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1984
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AMOCO CANADA - MINING DIVISION

MACKAY RIVER PELITIC SUITE

1 PETROGRAPHY

1.1 Mineralogy

1.1.1 Porphyroblastic, black pelitic schist, phyllite, phyllitic siltstone

Quartz

Quartz forms 40-70% of the groundmass and is very fine to fine grained, commonly with irregular or sutured grain boundaries indicating incomplete recrystallization. Quartz also occurs in small, discontinuous lenticular lamellae or segregations in association with medium grained carbonate. This quartz is somewhat coarser grained than in groundmass but it also has sutured grain boundaries and often shows undulatory extinction indicating stressed crystals (i.e. post crystalline deformation).

Quartz has been introduced on the scale of the thin section, as evidenced by cross-cutting quartz stringers in samples 2-7-A and 2-9. In 2-7-A the quartz occurs at the center of a stringer consisting mostly of carbonate. In 2-9 quartz occurs with pyrrhotite, chlorite and carbonate. The quartz is concentrated in the center of the 4-5 mm wide stringer. The margin of the stringer is marked by a 2 mm wide band of sericitization, clearly crossing and post-dating the development of the foliation of the enclosing schist.

Muscovite and Sericite

Sericite forms 20-40% of groundmass. It is very fine grained and highly birefringent. In the more schistose laminations and along cleavage and foliation planes the mica is coarser grained and individual muscovite laths can be seen.

Carbonate

Very fine grained carbonate commonly makes up 15-25% of the groundmass. It is colorless, anhedral with irregular grain boundaries and highly birefringent. Fine to medium grained carbonate segregations, surrounded by groundmass, are seen drawn-out in the foliation. This type of carbonate has very fine quartz inclusions. Schistose laminations of medium grained, colorless carbonate that have been fractured across the foliation plane during the latest post crystalline deformation occur in a few samples of pelitic schist (5-16).

This carbonate has the appearance of having been mobilized on the scale of the hand specimen but it could be also due to metamorphic differentiation.

Of most interest are the coarse porphyroblasts to 8 mm diameter that make up 10 to 30% of some varieties of the pelitic schist. The porphyroblasts are cloudy to neutral colored in thin section, dark and vitreous in hand specimen, hardness about 4-4 1/2, reacting only very slightly to cold dilute HCl, if at all, but giving a slight to moderate reaction to warm dilute HCl. In section most porphyroblasts are filled with quartz and opaque inclusions, have rounded to ragged outlines and are seen in some rocks to be drawn out in the foliation. This more common variety of porphyroblast, such as seen in the lower part of 2-1, has high birefringence and fairly uniform extinction. There is possibly a second type, seen in the upper part of 2-1, that has slightly higher birefringence (due to thickness of section) and sectored extinction. The differences could reflect the degree of recrystallization or the original chemistry (manifest in the original parent material) and be due to slight difference in iron or magnesium content. The porphyroblasts of one sample, 5-1, have been replaced by dark red-brown oxides. This could be taken to indicate a siderite component. However, most siderite (or the calcium-iron carbonate, ankerite) shows discoloration at grain boundaries or along micro-fracures and this was not observed in any of the porphyroblasts. Some porphyroblasts (2-9) have granular margins of fine grained, more clear carbonate, presumably due to post-tectonic recrystallization.

All porphyroblasts had very fine grained inclusions of quartz, sericite and opaques defining an internal s-plane (Si). In the majority of cases the inclusion trains lie in a simple, linear or curvilinear pattern (Figure 1). Cases were seen where Si was nearly parallel to the enclosing foliation or up to 45 degrees rotated from the crystallization schistosity. This texture is interpreted to have grown at the same time as the metamorphism and development of foliation (typical syntectonic "snowball" pattern with rotation in foliation outlasting crystallization).

Albite

Very fine grained albite occurs in the groundmass with sericite, quartz and carbonate. Zoning and polysynthetic twinning were seen in a few sections. It is probable that there is more albite in the rocks than is apparent, its recognition made difficult by the fine grain size and common lack of zoning or twinning in this type of rock.

Chloritoid

One section (5-1) has abundant euhedral porphyroblasts of slightly greenish gray to neutral chloritoid (Fe-Al silicate). The crystals are inclusion-filled, show polysynthetic twinning and hourglass structure. This mineral requires an abundance of alumina and iron oxide (low state of oxidation) with low calcium, magnesium and potassium contents. This concurs with the situation in 5-1, whose groundmass is of fine grained quartz, sericite and chlorite. Clear groundmass carbonate, seen in many of the other rocks is lacking in 5-1.

Chlorite

Pale green to colorless clinochlore occurs in a few of the pelitic schists where it is interleaved with muscovite in very minor amounts. Section 5-1 had the most chlorite and in this rock it had a replacement relation to the chloritoid.

1.1.2 Light gray siltite

Samples 5-5 and 5-8 are light gray, fine grained, equigranular siltites lacking the color and well developed schistosity of the black pelites. The groundmass of these is of very fine grained, anhedral quartz, albite, sericite and calcite with accessory opaques. Sample 5-8 has mostly irregular grain boundaries but some polygonal grain boundaries (triple point-junctions) were seen implying stable equilibrium. Calcite grain boundaries are very irregular and appear to have an intergranular relation. Its formation is definitely late to post-crystalline in relation to the remainder of the groundmass and it could have been introduced.

Sample 5-5 is similar but the fine quartz mosaic of the groundmass is even more sutured and in apparent disequilibrium. Calcite, present in lesser amounts than in 5-8, developed late in the paragenesis.

1.1.3 Carbonate

Sample 5-11 is of coarsely crystalline, creamy white magnesite/siderite (slightly effervescent in cold, dilute HCl, H:3 1/2 to 4). The carbonate is neutral in thin section and forms coarse crystal aggregates. The hand specimen has a brecciated aspect with fine grained black phyllitic siltite surrounding angular fragments of carbonate. The carbonate is very different in texture from that of the porphyroblasts in the pelitic schist, being crystalline and not having the fine granular appearance of the porphyroblasts.

1.2 Metamorphic Grade

The rock suite belongs to the upper greenschist facies of regional, dynamothermal metamorphism. The typical groundmass assemblage of quartz-albite-sericite (muscovite)-chlorite is characteristic of the chlorite zone. However the presence of chloritoid, which is also found north of Crooked Lake in the same rock unit, suggests a higher zone of the greenschist facies, but its appearance could be entirely due to compositional controls. There is also the possiblility that carbonate has pseudomorphed garnet porphyroblasts (widespread in these rocks in the area and discussed below). This would concur with assignment to the upper greenschist facies. Elswhere in the area chloritoid invariably appears with coarse albite porphyroblasts.

1.3 Structure

S0 is defined by compositional layering of the phyllites and schists. Samples 5-26, 3-1 and 5-26 are good examples of S0, light colored quartz-rich laminations separated by darker mica-rich layers representing original silt and clay laminations. Metamorphic differentiation has undoubtedly enhanced the laminated structure of the rock. The cyclic nature of the laminations is well expressed in sample 2-5. Compositional layering is also evident in sample 2-1 where there is clearly a difference in the amount and size of the carbonate porphyroblasts and in the amount of mica.

S2 is defined by a crystallization schistosity, with micas oriented along foliation planes parallel to the composition laminations. Examples of this are seen in 3-1 and 2-5. There is some evidence that S0 has been transposed (rotated) into parallelism with the axial plane foliation (S2). Mineral segregation and redistribution (metamorphic differentiation) accompanied the transposition. Sample 5-1, a fine grained, mica-rich pelitic schist, shows fine polygonal arcs of muscovite (Figure 2) between the dominant schistosity planes (S2). These are interpreted to represent an earlier crystallization schistosity (S1) that has been microfolded during regional metamorphism. The arcs represent relict hinges of the microfolds. A second piece of evidence, more commonly seen, is that the Si of porphyroblasts (internal s-plane) which has been rotated by S2 in some cases (2-1, 5-26).

S3 is a crenulation foliation which has microfolded or cleaved S2. Good examples of this are seen in mica-rich laminations of samples 2-5-B and 2-8. S3 arises from S2, becoming transecting and eventually cleaving the latter. In hand specimen 2-5, S3 is the axial plane of microfolded S0 and S2.

2 SPECIFIC TOPICS

2.1 Siliceous Material

Two questions are addressed here; the nature of the very fine grained silica in the groundmass of the pelitic rocks and the origin of the vein quartz.

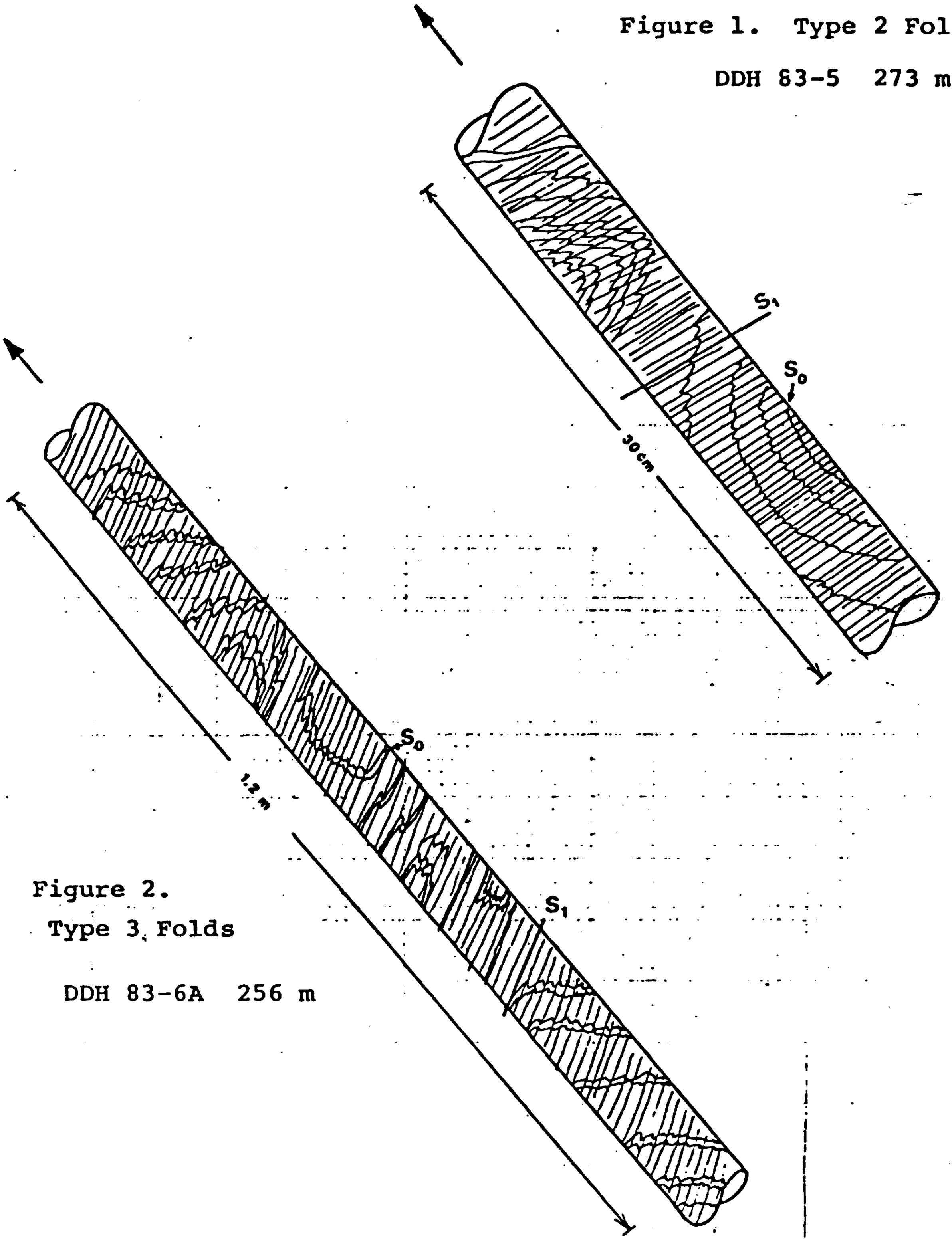

Figure 1. Type 2 Folds

DDH 83-5 273 m

Figure 2.
Type 3 Folds

DDH 83-6A 256 m

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Sept. 20/84	Frasergold Project
Figures 1, 2	STRUCTURAL STYLES

The anhedral, fine grained quartz in the groundmass is considered to have a clastic origin as part of the silt in the original argillaceous sediment, either interlaminated or admixed with clays. The pelitic, phyllosilicate-rich nature of the rocks is thought to rule against either a chert or volcaniclastic parentage. Cherty rocks of this metamorphic grade would have abundant spessartine garnet (manganese-rich) with only minor muscovite or chlorite. Metamorphic volcaniclastic rocks would most commonly be greenschists consisting of abundant chlorite and epidote.

The explanation for the origin of the vein quartz, most plausible to myself, is that it is derived from metamorphic secretions or sweats of silica fluids mobilized during the regional metamorphism. By implication, associated gold is derived from the same source. Similar origins for gold-quartz deposits in argillite-graphitic schist-quartzite rocks in the Keno Hill area, Yukon and slate-graywacke-quartzite rocks of the Meguma Group in Nova Scotia have been described by Boyle (1965 and 1966). Gold is relatively mobile during metamorphism and, aided by volatiles, moves down the temperature gradient and accumulates in the lower temperature facies, i.e.greenschist, at the same time depleting rocks in the amphibolite facies (in Boyle, 1979).

2.2 Porphyroblasts

I know of no instance of carbonate forming ragged, rounded porphyroblasts in pelitic schists. The internal texture of the porphyroblasts in the Mackay River suite are characterized by curvilinear inclusion trains. This implies that the texture at least, formed synkinematic to the regional metamorphism. Typically, dolomitic or calcareous shales metamorphosed to the greenschist facies would consist largely of calcsilicate minerals such as epidote. Any carbonate excess, over what could be accomodated by available iron, magnesium and aluminum, crystallizes as medium-sized carbonate grains with well developed cleavage and twinning lamellae. Such carbonate is often mixed intimately with quartz in elongated streaks (such as seen in several rocks of this suite). Another reason why I suspect that the carbonate did not form original porphyroblasts that were subsequently rotated is that the carbonates recrystallize very readily and are very susceptible to metamorphic segregation and local mobilization, i.e. any such large segregation of carbonate would be quickly sheared, transported or transposed and recrystallized throughout the formation of the penetrative foliation.

The fact remains that the porphyroblasts are now largely carbonate, probably mostly siderite or ankerite (I can make no definite determination on their chemistry). How then, did the porphyroblasts achieve their present make-up? I think that they are carbonate pseudomorphs after either (first choice) albite or second choice (garnet). The reasons for concluding this are as follow:

(1) Albite porphyroblasts of the same size and appearance, with rotated inclusion trains are a very typical feature of the black pelitic schists and phyllites of the Upper Triassic rock unit about the Eureka Syncline to the southeast and southwest. I have enclosed two thin sections (CAv-68-15-5 and 43-1) of such rocks. Both rocks also have large porphyroblasts of chloritoid and were taken from the garnet zone. No garnets or biotite is present in these two particular samples and this reflects the bulk rock composition controls necessary for the formation of chloritoid.

(2) Albite-chlorite-sericite schists are widely described in the literature occurring in low and medium grade pelitic schists. Their soda is derived from finely divided albite in the argillaceous parent material and in no way requires soda introduction. Fine grained albite was noted in groundmass of the Mackay River suite.

(3) The habit and texture of fine grained carbonate in the groundmass of the pelitic rocks indicates that its last (re)crystallization was late relative to the other minerals. I think that it is possible that carbonate has replaced and pseudomorphed albite porphyroblasts. This would explain their habit and texture and be more in keeping with their widepread occurrence elsewhere in the area coupled with the general absence of carbonate porphyroblasts in the black pelitic unit. The large porphyroblasts in sample 2-1, with sectored extinction, could represent a greater degree of carbonate recrystallization and "inclusion flushing" in these porphyroblasts.

(4) It is also possible carbonate pseudomorphs garnet porphyroblasts. The latter are very abundant on the south limb of the Eureka Syncline in the black pelitic schists. The latter have a very characteristic knotted appearance, not unlike the porphyroblastic pelitic schists of the Mackay River suite. It should be noted that the transition between the chlorite zone and the garnet zone is marked by the abrupt appearance of garnet porphyroblasts and the decrease in the amount of chlorite. Biotite is only present in a few localities, indicating restricted bulk rock

composition controls.

There is another feature that similar rocks to the southwest and east have that those from the Mackay River drill core lack. It could be of significance. This is the ubiquitous presence of small, elongate, glittery black ilmenite porphyroblasts. These are typically developed in the black pelitic schists and phyllites about the Eureka Syncline in the greenschist and almandine facies. Their absence in the Mackay suite could indicate a difference in the oxidation state (oxygen fugacity?) brought about by the supposed carbonatization process.

2.3 Facing

The Mackay River drill site is located on the northeastern limb of the northwest trending Eureka Syncline. Bedding dips steeply to the southwest(?) and the drill holes plunge about 50 degrees to the northeast, roughly perpendicular to the large scale bedding attitudes. An attempt was made to determine the presence of graded bedding in sample 2-5 by looking for variations in the grain size of the quartz-rich laminations or in the abundance of sericite. No consistent conclusions could be made. On the scale of the Mackay River valley older rocks are found to the northeast.

The foliation in sample 2-1 intersects the bedding plane marked by the difference in abundance or porphyroblasts and micas. The cleavage and bedding dip in the same direction with the cleavage dipping about 15 degrees more steeply. If the core is inclined at 50 degrees to the northeast and the rocks are dipping steeply to the southwest(?) then the core faces right-side up and the synformal axis is to the southwest. This agrees with the vergence direction determined from the cleavage-bedding intersection and the regional mapping.

2.4 Comparison of Samples from DDH-2 and 5

Samples 2-1, 2-3, 2-8 and 2-9 are typical black, porphyroblastic pelitic schists. Of the samples from DDH-5 only two rocks are similar; 5-9 and 5-1. Sample 5-9 is much like those from DDH-2. The porphyroblasts in 5-1 have been replaced by late-formed iron oxides. It is possible that these porphyroblasts may originally have been different material than those in DDH-2.

Samples 2-1a and 2-5 are finely laminated, light and dark, quartz siltite and sericite schist. These contain a few elongate carbonate porphyroblasts in the mica-rich laminations. Sample 5-26 is very similar to these in handspecimen. In thin section the sericite-rich laminations of 5-26 are not as well differentiated as in the two samples from DDH-2 but similar carbonate porphyroblasts occur although they have been rotated 30 to 45 degrees in S2.

Samples 2-6 and 2-7 are variations of black pelitic schist. 2-6 is a crenulated, finely laminated, light and dark siltite and phyllite. 2-7 is a kink-banded mica schist. The dark, opaque-rich phyllosilicate is thought to be a chlorite(?). One lamination incorporates a chloritoid(?) porphyroblast. This sample has been crosscut by a sericite-rimmed carbonate stringer. Sample 5-16 is comparable to these rocks. It is a dark mica schist with opaque dust-filled muscovite(?) interleaved with lenticular, clear, fractured carbonate.

The three remaining samples from DDH-5 are not represented in DDH-2. These are light gray, calcareous siltite (5-5 and 5-8) and creamy white, coarsely crystalline carbonate rock (5-11). The carbonate is either a vein or a remobilized layer in black, graphitic pelitic schist. I favor the vein origin.

In conclusion, I think that the rocks from the two holes are mostly similar. The points of difference can be reduced to the following:

(1) There is a similarity in the rock types (i) black porphyroblastic pelitic schists, (ii) finely laminated, light and dark quartz siltite and phyllite, and (iii) dark mica schists.

(2) There is a lesser number (but not exclusion) of the porphyroblastic pelitic schists in DDH-5. Is this a sampling bias?

(3) The light gray calcareous siltites are seen only in DDH-5.

(4) The carbonate vein (5-11) is seen only in DDH-5.

I do not think the samples from the two holes represent different rock suites or metamorphic grades. Of the schistose, well laminated rocks only the light calcareous siltites are absent from DDH-2. Depending upon the proximity of the drill holes and the thickness of these rocks their absence could be due to thinning-out caused either by original sedimentary aspect or by tectonic attenuation during the regional deformation. The coarse carbonate rock could be vein material (it certainly crosscuts the host phyllite on the scale of the handspecimen) and as such can not be taken to prove the holes pass through different packages of rocks.

2.5 Presence of Tourmaline

Fine grained accessory tourmaline was noted in black schists about the Eureka Syncline. During my previous work I concluded it originated from the parent sediment. No evidence was seen that could be taken to indicate tourmalinization. Accessory tourmaline was also seen in the Hadrynian quartz mica schists in the vicinity of the Perseus and Boss Mtn. anticlines.

No tourmaline was identified in the Mackay River suite.

2.6 Sequence of Events

The followiong is my interpretation of the sequence of events in the Mackay River area.

(1) Regional dynamothermal metamorphism in the mid-Mesozoic resulted in regional folding, penetrative schistosity and local metamorphic differentiation (on the scale of thin section and hand specimen). The rocks were metamorphosed in a typical Barrovian progression and in the Mackay River area achieved upper greenschist facies. Porphyroblastic chloritoid and albite pelitic schists typically developed.

(2) During the closing stages of metamorphism there was some relaxation of stress. This caused fracturing, particularly in the northeast direction perpendicular to the regional folding. Temperature conditions were such that siliceous fluids were mobilized, originating from quartz siltite, metamorphic secretions from the peltitic rocks or by metamorphic differentiation. These fluids became fracture-fillings, namely discontinuous laminations, stringers and veins. Iron, as pyrite or pyrrhotite accompanied the quartz fluids.

(3) Intrusion of the Eureka alkalic plugs into the core of the Eureka Syncline took place in post-metamorphic time (Jurassic or Cretaceous) and initialized the carbonatization process that is interpreted to have affected the Mackay River rocks. The results of this were pervasive carbonate materials being moved into the pelites as intergranular calcite in the groundmass, injection into phyllosilicate-rich laminations, replacement of albite porphyroblasts and injection of carbonate veins.

I do not know what role the carbonatization had in the gold formation. Is there any evidence to suggest a relation between the amount of carbonate and the gold content? If so then the gold could have originated in the alkalic intrusions. If not, I think that the ultimate source of the gold would have been the black clastic rocks. The conclusion of Boyle (in Section 2.1) that gold accumulates in the greenschist facies during metamorphism is relevant to the Mackay River situation.