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PETROGRAPHIC REPORT ON 26 SPECIMENS FROM THE LEMARE PROPERTY ON VANCOUVER ISLAND, BRITISH COLUMBIA

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Invoice attached

SAMPLES SUBMITTED:

ARL301-305, 308-310A,B,311-313, 315, 319, 322, 325-327, 335-342.

SUMMARY:

The Lemare property lies at the northern end of Vancouver Island, west of the producing Island Copper mine and along strike on a regionally mineralized trend extending from that mine. On the property, several zones (respectively the Culleet Creek Zone, including the Gorby and Boris showings, the Lake and South Lake zones on an arm of Le Mare Lake, and the South Gossan Zone) extend southeast from tidewater at Harvey Cove to the south end of Le Mare Lake. This petrographic work was undertaken in order to unravel some of the cryptic alteration types exposed on the property, aprticularly in the major South Gossan Zone, where phyllic, argillic, and advanced argillic alteration types were suspected. Previous work by the B.C. Geological Survey included four thin sections and some X-ray diffraction which confirmed that kaolinite and pyrophyllite were present, but not alunite (instead the sulfate was gypsum: Andre Panteleyev, pers. comm., 1991).

The rocks submitted (individual petrographic reports for each section are appended) are apparently all volcanic in origin, although some are so highly altered as to be of dubious protolith. Most were probably mafic volcanics (basalt to basaltic andesite) but a few may have been as felsic as dacite (ARL315, 337, and possibly 342; 335 is amygdular). The main mafic volcanic types are: porphyritic ?flow (ARL302, 304, 339, 340); fine ?flow (ARL319, 325, 338, 341) and fragmental (ARL301, 303, 305, 322, 326, 327, 336). The rest are classed as intensely hydrothermally altered (ARL310A/B, 311, 312, 313), breccia (ARL308, 342) or semi-massive pyrite (ARL309). Strong to intense quartz stockworking is noted in ARL322, 338, 339, 340, 341, and 342.

Alteration in these rocks is generally strong (well-developed and pervasive) and ranges from propylitic through argillic and ?advanced argillic (depending on X-ray confirmation of mineral species such as pyrophyllite) to potassic, phyllic and silicic. These alteration types fit roughly with the classifioations used in the field, as

depicted on the 1:5000 scale map appended to this report. After the petrographic analysis presented here (lacking X-ray diffraction confirmations), the rocks may be tentatively grouped as follows:

Propylitic (ARL302, 304, 315, 335, 341). This includes the type classed as propylitic but not the field type "apple green silicified"; the former is dark green and characterized by epidote-chlorite and pyrite while the latter is pale green, very hard and typically composed of chlorite-Kspar-quartz ± sericite and may contain pyrite and chalcopyrite; magnetite was found in one sample (315) and noted in the field in 341 but not in section. K-spar in the former (315) is apparently primary sanidine; the latter does not contain K-spar

Argillic-advanced argillic (ARL305, 310B, 311, 312, 313, 325, 326). Most of these samples are white to buff or creamy in hand specimen and lack primary texture, indicating very strong alteration. This includes samples like 305 composed of quartz-?clay-FeTi oxides and most of the rest listed above, consisting of quartz-?pyrophyllite-?diaspore-?kaolinite-?prehnite-rutile. The question marks indicate that X-ray confirmation of these species is badly needed, and is recommended, before confidence can be attached to this class (pyrophyllite and muscovite are indistinguishable in thin section, but important in separating advanced argillic from phyllic alteration; diaspore is an unusual mineral not often seen in thin section). Clay minerals tentatively identified in thin section appear to be kaolinite (as expected in argillic-advanced argillic alteration: Beane and Titley, 1981, p. 236). The chalky white weathering of some rocks in the Culleet Creek and Lake Zones appears to be due to bleaching (possibly replacement by clay) of chlorite, although the rock also becomes soft, suggesting that feldspars are also attacked by clay. Sulfate minerals (alunite, gypsum) were not seen in thin section except possibly in ARL311. Several samples (ARL309, 327) appear te straddle the transition from advanced argillic to phyllic (although this again reflects the difficulty of separating muscovite from pyrophyllite in thin section).

Potassic (ARL322, 336, 338, 339, 340, 342) are characterized by intense fine-grained ?replacement of original plagioclase by feathery K-feldspar (suspected in thin section, but the extent was not realized until confirmed by staining of the off-cut slabs with sodium cobaltinitrite. However, the K-spar is not obviously associated with any chalcopyrite mineralization, and in fact where chalcopyrite is seen it appears to be associated with quartz, and in particular mica, in veins cross-cutting the ?secondary K-feldspar. In some samples there is no clear indication that the K-spar is secondary and not simply derived from a trachyte.

Phyllic (ARL301, 303, 308, 319). These samples contain the standard quartz-sericite (muscovite)-pyrite assemblage (again, assuming the muscovite is correctly identified; X-ray confirmation is recommended). Minor K-spar on fractures and therefore probably secondary is found in 301 and 303.

Silicic (ARL310A, 337) contain quartz ± muscovite, ?prehnite, hydrobiotite (a common mineral at Island Copper) and (in 337) K-spar, although the K-spar is not clearly associated with copper mineralization. Others listed with the potassic and propylitic groups (ARL338-342) contain significant quartz (± sulfide) stockworks and so may be transitional to the silicified group.

The best copper mineralization appears (in thin sections) to be found in the apple-green material; this plus the suggestion of "mafic porphyry" potassic zone indicators such as magnetite (and hornblende/biotite: not seen in thin section but listed in the field notes), plus hydrobiotite (characteristic of the transitional phyllic-potassic zone) is similar to trends at Island Copper and suggestive of a lithocap (buried deposit) situation on the Lemare property. Although the areas with highest Cu geochemistry (Culleet Creek Zone, Lake Zone) have extensive pptassic alteration, the secondary K-feldspar does not seem to be directly related to chalcopyrite. Also, these areas appear to be peripheral to the most highly altered zone (South Gossan Zone), suggesting they could represent "leakage" around the edges of a system centered on the South Gossan Zone. Note that the advanced argillic alteration prominently exposed in the South Gossan Zone tends to overprint or destroy primary mineralization, while the phyllic alteration may contribute large amounts of sulfide that leachs copper out of the weathered rocks at surface.

Thus the South Gossan Zone could zone downwards into better-grade copper mineralization with decreasing amounts of muscovite, pyrophyllite, clay and pyrite and increasing amounts of albite ± K-spar, hydrobiotite/biotite, quartz, ?magnetite and hornblende, and chalcopyrite. This still appears to be the priority target. However, the peripheral zones, if the apparent potassic alteration proves unrelated to coppper mineralization, could also zone downwards into increasing silicic and/or biotite-magnetite-amphibole alteration with associated higher-grade chalcopyrite mineralization; they are also worthy of follow-up.

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Reference cited:

Beane, R.E., and Titley, S.R. (1981): Porphyry copper deposits, Part II. Hydrothermal alteration and mineralization; Economic Geology, 75th Anniv. Vol., pp. 235-269.

ARL301: PHYLLIC (QUARTZ-SERICITE-PYRITE-MINOR KSPAR ALTERED) FRAGMENTAL ROCK OF POSSIBLE MAFIC VOLCANIC ORIGIN

Light grey-green, intensely phyllic (quartz-sericite-pyrite) altered fragmental rock, composed of subangular to locally subrounded clasts of up to 2 mm diameter, averaging <1 cm. Strong limonite weathering on fractures, mainly goethitic/minor jarosite. Non-magnetic, no reaction to cold dilute HCl. Staining test with sodium cobaltinitrite shows minor K-feldspar along fractures. Modal mineralogy is:

Sericite (muscovite)	40%
Quartz (mainly secondary)	35%
?Clay (possibly kaolinite)	10%
Pyrite	7%
Secondary K-feldspar	5%
Rutile	3%

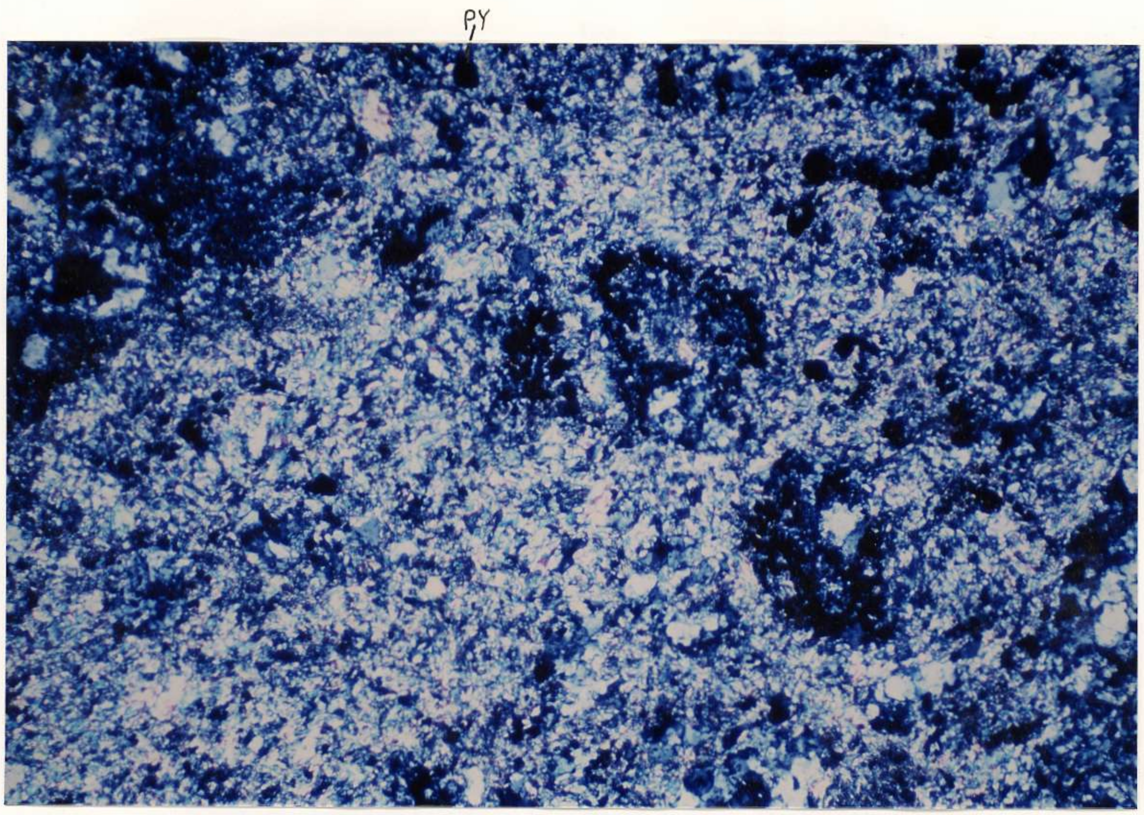
Sericite, probably mostly muscovite, forms subhedral to anhedral flakes up to 0.05 mm diameter, and is often found in rosettes up to 0.1 mm across. It is possible that some of this material could be pyrophyllite; only microchemical (SEM) or X-ray tests would properly differentiate them.

Most of the quartz found in this rock is secondary, forming anhedral grains ranging up to 0.15 mm across. Much of it is distributed in randomly oriented, anastamosing, irregular thin veinlets that are in part pre-fragmentation (cut off by clast boundaries) and partly post-fragmentation (cross clast boundaries). The quartz is moderately strained (undulose extinction) and virtually free of inclusions. Grain boundaries are sutured due to recrystallization.

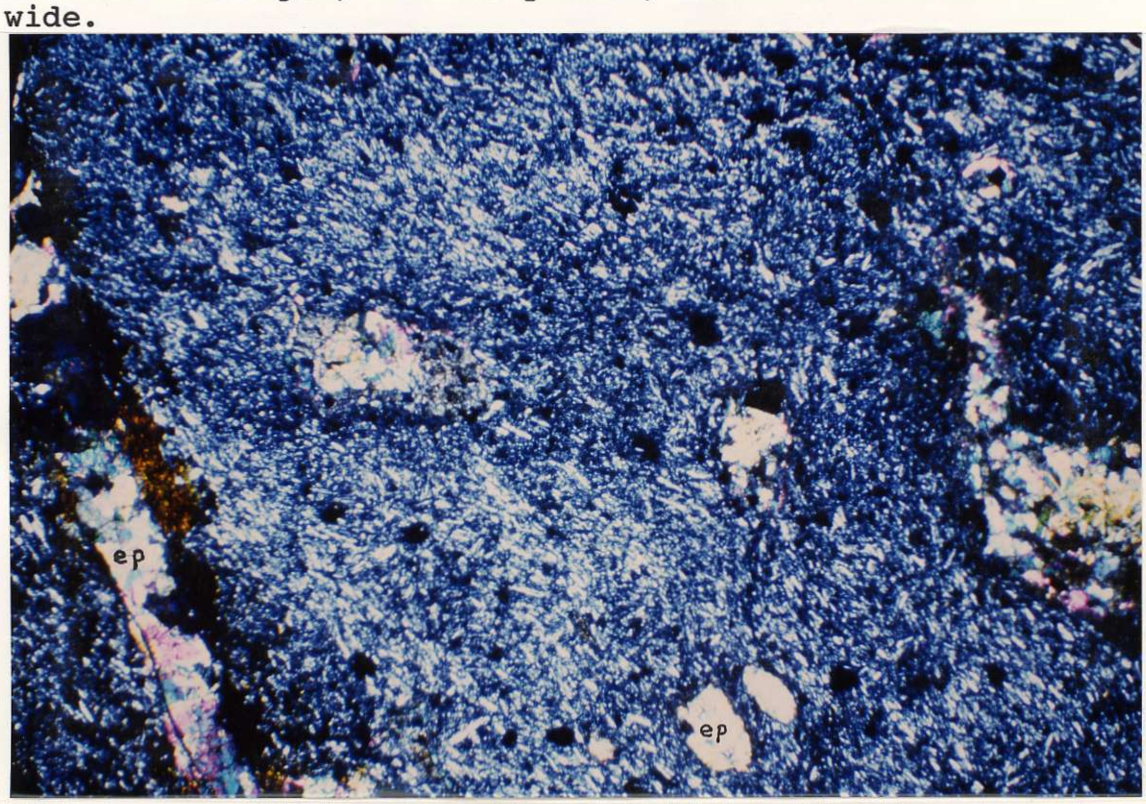
Patches of a low-birefringence, relatively low relief mineral may be clay, perhaps a member of the kaolinite group although X-ray diffraction would be needed to confirm this. The grains are anhedral to rounded, flaky, and up to 20 microns in diameter; there may be some fine-grained quartz intermixed with it. Much of this possible clay appears to be restricted to certain clasts, rather than distributed throughout the rock.

Thin veinlets to 0.05 mm thick contain subhedral grains of K-feldspar up to 0.1 mm long. Pyrite is the only sulfide mineral recognized; it forms euhedral to subhedral cubes up to 0.5 mm across distributed fairly evenly throughout the rock, but more abundant in the sericitic portions rather than the quartz areas. The only other opaque mineral is abundant rutile, forming subhedral crystals and aggregates of crystals up to 40 microns in size. This is the expected form of TiO_2 in strongly phyllic altered rock, and suggests that the protolith was a mafic volcanic (compared to the felsic look it now has).

It is difficult to be sure of the original lithology of this specimen, since the timing of fragmentation is ambiguous (possibly pre- and during alteration). It could be a fragmental volcanic or a hydrothermal breccia, or both. Alteration is strong phyllic, with a very high pyrite: chalcopyrite ratio; minor K-spar veining suggests a transition to the potassic alteration zone.



ARL301: **Phyllic-argillic alteration.** Fine-grained muscovite and quartz; dark areas are possibly clay, opaque is pyrite. Transmitted light, crossed polars, field of view 2.5 mm wide.



ARL302: **Propylitic alteration.** Epidote-chlorite altered phenocrysts in a groundmass of plagioclase microlites; cubes of pyrite, minor limonite. Transmitted light, crossed polars, field of view 5 mm wide.

ARL302: PROPYLITIC (EPIDOTE-CHLORITE-PYRITE ALTERED) PORPHYRITIC BASALT OR BASALTIC ANDESITE

Medium green, porphyritic mafic-intermediate volcanic rock characterized by blackish green mafic phenocrysts up to 1 mm long. Non-magnetic and no reaction to cold dilute HCl. Cut by reddish jaspery and limonitic fractures, plus irregular buff-coloured veins with alteration envelopes; a slight yellow stain in and near these is probably not secondary K-spar since the epidote patches also stain yellow. Mineralogy is approximately:

Plagioclase (microlites)	40%
Chlorite	25%
Epidote (phenocrysts and groundmass)	20%
Pyrite	5%
Limonite (mainly goethite)	3%
Quartz (secondary)	2%
Sphene, leucoxene	2%
Ilmenite	<1%
Hematite	<1%
Chalcopyrite	<1%

Former phenocryst sites are now occupied by coarse, euhedral epidote crystals up to 0.5 mm long with bright lemon-yellow pleochroism indicating a moderate Fe content. Minor amounts of strained quartz fill the interstices between epidote. The margins of the phenocryst sites are lined with botryoidal-textured chlorite in rosettes up to 0.1 mm diameter with dark green pleochroism again indicating a moderately high Fe content. Some sites are reversed: entirely filled by chlorite, with rims of epidote.

The groundmass is composed of trachytic-textured (flow-aligned) microlites of plagioclase, averaging about 0.1 mm long and 10 microns thick. Their composition is not determinable due to their small size. The interstices are filled by fine-grained, subhedral epidote and chlorite (individual grains about 10-30 microns in diameter).

Scattered throughout the rock are abundant subhedral 0.1-0.2 mm relicts of former Fe-Ti oxides that have now been completely replaced by sphene, leucoxene and minor ?rutile. There are traces of the former ?ilmenite remaining.

The same secondary minerals (epidote, chlorite and quartz) form random, irregular veins up to 2 mm thick crossing the rock in places. Minor cubic pyrite up to 0.3 mm diameter is associated with this veining, and part of the pyrite has been oxidized to goethite. In places there are also thin veinlets and fractures with specular and earthy hematite (bright red internal reflections) as flakes up to 0.02 mm. Rare grains of anhedral chalcopyrite to 0.02 mm across are present associated with the pyrite.

This is a fine-grained volcanic rock with extensive but low-grade (propylitic) alteration. Initially it was a mafic volcanic rock, as suggested by the former mafic (?pyroxene) phenocrysts and abundant TiO_2 minerals.

ARL303: PHYLLIC (QUARTZ-SERICITE-PYRITE+HEMATITE) ALTERED ?MAFIC VOLCANIC ROCK, POSSIBLY ORIGINALLY FINELY FRAGMENTAL

Pink and grey, strongly altered ?volcanic rock. Small (1-2 mm) rounded pink areas are set in a matrix of pyrite and sericite. The rock is not magnetic and does not respond to cold dilute HCl; moderate goethitic limonites are developed on fractures. Minor amounts of K-feldspar are suggested by weak yellow stain associated with pyrite. Modal mineralogy is:

Sericite (?muscovite)	45%
Quartz (mainly secondary)	35%
Pyrite	12%
Rutile (?)	3%
K-feldspar (?)	3%
Limonite (goethite and hematite)	2%

This rock is composed primarily of rounded, ameboid-shaped areas (the pink spots) made up of hematite-stained quartz and minor sericite, with interstitial areas made up of greyish sericite-pyrite and minor quartz. There are also some larger (up to 3 mm diameter), quartz-rich areas that look like clasts in the hand specimen. It is not clear if the pinkish areas are altered phenocrysts, amygdules, or clasts; I have a hunch that they are clasts, but this is not certain.

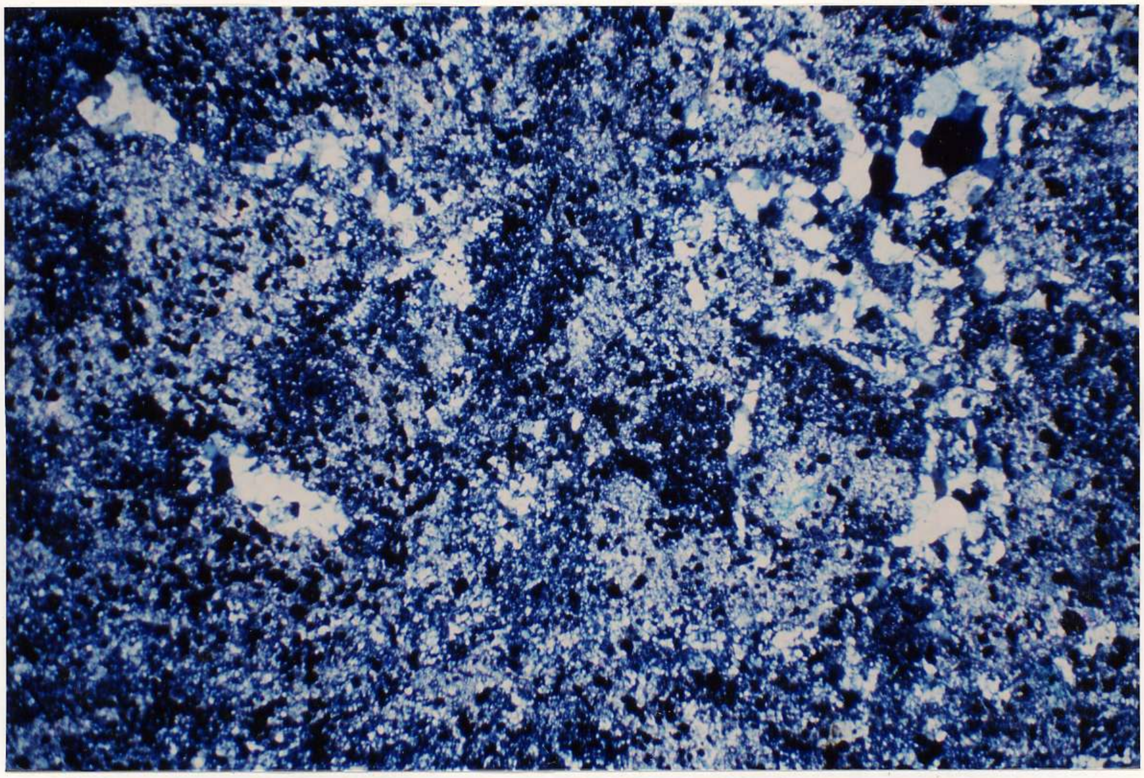
In the pink areas, fine-grained anhedral quartz averages about 25 microns in diameter, and is sprinkeled with very fine (1-5 micron) anhedral flakes of hematite and ?goethite. Patches of sericite and coarser (0.1 mm) quartz are also present.

In the interstitial areas, subhedral muscovite up to 0.1 mm in diameter and pyrite of similar size are abundant, with lesser quartz rarely up to 0.2 mm diameter. The presence of ?secondary K-spar is suggested in these areas by staining tests; rounded grains up to 0.2 mm diameter containing fine hematite and coarser pyrite could be K-spar.

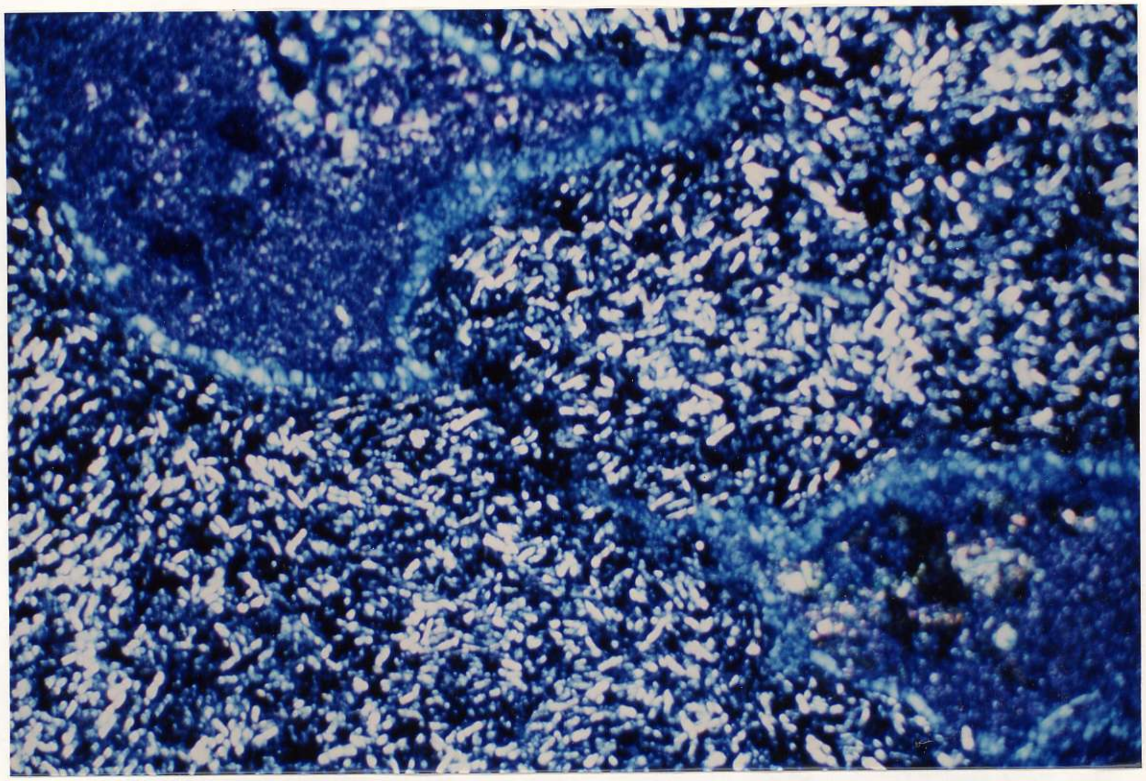
Irregular veinlets of strained quartz, with minor sericite and occasionaly associated pyrite, cross the rock.

Pyrite forms abundant subhedral cubes up to 0.25 mm diameter, found mainly with the sericite in the "matrix" between the pinkish spots. There is no sign of chalcopyrite. The pink celour of the rounded "spots" appears to be caused by extremely finely divided (1-5 micron) flakes of hematite (and goethitic limonite). Tiny (10-20 micron) anhedral to subhedral grains of ?rutile are scattered throughout the quartz-sericite matrix of the rock, apparently independent of the pyrite.

The presence of abundant TiO_2 material, as in other rocks of this suite, suggest that the protolith for this highly altered rock was a mafic (?basaltic) volcanic rock. It may have been a spherulitic-textured type, or it could have been finely fragmental; brecciation on a fine scale has partly destroyed the primary texture. Alteration is intense phyllic (quartz-sericite-pyrite) with traces of potassic.



ARL303: **Intense phyllic alteration.** Fine muscovite, coarser quartz, cubic pyrite. Transmitted light, crossed polars, field of view 5 mm wide.



ARL304: **Propylitic alteration.** Chlorite-epidote amygdules in trachytic-textured groundmass of plagioclase microlites and chlorite. Transmitted light, crossed polars, field of view 5 mm wide.

ARL304: PROPYLITIC (CHLORITE-EPIDOTE) ALTERED PORPHYRITIC BASALT OR BASALTIC ANDESITE

Dark green, very fine-grained mafic volcanic rock characterized by 2-3 mm white quartz ?amygdules. The rock is cut by thin bleached fractures with extremely fine pyrite along them; limonites on fractures arc goethite and only weakly developed. There is no reaction to HCl and the rock is not magnetic. Mineralogy is approximately:

Plagioclase (oligoclase-andesine)	40%
Chlorite (groundmass and amygdules)	35%
Quartz (amygdules)	10%
Fe-Ti oxides (hematite, minor ilmenite)	10%
Epidote (amygdules)	3%
Pyrite	2%

Plagioclase forms euhedral phenocrysts up to 0.8 mm long (<5% of the rock) as well as microlites averaging about 0.1 mm long, both displaying minor alteration to fine flakes of chlorite. A centered figure on a phenocryst gives Y^010=16°, Z^001=14°, suggesting oligoclase-andesine about An_{30}. The composition is difficult to determine on the small, poorly oriented, altered microlites; maximum extinction angles of 13° suggest similar compositions to the phenocrysts.

There are no mafic phenocrysts visible, but some of the chlorite masses called amygdules could be actually highly altered mafic sites. The interstices between microlites are filled by chlorite, as fine 5-10 micron flakes, and opaque Fe-Ti oxides up to 0.1 mm across. These oxides are mainly hematite as subhedral flakes up to 10 microns long, with minor ilmenite intermixed (5-10 microns) in the 0.1 mm aggregates. Near amygdules, the hematite forms flakes up to 50 microns in diameter.

Amygdules are filled primarily by quartz and chlorite, in all combinations of chlorite rims-quartz cores and vice versa. The quartz is anhedral and up to 0.75 mm diameter, with strain shown by undulose extinction. Chlorite is of two varieties, one with purple anomalous birefringence (?Fe-rich, amygdule cores) and the other without (Fe-poor, amygdule rims). Epidote, as in ARL302, forms euhedral crystals up to 0.5 mm long with brilliant pleochroism indicating high Fe contents.

Pyrite forms fine euhedral cubic crystals up to 0.05 mm across, occasionally replacing the Fe-Ti oxides; chalcopyrrite was not seen. Pyrite concentrations are strongest along chloritic fractures. There are also chlorite-quartz veins up to 1 mm thick, but with little or no pyrite associated. Alteration in this rock is moderately developed propylitic (chlorite-epidote) with a low total sulfide content and very high pyrite:chalcopyrite ratio. The original rock was likely a finely porphyritic basalt or basaltic andesite.

ARL305: ARGILLIC OR ?ADVANCED ARGILLIC (QUARTZ-?CLAY-RUTILE ALTERED) ?SPHERULITIC VOLCANIC ROCK

Light pinkish-grey, spherulitic-looking ?volcanic rock, characterized by pink-brown spherules or tubules about 1 mm in diameter and up to 4 mm long in a buff to creamy matrix. Similar to 305 in the pink areas, although the overall texture is different. No reaotion to dilute HCl and non-magnetic; no sulfides or limonite after sulfides. Mineralogy in polished thin section is:

Quartz (secondary)	60%
?Clay (?kaolinite group)	30%
Rutile, leucoxene	10%
Hematite	<1%

This is a strongly altered rock; it is not clear if the present texture preserves the original structure or if it is entirely due to the alteration. In brief, the pink rounded areas are made up of quartz, with the colour due to finely divided hematite; the buff matrix between them is mainly clay and rutile.

Quartz forms anhedral grains up to 0.25 mm diameter that are strained (undulose extinction) and recrystallized, showing sutured boundaries. Extremely fine inclusions within these grains (both fluid and ?hematite) are of the order of 1-2 μm diameter.

In the matrix to the quartz areas, a phyllosilicate mineral forms subhedral flakes up to about 40 μm in diameter. The optical properties (relief less than quartz, apparently low birefringence) do not fit illite, and are intermediate between kaolinite and montmorillonite group species. Although the relief is low, some member of the kaolinite group would be my guess from the optics, but X-ray diffraction is really the only way to find out. The birefringence is too low, even given the small size of the crystals, for pyrophyllite or diaspore; relief is too low for alunite. Minor fine-grained quartz (up to about 40 μm in diameter) is also found in the matrix. Opaque oxides are also common, generally 5-20 μm in size; much of this material may be best described as leucoxene or "proto-rutile"; the better crystallized material is rutile (see below).

There are no sulfides in this specimen; opaque minerals are entirely oxides, mainly rutile as euhedral to subhedral grains up to 0.2 mm long with light yellow-brown internal reflections.

Alteration of this specimen is apparently argillic (abundant clay) or advanced argillic (if, as it appears, the quartz is secondary). I recommend X-ray analysis of this specimen if you need to be positive about the type of alteration.

<u>ARL308: ?PHYLLIC (QUARTZ-SERICITE-?PREHNITE) ALTERED, BRECCIATED ?VOLCANIC ROCK WITH ABUNDANT GOETHTITE</u>

Rusty-weathering, pale grey, fine-grained, highly altered ?volcanic rock that appears to have been brecciated and cemented by sulfides, now oxidized to limonite. Secondary quartz and a micaceous mineral are evident in the hand specimen. In polished thin section, the minerals are tentatively identified as:

Sericite, muscovite	40%
Quartz (secondary)	35%
?Prehnite	15%
Limonite (goethitic)	5%
Rutile/leucoxene	3%
Pyrite	1%

The bulk of this rock is made up of a fine-grained mix of quartz and ?sericite, averaging around 25 microns in diameter. These minerals are tightly intergrown, although there is some separation into areas richer in quartz and others richer in phyllosilicate. Minor semi-opaque oxide, mainly leucoxene and ?rutile, forms 5-25 micron sized grains in the bulk of the rock.

Coarser-grained patches within the rock consist of a clear, well-crystallized mineral of questionable identity, commonly altered at margins or completely pseudomorphed to a coarse (0.1 mm) micaceous mineral in sub- to euhedral flakes and rosettes. It should be kept in mind that the micaceous mineral(s) in this rock identified as muscovite, could be pyrophyllite; optical means are not enough to distinguish them. Note that pyrophyllite has been positively identified in these rocks by Andre Panteleyev of the BCGS (pers. comm., 1991).

The clear, crystalline mineral forms sub-to euhedral crystals with the following optical properties: high birefringence about 0.025-0.030, depending on the actual section thickness; relief somewhat above quartz and epoxy (hard to judge due to heavily fractured boundaries); parallel extinction in most crystals; length-fast; biaxial with a large (?+) optic angle; occasional well-developed cleavage parallel to the length. These properties fit the mineral prehnite, but I do not feel confident of this identification. The mineral also resembles epidote; it is not flaky enough for pyrophyllite or alunite; relief is too low for diaspore. X-ray diffraction should be considered.

Limonite is abundant in this rock, often along clast boundaries; it probably represents the oxidation of former sulfides. Traces of pyrite are preserved as minute subhedral grains up to 0.05 mm diameter within the body of the rock.

Given the uncertainty of mineral identification in this rock, the alteration is difficult to typify with certainty; at a guess, it is a hydrothermally brecciated former fine-grained volcanic rock displaying phyllic alteration to quartz-sericite-prehnite-pyrite.

<u>ARL309: INTENSELY ?PHYLLIC OR ADVANCED ARGILLIC (QUARTZ-SERICITE OR PYROPHYLLITE) ALTERED ROCK VEINED BY PYRITE</u>

Fresh (unweathered) sample consisting mainly of massive pyrite as veins up to several cm thick cutting pale grey-buff intensely altered fine-grained rock. A trace of ?secondary K-feldspar may be present in the wallrock as suggested by a faint yellow stain along a fracture. In polished thin section, the mineralogy is as follows:

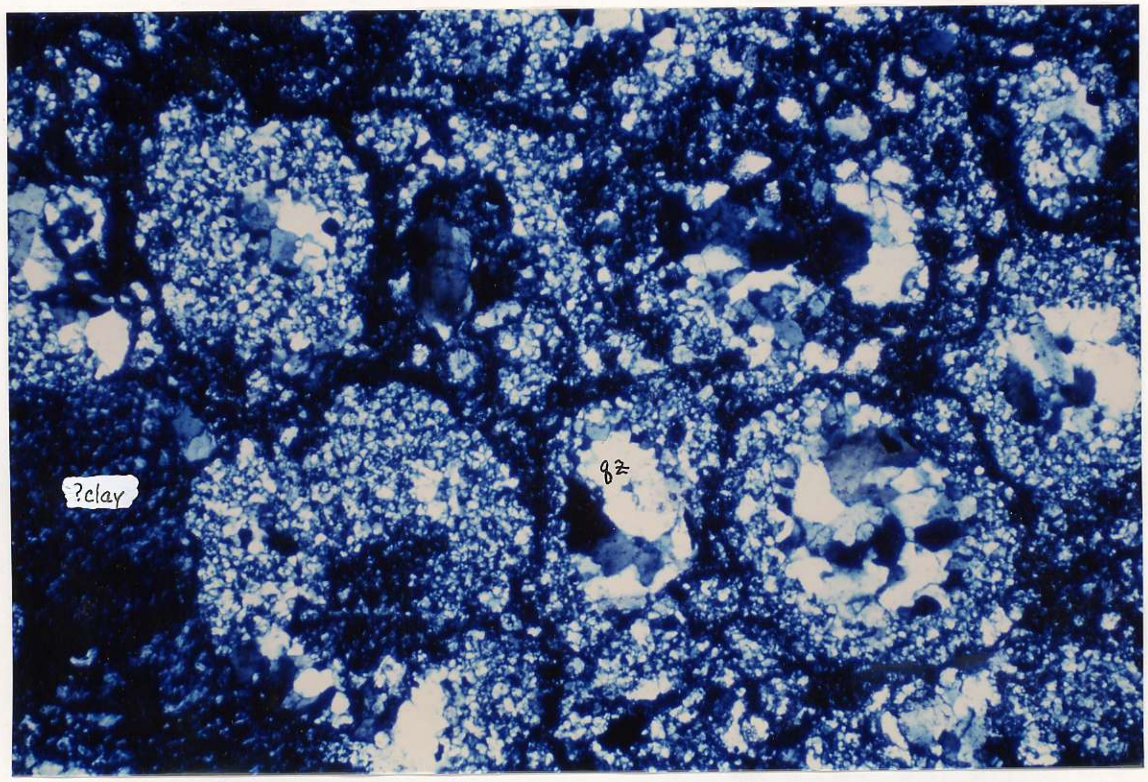
Pyrite	60%
Quartz (secondary, mainly veins)	25%
"Sericite": muscovite or ?pyrophyllite	15%
Rutile (?)	<1%
?K-feldspar (secondary)	tr
?Jarosite (primary)	tr

Pyrite forms very large, subhedral grains (up to 0.5 cm) that have been strongly fractured or brecciated. In many places they are veined by secondary silica along the fractures. No other sulfide minerals were identified.

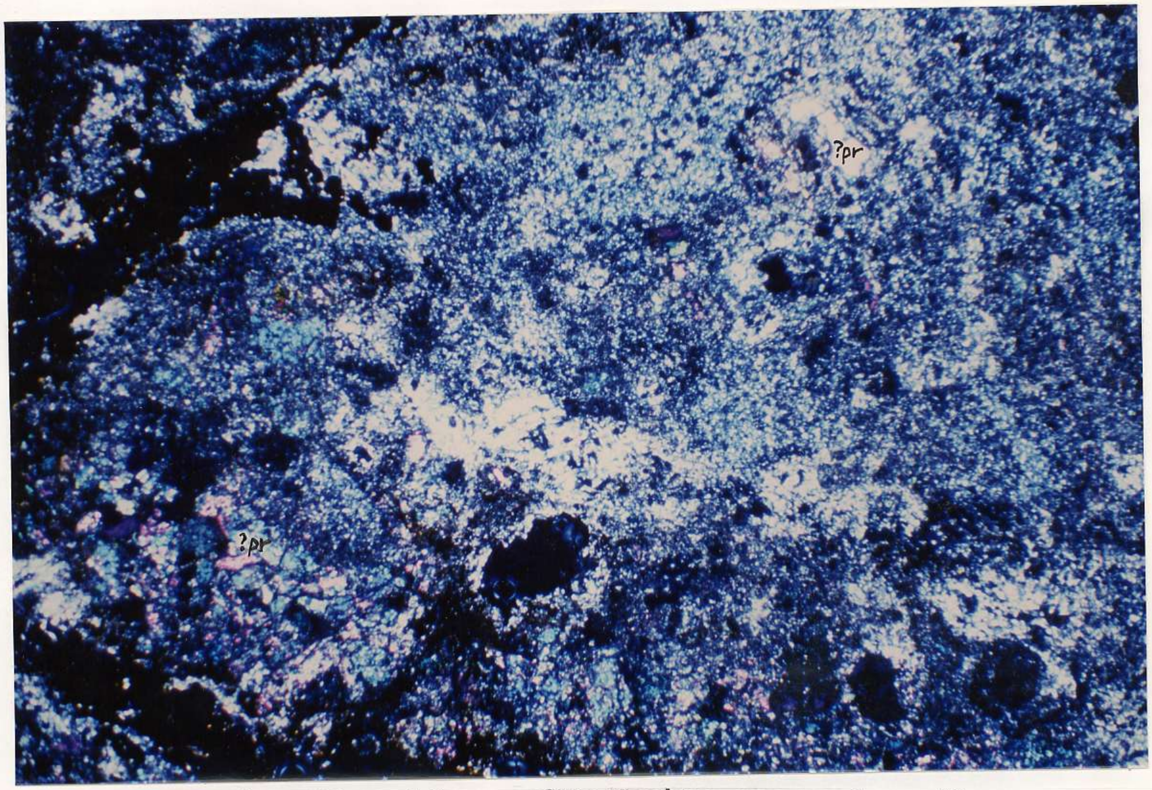
The host rock consists of remnants of a very highly altered, fine-grained mixture of quartz and micaceous mineral that could be either muscovite or pyrophyllite: X-ray diffraction would be required to be sure. There are traces of minute opaque oxides, probably rutile, as sub- to euhedral crystals up to 10 microns long. The quartz is anhedral and averages around 10-20 miorons diameter; the micaceous mineral is slightly coarser and subhedral, up to 30 microns diameter. Irregular patches and thin veinlets of secondary quartz are common traversing the wall rock as in the pyritic portion of the rock. In these, the quartz may be subhedral and up to 0.4 mm across. No K-spar could be recognized in the thin section.

The mineral tentatively identified as jarosite forms fine (0.05 mm) euhedral flaky crystals with strong relief against quartz, high birefringence and a pale yellow colour.

Depending on the actual identity of the micaceous mineral, the alteration in this rock could be either phyllic (if it is musoovite) or edvanced argillic (if it is pyrophyllite). The original rock type is impossible to identify due to the intense alteration.



ARL305: **Argillic alteration.** Quartz-?clay spherulites; ?clay vein. Transmitted light, crossed polars, field of view 2.5 mm wide.



ARL308: **Phyllic alteration.** ?Prehnite remnants, fine grained matrix minerals (quartz, sericite). Transmitted light, crossed polars, field of view 5 mm wide.

<u>ARL310A: WHITE (INTENSELY SILICIFIED) POSSIBLY VOLCANIC ROCK</u>

White and light buff-brownish, completely altered, fine-grained rock consisting of creamy white patches (?corroded fragments) up to 1 cm across in a buff-coloured "matrix". There are no sulfides visible; the rock is very hard throughout both "fragments" and "matrix". Mineralogy in thin section appears to be dominated by secondary silica; very little else can be recognized with certainty:

Quartz (secondary)	70%
?Mica (muscovite)	15%
?Prehnite	10%
Rutile/leucoxene	3%
?Fe-oxides (hematite)	1%

It is difficult to be sure of the mineralogy of this specimen; it appears in section and from its hardness to be mainly quartz, with the faint colour differences observable in hand sample and section due to minor quantites of oxides (Fe and Fe-Ti) and micaceous minerals. At one end of the section and in veinlets up to 3 mm crossing it, a dense white material is unidentifiable (semi-opaque in transmitted light). I have seen similar material in samples from the Juan de Fuca Ridge turn out to be quartz; that would be my best guess here also. This material contains small clear areas composed of anhedral grains of 10-25 micron quartz.

The bulk of the section consists of a very fine-grained (rarely over 25 microns) mixture of mainly quartz and minor ?mica - it is difficult to be sura that there is even any mica present with certainty. However, faint original textures are preserved in this part of the rock, that look like relict outlines of ?former phenocrysts about 0.5 mm long. They could however be spherulites; they are very close together, even touching, in places, similar to the textures seen in ARL303 and 305.

In a few places, there are patches that look like remnants of ?phenocrysts, replaced by a clear mineral with distinctly higher birefringence than the quartz adjacent - typical of prehnite in rocks from this part of the world. Grains are anhedral and up to 0.05 mm diameter; identification is tentative. In another area, minor quantities of a much more birefringent mineral form thin (20 micron) rims on former ?spherulites or phenocrysts. It looks like carbonate but shows no change of relief on rotation; it could be ?pyrophyllite.

Semi-opaque oxides, probably mainly rutile and /or leucoxene, are scattered throughout the rock as minute sub- to euhedral prisms up to 15 microns long, aggregated in places to 0.3 mm diameter patches. The pale buff-brown colour imparted to the rock in places is possibly due to extremely finely divided (sub-micron size) particles of Fe-oxides such ae ?hematite. White areas in hand specimen are clearer in section, and presumably quartz-rich.

The alteration in this specimen appears to be primarily silicification. It might be useful to check this interpretation with an XRD scan fer any peaks for mica.

ARL310B: ?ADVANCED ARGILLIC (?PYROPHYLLITE-QUARTZ-RUTILE ALTERED) ?FORMER MAFIC VOLCANIC ROCK

Creamy white, dense-looking, almost featureless rock that is very fine-grained and probably completely altered. There is no sulfide present; in contrast to 310A, this sample can be scratched by steel in places, indicating less secondary silica and more micaceous mineral. A faint yellow "wash" after staining may be due to potassium in ?mica. In thin section the mineralogy is approximately:

Micaceous mineral (?pyrophyllite or mica)	70%
Quartz (secondary)	25%
Rutile, leucoxene	2%
Limonite (goethite after ?pyrite)	1%

The bulk of this rock, in contrast to 310A, is made up of very finely crystalline micaceous mineral with a birefringence higher than that normal for muscovite; I tentatively would identify it as pyrophyllite. It forms subhedral flakes and rosettes averaging about 10-15 μm diameter, rarely up to 0.1 mm (100 μm) in diameter in irregular "veins" or patches. In places, there are patches of almost pure ?pyrophyllite up to 1 mm long - remnants of former phenocrysts? It must be borne in mind that X-ray confirmation of this identification is needed to impart confidence to it.

Quartz is subordinate in this specimen, forming very fine (10-20 μm) anhedral grains (so intimately intermixed with the micaceous minerak as to be almost unrecognizable). Rare very thin (30 μm) veinlets of quartz are seen.

Rutile forms subhedral grains or patches up to 0.2 mm across, probably composed of aggegates of finer grains and possibly with some leucoxene admixed. Similar material, with some very pale brown ?goethite, is found along rare fractures in the rock.

I would tentatively classify this as a highly altered rock of the advanced argillic (quartz-pyrophyllite) class, probably derived from a mafic volcanic rock (TiO_2 relics suggest this). The alteration is thorough and intense.

<u>ARL311: INTENSELY ALTERED (?ADVANCED ARGILLIC) FRAGMENTAL VOLCANIC ROCK OF UNCERTAIN MINERALOGY (NEEDS XRD)</u>

Creamy-buff, fine-grained, highly altered ?volcanic rock characterized by very pale orangey-brown network or matrix. The original texture appears to be preserved: white 1-2 mm ?phenocrysts amid clasts up to several cm across suggest a fragmental volcanic, such as typically seen in the Bonanza elsewhere. The rock can be scratched by steel quite readily. The mineralogy appears to be similar to that of 310 (A and B), but cannot be identified with certainty:

Mineral A (?pyrophyllite)	60%
Mineral B (?diaspore)	10%
Mineral C (?chalcedony or ?kaolinite)	10%
Mineral D (?prehnite or alunite)	10%
Mineral E (?kaolinite)	7%
TiO_2 oxides (?rutile, sphene)	3%

Mineral A is typically very fine-grained (about 10-15 μm) and brownish in thin section, with neutral to mildly positive relief and moderate birefringence (allowing for the fine grain size) of perhaps 0.020-0.030. It is compact and only vaguely flaky; since it forms the bulk of the rock, it must be soft; it might be pyrophyllite.

Mineral B is clear, with high relief and very high birefringence (possibly up to 0.04-0.05), as euhedral crystals or remnants (attacked by minerals A and E), has parallel extinction, length-fast, possibly the same mineral identified as prehnite in 310A. It could be diaspore.

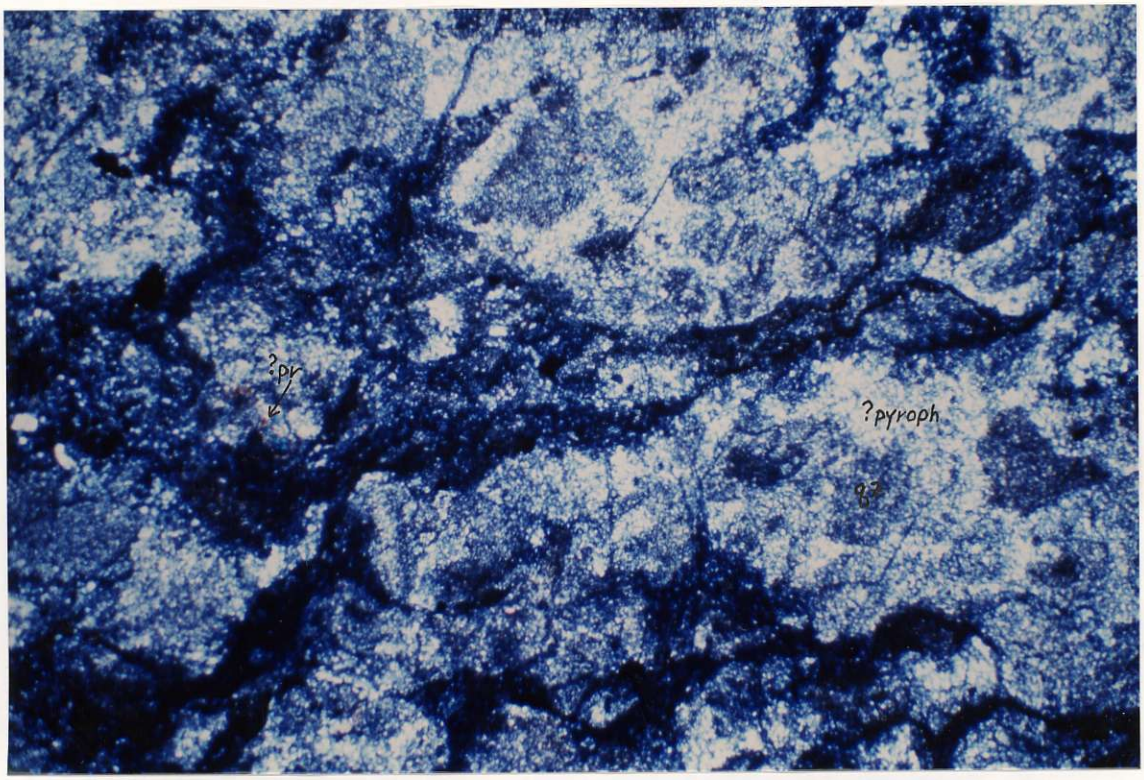
Mineral C (grain size to 0.1 mm), has low birefringence and moderate relief; it looks like quartz except for a very well developed fibrous habit suggesting it may be chalcedony; however, it could be a clay such as kaolinite.

Mineral D has moderate birefringence (0.020) and relief, forming anhedral patchy or flaky grains up to 0.1 mm diameter. It is distinctly brown in thin section; it has the appearance of prehnite, but could be alunite.

Mineral E has low relief and very low birefringence, forming aggregates of fine matted grains of 10-15 μm size, suggesting a clay mineral such as kaolinite.

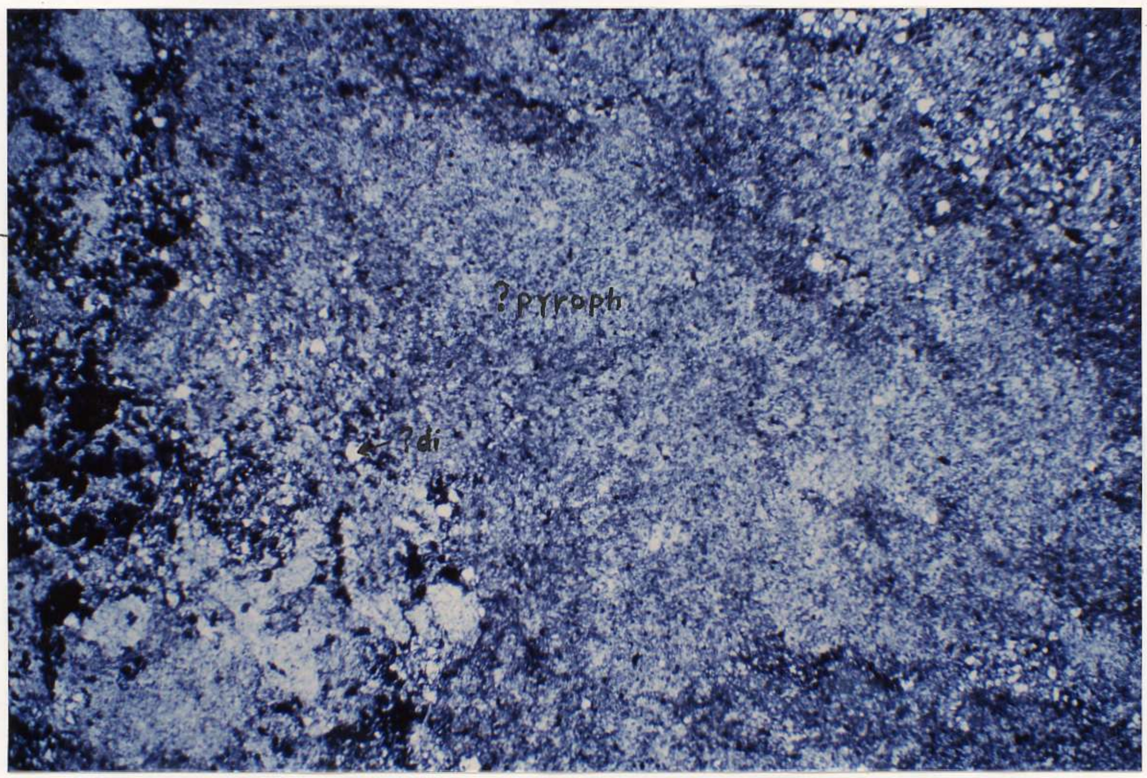
The textures in thin section confirm that this was originally a fragmental volcanic rock, composed of sub-angular clasts up to at least 3 cm diameter that vary from relatively fine-grained and featureless to highly porphyritic. Phenocrysts with clear euhedral outlines were of possibly three types, to judge by their present (alteration) mineralogy: abundant 1 mm ?plagioclase, now replaced by mineral A; less common 1-2 mm ?former mafics, now replaced by mineral B; and scattered 1 mm relics now replaced by mineral D. In addition, there are irregularly-shaped areas up to about 0.5 mm across composed of mineral C and mineral E. There are scattered TiO_2 relicts (subhedral, up to 0.5 mm) that are mainly rutile and some ?sphene.

This specimen cannot be regarded as understood until X-ray diffraction sorts out the mineralogy; it could be an example of intense advanced argillic alteration.



ARL311: **?Advanced argillic alteration.** ?Pyrophyllite, quartz, ?prehnite. Transmitted light, crossed polars, field of view 5 mm wide.

Ti-ox



ARL313: **?Advanced argillic alteration.** Patch of ?pyrophyllite, Ti oxides; clear areas are ?epoxy or ?diaspore. Transmitted light, uncrossed polars, field of view 5 mm wide.

<u>ARL312: ?ADVANCED ARGILLIC (QUARTZ-?CLAY-?PYROPHYLLITE ALTERED) ?SPHERULITIC VOLCANIC ROCK</u>

This specimen is very similar to ARL303, composed of small (1-2 mm) rounded pink ?spherules that are harder than steel and clear to grey spherules that are very soft, in a buff matrix that is also soft. These observations are difficult to reconcile with the thin section, where there are basically three major minerals:

Quartz (secondary)	50%
Mineral A (?clay - kaolinite)	30%
Mineral B (?pyrophyllite)	15%
Rutile, leucoxene	2%
Pyrite	<1%

The pinkish areas in hand specimen appear pale brownish and mainly quartz in thin section, and the only way to account for their softness is by considerable amounts of Mineral A (?clay) mixed with the quartz. The soft, clear areas are probably mineral B (Pyrophyllite?) with some mineral A (?clay). Areas of coarse quartz (uniaxial, positive) up to 2 mm in diameter are clearly evident in section but not obvious in scratching tests.

The coarse quartz (anhedral interlocking grains up to 0.5 mm diameter) forms patches that are highly irregular in shape and distribution, suggesting ?amygdules rather than former phenocrysts. The fine quartz, which forms a matrix to them, averages about 15-20 μm in diameter, and is finely locked and anhedral.

Areas of mineral A are also irregular and tend to be interstitial to the quartz areas; these may represent the soft, buff "matrix" seen in hand specimen. Mineral A has relief lower than quartz, a fibrous habit as flakes up to 20 μm diameter, and very low birefringence. It may be a clay mineral such as kaolinite.

Mineral B has very high birefringence and shows moderate change of relief on rotation, like muscovite or pyrophyllite. The euhedral flakes, up to 0.25 mm long, have the peculiar elongate habit of pyrophyllite, but XRD would be needed to confirm this identification.

Opaque minerals in this section include the same euhedral to subhedral TiO_2 relicts, up to 0.5 mm diameter, as seen in 311, and traces of pyrite as minute subhedral grains up to 0.05 mm across. The titanium mineral is mainly ?rutile, probably mixed with leucoxene, and implies a mafic volcanic protolith for this highly altered rock. Alteration, depending on the accuracy of identifications above, may well be advanced argillic (quartz-clay-pyrophyllite).

<u>ARL313: ?ADVANCED ARGILLIC (?PYROPHYLLITE-?CLAY-?DIASPORE ALTERED) ?VOLCANIC ROCK</u>

Buff-cream, very fine-grained, homogeneous, relatively featureless rock that appears to have been intensely altered. Its original character is not evident; it is uniformly soft, with some elongated, wispy light cream-coloured areas in a buff background. As in the last four pale-coloured rocks (ARL310-312), the mineralogy in section is not certain:

Mineral A (?pyrophyllite, ± ?muscovite)	70%
Mineral B (unidentified)	20%
Mineral C (?diaspore)	7%
Mineral D (?leucoxene)	2%

Mineral A, forming the majority of the slide as very fine (generally 10-20, rarely 40 μm) flakes, has high birefringence and moderate relief. It is similar to the mineral identified as pyrophyllite in 312, but could easily be muscovite. Some areas that are clearer, have a slightly different more flaky look; these might be muscovite.

Mineral B occurs as small, euhedral, very clear crystals about 20 to rarely 60 μm across. Outlines are rectangular or <u>triangular</u> to hexagonal; birefringence is very low to almost nil in the basal sections, possibly length-fast although extinction is extremely irregular. The relief appears to be positive with respect to the micaceous mineral surrounding; otherwise I would identify it as a clay such as kaolinite. I have never seen a clay as well crystallized as this, however. The birefringence is probably too low for alunite, even given the negligible thickness of the crystallites.

Mineral C occurs as sparse disseminations that in places have the appearance of being remnants of a former larger crystal. The grains are mainly less than 30 μm in length, with high relief and birefringence, parallel (length-fast) extinction; they look to be similar to mineral B in 311, identified there as ?diaspore. In 313, the grains are often brownish, indicating they are more altered than in 311. This mineral is concentrated in wispy zones that are probably the white areas in the hand specimen.

Fine (20 μm) sub- to euhedral grains of semi-opaque material are liberally sprinkled througheut the rock, more abundantly in the areas between major patches of ?pyrophyllite. They all appear to be fine crystals of rutile, better crystallized than in the other samples but with the same import: a mafic volcanic protolith. No sulfides were observed.

In summary, this appears to be a highly phyllic (if the micaceous mineral is muscovite) or advanced argillic (if it is pyrophyllite) altered rock. Note the apparent lack of quartz, attested to by the softness of the specimen. ?Diaspore and ?kaolinite, if present, would be expected in an advanced argillic alteration zone.

<u>ARL315: PROPYLITIC (CHLORITE-QUARTZ-HEMATITE-MAGNETITE) ALTERED ?DACITIC FRAGMENTAL VOLCANIC ROCK WITH CHALCOPYRITE</u>

Dark green, clearly fragmental volcanic rock containing deep red subangular fragments up to 1.5 cm long. Sulfide is much more abundant in this rock than in the argillic-phyllic altered samples, and iecludes obvious chalcopyrite as well as pyrite. The rock is hard and siliceous, and attracts a magnet. In thin section, the mineralogy is approximately:

Chlorite	50%
Quartz (largely secondary)	20%
Plagioclase (microlites)	10%
Opaque oxides (hematite, magnetite)	10%
Alkali feldspar (?sanidine)	5%
Pyrite	3%
Chalcopyrite	1%

There is a very wide variety of volcanic textures displayed in this fragmental rock; I will not attempt to describe them all. Amygdules, phenocrysts, and relicts of fragments within fragments are all common. The matrix, largely chlorite, as very fine flakes of a few microns, contains:

1) euhedral phenocrysts of feldspar up to 0.3 mm long with a very small, negative 2V (probably sanidine);

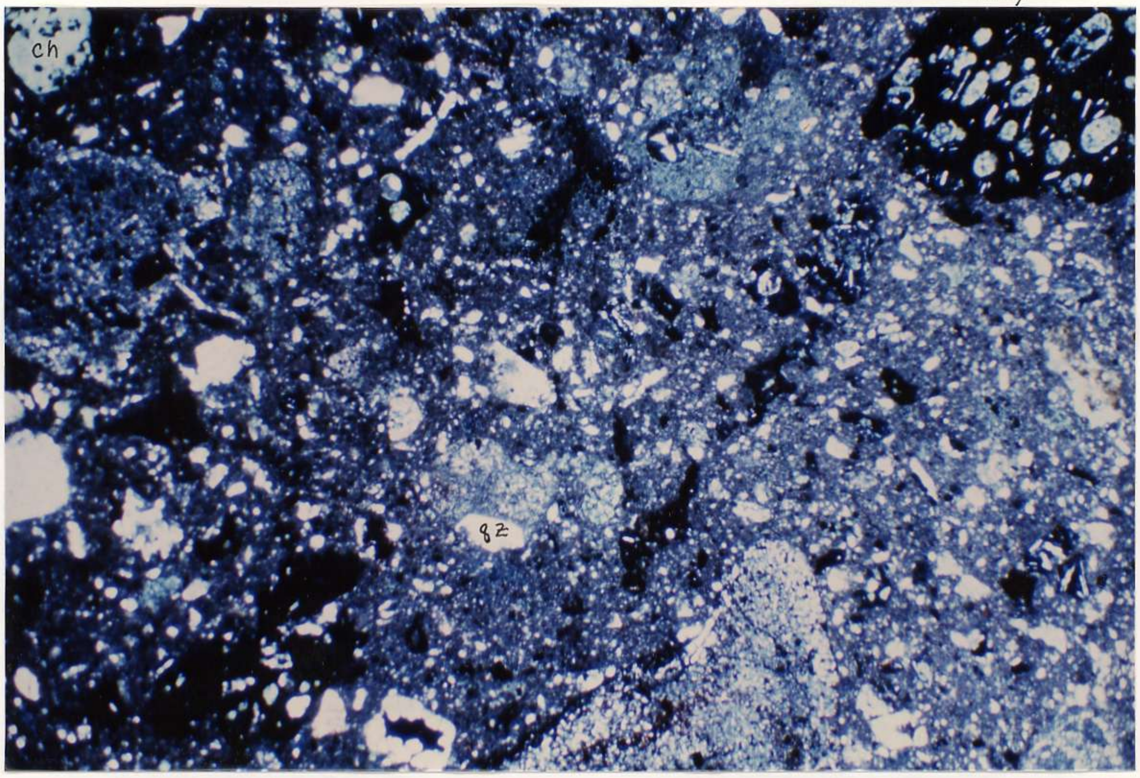
2) euhedral reliet mafic phenocrysts up to 0.5 mm long, now completely replaced by an Fe-Mg chlorite with bright yellow-green pleochroism and minor opaque Fe-Ti oxides;

3) rock fragments (ranging from chlorite amygdular to porphyritic with plagioclase microlites to mainly K-feldspar and chlorite to equigranular, high-level intrusives mainly altered by quartz, chlorite and Fe-Ti oxides;

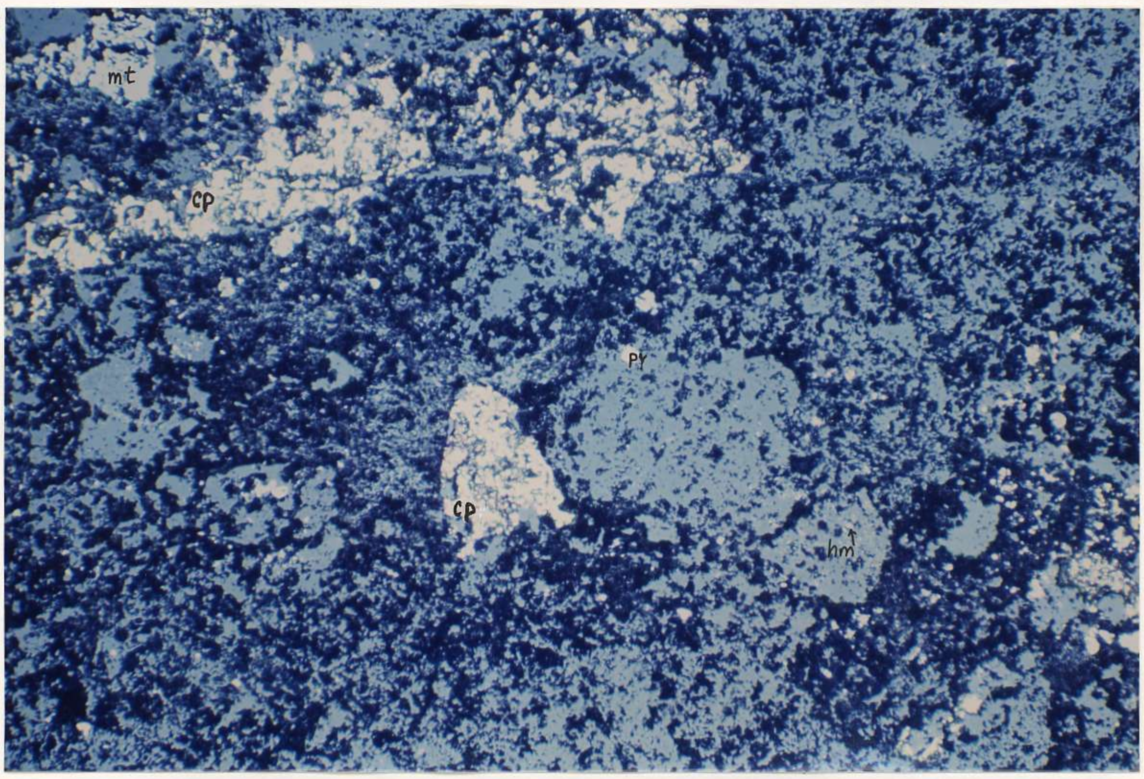
4) Oxide microphenocrysts and heavily replaced fragments up to 1.5 mm long (with chlorite and minor quartz)

5) Sulfides, mainly pyrite disseminated througout and chalcopyrite distributed along fracturesor microveinlets.

Quartz forms mostly anhedral grains up to 0.1 mm diameter, in aggregates up to 1 mm across, or rare euehdral phenocrysts of up to 0.2 mm diameter. The composition of the plagioclase is indeterminable in the small crystals. Overall, the composition of this volcanic is considerably more felsic than others in the suite, as indicated by the relative lack of plagioclase, abundance of quartz, and presence of quartz and ?sanidine phenocrysts. It could be dacitic in composition. Alteration is moderate propylitio (chlorite-quartz-hematite-sulfides; K-spar is not secondary) but contains significant copper. In reflected light, there is abundant sub- to euhedral pyrite as grains up to 0.5 mm diameter, in places associated with/fringed by chalcopyrite as sub- to anhedral grains up to 0.1 mm across. Plates of specular hematite up to 0.1 mm across, with minor exsolved ilmenite ribbons, as well as abundant "earthy" or finely disseminated specular hematite, and lesser subhedral magnetite grains up to 0.05 mm diameter are common; note that the magnetite-chalcopyrite association is typical of Island Copper. Titanium minerals are not obvious, another indication that the rock is not mafic.



ARL315: **Propylitic alteration.** Rock fragments of chlorite-hematite or quartz. Transmitted light, uncrossed polars, field of view 5 mm wide.



ARL315: Opaque minerals in propylitic alteration. Chalcopyrite (yellow), magnetite (vein), pyrite (white), fine hematite. Reflected light, uncrossed polars, field of view 1.3 mm wide.

ARL319: PHYLLIC (QUARTZ-SERICITE-PYRITE) ALTERED ?MAFIC VOLCANIC ROCK CUT BY RARE QUARTZ STRINGERS

Light grey-green, fine-grained, pyritic, probably phyllic (quartz-sericite) altered volcanic rock. There is minor thin quartz veining and orangish limonite on fractures; a faint yellow stain from cobaltinitrite is probably due to potassium in muscovite. The rock is relatively soft (scratched by steel) but does not react to cold dilute HCl, and is not magnetic. Modal mineralogy in thin section is approximately:

Sericite (?muscovite)	50%
Quartz (secondary)	40%
Pyrite	5%
Sphene	2%
Rutile, leucoxene	2%
Limonite	<1%

This rock consists of about 20% rounded quartz-pyrite ?amygdules to 0.7 mm diameter and 15% relict ?plagioclase phenocrysts to 2 mm long, plus 0.2 mm TiO_2 relict ?microphenocrysts in a fine quartz-sericite groundmass. The ?amygdules are made up of anhedral, unstrained quartz grains less than 0.1 mm in diameter and lesser pyrite.

Former euhedral to subhedral ?plagiclase phenocrysts are now represented by extremely fine sericite (?muscovite) flakes about 5-10 μm in diameter, plus lesser pyrite. In places, the cores of former glomerocrysts are replaced by quartz similar to that in the ?amygdules. No K-feldspar is visible in the thin section.

The groundmass consists cf fine-grained (about 25 μm) intergrown quartz, sericite, Fe-Ti oxides and minor pyrite.

Former Ti-oxide sites are marked in this highly altered rock by subhedral grains of sphene up to 0.15 mm across and anhedral to subhedral patches to 0.1 mm that appear to be rutile possibly mixed with leucoxene.

Pyrite forms subhedral, rounded grains less than 0.25 mm diameter; they are strongly concentrated in quartz-rich patches but not along veins. The veins are up to 0.5 mm thick and composed essentially of anhedral quartz grains up to to 0.2 mm diameter.

This is an intensely phyllic (quartz-sericite-pyrite) altered rock that clearly was a porphyritic, possibly amygdular volcanic of probably mafic composition.

ARL322: POTASSIC (CHLORITE-KSPAR-HEMATITE) ALTERED FRAGMENTAL ?MAFIC VOLCANIC ROCK CUT BY QUARTZ STOCKWORK

Greenish-grey, very fine-grained volcanic rock cut by extensive network of siliceous veinlets, grading in places to a red-purple hematitic breccia matrix. The rock weathers to a chalky white colour on the outside rim where it is much softer than the interior of the rock; this is probably clay weathering. The rock stains bright yellow for K-feldspar, but is not magnetic and does not react to cold dilute HCl. Modal mineralogy is approximately:

K-Feldspar (?secondary)	40%
Chlorite	30%
Vein quartz	20%
Fe-Ti oxides (hematite, leucoxene)	5%
Sericite (?muscovite)	3%
Sphene	2%
Pyrite	tr

The fragmental character of this rock is clear in thin section, where a wide variety of angular clasts (as in ARL315) up to 1 cm diameter are evident. The texture is partly obscured by the extensive stockworking/brecciation by quartz. The quartz veins are up to several mm thick, and are composed of anhedral, mildly strained and fractured quartz up to 1 mm long. Smaller veinlets and microfractures are made up of correspondingly finer quartz down to about 25 μm size, often oriented perpendicular to the vein walls. In places flakes of chlorite, or limonite-stained chlorite, are found in the larger veins. Most clasts are made up of principally of K-feldspar and chlorite with minor Fe-Ti oxides. The K-spar forms feathery interlocking an- to subhedral grains mainly replacing microlites (some is along fractures), suggesting it is secondary. Compared to adjacent quartz it appears to have slightly lower relief.

Interstitial to the feldspar grains, and cutting it in abundant thin microfractures and veinlets up to 0.5 mm thick, is chlorite as fine flakes to 0.05 mm diameter. The chlorite does not display anomalous interference colours, but has strong green pleochroism and is length-slow, suggesting a moderately Fe-rich variety. In places the place of chlorite is taken by a clear, colourless micaceous mineral that may bs muscovite.

Fe-Ti oxides are abundant in this specimen, but are extremely fine-grained, mainly flakes of specular hematite about 10 microns across or earthy hematite of sub-micron size. However, there are also larger (25-30 μm) subhedral grains of sphene and ?leucoxene sprinkled throughout the rock, the former in places along ?microfractures, indicating a hydrothermal origin.

This represents a highly silicified (quartz stockworked), potassic (chlorite-Kspar-hematite) altered fragmental volcanic rock of possible mafic-intermediate composition. It is just possible that the abundant K-spar is from an original tracytic composition, but the distribution along fractures argues against this.

ARL325: ?ADVANCED ARGILLIC (QUARTZ-?PYROPHYLLITE-RUTILE) ALTERED ?FORMER MAFIC VOLCANIC ROCK

Creamy white, fine-grained, intensely altered rock characterized by semi-foliated wisps and lenses of white or buff material. The rock is harder than steel; a faint yellow stain in places is unlikely to indicate K-feldspar (it may be due to potassium in mica). Mineralogy in section is:

Quartz (secondary)	60%
?Pyrophyllite or muscovite?	35%
Leucoxene/rutile	5%

This specimen appears to be composed principally of secondary silica, as both vague irregular patches (the majority) and lesser thin anastamosing veinlets (to 0.05 mm thick). The quartz forms anhedral, tightly interlocked grains averaging about 10-15 μm in diameter, rarely eceeding 20 μm. The colour in thin section varies from clear and colourless to pale brown, possibly due to finely divided inclusions of ?Ti oxides, which are common throughout this rock.

Intervening patches in the secondary silica are coarser and made up of a phyllosilicate mineral. It has high birefringence and sub- to euhedral form, as flakes up to 0.05 mm diameter; it forms rosettes in places. This mineral could be muscovite or pyrophyllite, but I suspect the latter due to the "brittle" look (as opposed to a softer, flakier look of muscovite) and the lack of "bird's-eye" look, also characteristic of muscovite. X-ray diffraction is needed to confirm such an identification, however.

Relict TiO_2 grains are abundant in this sample. They are probably composed mainly of leucoxene (?and some sphene), with laths of euhedral rutile up to 30 μm long contained in them. The overall particles range from common 10-20 μm size up to eu-to subheral aggregates up to 0.15 mm across.

If the phyllosilicate mineral in this rock is pyrophyllite, then the alteration would be classed as advanced argillic (otherwise it would be phyllic). The abundance of Ti minerals suggests the protolith was a mafic volcanic rock like the others in this series; however, alteration has been so intense as to obscure the original texture.

<u>ARL326: INTENSELY ?ADVANCED ARGILLIC (?PYROPHYLLITE-QUARTZ-?CHLORITE-?CLAY) ALTERED ?FRAGMENTAL MAFIC VOLCANIC ROCK</u>

Light buff-brown, chalky-looking but mainly hard rock (some parts will scratch with a needle). Fine fragmental texture, with angular to sub-angular pale-coloured clasts up to 0.5 cm across in a fine, slightly darker (brown) matrix. No reaction to cold dilute HCl, non-magnetic. In polished thin section, the mineralogy is:

Mineral A (?pyrophyllite, ± ?muscovite)	50%
?Quartz (secondary)	20%
?Chlorite (or mixed-layer clay-chlorite)	10%
Mineral B (unidentified)	10%
Mineral C (?diaspore)	7%
Limonite (hematitic)	2%
Rutile (±leucoxene)	1%

Mineral A forms the bulk of the slide as very fine (10-20, rarely 40 μm) flakes; it has high birefringence and moderate relief. It is similar to the mineral identified as pyrophyllite in 312 and 313, but could easily be muscovite.

Judging by the hardness of this rock, there must be a fair proportion of quartz present, particularly in some of the obvious clasts. In section, these clasts are made up of extremely fine-grained (5-10 μm) anhedral, tightly interlocked grains possibly mixed with some mica. In the rest of the rock, quartz grains are difficult to identify.

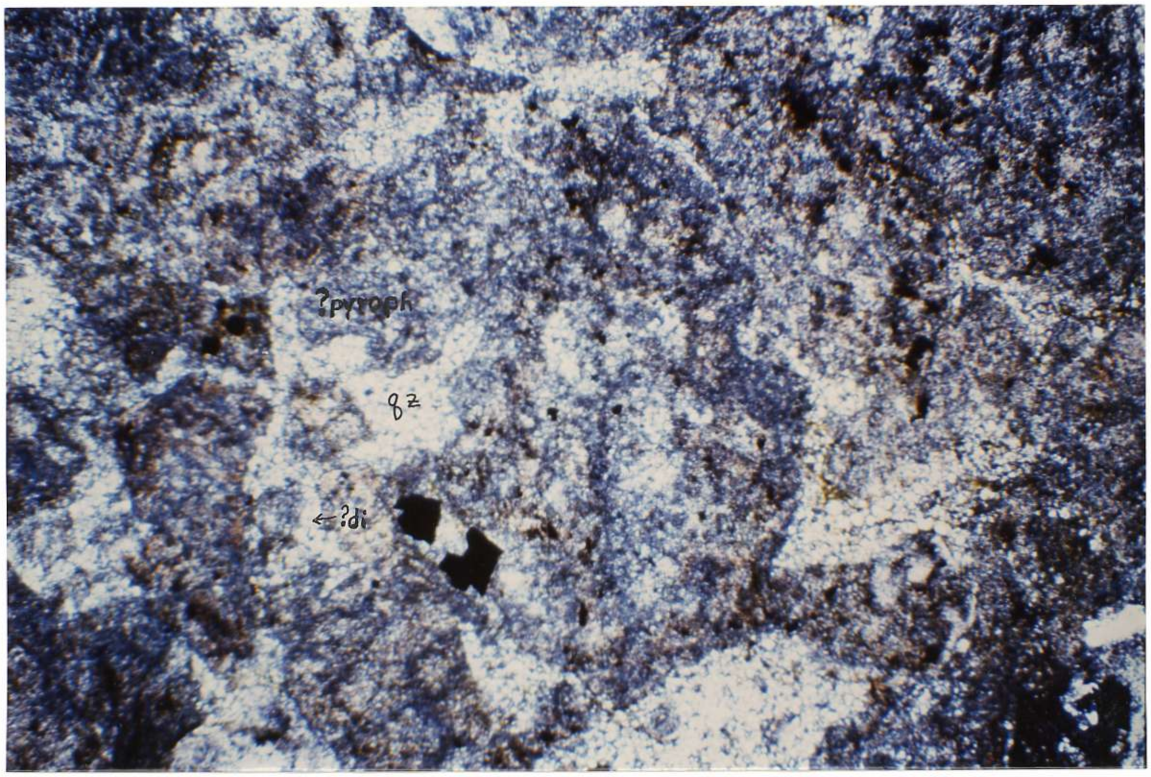
A flaky, moderate relief mineral with very low birefringence resembles a chlorite or clay-chlorite. It occurs as fine flakes or radiating rosettes up to 50 μm in diameter (a similar mineral was identified as clay in 312).

Mineral B occurs as small, euhedral, very clear crystals about 20-50 μm across identical to those seen in 313. Outlines are rectangular or <u>triangular</u> to hexagonal; birefringence is very low to almost nil in the basal sections, possibly length-fast although extinction is undulose. Relief appears to be positive; it may be a clay such as kaolinite, although I have never seen a clay as well crystallized as this. Again, the birefringence is probably too low for alunite.

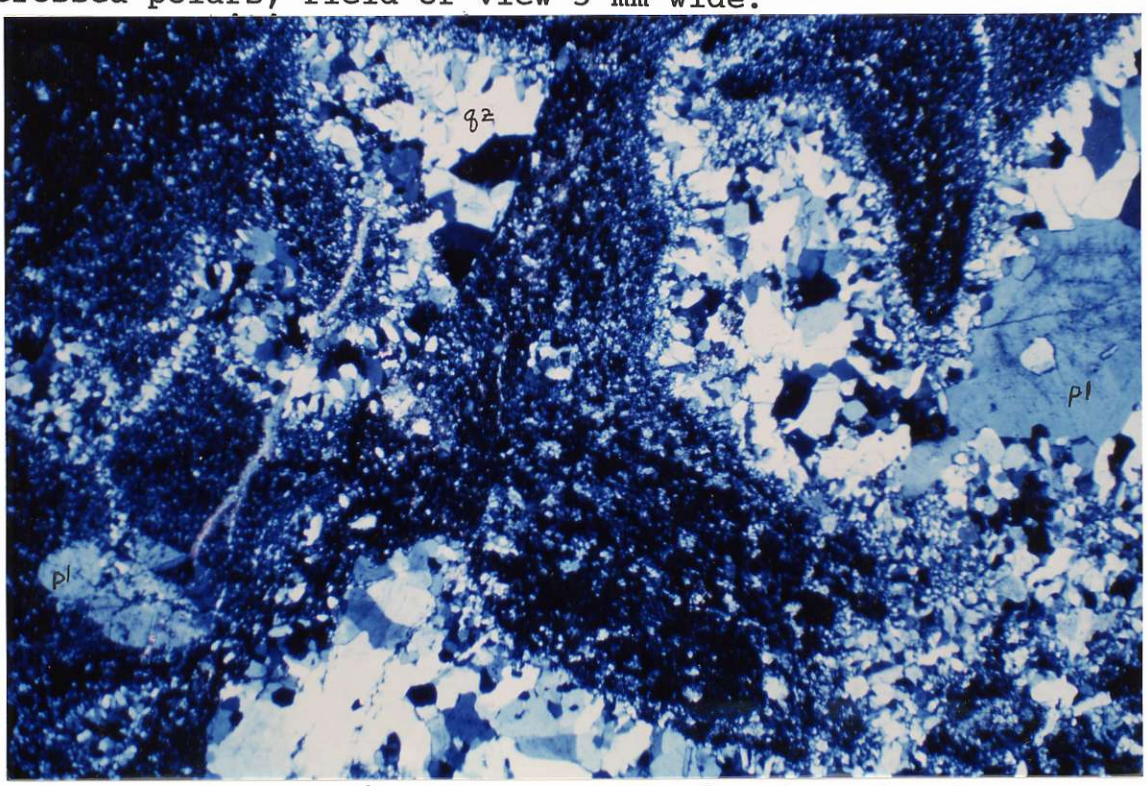
Mineral C occurs as large crystals up to 1 mm long, with high relief and birefringence, parallel (length-fast) extinction; they look to be similar to mineral B in 311/313, identified there as ?diaspore.

Fine (0.1 mm) sub- to euhedral cubic grains of limonite (goethite) are scattered throughout the rock; these appear to be after pyrite. Some grains of hematite (red internal reflections) are also present. There are also fine crystals of rutile, suggesting a mafic volcanic protolith.

In summary, this appears to be a highly advanced argillic (ifthe micaceous mineral is pyrophyllite) altered rock. ?Diaspore and ?kaolinite, if present, would be expected in an advanced argillic alteration zone.



ARL326: **?Advanced argillic alteration.** ?Pyrophyllite-quartz-?diaspore, pyrite (opaque). Transmitted light, uncrossed polars, field of view 5 mm wide.



ARL335: **Propylitic alteration, minor potassic.** Quartz amygdules, plagioclase phenocryst, veinlets of calcite, K-feldspar, quartz. Transmitted light, crossed polars, field of view 5 mm wide.

ARL327: INTENSELY ?PHYLLIC OR ADVANCED ARGILLIC (QUARTZ-MUSCOVITE OR PYROPHYLLITE-PYRITE-RUTILE) ALTERED, FRAGMENTAL MAFIC VOLCANIC ROCK

Pale greenish grey, highly altered, fine-grained volcanic rock with a suggestion of remnant porphyritic texture. Buff-coloured TiO2 relics suggest a mafic volcanic protolith; presence of pyrite indicates phyllic alteration. It is relatively easily scratched by steel, but there is no reaction to cold dilute HCl and no magnetism; a faint yellow stain in places is unlikely to indicate K-feldspar (it may be due to potassium in mica). Mineralogy in section is as follows:

Muscovite (or pyrophyllite?)	50%
Quartz (secondary)	35%
Pyrite	10%
TiO_2 (rutile, leucoxene)	5%

Most of this specimen consists of a very fine-grained micaceous mineral with high birefringence and moderate (?) relief. It could be muscovite or possibly pyrophyllite. It forms sub- to anhedral flakes about 10 to rarely 20 μm in diameter, and is concentrated in areas that appear to replace former ?phenocrysts (e.g. plagioclase) or ?shards, up to 0.5 mm long.

Between these concentrations of the micaceous mineral, a matrix of fine ?quartz and mica (or possibly some ?clay) has distinctly lower birefringence. These minerals are tightly intergrown and average less than 10 μm in diameter; this is at the limit of resolution of optical petrography, especially in view of the thickness of the section being three times this (minimum 30 μm), so that several grains are stacked up on top of each other.

In some places the clear mineral (labelled B in 326) appears; it is possible this "mineral" is actually epoxy, filling holes in these (uncovered) sections.

Pyrite is sprinkled abundantly throughout the slide, as subhedral to euhedral cubes rarely over 0.05 mm diameter, although aggregated in places to about 0.5 mm. No chalcopyrite was seen.

As in most of these specimens derived by alteration of mafic volcanic rocks, TiO_2 relics are abundant. It is difficult to be sure, but they appear to be mostly leucoxene (amorphous to sub-microcrystalline rutile/anatase) and lesser crystalline rutile to 30 μm long.

The alteration in this specimen, as in others of this suite, may be characterized as phyllic (if the mica is muscovite) or advanced argillic (if it is in fact pyrophyllite). This sample differs from other possible advanced argillic examples in its high pyrite content.

<u>ARL335: PROPYLITIC (QUARTZ-CHLORITE-CALCITE-SPHENE) ALTERED INTERMEDIATE VOLCANIC ROCK, MINOR PYRITE/CHALCOPYRITE</u>

This sample is from the Boris showing (part of the Cullet Creek zone). It is a medium green, very fine-grained, amygdular intermediate to mafic volcanic rock. Amygdules are elongate, up to 1 cm in length, and filled with white to reddish (hematite-stained) quartz; they show a distinct preferred orientation. Rock is harder than steel, but non-magnetic; it reacts to HCl (and stains for K-spar) along fractures only. Scattered blebs of chalcopyrite to 1 mm are seen. Mineralogy is approximately:

Plagioclase (?albite)	50%
Chlorite	25%
Quartz (amygdules, veins)	17%
Secondary K-feldspar	3%
Sphene	2%
Carbonate (calcite, veins)	2%
Mica (?muscovite)	<1%
Chalcopyrite	<1%
Pyrite	<1%

The bulk of this rock is made up of plagioclase microlites averaging around 0.05 mm long. Their composition is indeterminable, but there are scattered (3-5%) plagioclase phenocrysts up to 0.75 mm long that are of albite ($Y\hat{}010=16°$, $Z\hat{}001=13°$). The matrix to the plagioclase microlites is mainly chlorite, as fine subhedral flakes to 10 μm in diameter. Rare chlorite flakes to 0.05 mm could represent former mafic phenocrysts.

Quartz-filled amygdules consist principally of anhedral quartz grains up to 1 mm diameter; these are moderately strained, with undulose extinction and some granulation (recrystallization) evident. Minor chlorite, albite, calcite, and sphene are found in the amygdules, and in some rims the quartz is sprinlked with fine hematite dust (particles <1 μm).

Thin (<1 mm) veinlets crossing the rock consist of calcite (anhedral grains to 0.2 mm long) and lesser sphene (subhedral crystals te 0.05 mm long), plus minor anhedral K-feldspar to 0.05 mm and muscovite (?) as subhedral flakes to 0.05 mm long. There are scattered large aggregates of chalcopyrite consisting of subhedral grains up to 0.3 mm diameter, and fine sub- to euhedral pyrite crystals to 0.15 mm are sprinkled throughout the rock. The sulfides are not, however, clearly associated with the veining.

In summary, this appears to have been a porphyritic, amygdular volcanic rock of possibly intermediate composition that has undergone propylitic (quartz-chlorite-calcite-sphene) alteration and minor veining (some with K-spar alteration associated); copper sulfide mineralization may have been due to a separate event, and significantly does <u>not</u> appear to be related to the K-spar veining.

ARL336: POTASSIC (KSPAR-CHLORITE-QUARTZ) ALTERED MAFIC FRAGMENTAL VOLCANIC ROCK WITH MINOR PYRITE, CHALCOPYRITE

This sample is from the Gorby showing, part of the Culleet Creek zone. It is a variegated purple/green fragmental intermediate volcanic rock, composed of clasts up to several cm across that are mainly fine-grained, green and homogeneous; there are also a few smaller, white ?quartz clasts. The body of the rock consists of very large ?clasts (nearly the size of the specimen) of highly pyritized pale green rock in a purplish hematitic matrix. All parts of the rock are harder than steel. Mineralogy in thin section is:

Plagioclase (possibly albitic)	25%
K-feldspar (?scondary)	25%
Chlorite	20%
Quartz (secondary)	20%
Sphene	2%
Pyrite	2%
Hematite, limonite (goethitic)	2%
Carbonate	2%
Chalcopyrite	1%
Rutile, leucoxene	1%

The bulk of this slide is made up of feldspar, which includes trachytic-textured plagioclase microlites (<0.05 mm long) in the fine-grained clasts to feathery, interlocking anhedral grains of ?secondary Kspar also less than 0.05 mm across. It is impossible to be sure of the composition of each feldspar grain, but the refractive index is apparently less than that of adjacent quartz in veins, suggesting microlites are albitic; staining tests confirm that the rest is K-feldspar.

Mixed with the feldspar is very fine chlorite (10-20 μm diameter flakes). It is length-slow, has anomalous birefringence and strong green pleochroism (probably Fe-rich).

Most if not all the quartz present in this section, as anhedral grains to 0.2 mm diameter, is found in thin veinlets (0.1-0.2 mm thick) and irregular patches up to 0.5 mm across. The quartz is relatively unstrained and clear. Rare subhedral grains of carbonate (possibly dolomite or ankerite) and ?sphene, up to 0.05 mm across, are also found in the veins; minor chlorite is also present.

Former titanium minerals are represented by patches of sphene (subhedral crystals up to 0.1 mm), with admixtures of rutile and ?leucoxene. Extremely fine hematite (sub-micron size) is common disseminated in places in the silicates.

Pyrite is common, sprinkled through the rock as fine cubic disseminated grains up to 0.5 mm diameter. Much of it shows incipient oxidation to rims of goethitic limonite. One large bleb (1.5 mm across) of chalcopyrite in a quartz vug is composed of subhedral grains up to 0.5 mm. Bladed ?crystals of limonite, mainly the goethite called "pitch limonite" are found along the margins of the chalcopyrite.

This is a potassic (Kspar-chlorite-quartz-hematite) altered, probably mafic-intermediate fragmental volcanic. However, chalcopyrite is not found with K-spar.

<u>ARL337: SILICIC-POTASSIC ALTERED ?DACITIC VOLCANIC ROCK</u>

Pale green (chalky-weathering) ?intermediate fragmental volcanic rock characterized by abundant siliceous veining (stands out in relief on weathered surface). The rock is very hard and siliceous throughout, shows no reaction to cold dilute HCl, and is not magnetic. It, like 336, is from the Gorby zone. In polished thin section, the minerals are:

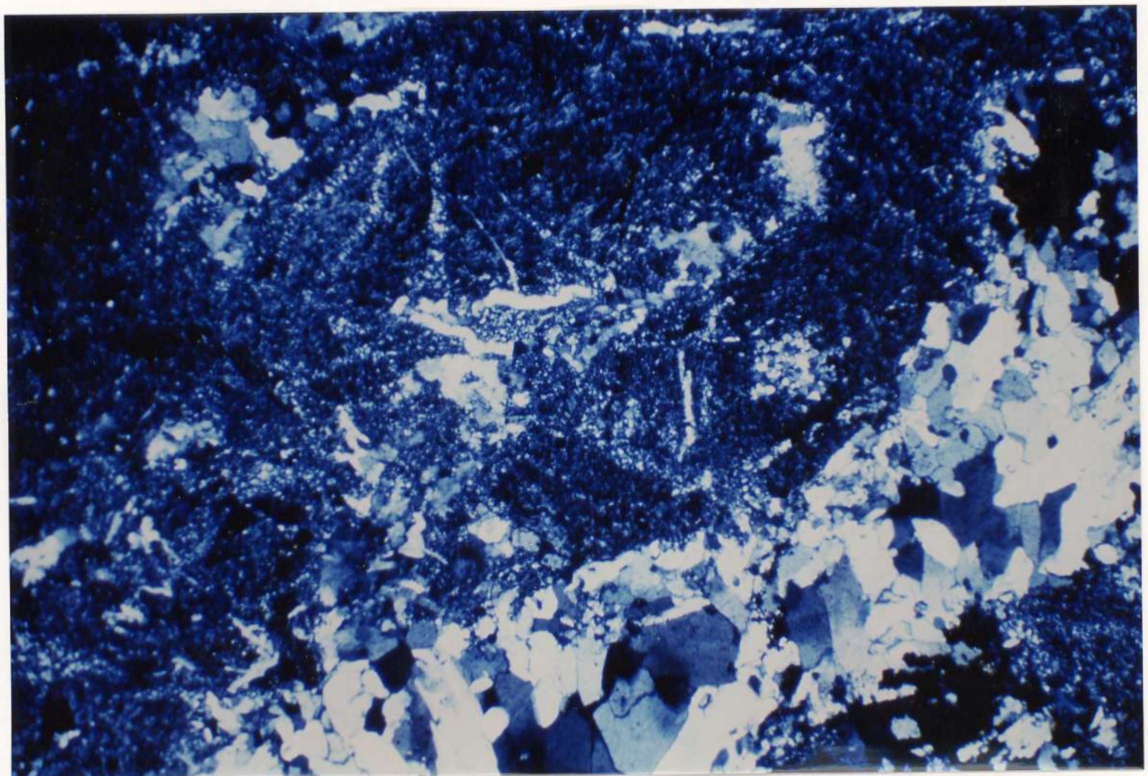
Vein quartz, ?amygdules	40%
Quartz (secondary)	20%
Green biotite ("hydrobiotite")	20%
K-feldspar (secondary)	10%
Muscovite (or ?pyrophyllite)	3%
Pyrite	3%
Limonite (goethitic)	3%
Rutile	1%

This is a highly silicified rock, comprising more than half secondary silica in the form of both an extensive stockwork of veins and pervasive silicification. In the veins, which range from microveinlets up to 3 mm thick, the quartz is sub- to anhedral, moderately strained, fractured and recrystallized, forming grains up to 0.5 mm long. Rounded areas (described as amygdules in field notes) contain similar quartz, but are fringed by fine-grained (25 μm) quartz and feldspar (rims visible in hand specimen). Thus they are not likely to be fragments, even although the hand specimen has a fragmentary appearance due partly to veining.

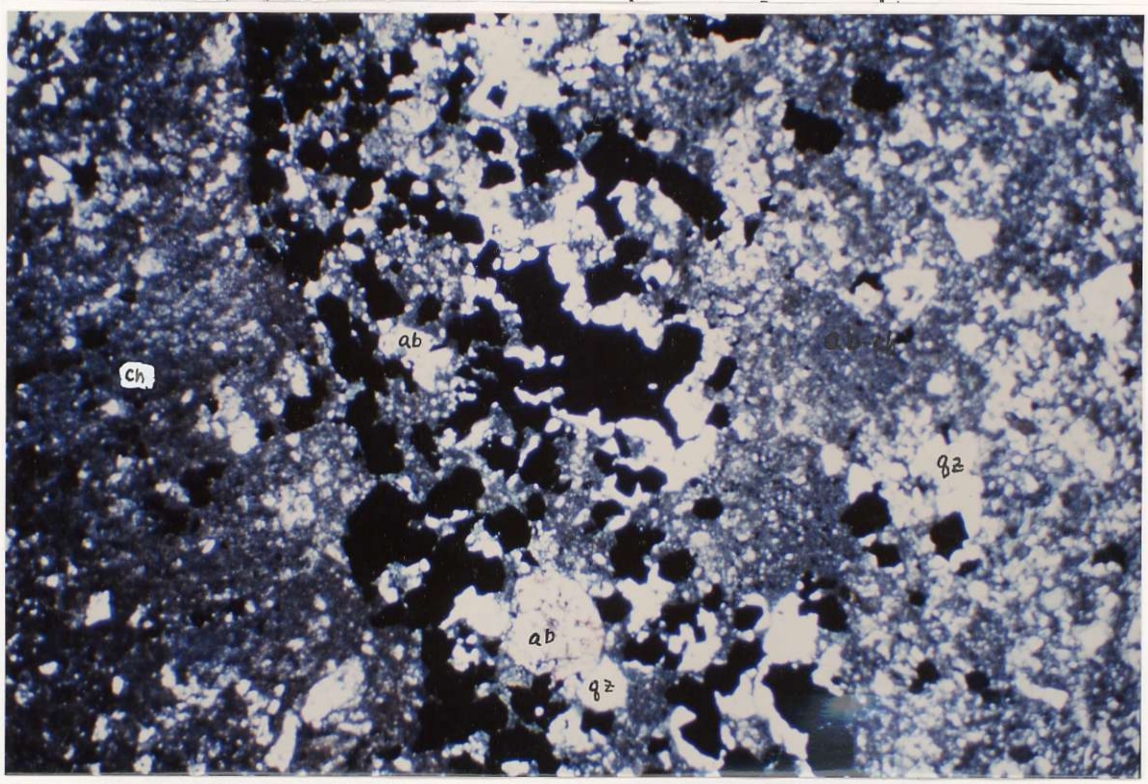
No phenocrysts are recognizable. The groundmass of the rock consists of fine-grained (10-30 μm) anhedral quartz and lesser alkali feldspar, mainly secondary. Most of the K-feldspar forms feathery interlocking grains to 50 μm long with an index less than quartz; it is found mainly as envelopes to quartz veins and a few thin veinlets (cut by the quartz stockwork). No chalcopyrite is associated.

Scattered through the groundmass and to a minor degree the veins are patches, clots and flakes of micaceous mineral which are either greenish-brown or clear. The flakes are subhedral, often in rosettes, and up to 20 μm in diameter. The greenish-brown ones are best described as "hydrobiotite" or Fe-rich phyllosilicate part-way between chlorite and biotite. The clear mineral is likely muscovite (but could be pyrophylite). The main difference between the fresh and weathered portions of the rock appears to be the "bleaching out" of the colour of the hydrobiotite, i.e. a loss of Fe and Mg attendant on weathering.

Pyrite forms fine euhedral cubic crystals to 0.3 mm across seemingly disseminated through the rock, but in reality distributed along microfractures/veinlets. Most are partly to completely oxidized to a goethitic limonite. Very fine needles of ?rutile to 5 μm long are found in places, but they are not as abundant as would be expected in a mafic volcanic rock; thus this may be an intermediate (dacitic) amygdular volcanic that has been extensively silicified. Potassic alteration appears to be related to pyritic rather than copper mineralization.



ARL337: **Silicic-potassic alteration.** Quartz stockwork cutting rock altered to fine feathery interlocking grains of ?secondary K-feldspar. Pyrite cubes, limonite patches. Transmitted light, crossed polars, field of view 5 mm wide.



ARL341: **Propylitic alteration.** Pyrite-chalcopyrite (opaques)-quartz vein in albite-chlorite altered wallrock. Transmitted light, uncrossed polars, field of view 5 mm wide.

ARL338: PROPYLITIC-POTASSIC (CHLORITE-HEMATITE-KSPAR) ALTERED,PERVASIVELY SILICIFIED/STOCKWORKED VOLCANIC ROCK

Pale pink and green, strongly altered ?volcanic rock characterized by a spherulitic, but disrupted texture; remnant patches of green rock that stain yellow for K-spar appear to be left as islands in the pinkish enveloping mass. Described as "apple green" silica-pyrite alteration in field notes. There is minor pyrite, but no appreciable limonites; the rock is not magnetic, and mainly harder than steel. In sectien, the modal mineralogy is roughly as follows:

Secondary quartz	40%
K-Feldspar (mainly secondary)	40%
Chlorite	15%
Sphene, leuccxene	2%
Hematite	1%
Pyrite	1%
Carbonate (dolomite)	1%
Sericite (?muscovite)	<1%

The extent of silicification in this sample, not evident in the sawn slab, is clear in thin section: a good portion of the slide is made up of tightly interlocked, anhedral quartz grains up to 0.3 mm in diameter forming highly irregular anastamosing veinlets up to 1 mm thick. The effect given is of silica replacement starting along fractures and proceeding to almost pervasive silicification in places. Locally there are concentric colloform banded textures indicating a chalcedonic character to the quartz.

The intervening islands of wall rock are composed of fine, feathery interlocking feldspar grains up to 0.05 mm long that have vaguely trachytic texture that suggests they were formerly microlites of plagioclase in a mafic-intermediate volcanic rock. A refractive index generally less than that of adjacent quartz suggests an albitic composition; most are replaced by ?secondary K-feldspar.

Interstitial to the feldspar, and cutting it in thin microfractures is fine flaky chlorite of 5-15 μm diameter, probably a moderately Fe-rich variety as in 322. Rarely, the micaceous mineral is clear, suggesting musoovite.

Sprinkled throughout the rock are fine flakes (5 μm) and earthy (<1 μm) disseminations of hematite, pyrite cubes to 0.2 mm across, and vague irregular patches of Fe-Ti oxide remnants to 0.05 mm. The latter are composed of sphene and possibly some admixed leucoxene. In some of the quartz veins, euhedral sphene up to 0.1 mm long and associated sprays of rutile needles up to 10 μm long are found, as are rare reopenings of the veins marked by small (0.05 mm or less) subhedral carbonate grains. There is no reaction to cold dilute HCl, but the grains may be too sparse for reaction to be visible; it could be calcite or dolomite.

This is a propylitic-potassic (Kspar-chlorite-hematite) altered volcanic rock of probably originally mafic composition, that has been extensively silicified along a network of veins and fractures, with addition of minor pyrite. Chalcopyrite is not assooiated with K-spar.

ARL339: POTASSIC (KSPAR-CHLORITE) ALTERED PORPHYRITIC MAFIC VOLCANIC ROCK CUT BY QUARTZ-PYRITE-CHALCOPYRITE VEINS

Apple green, siliceous, fine-grained altered volcanic rock cut by a network of thin siliceous stringers with pyrite and rare chalcopyrite. The rock is not magnetic but intense yellow stain indicates K-spar. From the Gorby zone of Culleet Creek zone; similar to the greenish (propylitic) altered portions of ARL338. Modal mineralogy is:

K-feldspar (?secondary)	30%
Chlorite	30%
Plagioclase (phenocrysts)	10%
Vein quartz	10%
Sericite (?muscovite)	10%
Fe-Ti oxides (rutile, limonite)	5%
Pyrite	3%
Sphene	2%
Chalcopyrite	<1%

As in 338, this was a porphyritic rock before alteration, with 10-15% 2 mm scattered elongate euhedral plagioclase and 5-10% 0.8 mm euhedral mafic phenocrysts set in a groundmass of ?secondary K-feldspar and interstitial chlorite. Plagioclase phenocrysts are mainly visible only as outlines replaced by fine-grained sericite (?muscovite) as subhedral flakes to 20 μm diameter. In a few instances some remnant feldspar is left; it has a refractive index less than that of quartz replacing it, so the composition is likely albitic. Mafic phenocrysts are pseudomorphed by a dark green, Fe-rich chlorite as euhedral to subhedral flakes to 30 μm diameter, plus lesser sericite and Fe-Ti oxides.

The groundmass consists of feathery K-feldspar grains that vary from equant to elongate microlites with a trachytic orientation; they average about 0.05 mm long. Thus their secondary origin is questionable. Interstices are filled by very fine-grained chlorite (10 μm) and Fe-Ti oxides that range from disseminated 5-10 μm grains to microphenocrysts of 0.1 mm diameter. In short, the original volcanic texture of this rock is well preserved.

Fe-Ti oxides include sphene as subhedral aggregates up to 0.1 mm diameter, plus varying amounts of rutile and leucoxene in similar aggregates. Limonite is mainly goethitic, and can be seen to rim and replace sulfide grains as well as forming transported material along fractures.

Quartz veins are irregular, anastamose and up to 2 mm thick. They consist of an- to subhedral quartz grains up to 0.5 mm long plus cubic pyrite generally less than 0.2 mm long. In places there are also minor amountes of sericite associated with the vein, and in these places there is minor chalcopyrite as anhedral grains to 0.1 mm diameter.

In summary, this rock is similar to 338 in potassic (Kspar-chlorite) alteration, but is oonsiderably less silicified. However, it shows transition to phyllic alteration, with an association of sericite and chalcopyrite (<u>not</u> K-spar and chalcopyrite). It was probably originally a porphyritic basaltic flow.

<u>ARL340: POTASSIC-PHYLLIC (KSPAR-CHLORITE-SERICITE) ALTERED ?FINE FLOW ROCK CUT BY QUARTZ AND SULFIDE STRINGERS</u>

This sample is from a white weathering outcrop with apple green siliceous-sericite alteration in the South Lake Zone. On the fresh surface, it is a pale greenish grey colour, probably less propylitic than 338-339; on the outside is a weathering rind about 1 cm thick of chalky ?clay alteration, in which an extensive network of fine siliceous veinlets stand out clearly and the rock may be scratched by steel. Oxidation to limonite is more extensive than in 339. Mineralogy in thin section is:

K-feldspar (?secondary)	55%
Chlorite	20%
Serioite (muscovite)	10%
Vein quartz	10%
Fe-Ti oxides (sphene, rutile)	2%
Limonite (mainly after pyrite)	2%
Pyrite	1%

This is not a porphyritic rock like 339, but alteration is similar. It is a fine-grained homogeneous (?chilled) flow rock consisting of fine feathery interlocking grains of ?secondary K-spar to 0.05 mm with lesser chlorite replacing mafic microphenocrysts to 0.1 mm long. The elongate shape of the mafic relics suggests former hornblende or augite. There is also abundant anhedral to needle-like Fe-Ti oxide material that appears to be sphene with included euhedral rutile. These grains are rarely over 20 μm diameter, although aggregates are up to 0.1 mm across.

Limonite after pyrite is disseminated throughout the rock and found along certain veins as cubic pseudomorphs up to 0.1 mm across. In places, remnant pyrite oan be seen at the centers of the limonite grains. Along some veins are anhedral limonite aggregates, possibly after ?chalcopyrite.

There are several veining episodes displayed in this specimen. Only those veins with phyllosilicates (mainly chlorite, but also including muscovite) appear to carry sulfides. They appear to cut or be contemporaneous with barren, coarse-grained quartz veins, which are cut by thin, fine-grained quartz veins. However, the sulfide-phyllosilicate fractures cut the fine quartz veins, so the sequence may be: 1) coarse quartz, 2) fine quartz, 3) sulfide fracturing.

The alteration of this rock is transitional from potassic (Kspar-chlorite) to phyllic (muscovite-sulfides). The intense ?secondary K-spar does not appear to be directly associated with sulfide mineralization. The white weathering rind appears to be caused by the bleaching of chlorite to colourless (probably replacement by clay). Although not clearly visible in the slide, there is also probably some breakdown of feldspar to a clay such as kaolinite, to explain the loss of hardness in the weathered rind.

<u>ARL341: PROPYLITIC (?ALBITE-CHLORITE-QUARTZ) ALTERED FINE FRAGMENTAL ?MAFIC VOLCANIC WITH PYRITE-CHALCOPYRITE STRINGER</u>

Dark green, intensely altered, fine-grained volcanic rock cut by extensive sulfide stringers and disseminations. It does not stain for K-feldspar. The rock is hard and does not visibly attract a magnet, although it is from the Lake Zone and described as magnetite chlorite-chalcopyrite facies in field notes. Mineralogy in section is roughly:

Feldspar (mainly plagioclase, ?albitic)	40%
Chlorite	35%
Secondary quartz	15%
Pyrite	7%
Fe-Ti oxides (sphene, rutile)	2%
Chalcopyrite	1%

The remnant texture of this rock suggests it was a fine fragmental volcanic, with subrounded clasts to several mm size set in a finely comminuted matrix. Clasts are mostly made up of fine plagioclase microlites of less than 0.1 mm length, although some have a coarser-grained highly altered texture where replaced by quartz and pyrite.

The matrix consists of very fine deep green chlorite of 10-20 μm size, hosting plagioclase microlites up to 0.15 mm long and occasional broken phenocrysts (?shards) up to 0.5 mm diameter. Minor amounts of very fine (5-10 μm) oxide material, mainly sphene but possibly including some needles of rutile, are scattered throughout the matrix. The absence of K-feldspar in this rock lends credence to the K-spar in other samples (the "apple green siliceous") being secondary, formed by replacement of plagioclase.

Most of the secondary quartz in this sample takes the form of irregularly-shaped clots rather than the veins found in other samples of this suite. The quartz is clear, subhedral to anhedral, and up to 0.2 mm across; it is strained (undulose extinction) but relatively unfractured. It is closely associated with sulfides, and in places with coarser chlorite.

Sulfides are mostly pyrite, as euhedral cubes up to 0.25 mm diameter, but locally aggregating to 1 mm grains. However, there is also commonly chalcopyrite associated, as anhedral grains up to 0.3 mm long. This sample contains the most copper of any in the suite. Magnetite is not visible in the section.

The alteration in this specimen is propylitic (chlorite-albite-quartz) but it has important sulfides, including chalcopyrite. The original rock was probably mafic in composition, judging by the abundance of sphene. Perhaps significantly, chalcopyrite in this sample is not accompanied by potassic (K-feldspar) alteration.

<u>ARL342: LAMINATED KSPAR-HEMATITE FELDSPATHIC VOLCANIC ROCK CUT BY BRECCIA MATRIX OF QUARTZ-CHLORITE-SULFIDES</u>

This sample is from the South Lake Zone, described in field notes as a laminated breccia; it is characterized by white to pinkish fragments to 0.5 cm that stain brilliant yellow for K-spar, in a greenish breccia matrix that is enriched in sulfides, mostly pyrite. One larger (5 mm) vein contains significant chalcopyrite. Both fragments and matrix are harder than steel; the rock is not magnetic. In polished thin section, the mineralogy is approximately:

K-feldspar (?secondary)	65%
Secondary quartz (veins, matrix)	15%
Chlorite (matrix)	10%
Sericite (muscovite)	5%
Pyrite	2%
Chalcopyrite	1%
Hematite, limonite	1%
Sphene, rutile	1%

The white to pinkish portion of this rock appears in thin section to be mainly composed of K-feldspar, with minor amounts of hematite adding the reddish colour. This feldspar has a low refractive index with a feathery form, and is probably secondary, although it could be merely an original trachyte present in the volcanic sequence. Grain size averages around 0.05-0.1 mm, and there is a strong preferred orientation that defines the lamination. Extremely fine (micron-sized) particles of hematite and slightly coarser (to 5 μm) rutile and ?sphene grains make up the rest of the original host rock. Sphene is found in coarser euehdral to subhedral grains to 25 μm diameter in thin quartz stringers crossing the fragments.

The matrix consists of fine anhedral quartz grains up to 0.05 mm diameter with intersitial chlorite and disseminated sulfides. The chlorite has no appreciable colour or pleochroism, and very low (almost nil) birefringence; it is not Fe-rich. It is not sericite, but it could be a mixed-layer clay-chlorite. This fine-grained material is cut by coarser-grained quartz (0.5 mm) vein material, occasionally with coarse chalcopyrite aggregates up to 1 mm long. The coarser quartz is strained and fractured, but essentially devoid of any phyllosilicate.

In reflected light, pyrite forms eu- to subhedral cubic grains up to 0.5 mm across, with chalcopyrite forming sub- to anhedral grains to similar diameter; there are traces of covellite on chalcopyrite. Pyrite and chalcopyrite rarely occur together, suggeeting a separate episode of copper mineralization (also suggested by the restriction of chalcopyrite to the major quartz vein in the slide).

This rock differs from the others in lacking a clear potassic or phyllic signature, although possibly the ?secondary K-spar represents potassic alteration of an originally feldspathic volcanic, cut by quartz-sulfide (phyllic) stringers. As in other samples, there is no clear association between potassic alteration and chalcopyrite.