long (could be due to dismemberment during deformation). The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	35%
Quartz	30%
Sericite	15-20%
Carbonate (?ferroan)	10%
Sphalerite	2-3%
?Carbon	2-3%
Chalcopyrite	1-2%
Galena	<1%
Rutile	<1%

Laminae composed mainly of fine-grained (<50 micron) euhedral pyrite, quartz, sericite and possible ?carbon, contain scattered ?megacrysts of pyrite up to about 1 mm in diameter (possibly grown during metamorphic recrystallization), and are separated from each other by layers of quartz-ferroan carbonate-sericite. Quartz forms subhedral to commonly bladed (pressure-shadow) crystals up to 0.5 mm in length; carbonate forms subhedral crystals up to 0.6 mm long. Sericite occurs as flakes to 0.25 mm in diameter that could in places be mixed with colourless chlorite (?or basal sections of sericite), containing traces of sagenitic rutile as minute needles to 15 microns long. The coarse pyrite crystals contain very fine crystals of chalcopyrite, sphalerite, and galena, mainly <35 microns in diameter (sphalerite is colourless, low in Fe content, and reaches 0.2 mm diameter). Chalcopyrite also rarely reaches 0.25 mm in diameter in irregular-shaped masses, but galena is mainly very fine-grained and complexly intergrown with pyrite. Rarely, vaguely defined collomorphic and ?framboidal textures are preserved in the pyrite, suggesting that these were originally syngenetically precipitated sulfides.

Plate 12

a) & b) Marg **DDH96-49 258.9**: ?Relict collomorphic textures in pyrite-chalcopyrite-sphalerite aggregates in quartz-ferroan carbonate gangue (reflected light, uncrossed polars, field of view 1.6 mm wide in top photo, 0.7 mm in lower photo).

c) Marg **DDH96-49 274.6**: Teardrop-shaped, sericite-rich clast in quartz-pyrite-chalcopyrite-sphalerite-minor galena, tetrahedrite matrix. Transmitted light, crossed polars, field of view 2.5 mm wide.

d) Marg **DDH96-49 276.2**: Scattered remnants of collomorphic texture preserved in pyrite in aggregates with chalcopyrite, sphalerite and galena; euhedral arsenopyrite (as). Reflected light, uncrossed polars, field of view 1.6 mm wide).

e) Marg **DDH96-49 276.2**: Larger relict collomorphic structure (central, almost framboidal pyrite ball surrounded by chalcopyrite-minor sphalerite layer, more crystalline pyrite, rare galena (gn), in matrix of quartz- ferroan carbonate (reflected light, uncrossed polars, 2.0 mm wide).

f) Marg **DDH96-49 277.32**: Coarser-grained layer containing pyrite-chalcopyrite-tetrahedrite-sphalerite-galena-quartz-ferroan carbonate in adjacent, faintly collomorphic aggregates of pyrite-chalcopyrite-sphalerite-galena (reflected light, uncrossed polars, field of view 2.0 mm wide).

g) Marg **DDH96-49 277.8**: Faintly collomorphic, layered, fine-grained pyrite-chalcopyrite-sphalerite-tetrahedrite with coarser, ?recrystallized pyrite-chalcopyrite-sphalerite-galena-quartz-ferroan carbonate-sericite (reflected light, uncrossed polars, field of view 2.0 mm wide).

h) Marg **DDH96-56 255.25**: Relict collomorphic structures outlined by galena and chalcopyrite inclusions in pyrite (reflected light, uncrossed polars, field of view 0.7 mm wide).

Marg **DDH96-56 255.25**: MASSIVE TO LAYERED, FINE-GRAINED PYRITE-CHALCOPYRITE-SPHALERITE-TETRAHEDRITE-GALENA-ARSENOPYRITE/QUARTZ-CARBONATE-SERICITE

Fine-grained, massive pyritic sulfides with a very crude layering defined by very fine-grained, more massive zones up to 1.5 cm thick alternating with less massive (more gangue-rich), slightly coarser-grained layers of similar thickness. The rock is not magnetic and shows no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	65%
Quartz	10%
Sphalerite	7%
Chalcopryite	5%
Carbonate (ferroan)	5%
Sericite	3%
Chlorite (?magnesian)	2%
Tetrahedrite	1%
Arsenopyrite	1%
Galena	1%

This sample consists mainly of pyrite with interstitial pale yellow coloured (low Fe) sphalerite, chalcopryite, and minor tetrahedrite-tennantite, arsenopyrite, and galena in gangues that include quartz, carbonate, sericite and chlorite. Fine-grained to larger-scale atoll and collomorphic textures are common, generally involving rims or layers of pyrite with cores or layers of chalcopryite, galena or less commonly sphalerite. Tetrahedrite is common as subhedra to 0.5 mm included in or intergrown with chalcopryite masses up to 1 mm across. Rare arsenopyrite euhedra are up to 0.4 mm across, with atoll texture caused by cores of chalcopryite-tetrahedrite. Quartz and carbonate (likely ferroan dolomite, or ankerite) form subhedra to 0.5 mm in diameter; sericite and interleaved chlorite form subhedral to bent flakes mostly <0.2 mm in diameter. Chlorite optical characteristics (no pleochroism, first-order grey-white length-fast birefringence) suggests a magnesian composition (F/M about ?0.4).

Marg **DDH96-56 256.67**: MASSIVE, LAMINATED PYRITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE-ARSENOPYRITE/QUARTZ-SERICITE GANGUE

Offcut is not magnetic and shows no reaction to cold dilute HCl; both it and the polished thin section show distinctly layered to laminated pyritic massive sulfides, with alternating layers up to 3 mm thick rich in sphalerite-arsenopyrite or chalcopryite (both mainly interstitial to the pyrite framework). Other layers contain clotty concentrations of gangues (quartz 10%, sericite 10%; note the apparent paucity of ferroan carbonate, 1-2%, in this sample). The slide contains about 50-60% eu- to subhedral pyrite to 0.35 mm (subhedral aggregates to 1 mm), 10% subhedral/irregular chalcopryite to 1.5 mm (in places containing subhedral tetrahedrite to 0.1 mm; 1%), 5-10% pale yellow, low Fe sphalerite sub- to euhedra to 0.15 mm (in places mixed with subhedral galena to 0.1 mm; 2-3%) and scattered euhedral arsenopyrite to 0.3 mm (2-3%). Both small-scale and larger-scale (1 mm diameter) circular structures, commonly of inclusions of galena or chalcopryite in pyrite, are present although poorly defined, likely indicating the former presence of collomorphic texture of syngenetically precipitated sulfides.

Marg **DDH96-56 257.3**: PYRITE/?MARCASITE "BALLS" IN MATRIX OF QUARTZ-CHALCOPYRITE SPHALERITE-FERROAN CARBONATE-SERICITE-MINOR GALENA

Semi-massive pyrite-chalcopryite rich sulfides, with abundant siliceous matrix. The rock is not magnetic and shows only trace slow reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite, ?marcasite	35%
Quartz	35%
Chalcopryite	10%
Sphalerite	10%
Carbonate	5%
Sericite	3-5%
Galena	1-2%

Pyrite occurs as mainly subhedral aggregates up to about 1.2 mm in diameter, composed of smaller (<50 micron) euhedral cubic to anhedral crystals, and in places including abundant chalcopryite of similar size. Some of the iron sulfide aggregates are rounded balls (formerly ?collomorphic and/or framboidal balls), and

contain a distinctly anisotropic phase, suggesting they contain remnants of ?marcasite (subhedral to bladed crystals to 0.2 mm long). Chalcopyrite mainly occurs as sub- to anhedral masses to 0.8 mm diameter interstitial to pyrite, associated with sub- to euhedral sphalerite (pale orange-brown, fairly low Fe content) mainly <0.2 mm in diameter, and subordinate galena to 0.25 mm; tetrahedrite and arsenopyrite are not seen. Gangues are mainly subhedral to bladed quartz up to 0.4 mm in diameter, and lesser carbonate, likely ferroan, as subhedra to 0.3 mm. A laminated, foliated zone at one end of the slide is sericite-rich (subhedral flakes to 0.2 mm) and sulfide-poor.

Marg **DDH96-56 257.8**: QUARTZ-SERICITE-FERROAN CARBONATE-SULFIDE SCHIST (FORMER ?EXHALITE)

This sample comes from within massive sulfide horizon C, although it is composed of disseminated pyrite in quartz-sericite schist. It does not react to cold dilute HCl and is not magnetic; modal mineralogy in thin section is roughly:

Quartz	60%
Sericite	25%
Ferroan carbonate	7%
Opaque (pyrite, chalcopyrite, arsenopyrite)	7%
Sphalerite	1%
Rutile	<1%

This sample is similar to that from Marg DDH96-49 242.05 but lacks the larger quartz ?phenocrysts; segregation into quartz-rich and sericite-rich laminae is very strongly developed, and pressure-shadow quartz is common around cubic pyrite crystals up to about 1 mm in diameter (associated with sub- to euhedral pale-coloured, low Fe sphalerite up to 0.5 mm; minor chalcopyrite and arsenopyrite can be seen in the offcut slab). Minute rutile needles in sericite are mainly <15 microns in length. It is possible that this sample could represent an ?exhalite horizon.

Marg **DDH96-56 258.75**: MASSIVE/LAMINATED PYRITE-CHALCOPYRITE-QUARTZ-SPHALERITE-ARSENOPYRITE-CARBONATE-SERICITE-GALENA

Massive to laminated, pyritic sulfides (no offcut remaining). Modal mineralogy in polished thin section is approximately:

Pyrite	45%
Chalcopyrite	20%
Quartz	15%
Sphalerite	10%
Arsenopyrite	3%
Carbonate	3%
Sericite	3%
Galena	1%

Massive pyrite-chalcopyrite-minor arsenopyrite layers up to 1.5 cm thick are associated with quartz and coarse-grained (?recrystallized) masses of chalcopyrite; laminated, fine-grained pyrite-sphalerite-chalcopyrite-minor galena layers are associated with sericite. Quartz mainly forms subhedral, 0.1-0.5 mm, to bladed, up to 0.8 mm long, crystals in pressure shadows near the sulfides. In places the quartz is mixed with minor carbonate as subhedra to 0.35 mm. Chalcopyrite masses are up to 3 mm long, containing inclusions of pyrite, sphalerite and galena mostly <0.25 mm in size. Arsenopyrite commonly occurs as either very fine-grained rounded aggregates or euhedral rhombic crystals up to 0.1 mm in diameter that are distinctly white compared to pyrite, restricted to laminae <1 mm thick that are also enriched in sphalerite (pale yellow to orange-brown, low Fe) and galena.

Marg **DDH96-56 265.33**: MASSIVE PYRITE-SPHALERITE-CHALCOPYRITE-QUARTZ-FERROAN CARBONATE-GALENA-ARSENOPYRITE-TETRAHEDRITE

Massive pyritic sulfides (notably enriched in sphalerite and galena compared to most other samples in this suite); non-magnetic, no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite	50%
Sphalerite	15%
Chalcopyrite	10%

Quartz	10%
Carbonate (?ferroan)	10%
Galena	3%
Arsenopyrite	2%
Tetrahedrite-tennantite	<1%

Most of the section consists of massive fine-grained aggregates of pyrite, with abundant interstitial sphalerite, chalcopyrite and galena; minor arsenopyrite occurs in places. Layering is very faint in this section, mainly indicated by narrow zones <1.5 mm thick containing more gangue minerals (quartz and carbonate in about equal proportions, forming subhedral interlocking crystals mainly <0.25 mm in diameter). Pyrite crystals are generally euhedral or fine-grained aggregates up to about 0.25 mm in diameter, with the aggregates displaying traces of relict ?collomorphic banding. Sphalerite crystals are mainly eu- to subhedral and <0.2 mm in size, with yellow to orangish colour indicating low to moderate Fe content. Sphalerite is intergrown with shapeless to subhedral masses of chalcopyrite and significant galena, up to 0.7 mm in diameter; minor tetrahedrite-tennantite is intergrown with chalcopyrite as subhedra to 0.4 mm. Galena is most closely associated with carbonate gangues. Subhedral arsenopyrite crystals are mainly <0.25 mm in diameter.

Marg **DDH96-56 265.96**: MASSIVE, POSSIBLY CLASTIC SULFIDES (PYRITE/?MARCASITE-CHALCOPYRITE-SPHALERITE-GALENA IN QUARTZ-SERICITE-FERROAN CARBONATE)

Massive pyritic sulfides, but with a vaguely ?fragmental texture and segregated into bands several cm thick enriched alternately in chalcopyrite or in gangue minerals (mainly quartz; no reaction to cold dilute HCl) and minor sphalerite. In the polished thin section, Cu-rich bands consist of subhedral crystals of pyrite to about 1.25 mm diameter, and subrounded ?clasts of fine-grained pyritic material up to about 0.5 cm in size, in a matrix of subhedral to irregular masses of chalcopyrite up to 1.5 mm across, quartz and sericite. Quartz mostly forms bladed (pressure-shadow) crystals up to 0.75 mm long; sericite flakes are subhedral and mostly <0.25 mm in diameter, accompanied in places by similar-sized chlorite (likely magnesian; first-order, length fast birefringence, no colour or pleochroism) and lesser carbonate. Less massive bands consist of scattered aggregates of pyrite-?marcasite (surrounded/rimmed by minor sphalerite and chalcopyrite) up to about 1.5 mm in diameter, in a matrix composed mainly of sericite and minor quartz and ferroan carbonate. The aggregates have, in places, a vague radiating structure typical of early-formed cockscomb-textured marcasite in known or inferred sea-floor sulfides observed elsewhere (Leitch, 1981, 1990). Sphalerite is pale yellow to orangish, indicating low Fe content; it contains minute inclusions (<10 microns) of chalcopyrite. Galena is rare, mainly forming irregular inclusions to 60 microns in pyrite. In the presence of the anisotropic ?marcasite it is difficult to be sure, but arsenopyrite appears to be absent; tetrahedrite also appears to be absent or very minor.

Marg **DDH96-56 268.88**: MASSIVE, ?FINELY CLASTIC, PYRITE-MARCASITE/ARSENOPYRITE-CHALCOPYRITE-SPHALERITE-CARBONATE-QUARTZ-GALENA-SERICITE-TETRAHEDRITE

No offcut remaining; polished thin section shows massive, possibly finely clastic, sulfides composed of pyrite, arsenopyrite, chalcopyrite and sphalerite with lesser galena and tetrahedrite-tennantite. The proportion of arsenopyrite/?marcasite is difficult to estimate, but modal mineralogy may be approximately as follows:

Pyrite	30%
Chalcopyrite	20%
Sphalerite	20%
Arsenopyrite (or ?marcasite)	10%
Carbonate	10%
Quartz	5%
Galena	3%
Sericite	2%
tetrahedrite-tennantite	<1%

Pyrite forms mainly euhedral cubic crystals <0.5 mm in diameter, commonly mixed with arsenopyrite or marcasite (fine-grained aggregates of 10-20 micron crystals or sub- to euhedra up to 0.25 mm diameter with pale bluish to straw-yellow anisotropic colours) in a matrix of chalcopyrite (masses to several mm diameter) and sphalerite (pale yellow-orange, low Fe, sub- to euhedral crystals up to 0.25 mm in size) plus lesser galena (subhedra to 0.35 mm), and gangues (quartz, carbonate, sericite). Chalcopyrite rarely contains

included tetrahedrite to 0.15 mm. Rarely preserved ?radially cracked or cockscomb aggregates, possibly after former marcasite, are outlined by septae of pyrite infilled by chalcopyrite and minor galena. Carbonate and quartz form subhedra mainly <0.4 mm in diameter; sphalerite-rich areas are commonly intergrown with minor fine (<0.2 mm) shreddy sericite.

Marg **DDH96-56 271.85**: LAMINATED PYRITE/?MARCASITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE AND QUARTZ-SERICITE-FERROAN CARBONATE

Finely laminated massive sulfides and siliceous gangues (layers 1-3 mm thick); non-magnetic, no reaction to cold dilute HCl. Modal mineralogy in polished thin section is approximately:

Pyrite/marcasite	45%
Quartz	35%
Sericite	10%
Carbonate (?ferroan)	5%
Sphalerite	2-3%
Chalcopyrite	2-3%
Galena	<1%
Tetrahedrite/tennantite	tr

Sulfide-rich layers mainly consist of scattered subhedral aggregates of pyrite and ?marcasite (distinctly anisotropic), or cubic crystals of pyrite, up to 1 mm in diameter, generally set in a matrix of finer (<50 micron) pyrite crystals mixed with variable proportions of gangue (quartz, sericite); chalcopyrite, sphalerite and galena are minor to rare. Some circular (?relict collomorphic) textures are preserved in the iron sulfide aggregates, in places highlighted by inclusions of base-metal sulfides such as sphalerite and galena. Rare narrow (<1 mm thick) chalcopyrite-rich layers also contain anomalous amounts of sphalerite and minor galena. Chalcopyrite forms subhedral to irregular masses up to several mm long that rarely contain subhedral tetrahedrite to 0.2 mm; sphalerite is almost colourless (very low Fe), forming sub- to euhedral crystals up to 0.2 mm in diameter; galena forms irregular masses up to 0.5 mm across.

Marg **DDH96-56 282.82**: LAYERED MASSIVE PYRITE/?MARCASITE-CHALCOPYRITE-SPHALERITE-GALENA-TETRAHEDRITE-QUARTZ-FERROAN CARBONATE-SERICITE

Layered, pyritic massive sulfides (non-magnetic, no reaction to cold dilute HCl). In polished thin section, layers up to 1.5 cm thick are composed mainly of pyrite with interstitial gangues, and minor chalcopyrite, sphalerite and galena; less common layers <1 cm thick are composed of quartz, sphalerite, arsenopyrite, chalcopyrite and galena, or are enriched in chalcopyrite and tetrahedrite-tennantite. Pyrite forms subhedral to euhedral crystals up to 3 mm in diameter, set in a matrix of fine-grained iron sulfide that may include pyrite and marcasite (some of the mainly <50 micron crystals are weakly anisotropic), lesser chalcopyrite, sphalerite and minor tetrahedrite and galena; gangues include quartz and sericite. Rarely, relicts of former ?collomorphic texture are highlighted by inclusions of base-metal sulfides (galena, chalcopyrite) in aggregates of pyrite/?marcasite. Chalcopyrite forms subhedra mainly <0.5 mm except in the chalcopyrite-rich layers, in which irregular masses are up to several mm long; both types contain subhedral tetrahedrite, up to 0.35 mm diameter in the latter. Sphalerite forms sub- to euhedral crystals up to 0.2 mm in size, with very pale yellow colour indicating low Fe content. In the sphalerite-rich layers, arsenopyrite (?) crystals are euhedral, rhomb-shaped, <0.2 mm in size and distinguishable with difficulty from pyrite; galena forms subhedral masses up to 0.5 mm in diameter associated with the sphalerite, which forms masses up to several mm across hosting the iron sulfides, and intergrown with quartz (subhedra to 0.5 mm) and minor ferroan carbonate (subhedra to 0.3 mm).

PRIMO PROPERTY

The Primo prospect is located 90 km northeast of the Kudz Ze Kayah deposit. At the Primo, pyrite-pyrrhotite and lesser galena and sphalerite are associated with tuff, rhyolite, argillite and carbonate (Burke, 1997, in Hunt, 1998). Only one sample was examined from the Primo prospect (**JH 96-PRIMO**) and this is a grey-green, vaguely quartz-feldspar porphyritic rock with white, in places vuggy and pyrite-bearing quartz veins. The rock is weakly magnetic but shows no reaction to cold dilute HCl; modal mineralogy in thin section is approximately:

Quartz (phenocrysts, matrix, veins)	65%
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Sericite	15%
Relict plagioclase	15%
Opaque (mostly ?pyrite)	2%
Chlorite, hydrobiotite	2%
Limonite	<1%
Rutile	<1%
Carbonate	<1%
Sphalerite	tr

This appears to be a very quartz-rich rock, with abundant subhedral to irregular-shaped relict ?phenocrysts up to 3 mm in diameter, and lesser rounded plagioclase relict phenocrysts of similar size (distinguishable only where twinned) in a matrix of quartz, lesser plagioclase (in part sericitized) and coarser sericite and minor chlorite (possibly after former minor mafic minerals such as biotite). Due to ubiquitous traces of sericite between all crystals, it is almost impossible to compare refractive indices of plagioclase with quartz; thus composition of plagioclase is uncertain, but I would guess likely oligoclase. Lack of an etched and stained slab makes it impossible to be sure, but some relict feldspar phenocrysts have the appearance of K-feldspar (possibly in part after plagioclase). Traces of interstitial carbonate (subhedra to 0.2 mm) and rutile (euhedral brown needles to 80 microns) are present. It seems likely this sample represents a sheared, disrupted, possibly originally sericite altered, quartz-feldspar porphyry that could have been a high-level intrusive or a volcanic.

Veins are difficult to distinguish in thin section due to the high original quartz content of the rock, but consist of zones of finer-grained (<0.2 mm), subhedral quartz crystals containing subhedral pyrite to 1 mm (aggregates to several mm) associated with minor brownish, non-pleochroic "hydrobiotite" as minute scaly flakes <10 microns in diameter, or colourless chlorite as radiating rosettes up to 50 microns in diameter. Rare red-brown (Fe-rich) sphalerite forms subhedra to 0.35 mm diameter; galena may be present but is not identifiable without a polished surface.

Plate 13

- a) Marg **DDH96-56 257.8**: Rounded, ?collomorphic ball containing anisotropic ?marcasite as well as pyrite, surrounded by chalcopyrite-sphalerite-galena (reflected light, uncrossed polars, field of view 2.0 mm wide).
- b) Marg **DDH96-56 258.75**: Lamina containing euhedral to rounded arsenopyrite and pyrite in matrix of chalcopyrite, sphalerite and galena; gangues are mainly sericite (reflected light, uncrossed polars, 2 mm field of view)
- c) Marg **DDH96-56 265.33**: Fine-grained, ?former collomorphic aggregates and cubic crystals of pyrite, rare arsenopyrite, in somewhat layered matrix composed of either sphalerite-tetrahedrite or quartz-carbonate-galena-sphalerite (reflected light, uncrossed polars, field of view 2 mm).
- d) Marg **DDH96-56 265.96**: Possible relict "radiating cockscomb" texture of pyrite-?marcasite ball, rimmed by sphalerite and chalcopyrite, in matrix of sericite (reflected light, crossed polars, field of view 2 mm wide).
- e) Marg **DDH96-56 268.88**: ?Radially cracked or cockscomb aggregates, possibly after former marcasite, outlined by septae of pyrite infilled by chalcopyrite and galena (reflected light, uncrossed polars, field of view 1.6 mm).
- f) Marg **DDH96-56 271.85**: Collomorphic ball of pyrite/?marcasite highlighted by inclusions of sphalerite and galena, in laminated semi-massive sulfides (reflected light, uncrossed polars, field of view 0.7 mm wide).
- g) Marg **DDH96-56 282.82**: Aggregate of pyrite-?arsenopyrite (rhombic)-sphalerite-galena in quartz-ferroan carbonate, Zn-rich layer in massive sulfides (reflected light, uncrossed polars, field of view 1.6 mm wide).
- h) **PRIMO**: Subhedral, polysynthetic twinned plagioclase (veined by sericite, minor quartz), and similar-sized sub- to anhedral quartz phenocryst in matrix of quartz, sericitized plagioclase and sericite, felsic quartz-feldspar porphyry. Transmitted light, crossed polars, field of view 2.5 mm wide.