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PETROGRAPHY OF FIVE POLISHED THIN SECTIONS

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Samples submitted: 3-97.5, 9-64.0, 7-65.9, 1-83.2, 7-98.1.

SAMPLE 3-97.5: KYANITE-QUARTZ-SERICITE-PYRITE SCHIST

Light grey, sheared, intensely quartz-sericite altered, possibly fragmental volcanic rock. Ill-defined ellipsoidal white areas, averaging about 5 mm long, look like original lapilli in a tuffaceous rock, but in thin section are kyanite porphyroblasts. The intervening matrix is grey, with abundant pyrite and a buff-pink mineral that looks like carbonate, but there is no reaction to acid and none visible in thin section. In polished thin section, the mineralogy is all secondary (or metamorphic):

Quartz	40%
Muscovite (sericite)	30%
Kyanite porphyroblasts (altered)	20%
Pyrite, trace chalcopyrite	10%
Rutile, sphene	<1%
Zircon	tr
Apatite	tr

The kyanite porphyroblasts are corroded (attacked at their margins by fine-grained quartz and sericite). There is also an incipient alteration to a high-relief, fibrous mineral that is too fine-grained (10-20 microns) to identify, but might be sillimanite (?). The kyanite crystals were originally about 0.5 to 1 cm long. They are colourless in thin section. This rock is similar in thin section to kyanite-bearing schistose rocks at a massive sulfide prospect near Clearwater, B.C.

The bulk of the rock, forming the matrix to the large kyanite blasts, is composed of fine-grained quartz and sericite. Commonly, areas of coarser sericite (muscovite) surround the kyanite grains, and form discontinuous stringers through the rock that serve to define the foliation. Individual flakes are about 0.01 to 0.05 mm long, but areas of aggregates up to 1 cm across are common. The foliation in the mica is often strongly kink-banded.

Quartz forms smal interlocking grains of about 0.02 to 0.03 mm diameter, with no preferred elongation evident. The grains are strongly strained, however, as shown by undulose extinction and sutured boundaries. Occasional coarser areas have grains up to 0.2 mm across.

Pyrite is the only sulfide visible in reflected light in quantity, forming subhedral grains averaging less than 0.5 mm across. Rarely, trace amounts of chalcopyrite are found as inclusions up to 50 microns long in the pyrite. The only other opaque mineral is rutile, with yellow-brown internal reflections, forming minute prisms 10-20 microns across. They are often present as inclusions in the kyanite remnants.

Minute euhedral prisms of zircon may also be present in the kyanite relics, averaging less than 0.02 mm long. Rarely, small grains of sphene up to 0.03 mm across are present in sericitic areas. Traces of apatite as prisms up to 0.02 mm long are also present in these areas.

SAMPLE 9-64.0: KYANITE-QUARTZ-MUSCOVITE-PYRITE SCHIST

This sample looks very similar to that from 3-97.5. It is also light grey, and has the same tuffaceous look caused by kyanite porphyroblasts in a quartz-sericite-minor pyrite matrix. A foliation is defined by alignment of sericite (muscovite) and darker layers slightly richer in sulfide. In polished thin section, the mineralogy is the same as 3-97.5:

Quartz	50%
Kyanite (porphyroblasts)	25%
Muscovite (sericite)	20%
Pyrite	5%
Rutile	<1%

Kyanite porphyroblasts were up to 1 cm long, and are aligned subparlallel to the foliation. They also tend to be confined to layers, with intervening layers richer in quartz and sericite. The kyanite displays occasional polysynthetic twinning, and an extinction angle of about 30 degrees. It is replaced, particularly at its margins, by sericite, quartz, and some pyrite. This process often leaves only a core of relic kyanite. There is also an incipient alteration in places to an almost amorphous, pale pinkish-brown, fine-grained mineral that is not identifiable.

Quartz is more abundant than in 3-97.5, and shows a distinct flattening (ratio of about 2-3:1) in a plane parallel to the foliation. The quartz grains are about 0.05 to 0.1 mm long on average.

Muscovite flakes are up to 0.1 mm long, and form layers up to 1 mm thick. However, most commonly the layers are only 0.01 mm thick, forming interleaves with the layers of quartz that are also a single grain thick.

Pyrite forms euhedral to subhedral grains about 0.3 mm across, occasionally aggregating to 1 mm. No chalcopyrite was observed as inclusions in this pyrite, but inclusions of rutile are present. Rutile also forms small prismatic crystals with pale yellow-brown internal reflections, scattered through the kyanite porphyroblasts and the matrix, or as minute needle-like aggregates.

It is difficult to speculate on the origin of these two specimens, but a felsic volcanic protolith seems likely. As noted for 3-97.5, the apparently tuffaceous texture may be a metamorphic texture, caused by the growth of large kyanite porphyroblasts. The resemblance of these rocks to rocks of the Eagle Bay Group on the south side of the North Thompson River near Clearwater is striking.

SAMPLE 7-65.9: KYANITE-QUARTZ-PYRITE-SERICITE-?CORDIERITE SCHIST

This is a grey and white mottled to laminated rock that is similar in appearance to the specimens from 3-97.5 and 9-64.0. Modest amounts of pyrite are present in stringers roughly parallel to the laminations, but also crosscutting it in places. There are also hairline dark grey stringers and veinlets; their dark colour appears to be caused by crushed and smeared pyrite. In polished thin section, the mineralogy is similar to that of the previous two slides:

Kyanite	40%
Quartz	40%
Pyrite	10%
Sericite (muscovite)	5%
?Pinite (altered cordierite)	5%
Rutile	<1%

In the drill core or slabbed surface, the white material is kyanite; the grey is quartz. If there were lapilli present forming a tuffaceous texture, it is very difficult to discern now; the texture is entirely metamorphic. Field relations would be more definitive than thin section studies in answering this question.

Kyanite forms coarse subhedral grains often up to 0.5 cm long. Although there is a tendency for the long axes to be parallel to the foliation, there are also grains oriented at random angles, including perpendicular. The kyanite is in general less altered than in the two previous slides; alteration is to minor amounts of sericite. The kyanite is strongly polysynthetically twinned, and even displays concentric zoning in places, looking like plagioclase except for the very high relief.

Quartz is present as anhedral, interlocking grains of about 0.2 mm average diameter. It is intergrown with the kyanite, and also forms almost monomineralic layers up to 1 cm thick. Thus a crude compositional layering is developed of kyanite-rich and quartz-rich layers. There is no obvious tendency for the quartz to be flattened in the plane of foliation. However, the quartz is strongly strained, with undulose extinction, sutured grain boundaries, and strong fracturing evidenced by myriad trains of secondary fluid inclusions. Without knowing the protolith, it is hard to say if the bulk of this quartz is secondary (as opposed to metamorphic). The thin veinlets are certainly secondary, so there has been some silicification.

A weak foliation is developed by flaky muscovite of about 0.1 to 0.3 mm length; the mica is sometimes present as thin layers up to 0.2 mm thick separating quartz-rich laminations.

In places the kyanite is found as kernels in the center of larger grains that may in fact be altered cordierite. That is to say, the characteristics are permissive for cordierite: the relief is low (less than quartz), birefringence is similar to that of quartz, interference figure is biaxial positive with a moderate axial angle, and there is vague polysynthetic twinning. Alteration to sericite is common, beginning along these twin planes and eventually replacing the margins of the grains completely. Thus they could be pinite, but I must admit I would not have considered the possibility if you had not suggested it. Two disturbing features of this mineral are that the relief is very low, always less than that of quartz, and the apparently psuedomorphic relation to kyanite is unusual if it is cordierite. The identification would have to be confirmed (possibly by SEM; there should be no peaks for K or Fe in the pure Mg silicate cordierite), if the identification is important.

barite ?

In reflected light, the major opaque phase is pyrite, as subhedral grains ranging from 0.01 mm up to 1 mm across. Aggregates are present in layers, up to several millimeters thick. The pyrite is unusually anisotropic, enough to suggest that its arsenic content be checked (either by SEM or geochemical analysis). Rutile is common as inclusions in the pyrite, forming anhedral grains up to 0.1 mm long but generally only 10-30 microns. Larger grains are also present, though, up to 0.3 mm across, in the coarser pyrite layers. These have dark to light brown internal reflections and are strongly anisotropic. There are also occasional anhedral grains, up to 0.3 mm long, with slightly higher reflectivity than the rutile, apparently isotropic, and lacking internal reflections; these may be tetrahedrite-tennantite. Again, this identification is tentative only and requires checking by SEM for confirmation. There appears to be no difference in mineralogy in the later veinlets, except that the pyrite is crushed to smaller grain size. The grains do not display obvious triple junctions indicating recrystallization, but this may have been disrupted by later deformation. Apart from the sulfide emplacement preceeding the veining, I can say little about the timing of mineralization, e.g. if it precedes or post-dates metamorphism.

SAMPLE 1-83.2: QUARTZ-KYANITE-PYRITE-SERICITE SCHIST

Grey and white mottled rock, with a well developed lamination formed of grey (quartz-rich) and white (quartz-poor) layers. There are also prominent white areas of quartz that may be secondary silicification. Wispy pyrite lenses and layers are parallel to the lamination; disseminated pyrite is also present. In polished thin section, the mineralogy is as follows:

Quartz	70%
Kyanite	20%
Pyrite	5%
Sericite	5%
Rutile	<1%
Tetrahedrite-tennantite (?)	tr

The mineralogy of this specimen is similar to 7-65.9, but it has considerably more quartz and less kyanite, sericite, pyrite. There does not appear to be any pinite (cordierite altered to sericite).

Kyanite forms the white areas in the cut slab, as coarse subhedral crystals up to a centimeter long. They are not noticeably altered to sericite; the small quartz grains found in them could be due to silicification, but it also could be merely metamorphically intergrown. The kyanite is polysynthetically twinned.

The bulk of the quartz that makes up most of this rock is about 0.2 to 0.3 mm in diameter, and shows a tendency to flattening of about 2:1 parallel to the lamination and foliation. The grains are strongly deformed, displaying undulose extinction, sutured boundaries, and occasional fracturing. Some areas have finer-grained quartz that may be secondary silicification; or they may be relict fragments

Minor sericite (muscovite) forms flakes about 0.05 to 0.1 mm long, usually around kyanite grains. Minute prismatic grains of rutile, often less than 10 microns long, are common in these areas. Sulfides are closely associated with kyanite grains and kyanite-rich layers, sometimes surrounding the kyanite as if they were reaction rims.

In reflected light, the major opaque is again pyrite (as in 7-65.9). It is present as euhedral to subhedral pyritohedrons (?), or at least as polygonal-outlined grains, that suggest recrystallization and annealing. Triple junctions are abundant, and there also appears to have been remobilization of softer phases to the interstices between the harder pyrite grains, in the fashion classically described by Stanton in his textbook on ore petrology (1974). The minor phase, as in 7-65.9, appears to be tetrahedrite (isotropic, no internal reflections; reflectivity too low for galena), but this should be confirmed if it is important. There is also minor rutile, as in all the other slides of this suite, as grains up to 0.2 mm across. It also occasionally forms skeletal intergrowths in quartz, probably as relics of former titaniferous grains such as ilmenite, and euhedral grains included in pyrite.

<u>SAMPLE 7-98.1: QUARTZ-CHLORITE-SERICITE-CALCITE-EPIDOTE SCHIST, PROBABLY AFTER A QUARTZ PHYRIC FELSIC VOLCANIC</u>

Medium green, well foliated intermediate to felsic volcanic with minor quartz eyes and rare white-buff Ti-mineral relics. In polished thin section, the mineralogy is as follows:

Quartz (matrix)	25%
(phenocrysts)	5%
Chlorite	20%
Sericite	20%
Carbonate (calcite)	15%
Epidote	10%
Rutile	3%
Pyrite, chalcopyrite	1%

This rock is composed of a fairly fine, even-grained mixture of metamorphic minerals; only the quartz eyes show that it was originally a volcanic rock, and probably intermediate to felsic in composition (?dacitic).

The quartz eyes are generally less than 0.5 mm in diameter; rarely up to 1 mm. They are rounded, strained (undulose extinction), with small inclusions whose shape suggests a resorbed texture to the quartz phenocrysts. Other metamorphic minerals are intergrown at the margins of the quartz eyes. Quartz grains of the matrix are also strained, sutured and undulose, and average about 0.05 mm across. They are slightly flattened parallel to the foliation, which is defined by layering richer in the other minerals, and the orientation of the flaky minerals.

Chlorite forms fine flakes of about 0.05 to 0.1 mm length, and is often in layers up to 0.1 mm thick. It has pale green pleochroism. Epidote forms small prismatic grains, generally less than 0.05 mm long, intimately mixed with the chlorite layers. There is no yellow pleochroism visible, so the epidote may be Fe-poor. Some of the grains identified have oblique extinction and low birefringence; because of the lack of pleochroism, these could be kyanite, but this cannot be confirmed because of the small grain size. Sericite, as flakes similar in size to the chlorite, may be intermixed or may form layers separately.

Carbonate appears to be all calcite, judging by its eay reaction to dilute HCl. It forms slightly larger grains than the other minerals, averaging about 0.3 mm long, elongated parallel to the foliation.

Elongate masses of ultra fine-grained opaque and semi-opaque material, up to several millimeters long, are found in the foliation in places. These appear to be a mixture of rutile and possibly epidote; the grain size is too fine (less than 10 microns in general) to be positive of the identifications. Small grains of apatite, as stubby prisms up to 0.1 mm long, are also found in these patches. I suspect these patches represent former mafic phenocrysts that have been altered and extremely sheared to their present shapes. Pyrite forms scattered 0.5 mm euhedra, and smaller anhedral grains of chalcopyrite are also found elongated parallel to the foliation. The chalcopyrite ranges from less than 10 microns to several hundred microns long. Such finely disseminated chalcopyrite is common in chloritic Eagle Bay and related rocks that I have seen in the northern Adams plateau-Vavenby area of B.C.

I am not sure whether the chlorite of this specimen is a hydrothermal alteration product or simply the product of regional metamorphism. Field relations (of the chloritic area) may help to solve this problem.

If there are any questions, or if you feel further work is warranted, please call me at 921-8780. SEM studies are possible at UBC, where I am based (approximately $120/hr).

CHB Leitch

Craig H.B. Leitch, P. Eng.

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