Current Research (1990) Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 90-1, pages 201-215

PRELIMINARY GEOLOGICAL AND MINERALOGICAL NOTES ON THE NUGGET POND GOLD DEPOSIT, BAIE VERTE PENINSULA, NEWFOUNDLAND

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Mineral Deposits Section

ABSTRACT

The Nugget Pond gold deposit, discovered by Bitech Energy Resources Limited in 1988, is one of Newfoundland's most significant new gold discoveries. To the end of 1989, 106 diamond-drill holes have outlined drill-indicated reserves of 514,000 tonnes, grading 14.1 g/t gold. The deposit is hosted by volcaniclastic and hydrothermal sediments within the pillow lavas of the Betts Cove (ophiolite) Complex. Mineralization is stratabound, and is concentrated in a dark-green to black pyritic argillite horizon. Highest gold grades are associated with very coarse euhedral pyrite. There is little evidence of shearing, widespread hydrothermal alteration or metasomatism.

Microscopic studies reveal a complex history of mineralization and veining, reflecting both syngenesis and processes related to weak regional deformation. Syngenetic and later epigenetic pyrite is the major sulphide phase, with accessory chalcopyrite, galena and pyrrhotite. Gold occurs as electrum and is commonly late in the paragenetic sequence. Stilpnomelane is widespread in iron-rich horizons and veins proximal to ore.

Although gold observed, to date, is generally late in the paragenetic sequence, it has probably been remobilized, and the present evidence does not constrain the timing of its original introduction into the environment. Both syngenetic and epigenetic models of mineralization can be entertained. Further detailed studies of the ore are needed to fully document the mineralization and interpret its genesis.

INTRODUCTION

The Nugget Pond gold deposit is located on the southeastern side of the Baie Verte Peninsula, Newfoundland (Figure 1), and is hosted by volcaniclastic sedimentary rocks within the pillow lava sequence of the Betts Cove (ophiolite) Complex. Discovered in the summer of 1988 by Bitech Energy Resources Limited, the deposit is unique among central Newfoundland gold-only deposits in several respects. As pointed out by Dubé (1990), it is the sole representative of the stratabound, sediment-hosted class of gold-only deposits in Newfoundland. The mineralization is hosted by volcaniclastic—hydrothermal sediments, which do not show extensive evidence of structural disruption. There is no obvious relationship between the mineralization and major structures. There is little evidence of widespread alteration and/or metasomatism, and the sulphide mineralogy is relatively simple, dominated by pyrite with very minor base metals and no anomalous concentrations of the common 'gold tracers' (e.g., Sb, As). The lack of structural control and significant hydrothermal alteration make this an unusual type of gold deposit, and suggest that pyritized black argillites—shales and volcaniclastic sedimentary rocks elsewhere in the Appalachians may be an important exploration target for gold.

This paper is an initial attempt to describe and synthesize the geological and preliminary petrographic data for the deposit. Description of the geological setting of the deposit is taken mainly from mapping and drill-core logging by Bitech geologists, supplemented by contract mineralogical studies on selected rock samples, and follows previous descriptions by McBride (1988). Petrographic and mineralogical studies reported in this paper were carried out on samples collected from trenches on the property, during the summer of 1989. The petrographic work did not involve systematic sampling of drill core, and is not a comprehensive study of the mineralization. This report, therefore, cannot address details of the genesis of the deposit, although the data do provide some constraints in this regard.

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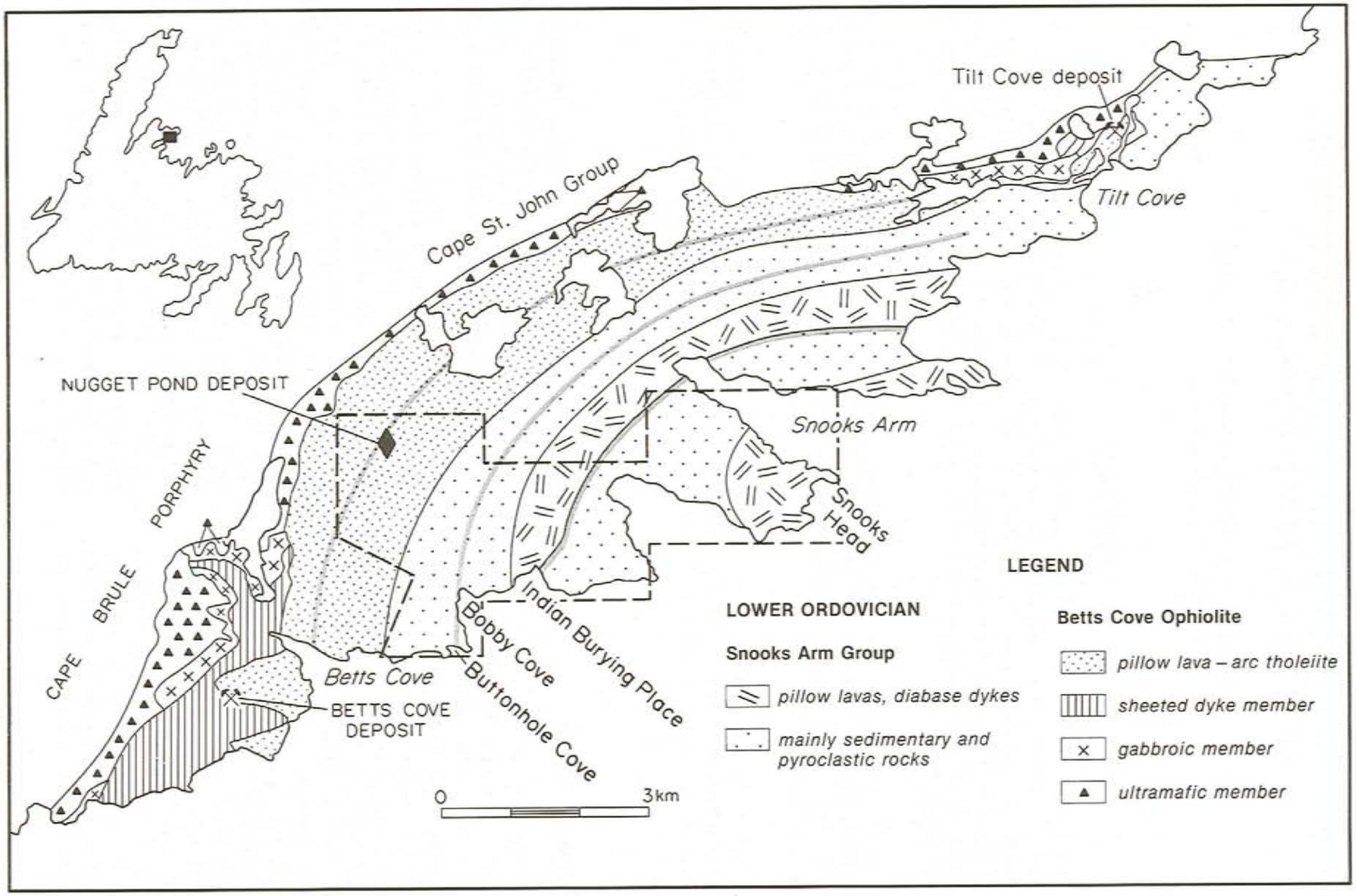

Figure 1. *General geology of the western part of the Betts Cove (ophiolite) Complex and the Snooks Arm Group, and location of the Nugget Pond deposit. Three grey bands represent red and maroon volcaniclastic and hydrothermal sedimentary units. The Bitech Nugget Pond claim block is shown by the dotted line. The Betts Cove and Tilt Cove deposits are volcanogenic massive sulphides.*

DISCOVERY

A property submission originally drew the attention of Bitech Energy Resources Limited to the area. Interest in the gold potential of the ophiolitic rocks of the Betts Cove–Tilt Cove area was stimulated by comparisons of the volcano–sedimentary sequence, with similar Archean gold-bearing rocks in the Beardmore area, northwestern Ontario (McBride, 1987). Ground acquisition began in mid-1987 by Tashogan Minerals Limited and individuals, to cover the favourable geology.

Reconnaissance soil geochemistry was used in 1987 to assess the gold potential of all claim blocks. The most encouraging results consisted of two values above 500 ppb in the northeastern corner of the central claim block. Follow-up surveys on this and two other soil geochemical anomalies, yielded soil anomalies of 4600, 6700 and 34,000 ppb in the Nugget Pond area. Panning gravels on the shore of Nugget Pond yielded delicate gold flakes and leaves; trenching uphill from these sites led to the discovery of gold in bedrock at the end of July, 1988. In the succeeding months, extensive drilling on a 25-m spacing outlined the zone. To the end of 1989, 106 diamond-drill holes have yielded a drill-indicated reserve of 514,000 tonnes, grading 14.1 g/t Au, which includes a dilution of 25 percent at zero grade.

REGIONAL SETTING

The Betts Cove (ophiolite) Complex, host to the Nugget Pond deposit, outcrops along a strike length of more than 30 km along the eastern side of the Baie Verte Peninsula (Figure 1). The ophiolitic sequence, although somewhat disrupted by faulting, includes, in ascending stratigraphic order, a basal cumulate ultramafic unit up to 750-m thick, layered and massive gabbro up to 330-m thick, sheeted dykes ranging from 400-m to 1.6-km thick and pillow lavas (having minor intercalated volcaniclastic sedimentary rocks up to 1.5-km thick (Upadhyay, 1973)). The ophiolite is conformably overlain by an approximately 3-km-thick sequence of interbedded volcanic (dominantly mafic) volcanic rocks and epiclastic turbidites assigned to the Snooks Arm Group (Hibbard, 1983). Pegmatitic gabbro in the ophiolite has been dated by U–Pb (zircon) as 488^{+3}_{-2} Ma (Dunning and Krogh, 1985), consistent with the occurrence of lower to middle Arenigian (Lower Ordovician) graptolites in the basal part of the Snooks Arm Group (Snelgrove, 1931; Williams, 1989).

The Betts Cove complex is unconformably overlain by Silurian volcanic rocks of the Cape St. John Group (DeGrace *et al.*, 1976). It is intruded at its southwestern end by the Ordovician Burlington Granodiorite and on its western side by the Silurian Cape Brule Porphyry.

Detailed mapping by Bitech geologists in the Betts Cove Complex–Snooks Arm Group succession suggests that at least four volcano–sedimentary cycles can be defined, each comprising sustained eruption of dominantly pillow lava, followed by an interval of volcaniclastic–hydrothermal sedimentation. The lower two cycles are in the Betts Cove Complex as presently defined, the latter two in the Snooks Arm Group. Gold is concentrated to some extent in intervolcanic sedimentary rocks at the end of each volcanic cycle.

The basal volcanic cycle in the Betts Cove Complex overlies the sheeted dyke and plutonic complex and consists of a 1.5-km-thick sequence of pillow lavas overlain by the Nugget Pond volcaniclastic sedimentary rocks (Figures 1 and 2).

The base of the second volcanic cycle is composed of a rock of intermediate composition with pale grey-weathering lapilli, and plagioclase crystals and glomerocrysts up to 1-cm in diameter set in a medium grained matrix. This passes up into more than 1 km of pillow lavas, which locally contain felsic dykes. The lavas are conformably overlain by a second sequence of fine grained, maroon and green volcaniclastic and exhalative sediments, which comprise the Bobby Cove Formation, the basal unit of the Snooks Arm Group.

The third sequence of pillow lavas, the Venams Bight Formation, comprises dominantly pillow lavas, which culminate once again in a sequence of maroon and green volcaniclastic slates that underlie Indian Burying Place, and are exposed along Snooks Arm and on the old trail between the two settlements. These sediments are again overlain by pillow lavas (the Round Harbour Formation), which constitute the fourth pillow lava cycle and the top of the Snooks Arm Group.

Bedding in the Betts Cove–Snooks Arm sequence in the Nugget Pond area is generally southeasterly dipping and south-facing. Dips flatten from north to south across the succession. A weak slatey cleavage, parallel to bedding, is locally evident but of unknown significance. Open folds with axial planes roughly perpendicular to the regional bedding, but lacking an axial plane cleavage, are present in the sedimentary horizons at Bobby Cove and Betts Cove. On the scale of a few hundreds of metres, this folding has locally warped the regional trend of the mineralized horizon.

The Betts Cove Complex is host to numerous prospects and two former base- and precious-metal producers, the volcanogenic massive sulphide (VMS) deposits at Tilt Cove and Betts Cove. Both were mined before the turn of the century for their copper and in later years, zinc and some gold were recovered from the Tilt Cove deposit as well. Both deposits contain significant associated gold (Hurly and Crockett, 1985; Saunders, 1985) and recent work has shown significant silver, zinc and lead to be present at the Betts Cove deposit (Strong and Saunders, 1988).

Minor gold-only and gold-copper occurrences are found throughout the Betts Cove Complex (Hudson, 1988; Al, 1989). These include the Nudulama prospect near Tilt Cove and the Burton's Pond prospect west of Betts Cove, both described as narrow veins and/or sulphide-rich bands, hosted by ultramafic rocks. To date, no deposit of this type has proven

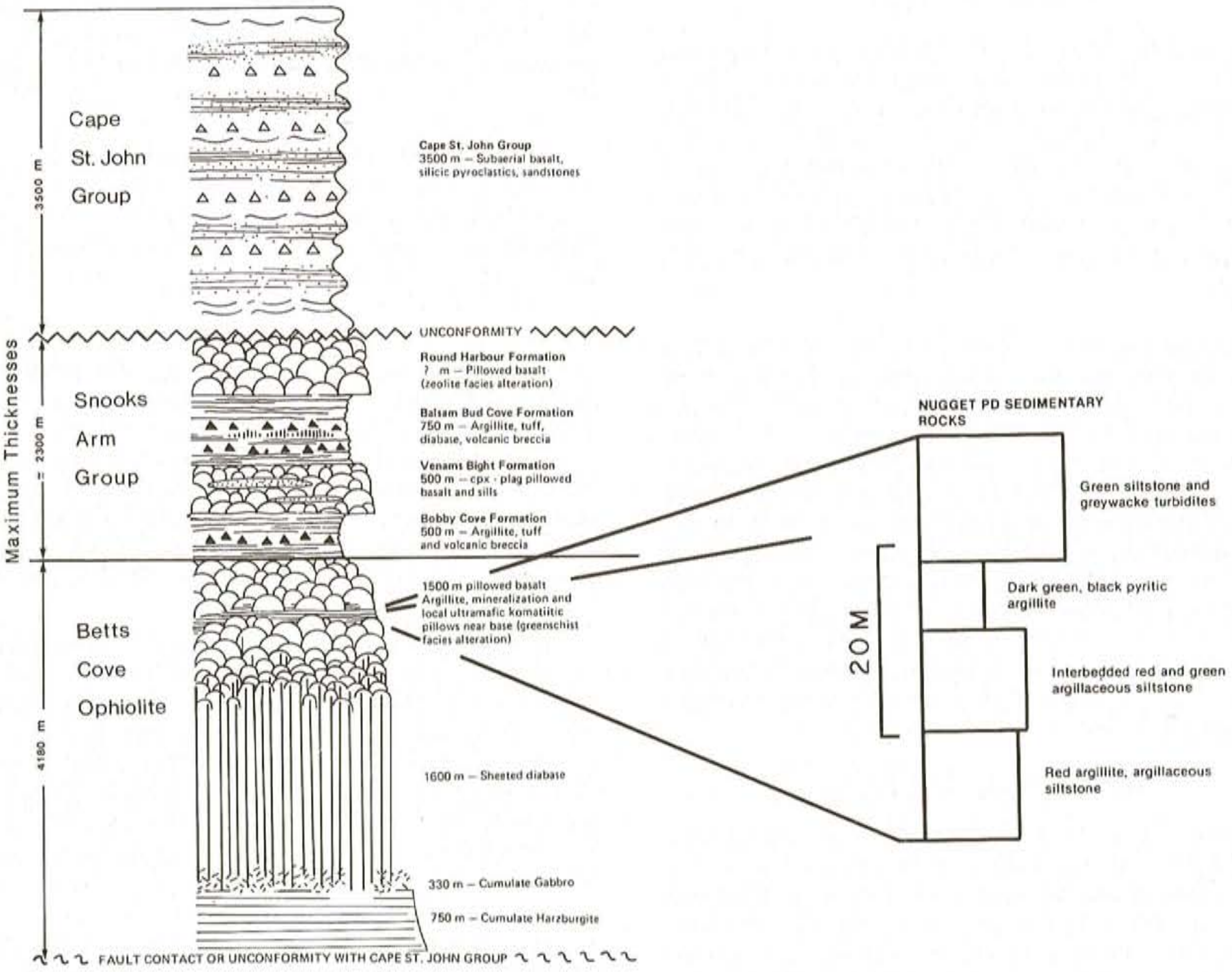

Figure 2. *Generalized stratigraphy of the Betts Cove (ophiolite) Complex, Snooks Arm Group and Cape St. John Group, from Strong and Saunders (1988). Detailed stratigraphy of the sedimentary interval that hosts the Nugget Pond deposit is expanded to the right. Economic grades of mineralization occur mainly in the dark-green to black pyritic argillite.*

to be economically significant. The Nugget Pond prospect is the only gold-only deposit hosted by mafic volcanic rocks of the Betts Cove ophiolite.

GEOLOGY OF THE CLAIM BLOCK

The Bitech Nugget Pond claim block (Figure 1) includes an almost complete section of the Snooks Arm Group and a substantial thickness of the Betts Cove Complex pillow lavas. The lowest stratigraphy on the property is in the northwest corner, where the top part of the cycle 1 Betts Cove Complex pillow lavas are overlain by a thin 'umber' type volcaniclastic sequence (Figure 2), comprising a basal maroon unit grading upward into a well-bedded, green sequence of moderately siliceous fine grained clastic sedimentary rocks. Above these rocks, is a succession of medium green lapilli tuffs and/or porphyritic lavas, which are in turn overlain by a thick succession of pillow lavas of the second cycle. These contain some crosscutting and possibly conformable felsic members toward the top of the succession. This cycle culminates in a thick succession of green- and red-bedded siliceous rocks, assigned to the Bobby Cove Formation, which outcrop in Bobby Cove and Button Hole Cove.

The next mafic pillow sequence terminates in a red and green sequence seen in the Snooks Arm area. These rocks are overlain by pillow lavas exposed at Snooks Head.

The Nugget Pond deposit is hosted by epiclastic sedimentary rocks at the top of the first volcanic cycle (Figure 2). In the vicinity of the deposit, the horizon strikes northeast and dips southeast at 45 to 50°, and abundant facing evidence from pillow tops and graded beds, indicates a tilted but generally upright sequence. In the discovery area, the basal pillow lavas are overlain by a succession of finely laminated red to maroon slates and argillaceous siltstone from 3- to 4-m thick (Figure 2). These grade upward through approximately 3 m of alternating red- and green-bedded argillaceous siltstone and sandstone, into 2 to 3 m of predominantly dark-green to black argillites, which locally contain banded and disseminated pyrite. These are in turn overlain by 12 m of green, well-bedded siltstone and greywacke turbidites. The green sediments are overlain by green porphyritic lava and lapilli tuff, which forms the base of the second cycle volcanism.

Both the basal, red sedimentary rocks and the dark-green to black argillites form a continuous mappable unit across the property. The hanging wall green siltstone and greywacke turbidites can be traced over many kilometres as a 10-m thick band (Figure 1).

MESOSCOPIC FEATURES OF MINERALIZATION

Pyrite is the only sulphide mineral observed in hand specimen. It is most abundant in the dark-green to black argillites, where it most commonly occurs as fine grained laminae and veinlets and as discrete crystals up to 5 mm in diameter. Pyrite contents range from 1 to 60 percent of the rock and average about 5 to 10 percent.

Very coarse pyrite cubes are locally present in the dark-green to black argillites and in the red and green siltstones in the lower part of the sedimentary interval. This pyrite forms disseminated cubes up to 2 cm across, which are concentrated parallel to bedding. The gold content varies directly with this coarse grained pyrite.

Diamond drilling indicates that economic mineralization is stratabound within the dark-green to black sedimentary rocks (Figure 3), in a trough that rakes at 45° to the south. On both sides and bottom, the grain size of the pyrite and thickness of the mineralized section decrease rapidly, accompanied by a decrease in the gold content to maximum values of less than 100 ppb.

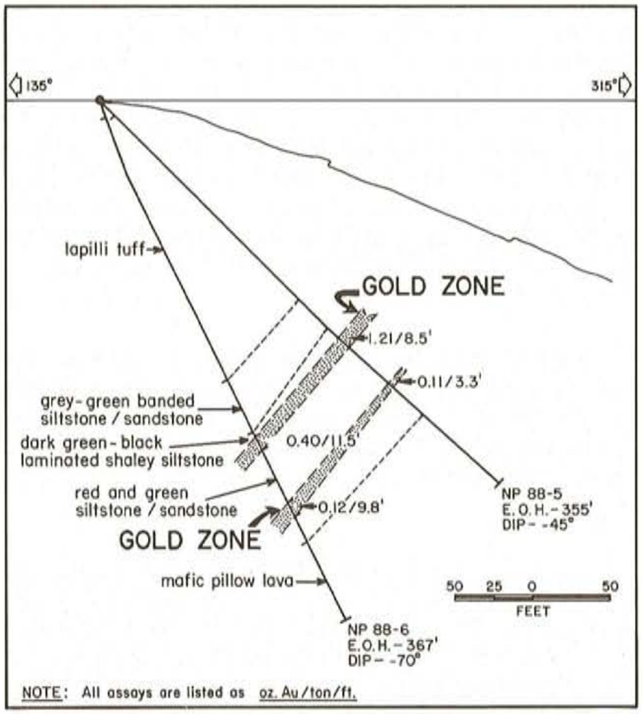

Figure 3. *Cross-section of the Nugget Pond deposit from drill sections.*

The coarse pyrite cubes are well formed and many have traces of sedimentary laminae within them, which preserve a ghost stratigraphy through the grain. Where fine grained sedimentary bands exist in the sedimentary sequence, it is common to see the cubes concentrated along the bedding planes. At the same time, pyrite occurs in crosscutting albite–carbonate veins, which only are found in the favourable horizon and below, are not auriferous.

Locally, conformable sulphide-rich layers have been observed to be folded, with pyrite still outlining the bedding. It other cases, pyrite forms veinlets that trace a fanning slatey cleavage, axial planar to minor tight folds.

The host sedimentary horizon can be traced to both property boundaries as a continuous 3- to 5-m-thick, green chloritic sediment but it never contains more than a few 100 ppb gold, except within 100 m of the deposit. Although locally cut by small (<0.5-m wide) schist zones, there is no evidence in outcrop or drill core for widespread hydrothermal alteration or deformation associated with the mineralization and major structures have not been identified in the vicinity of the deposit, which might be related to the ore.

MICROSCOPIC FEATURES OF THE MINERALIZED ZONE

Thin sections of all rock types in the Nugget Pond sedimentary interval were examined to determine the nature of the sedimentary succession, to look for evidence of alteration or metasomatism related to mineralization, and to determine the relative chronology of events that might be related to mineralization. Polished sections were examined in reflected light to determine sulphide mineralogy and paragenesis and by scanning electron microscope (S.E.M.), to confirm mineral identifications and to test for the presence of mineral phases too fine to be resolved optically.

Rock Types

In thin section, the basal red argillaceous siltstone comprises very fine grained, laminated rocks. The groundmass is generally too fine to resolve optically and may have been in part volcanic ash. Resolvable clastic grains are dominantly altered feldspar, having lesser quartz and mafic volcanic lithic fragments. Laminae on a scale of less than 1 mm are defined by varying concentrations of very fine grained hematite dust, and locally by thin bands of euhedral carbonate crystals, probably of diagenetic origin. The gradation upward into the interbedded green and red sediments (Plate 1) is mainly a function of decreasing hematite contents, at the expense of chlorite. Proximal to mineralization, these rocks locally contain up to 20 percent stilpnomelane (identification confirmed by S.E.M., Figure 4), which variously occurs (Plate 2) as individual crystals and crystal sheaves randomly oriented in the rocks, and as thin laminae (<1 mm) of almost massive stilpnomelane, in clusters adjacent to porphyroblastic pyrite grains, and as aureoles to hematite–pyrite veinlets.

The groundmass and clast mineralogy of the dark-green to black argillites in the mineralized horizon is similar to the

Plate 1. *Interbedded red (dark) and green (light) volcaniclastic sandstone and siltstone near the base of the Nugget Pond sedimentary interval.*

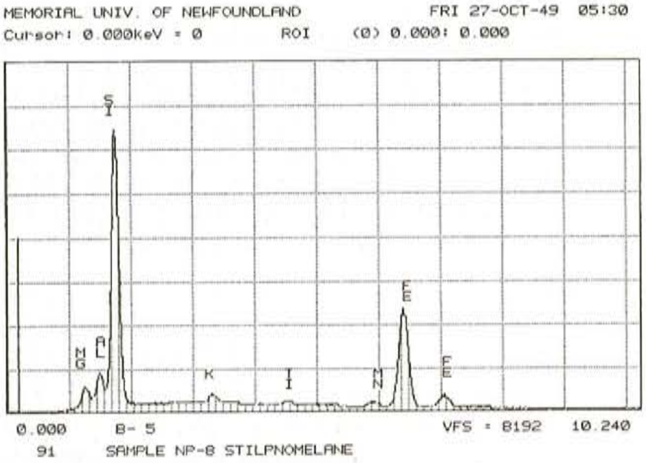

Figure 4. *Scanning Electron Microscope spectrum of stiplnomelane from the Nugget Pond deposit.*

underlying green and red slates, with the exception that green chlorite and pyrite, rather than hematite, are the dominant iron-bearing phases. Chlorite makes up to 30 to 50 percent of the rock, with most of the remainder being a fine grained quartzofeldspathic groundmass. Feldspar crystal fragments and mafic volcanic clasts are locally present. Laminae are defined by varying proportions of chlorite and are locally defined by pyrite.

Green siltstones and greywackes above the mineralized horizon comprise altered feldspar, quartz and mafic volcanic clasts in a quartzofeldspathic, variably argillaceous groundmass. Traces of diagenetic carbonate are also locally observed.

Mineralization

As noted, there is no petrographic evidence of widespread alteration or metasomatism of the sedimentary sequence that hosts the mineralization, with the exception of some small, chloritic schist zones and the local presence of stiplnomelane (see below). However, study of thin and polished sections provides some constraints on the geological history of the mineralized horizon. The mineralization and alteration history at Nugget Pond is mainly recorded in the pyrite, the most abundant sulphide phase, and in the minor veins and veinlets that have cut the zone at various stages of its history. Some aspects of the chronology of events that have affected the mineralization can be deduced by mutual crosscutting relationships between the principal mineralogical (mainly pyrite, stilpnomelane) and geological (mainly folding, cleavage) elements. Because we have examined only a limited number of thin sections, the story is far from complete. However, our observations do provide a description of the main features of the mineralized zone, some constraints as to the mineralization history and suggestions for areas for further work.

Pyrite. Pyrite is the most abundant sulphide phase in the mineralized zone. At least five stages of pyrite crystallization can be recognized from crosscutting relationships, herein termed pyrite 1 to pyrite 5 inclusive.

Pyrite 1 is the earliest pyrite that can be recognized (Plate 3). It occurs only in the dark-green to black argillites, forming small (<0.5 mm) subhedral to euhedral grains disseminated through the groundmass, laminae of fine grained pyrite parallel to bedding, and very coarse (up to 2 cm) pyrite cubes locally concentrated parallel to bedding planes. Pyrite 1 laminae are locally crosscut or overgrown by younger pyrite and/or gangue veinlets (veinlets 1 to 3, see below; pyrite 3, Plate 2c). The disseminated pyrite does not generally show evidence of recrystallization and may be original sedimentary pyrite, generated through the decay of organic material and the activity of anaerobic bacteria, although this cannot be conclusively demonstrated.

Pyrite 2 occurs in early quartz–feldspar–chlorite veins (veinlets 1, see below) that are deformed and cut by younger quartz–chlorite veinlets (veinlets 2 and 3). The veins apparently formed through open space filling, and medium grained, euhedral crystals of pyrite locally line their edges (Plate 4).

Pyrite 3 occurs as subhedral to euhedral grains that have crystallized, associated with minor chlorite and quartz, in a fanning cleavage, which is axial planar to minor tight folds (Plates 3a and c; Plate 5). This may represent pyrite that has been remobilized into the cleavage planes during deformation. The cleavage clearly crosscuts pyrite 1 laminae. Besides remobilization into cleavage, there has been significant recrystallization of earlier pyrite, evidenced by pyrite overgrowths on earlier pyrite euhedra. Some of this recrystallization may also represent this phase of pyrite crystallization.

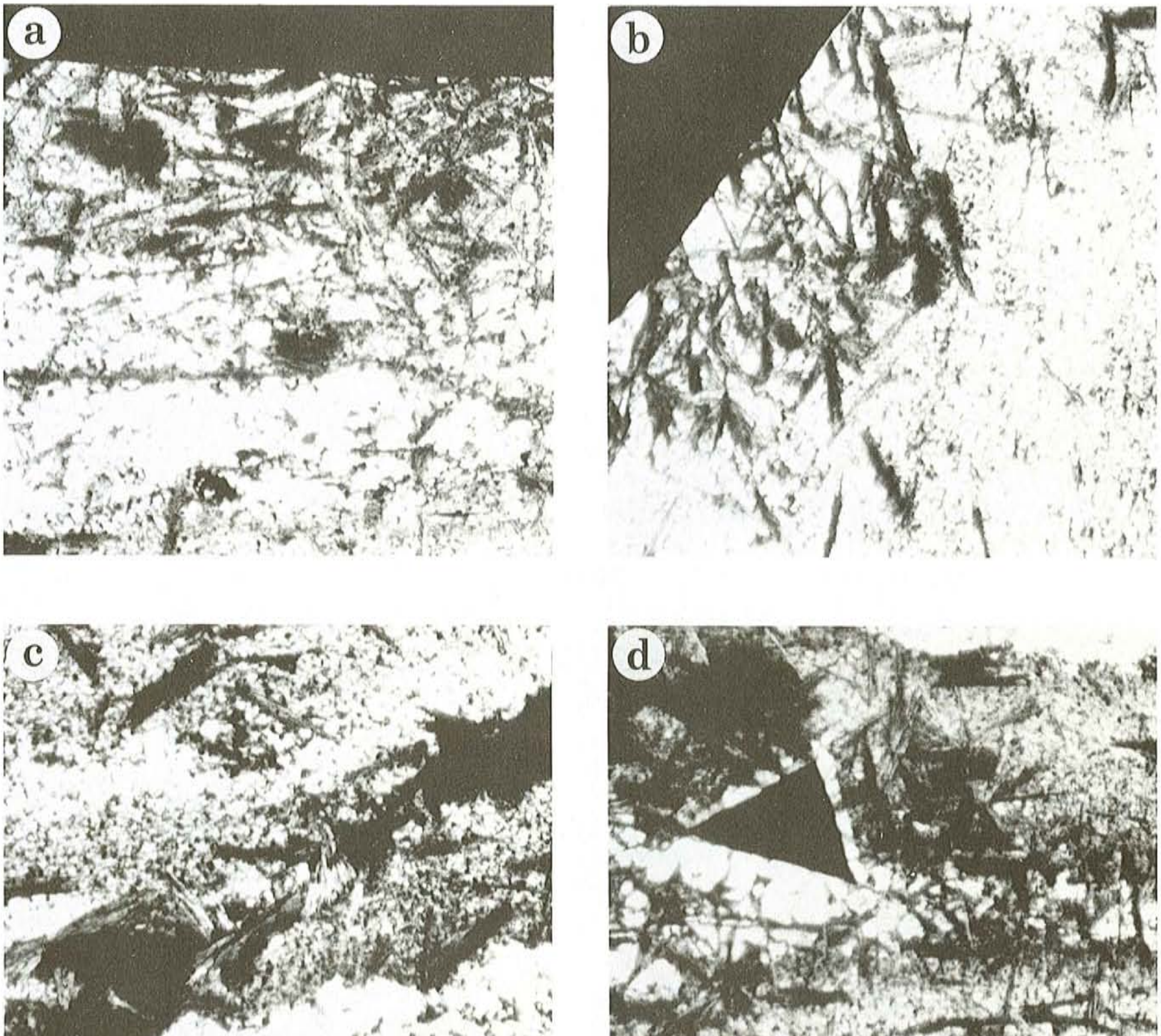

Plate 2. *Photomicrographs of stilpnomelane (acicular dark-grey and black crystals) near the Nugget Pond deposit. All are in transmitted plane polarized light, field of view approximately 2.5 mm; 2a—concentrated in an iron rich lamina in volcaniclastic sediments (bedding is horizontal); 2b—clusters of randomly oriented crystals; 2c—a veinlet (veinlets 4) of hematite, pyrite and stilpnomelane crosscuts and offsets bedding (horizontal); 2d—randomly oriented crystals clustered around a coarse pyrite crystal (black triangle). Bedding is horizontal.*

Pyrite 4 occurs in thin veinlets associated with stiplnomelane and chlorite (Plate 2c), in footwall red argillaceous siltstones near the mineralized zone. The pyrite both overgrows and is overgrown by stilpnomelane, and the two minerals are interpreted to be coeval (see below).

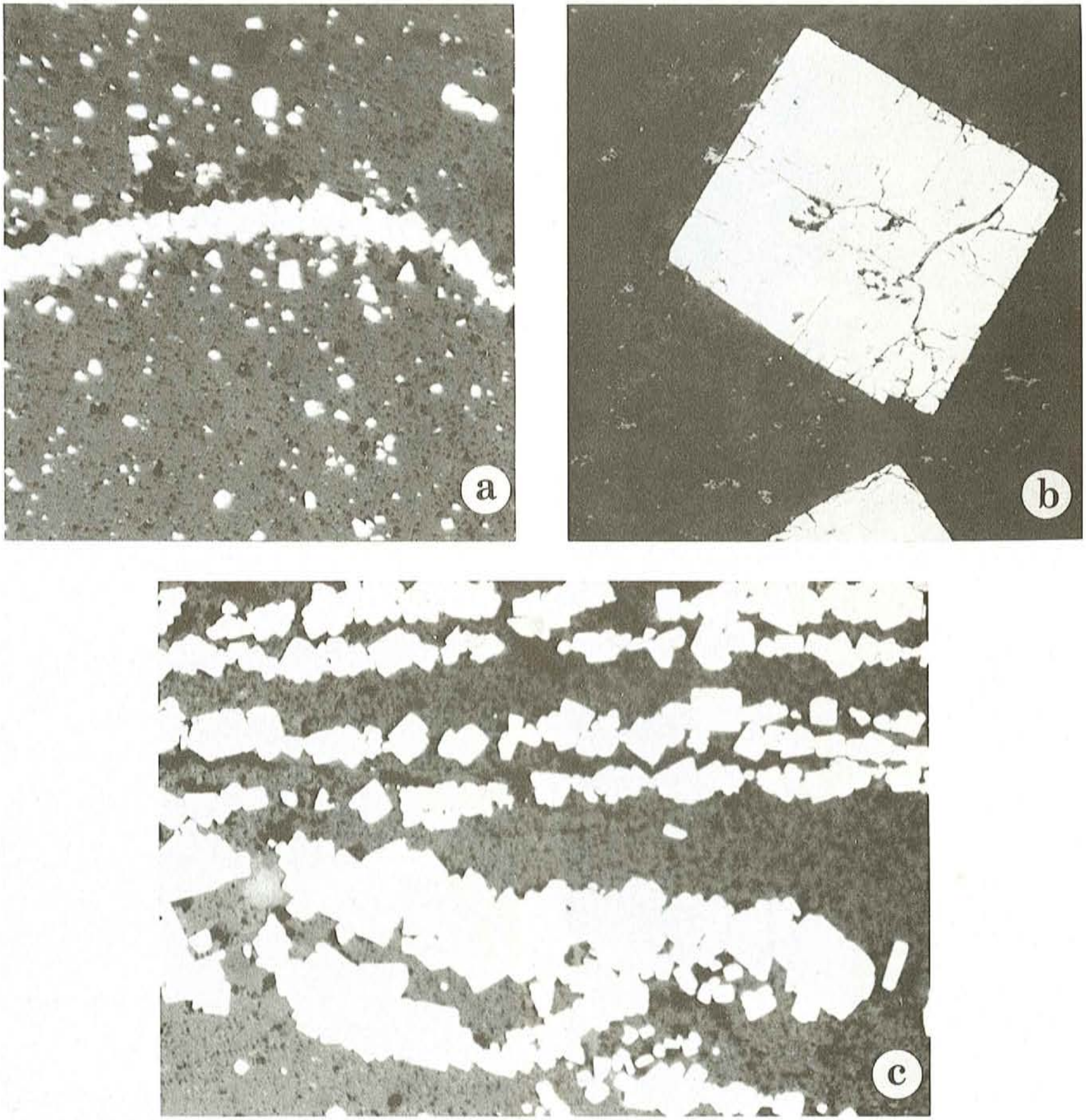

Plate 3. *Modes of pyrite 1 occurrence. All photomicrographs taken in reflected light; 3a—disseminated fine grained pyrite in dark-green argillaceous siltstone. Curved veinlet of coarser grained pyrite in centre of photo is pyrite 3 following a cleavage plane; field of view is 2.5 mm; 3b—coarse grained euhedral pyrite. field of view is 2.5 mm; 3c—fine grained pyrite laminae (horizontal at top of photo) are parallel to bedding. Coarser grained pyrite veins at an angle to bedding are pyrite 3 following cleavage planes; field of view is 4 mm.*

Pyrite 5 comprises very coarse (up to 2 cm) subhedral to euhedral pyrite cubes, found both in the dark-green to black argillites and in the underlying red and green argillites. The crystals locally can be seen to cut a flattening fabric, which is probably related to formation of the cleavage and pyrite 3, and therefore are younger than the coarse pyrite 1 crystals, which they otherwise resemble. This generation of pyrite also overgrows the local chloritic schist zones. Pyrite 5 commonly has small pressure shadows of chlorite and/or quartz suggesting that it crystallized during the last stages of deformation (see schist zones below).

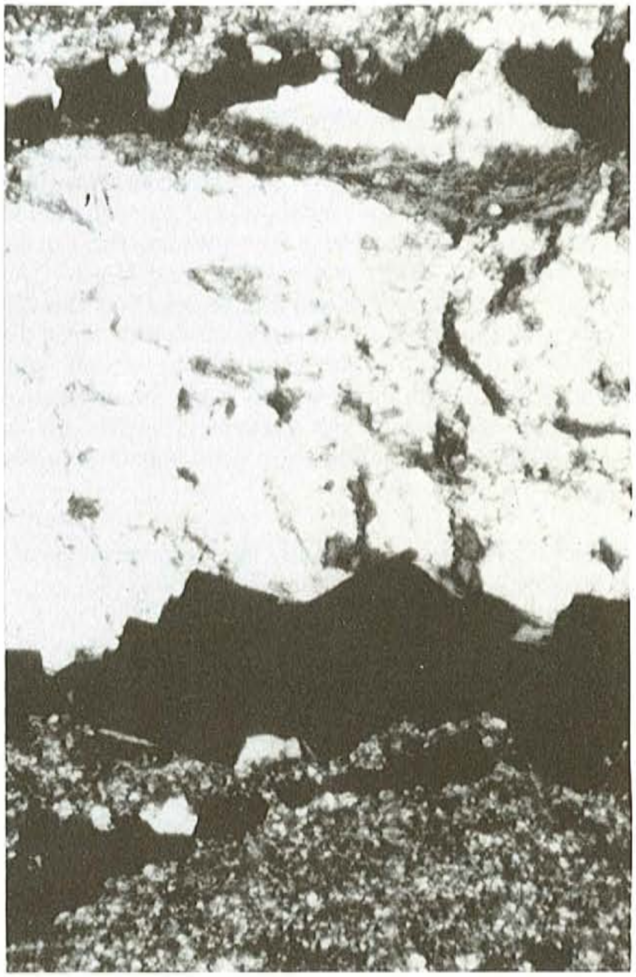

Plate 4. *Photomicrograph of pyrite 2 in a quartz (white)—chlorite (grey) veinlet cutting volcaniclastic siltstone. Coarse pyrite 2 lines both top and bottom of the veinlet. Plane, transmitted light; field of view is 2.5 mm.*

Other Sulphides. Chalcopyrite is the most abundant minor sulphide phase. Although most commonly observed as anhedral inclusions in pyrite of all generations (Plates 6 and 7), it also occurs as anhedral blebs along the boundaries of later generation pyrite crystals (pyrite 3 to 5), and locally in thin fracture fillings cutting both pyrite and nearby gangue. Although ubiquitous, chalcopyrite seldom exceeds 0.5 percent of total sulphides.

Accessory galena and pyrrhotite have been identified with the S.E.M. (Plate 7). Like chalcopyrite, these minerals commonly occur as inclusions in all generations of pyrite. Unlike chalcopyrite, they are commonly very fine grained, in the 5- to 50-μ range. Galena is locally seen as fracture filling inside pyrite crystals or along pyrite grain boundaries.

Veinlets. Thin sections reveal a generally consistent sequence of crosscutting relationships among several types of minor veinlets that cut the mineralized zone. These types are herein termed veinlets 1 to 6 inclusive.

Plate 5. *Hand specimen of black argillite and argillaceous siltstone from the mineralized zone. Disseminated pyrite 1 is abundant. The bedding outlines a small fold nose at the top of the sample, and pyrite 3 veinlets define a fanning cleavage that is axial planar to the fold. Width of the sample at the base is about 10 cm.*

Veinlets 1: The earliest veining identified in thin section is the quartz—feldspar—chlorite veinlets that host pyrite 2 (Plate 4, see above). These are relatively thick (2 to 4 mm) veinlets and are clearly cut by later quartz veinlets (veinlets 2, see below) and are locally deformed in small chloritic schist zones (see below).

Veinlets 2: These include a series of thin (<0.5 mm), mainly quartz-only veinlets that cut the first stage veinlets and are themselves cut by the pyritic cleavage traces that are axial planar to the minor folds (pyrite 3). Locally, these veins are folded and some have been offset along cleavage traces (Plate 8). They show complex and mutually confusing crosscutting relationships among themselves. Locally, these veinlets contain minor chlorite, particularly when cutting across an earlier veinlet; no pyrite in this vein.

Veinlets 3: These are quartz (± minor chlorite) veinlets that are similar in size and appearance to veinlets 2, but which

Plate 6. *Photomicrograph of coarse euhedral pyrite (pyrite 5?) with inclusions of chalcopyrite (cpy). Reflected light; field of view is 0.3 mm.*

cut pyrite 3-bearing cleavage traces. These veinlets are locally overgrown by individual subhedral pyrite crystals that are coarser than those in the cleavage traces and are probably pyrite 5.

Veinlets 4: These comprise coarse grained, feldspar-rich veinlets, seen in only one thin section. They have been described more extensively in hand specimen and drill core, where they are found to be vuggy, relatively late paragenetically, and unmineralized.

Veinlets 5: These are very thin, iron-rich veinlets that occur mainly in the ferruginous sediments below the mineralized horizon. They normally comprise a very thin core of hematite, quartz, and pyrite (pyrite 4, see above) and generally exhibit a wide aureole of stilpnomelane. These veinlets crosscut the fabric related to folding and cleavage development, and veinlets 4. Stiplnomelane related to these veins both cuts and is cut by stiplnomelane crystals in the country rock and the veinlets are therefore interpreted to be coeval with stiplnomelane growth in the country rock. Similar mutual crosscutting relationships with coarse pyrite euhedra (pyrite 5) suggest that they are probably also synchronous with pyrite 5 growth.

Veinlets 6: These are numerous, late, very small quartz veinlets that seem to crosscut everything (Plate 9).

Schist Zones. Small chlorite–quartz ± feldspar schist zones are locally present in the mineralized zone, although they do not show any spatial association with higher grade mineralization. The schist zones all contain fine- to medium-grained pyrite. Locally, fine pyrite grains are augened by the schistosity. More commonly, however, coarse pyrite euhedra overgrow the schist fabric. Quartz–feldspar–chlorite veinlets (probably veinlets 1) are deformed in these zones and they are cut by later quartz veinlets, possibly veinlets 3. The schist zones, therefore, seem to be bracketed by the same events that bracket the formation of cleavage related to minor folds and are interpreted to be coeval with the folding.

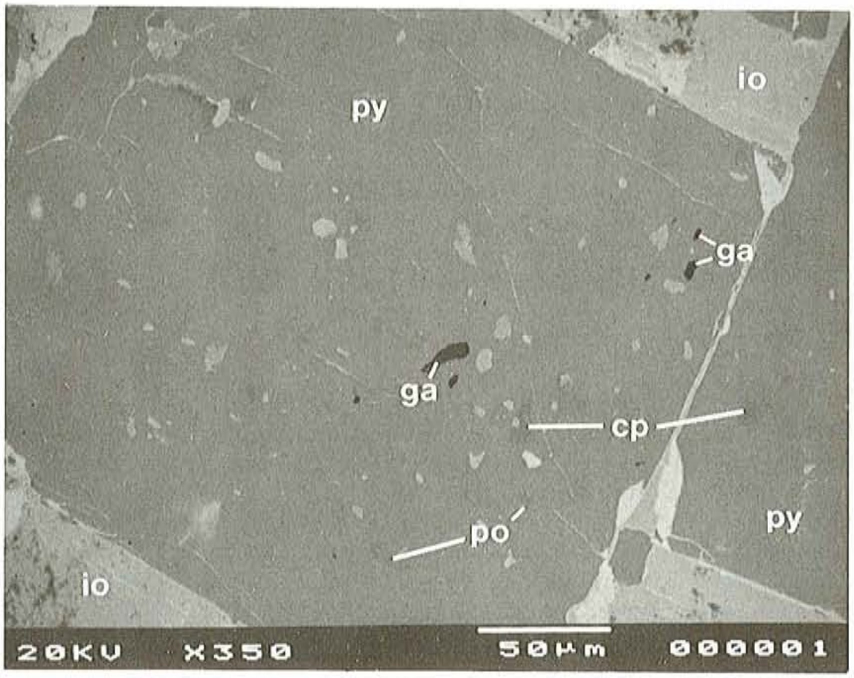

Plate 7. *Electron backscatter image of sulphides in the mineralized zone. Coarse, euhedral pyrite has inclusions of galena (ga), chalcopyrite (cp) and pyrrhotite (po).*

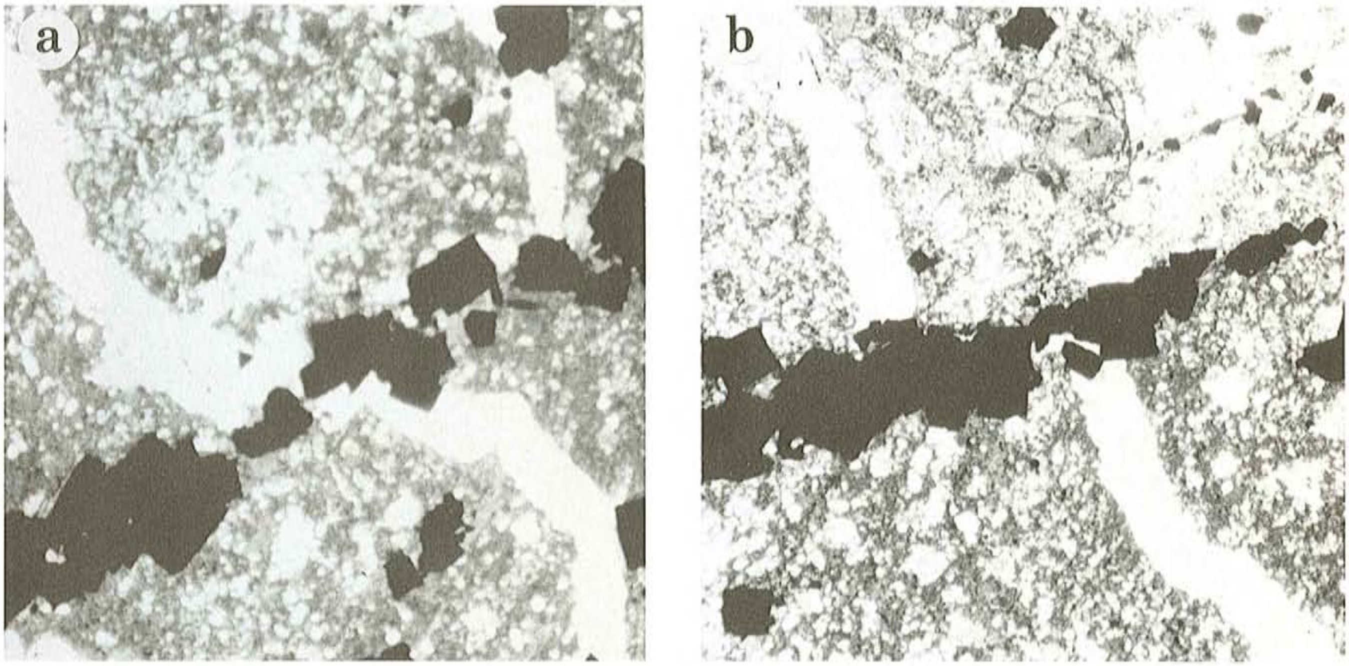

Plate 8. *Photomicrographs showing veinlets 2. Both taken in transmitted plane polarized light; field of view is 2.5 mm; 8a–quartz veinlet (sinuous white band) is folded and cut by pyrite 3, which is following a cleavage plane; 8b–the same veinlet is offset along a pyrite 3-filled veinlet that follows the cleavage.*

Plate 9. *Photomicrograph shows a narrow veinlet 6 of quartz, which crosscuts an earlier quartz–chlorite veinlet (veinlets 2?) and stilpnomelane crystals (black, acicular crystals). Taken in transmitted, plane polarized light; field of view is 2.5 mm.*

Gold. Gold has been observed in only one polished thin section. However, additional observations of gold in polished section have been reported by Lewczuk (1989). Considerable further systematic petrographic work is needed to fully document the occurrence of gold in this deposit. The gold that we have observed is closely associated with coarse subhedral to euhedral pyrite, which is either pyrite 1 or pyrite 5. In our mineralized specimen, the pyrite occurs in elongate clusters of crystals and the gold locally occurs within the pyrite crystals, although always within about 50 μ of the edge of the crystal. More commonly, it is observed at the pyrite crystal boundaries and locally is within the nearby gangue (Plate 10). Gold grains range from 10 to 100 μ in size. Similar settings for gold are also described by Lewczuk (1989), and this, coupled with the fact that gold grades in the deposit are closely tied to the abundance of coarse grained pyrite, indicate that this setting may be representative of gold in the deposit as a whole.

Lewczuk (1989) reports a further setting of gold, which we did not observe, associated with stilpnomelane, pink albite and manganiferous calcite.

Scanning electron micrographs show the gold grains to contain significant silver (Figure 5). Lewczuk (1989) reported microprobe results indicating that these grains are dominantly electrum, with approximately 82 percent Au and 18 percent Ag.

DISCUSSION

Sequence of Events

Field and petrographic observations reported above allow a tentative reconstruction of events related to mineralization in the Nugget Pond area.

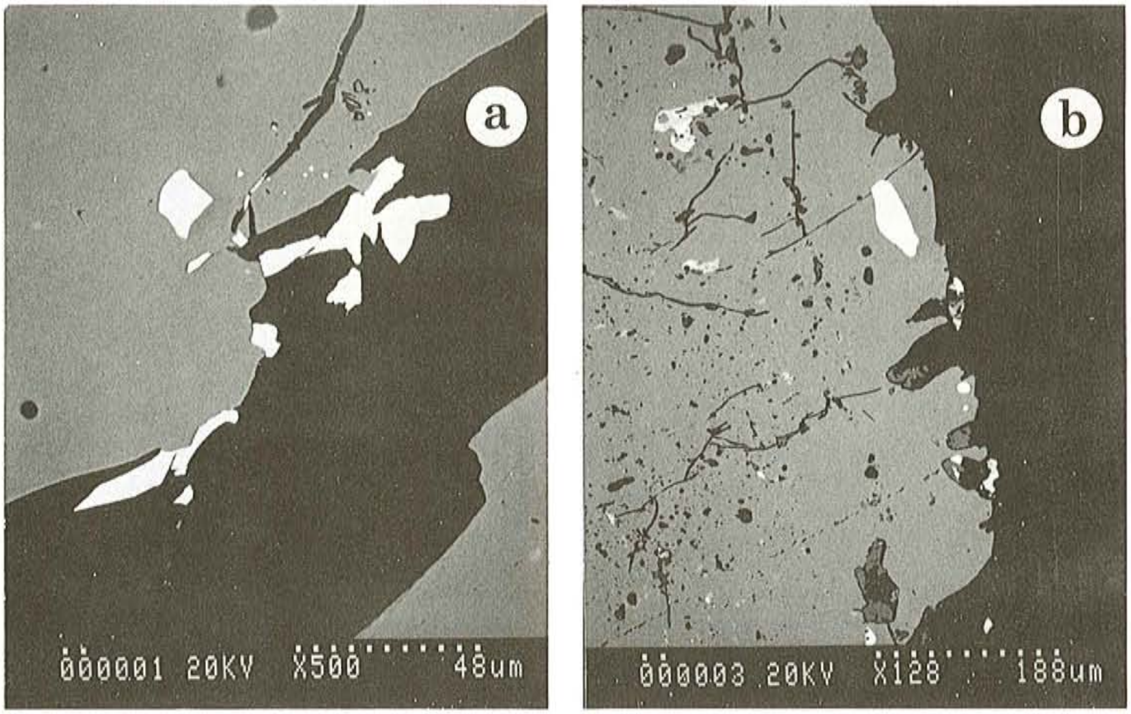

Plate 10. *Electron backscatter images of electrum (bright white) from the mineralized zone; 10a—electrum forms fine and coarse irregular blebs that are variously enclosed in the margin of a coarse pyrite grain (light grey), along the margin of the grain at its contact with the gangue (black), and wholly within the gangue; 10b—large, ovoid grain of electrum and several smaller blebs near the margin of a coarse pyrite grain.*

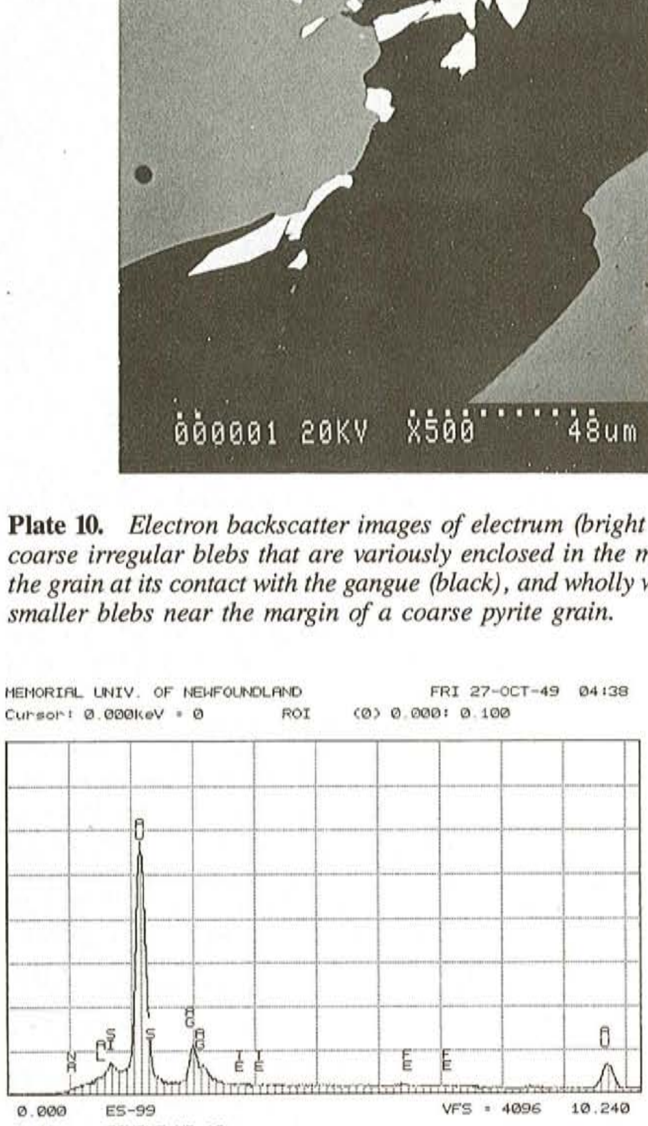

Figure 5. *Scanning electron microscope spectrum of electrum from the Nugget Pond deposit.*

The sedimentary interval that hosts the mineralization was deposited during a hiatus in submarine mafic volcanism associated with the Betts Cove ophiolite. Clastic input consisted mainly of mafic volcanic detritus. Significant hydrothermal activity in the early part of sedimentation is indicated by the presence of hematite in the basal red argillaceous siltstones (Swinden, 1976) and pyrite (pyrite 1) in the overlying dark-green to black argillites. A change in redox conditions from oxidizing to reducing is indicated by the transition from hematite to pyrite in this part of the sedimentary interval. The absence of sedimentary hematite and/or pyrite in the green clastic sediments above the mineralized horizon may reflect waning of the hydrothermal activity or increased rate of clastic sedimentation.

It seems likely that copper was also introduced by the hydrothermal activity at this stage, because even the finest disseminated pyrite grains as well as those in conformable pyrite laminae (i.e., those most likely to be original sedimentary pyrite) contain chalcopyrite inclusions near their centres. It is not clear whether galena also formed at this time, as it seems to be prevalent mainly in the later pyrite grains, suggesting that it may reflect lead taken from the argillite country rocks during recrystallization and remobilization of the pyrite. Gold may also have been introduced syngenetically although our observations are not conclusive in this regard.

The next event that can be recognized is injection of quartz—feldspar—pyrite (pyrite 2) and quartz-only veins (veins 1 to 3) that are slightly folded, locally sheared, and cut by a weak cleavage related to the regional deformation. Although it is possible that these are earlier than, and unrelated to, regional tectonics, it seems more likely that they are the earliest manifestations of regional deformation. As such, these veinlets might be regarded as 'early tectonic'.

The main deformation of the Betts Cove—Snooks Arm sequence is recorded in the Nugget Pond deposit by formation of minor folds having an associated axial planar cleavage. Pyrite was locally remobilized into the cleavage planes (pyrite 3) and deposited with minor quartz and chlorite. Minor local chloritic schist zones formed during this time.

Quartz veining continued past the peak of deformation, as indicated by veins cutting the cleavage (veinlets 3) and was locally accompanied by coarse vuggy feldspar-rich veins and ferruginous veins that are now filled with pyrite–hematite and have aureoles of stiplnomelane. At this time, stiplnomelane also grew in iron-rich rocks in the vicinity of the mineralization, as did very coarse pyrite cubes (pyrite 5). The significance of the stilpnomelane is not clear. It does not seem to be a regional metamorphic effect, as similar rock types distal to mineralization do not have any. It may reflect either introduction of Fe^{3+} during hydrothermal activity related to deformation, or a hydration reaction, related to hydrous fluids circulating during deformation, with no attendant metasomatism. These events probably closely followed the main stage of deformation, as indicated by small pressure shadows of quartz and chlorite on many of the pyrite grains.

It should be emphasized that features related to deformation in rocks at the Nugget Pond deposit are never strongly developed. The cleavage is not generally penetrative and fabrics related to this event are only locally developed. Although regional deformation is recorded in the rocks, and most of the minor veining in the area of the deposit is clearly related to or follows this deformation, details of relationships between deformation and hydrothermal activity are not well constrained and require further study.

Timing of Gold Introduction

McBride (1988) suggested that the gold at Nugget Pond was introduced syngenetically during seafloor hydrothermal activity, based on the stratabound nature of the deposit, the lack of shearing and alteration closely associated with the highest grade mineralization, and the geochemical enrichment of gold in similar sedimentary sequences throughout the Betts Cove–Snooks Arm sequence. Our data do not provide any more direct evidence in this regard. Much of the gold occurs in the outermost parts of the pyrite crystals, at the grain boundaries, and in the adjacent gangue and does not appear to be early in the paragenetic sequence. This is not unexpected, as much of the pyrite has been recrystallized, and any gold that was originally present would have likewise been remobilized and would appear late in the paragenetic sequence (Romberger, 1986). However, our limited observations of the occurrence of gold do not permit a detailed assessment of the timing of gold introduction or its place in the mineral paragenesis in the deposit.

The only possible evidence of metasomatism associated with mineralization is the presence of stiplnomelane, and it is not at all clear whether or how this might be related to the gold mineralization.

Our evidence is consistent with, but does not require, the earlier proposed genetic model involving initial concentration of gold in pyritic sediments as a result of seafloor hydrothermal activity during a hiatus in mafic volcanism (McBride, 1988). If the gold was introduced syngenetically, it has been locally remobilized during deformation and limited hydrothermal activity, most or all of which was related to regional deformation. However, although the data do not provide any indications of an epigenetic process that might have introduced gold to the Nugget Pond area, neither do they rule out such a process. Further mineralogical studies coupled with stable isotopic investigations are needed to accurately constrain the possible genetic models.

CONCLUSIONS

Preliminary geological and petrological observations on the Nugget Pond deposit show it to be a stratabound, sediment-hosted deposit, hosted by chloritic, graphitic sediments that formed during a hiatus in marine volcanic activity. The deposit type is unique in Newfoundland, but may have Archean analogues in the Superior Province of the Canadian Shield (McBride, 1987; Valliant *et al.*, 1982). Petrographic studies of the mineralization reveal a complex history involving early syngenetic deposition of pyrite and later remobilization of sulphides during regional deformation. Gold is not early in the paragenetic sequence, but our data do not rule out the possibility that gold was introduced into the sediments during seafloor hydrothermal activity and remobilized with pyrite during later tectonism. Support for such an interpretation is granted by the lack of shearing, absence of intense hydrothermal alteration or metasomatism associated with the deposit and the presence of geochemically anomalous gold in similar sedimentary intervals elsewhere in the Betts Cove–Snooks Arm sequence.

The possibility of a genetic association between gold deposition and clastic/hydrothermal sedimentation in ophiolites is intriguing. Ophiolite-hosted volcanogenic massive sulphide deposits in Newfoundland are commonly gold-rich (Swinden and Kean, 1986; Tuach *et al.*, 1988), suggesting that hydrothermal activity associated with ophiolitic volcanism can deliver significant amounts of gold to the seafloor. If the gold in the Nugget Pond deposit is syngenetic, it suggests that pyritic sediments in ophiolites elsewhere in Newfoundland should be prospected for gold. A comparison might be drawn with the 'Fox Neck type' pyritic iron formations that lie atop the Lushs Bight Group in Green Bay and may record a hiatus in ophiolitic volcanism similar to that at Nugget Pond. To date, these deposits are not known to contain gold (Kean, 1983, 1984; Swinden *et al.*, 1988). Further studies of the mineralization at Nugget Pond should clarify details of the geological history and controls on mineralization, and help focus exploration for this unique deposit type in Newfoundland and elsewhere in the Canadian Appalachians.

ACKNOWLEDGMENTS

Careful mapping and drill-core logging by Bitech geologists, particularly Greg Ovens, Gerry Whalen, Craig Baker, Rob van de Poll, Jim Butler and Gerry Shepherd, was instrumental in the development of geological concepts in the area. We would like to thank Toby Rivers for access to his microscope for photomicroscopy and Mark Wilson for comments on the manuscript.

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