Natural Resources Canada   Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA   COMMISSION GÉOLOGIQUE DU CANADA

DESCRIPTIVE NOTES

REGIONAL CONTEXT

The Betts Cove ophiolitic complex and its cover rocks belong to the Notre Dame Subzone of the Dunnage Zone of the Newfoundland Appalachians (Williams et al., 1988). The ophiolite is a relic of Ordovician (Dunning and Krough, 1985) marginal oceanic crust, and is overlain by a volcano-sedimentary cover sequence known as the Snooks Arm Group (Hibbard, 1983). The ophiolite and its cover rocks were accreted to the North American Margin during the Taconic Orogeny, and were affected by Silurian and Devonian plutonism and deformation (Hibbard, 1983; Dunning et al., 1990; Keppie, 1993; Cawood et al., 1994; Tremblay et al., 1997).

Field data were collected during the summers of 1994 to 1997, complemented by airphoto and thin-section interpretation, and geochemical correlations. Information was also compiled from Snelgrove (1931), Riccio (1972), Upadhyay (1973), and Newmont Exploration (1989). Geochemical data are from this study and Upadhyay (1973), DeGrace et al. (1976), Jenner (1977), Coish (1977), Coish et al. (1982), Hurley (1982), and Saunders (1985).

BETTS COVE OPHIOLITIC COMPLEX (Obcs - OBH)

We define the Betts Cove ophiolite massif or complex as the ophiolite sensu stricto, composed of six mappable units.

Cumulate Rocks (Obcc)

Layered cumulates form steeply dipping homoclinal sections up to 1 km thick, separated by sheared serpentinite and/or peridotitic breccia zones, some of which are synoceanic faults. Cyclic sequences range from peridotite to pyroxenite and gabbronorite. Layered cumulates are at an angle of 44 from the plane defined by intralava sediments. Medium- to coarse-grained peridotites weather orange to brick red, and are black to dark green on fresh surfaces. Most are lherzolites, with cumulus spinel+olivine±orthopyroxene, and poikilitic clinopyroxene±orthopyroxene. Orthopyroxene is replaced by talc-rich assemblages; olivine by serpentine±talc; clinopyroxene is partly replaced by actinolite and chlorite. Chromite has thin magnetite rims. Peridotites are interbedded with an upwardly increasing proportion of pyroxenites, including brown/red-weathering orthopyroxenite (grains up to 1 cm), websterite, and green-weathering clinopyroxene-rich websterite. Interbeds of pink-weathering foliated quartz gabbronorite (with saussuritized feldspar) occur near the top of the unit. Modally graded beds show a regular lithological progression (e.g. orthopyroxenite - websterite - gabbronorite) that implies fractional crystallization. Individual beds (5 cm to 3 m thick) may display basal loading structures, size grading, and modal grading, suggesting a gravitational deposition mechanism. The mineral foliation of the underlying gabbro is deflected by the loading structures. Some of the thicker gabbroic layers contain pyroxenitic lenses, representing either disrupted pyroxenite beds, disrupted dykes, or xenoliths.

The layered cumulates are dissected by dykes and sills of wehrlite, pyroxenite, gabbronorite, and trondhjemite that locally coalesce into intrusive breccias. These may be apophyses of the late intrusive suite (Obcg), feeders for the uppermost cumulate beds, or they could have precipitated from residual magmas segregating from the layered cumulates. The uppermost layered cumulates are cut by fine-grained dykes of the sheeted dyke complex (cf. Church and Riccio, 1974).

Talc-Serpentinite Schists (Obcs)

These are altered and deformed metaperidotites that line the northern contact of the ophiolite. Serpentinites are phacoidally cleaved and rusty weathering; dark green or blue on fresh surfaces. Locally, they grade into peridotite or serpentinite mélanges. Peridotite breccias are common along the shores of Long Pond, with angular fragments of metaperidotite in a carbonate-rich hydrothermal matrix. Talc-magnesite-carbonate schist domains commonly occur as diffuse haloes around shear zones and faults in the serpentinites. They typically contain rusty-weathering iron carbonate, cubic pyrite, and euhedral magnetite bi-pyramids, some of which have relict holly-leaf chromite cores with lower Cr/Al than is typical of chromites from the layered cumulates.

Late Gabbroic Intrusive Suite (Obcg)

This unit is dominated by massive, pink-weathering, quartz-Fe-Ti-oxide gabbronorite (commonly with interstitial granophyre), gabbro, and trondhjemite. Rhythmic modal layering is developed locally. Dykes of websterite, orthopyroxenite, and pegmatitic clinopyroxenite that cut the layered cumulates (Obcc) may constitute a primitive stem to this suite.

The largest body attributed to this suite (Obcg) is at the transition between the layered cumulates (Obcc) and the sheeted dykes (Obcd), north and west of Betts Cove. Local crosscutting relationships suggest the gabbros are intrusive (cf. Church, 1977). Paleo-vertical shear zones may control the emplacement of plagioclase-phyric Fe-Ti-oxide-rich quartz-gabbronorites. Gabbronorite intrusions (30-150 m wide) are common within the sheeted dykes (Obcd) south of the Betts Cove mine. The largest intrusions grade out to finer grained, red-weathering microgabbros, and some appear to have been emplaced along oceanic normal faults. These high-level intrusions probably drove the hydrothermal circulation cells from which the Betts Cove copper mine formed (Saunders and Strong, 1986).

From Long Pond to Tilt Cove are several bodies of massive, layered and brecciated gabbros and pyroxenites. We infer that the brecciated bodies were emplaced into active faults, and that they played a role as the heat source driving the hydrothermal cell from which the Tilt Cove copper deposit formed. A gabbro on the north shore of Long Pond was dated by Dunning and Krogh (1985) at 488.6 +3.1/-1.8 Ma.

Sheeted Dyke Complex (Obcd)

Red-weathering low-Ti boninite dykes are bright green on a fresh surface, with spinel+olivine+orthopyroxene phenocrysts (1-5%), in a groundmass dominated by prismatic pyroxene and anhedral feldspar +quartz. Recessive-porphyritic 'perknite' dykes are porphyritic equivalents. The perknites and low-Ti boninite dykes are compositionally identical to the low-Ti Betts Head (OBH) boninite lavas (Bédard et al., 1998). A subpopulation of intermediate-Ti dykes contain small phenocrysts of clinopyroxene and feldspar. Blue-green -weathering diabases and pink-weathering microgabbroic dykes are dominated by clinopyroxene and feldspar, and most represent differentiation products of these same boninitic magmas. Rare diabases have Mount Misery Formation affinities.

Dilatant breccias between dykes imply extension. Some of the latest dykes were injected along shear planes. Rare evolved orthopyroxene(?)+feldspar(?)+hornblende-phyric 'sills' with shallow paleo-dips crosscut the sheeted dykes and may have been injected along décollements. High-grade (amphibolite) shear zones, and rare felsic dykes have similar shallow paleo-dips. Basal and upper contacts of the sheeted dyke complex (Obcd) are either gradational, characterized by a progressive decrease in the proportion of dykes, or faulted. Some of the fault breccias are impregnated with boninitic magma. Anastomosing brittle/ductile chloritic shear zones were probably reactivated during obduction.

Mixed Dykes and Lavas (Obcm)

This unit is composed of 5-20 m wide dyke swarms and spherulitic, boninitic, pillow-lava septa 2-10 m wide.

Betts Head Formation (OBH)

This unit is principally composed of spherulitic, sparsely porphyritic, sparsely amygdaloidal, low-Ti, boninite pillow lavas and flow tubes. The lavas are well exposed along the spine of Betts Head, which we propose as the type section. The unit was defined by Snelgrove (1931). Red chert is the most common interpillow material. There are local red chert±ironstone ±sulphide interlayers. Thick (5-20 m) pillow-breccia layers are common. Low-Ti and intermediate-Ti lava series (Coish, 1989) are interbedded. Low-Ti lavas carry olivine+orthopyroxene+ chromite phenocrysts. Mineralogical and geochemical signatures indicate they are true boninites (Coish and Church, 1979; Coish et al., 1982; Bédard et al., 1998). Intermediate-Ti lavas carry clinopyroxene±plagioclase±olivine phenocrysts, and are gradational to the arc tholeiites of the Mount Misery Formation.

Northwest-to southwest-trending corridors of breccia 1-10 m wide represent synoceanic faults or fissures. Axial mafic dykes are common in these breccias, confirming their synoceanic origin. Most dykes are boninitic, representing feeders to overlying Betts Head lavas; but some dykes are tholeiitic, resembling the Mount Misery (OMM) lavas, which implies that the ophiolite is the basement to the Snooks Arm Group lavas. Immediately to the north of Betts Cove, the boninites (OBH) are truncated by a thrust fault. Northwest of Fly Pond, and at Tilt Cove, the Mount Misery lavas (OMM) appear to have been deposited conformably upon boninitic pillow breccias, although the contact is not well exposed.

Intermediate-Ti boninitic lava olistoliths outcrop in the complex breccias that line the shores of Long Pond. The talc-serpentinite shear zone that bounds the ophiolite north of Tilt Cove also contains slivers of boninitic lava, some interbedded with Mount Misery (OMM) tholeiites. Chalcopyrite-bearing massive-sulphide layers, red chert, and ironstone occur at these boninite/tholeiite contacts (Hurley, 1982). Many of the boninites in the Tilt Cove area are brecciated, as are the Mount Misery tholeiites. The mineralized breccias at the Tilt Cove mine appear to be a mixture of primary hyaloclastite, fault-talus breccia, and hydraulic breccia, cemented by quartz+calcite+hematite+epidote and locally abundant sulphides. The mineralization is mostly located at or near the interface between the Betts Head and Mount Misery formations, and may originally have formed as a conformable volcanogenic massive-sulphide deposit, subsequently reworked by multiple intrusive/faulting/hydrothermal events. In places, breccias contain fragments of gabbro and basalt that were injected and impregnated by boninitic magma. Elsewhere, large (10 m) pillow-basalt olistoliths float in an epiclastic matrix. We infer an origin for many of these breccias as oceanic fault-talus deposits developed during seafloor spreading. Some were reworked by later extensional faults during eruption of Snooks Arm Group basalts.

SNOOKS ARM GROUP (OMM - OSAM)

The Snooks Arm Group is composed of 6 formations and one intrusive unit.

Mount Misery Formation (OMM)

In the field, the spherulitic pillow lavas and flow tubes of the Mount Misery Formation closely resemble the lavas of the Betts Head Formation (OBH), and can only reliably be distinguished using geochemistry (Coish and Church, 1979; Coish et al., 1982; Bédard et al., 1998). These lavas are best exposed in the high spine extending north-northeast from Mount Misery (which we propose as the type section). The basal Mount Misery lavas are olivine-phyric, grading up to plagioclase+clinopyroxene-phyric basaltic and ferrobasaltic lavas at the summit. Thick (5-20 m) pillow-breccia layers are common. Locally, there are thin bands of laminated green chert with minor sulphides. Northwest-to southwest-trending corridors of breccia (2-40 m wide), commonly with axial mafic dykes, represent synoceanic normal faults. Most fragments in these faults are angular, but some display conspicuous flattening. Some breccia zones are transformed to chlorite+albite-rich greenschist-facies assemblages, suggesting considerable hydrothermal throughflow. Pillow lavas between closely spaced breccia corridors have a crackled appearance, with red-weathering oxidized cores and green-weathering reduced rims. The uppermost Mount Misery lava flows are commonly magnetic, with a characteristic dark grey to black colour on the fresh surface, weathering very dark brick red. The magnetic lavas are spatially associated with ironstones of the overlying Scrape Point Formation. Just north of Betts Cove, near Mount Misery, there is a zone of pervasive hematization up to 40-50m thick and almost 1 km long.

Most of the lavas with Mount Misery chemistry found near Long Pond and Tilt Cove occur as clasts in complex breccias and possible sheet flows. We interpret most of the breccias to be fault-talus deposits; but some of them appear conglomeratic, containing rounded clasts of basalt and peridotite in an epiclastic matrix with detrital chromite grains. This suggests exhumation of mantle and/or deep crustal rocks along extensional faults.

Scrape Point Formation

The formation is well exposed along the shores of Scrape Point, the proposed type section. We recognize sedimentary (OSPs) and volcanic (OSPv) members. In the southern part of the map area, the sedimentary member is thin and appears to be restricted to the base of the formation. North of East Pond, sediments are more abundant and are not restricted to the base of the unit.

Scrape Point Formation, Sedimentary Member (OSPs)

The base of the formation is an erosional unconformity that bevels a series of tilted fault blocks between East Pond and Betts Cove. South of East Pond, the lowermost Scrape Point sedimentary rocks are laterally discontinuous boulder conglomerates to pebbly sandstones. The conglomerate contains fragments of basaltic lava and red chert up to 0.5 m in size, derived from the underlying Mount Misery basalts. The clasts are either veined and cemented by nearly pure magnetite+hematite, or they sit in a sandy matrix rich in euhedral magnetite. Where the conglomerate is absent, a dominantly red-weathering, thin-bedded sequence of sandstone, siltstone, and ironstone dominates the base of the unit. Dark brown to black, magnetic sandstones contain up to 80% euhedral magnetite, associated with hematite, acicular stilpnomelane, quartz, and sericite. Locally, coarse, cubic, auriferous pyrite is developed (see below, Nugget Pond mine, also Swinden et al., 1990, Sangster et al., 1994). South of East Pond, the upper part of the section is typically composed of green-weathering, tuffaceous, sandstone-siltstone turbidites (cf. Swinden et al., 1990). Pebbly volcaniclastic sandstone beds are normally graded, and siltstones exhibit fine laminations. The faults that cut the Mount Misery lavas (OMM) also offset the Scrape Point sedimentary rocks, though with lesser throws, implying that these are syndepositional normal growth faults. Chaotic slump folds and small growth faults are common in Scrape Point sedimentary rocks. Swarms of medium- to coarse-grained, mafic sills (OSAm) commonly split the sedimentary unit into thinner packages. Contact-metamorphic effects produced black slates and purple-silver phyllites.

North of East Pond, the sedimentary member is not restricted to the base of the formation, being interbedded with lavas throughout. It is composed of green turbiditic and tuffaceous sandstones and siltstones, red mudstones and locally pyritiferous, stilpnomelane-bearing ironstones. North of East Pond, the red mudstones and ironstones can occur anywhere in the section. Green tuffaceous sandstones, some welded, may have 1-2 cm sized lapilli of amygdaloidal, plagioclase-porphyritic andesite, petrologically and geochemically similar to tuffs of the Bobby Cove Formation (OBCb).

Scrape Point Formation, Volcanic Member (OSPv)

These are amygdaloidal, sparsely plagioclase+clinopyroxene-phyric, Fe-Ti-oxide-rich, tholeiitic pillow lavas and massive flows. Massive flows have thin, lobed, or pillowed tops and bases. Plagioclase-porphyritic facies may contain up to 50% plagioclase phenocrysts (up to 2 cm). Southeast of Long Pond, the basal lavas of this formation commonly form massive, 2-5 m thick, clinopyroxene+plagioclase-phyric sheet flows. The sparsely porphyritic sheet flows can easily be misidentified as sills or tuffs in the field, but the dark, chloritized, clinopyroxene phenocryst pseudomorphs are generally diagnostic. Dark grey, magnetite-rich lavas are associated with sedimentary ironstones.

Bobby Cove Formation (OBC)

This formation was deposited on an erosional unconformity with minor relief. Two members are recognized.

Bobby Cove Formation, Basal Member (OBCb)

This member is dominated by volcaniclastic conglomerates and pyroclastic subaqueous blocky tuffs. These are very proximal to their source and most represent subaqueous debris flows, some of which were pyroclastic eruptions of juvenile basalt or andesite. The amalgamated conglomerates can be more than 100 m thick and can be traced along strike for several kilometres. Significant erosion and truncation of underlying deposits is observed. One deposit contains extremely large (>2 m) tabular rafts of a thin-bedded, mafic crystal tuff. Flow units grade up from clast-rich bases (<60% boulder-sized clasts) into finer deposits with similar clasts (although smaller). Reversed size-grading may be present at the base of some flow units, and imbrication of clasts is common. The matrix is a crystal-lithic-vitric tuff derived largely through disaggregation of cobbles. The most common clasts are amygdaloidal clinopyroxene+hornblende+plagioclase-porphyritic andesites and basalts with calc-alkaline geochemical signatures. Some of these appear to have been deposited while still hot. Other clast populations may dominate locally. These include vesicular andesite, bedded medium-grained volcaniclastic sandstones or tuffs, hornblende+plagioclase+clinopyroxene+magnetite-phyric dacite, red siltstone, feldspathic hornblendite, hornblende pyroxenite, mafic schist, metabasalt, and basaltic bombs.

The coarse flow units alternate with sequences (1-100 m) consisting of massive, normally graded, volcaniclastic, tuffaceous sandstones and welded crystal-lithic-vitric tuffs (20 cm to 5m); and thinly laminated volcaniclastic sandstones and siltstones (1-50 cm). The sandy beds may form loading structures in the underlying, finer grained beds. Rip-ups and synsedimentary growth faults are common. The tuffaceous beds contain crystal fragments (plagioclase > clinopyroxene > hornblende > magnetite ~ quartz), metavolcanic fragments (porphyritic and vesicular andesite and basalt), and up to 30% flattened glass shards, some with enclosed euhedral microphenocrysts (feldspar and pyroxene). The flattened glass shards and devitrification structures suggest a pyroclastic origin for some of these tuffs.

Immediately south of East Pond, there is a lensoid domain of poorly bedded dacitic crystal tuff that contains abundant (10-15%) small (1-2 cm) xenoliths. Subeuhedral sericitized feldspar crystals dominate (60-80%). Acicular black hornblende (10-20%) may have fresh clinopyroxene cores. Thin (<3 m), pink-or green-weathering graded felsic tuffs are subordinate, and may represent subaqueously deposited ashfalls. Subordinate flows and dykes of clinopyroxene±plagioclase-phyric andesite and basalt are also present. They appear to belong to two series, one tholeiitic (similar to the OMM), the other calc-alkaline.

Bobby Cove Turbiditic Member (OBCt)

These are sheet-like, epiclastic, volcanogenic, outer-fan turbidites with a significant feldspathic component, interbedded with purplish, pelagic, siliceous mudstones, and rare felsic tuffs. The first appearance of purple mudstones marks the base of the member.

Venam's Bight Formation (OVB)

This formation is dominated by pillow lavas and sheet flows. Lavas are locally clinopyroxene+plagioclase±magnetite-porphyritic and commonly amygdaloidal. Thin, inter-lava layers of red siliceous mudstone or ironstone occur locally. They are evolved Fe-Ti-tholeiites (cf. Jenner and Fryer, 1980), very similar to evolved Scrape Point tholeiites.

Balsam Bud Cove Formation (OBB)

This formation is divided into two members.

Balsam Bud Cove Basal Member (OBBb)

The base of the formation is composed of ~100 m of interbedded pelagites, volcaniclastic turbidites, welded(?) crystal tuffs, and subordinate mafic lavas similar to those of the Venam's Bight Formation. Some of the sedimentary rocks and lavas are disturbed, and may represent slumps or mélanges. These basal sedimentary and volcanic rocks are succeeded by a sequence (~150-200 m) of white- to grey-blue-weathering, thick-bedded (1-2 m) or laminated (1-10 cm), quartz+feldspar+pyroxene(?)-phyric rhyolitic tuffs, which dominate locally. Fine-grained pyrite is commonly present along bedding planes and microfaults. The tuffs are interbedded with black, sulphidic, graptolitic shales (Snelgrove, 1931; Williams, 1992) of probable lower Didymograptus bifidus Zone age (lower Llanvirn, about 477 Ma).

Balsam Bud Cove Debrite Member (OBBd)

The base of this Member is defined as the first, thick-bedded, mass-flow deposit. A basal mass flow is over 50 m thick and contains large fragments (up to 20 m) of massive and pillowed basalts, leucoxene-rich diabase, basalt breccia, polymictic breccia, and felsic tuff. The basaltic fragments are petrographically and geochemically almost indistinguishable from typical Venam's Bight basalts. This debrite is overlain by ~50 m of amalgamated, coarse, debris-flow conglomerates or debrites; with individual beds ranging from 0.9 to 9 m. Most clasts are basaltic or andesitic. Some debrite conglomerates are capped by horizontally stratified and low-angle cross-stratified sandstones, thin-bedded turbiditic mudstones and sandstones, and pelagic mudstones. There follows a sequence (~100 m) of cohesive debris-flow deposits (0.7 to 8 m thick), with clast populations that may vary from volcanic-dominated fragments at the base to more abundant sedimentary fragments at the top. Further up in the section, these debrites are interbedded with and succeeded by turbidites, pelagites, and rare rhyolitic tuffs. The epiclastic Balsam Bud Cove sedimentary rocks appear to be derived principally from the reworking of mafic volcanic and volcaniclastic deposits.

Round Harbour Formation (ORH)

These lavas were deposited on, and are locally interbedded with, the uppermost red and green mudstones of the Balsam Bud Cove Formation. They are clinopyroxene+plagioclase-phyric pillow lavas and sheet flows almost indistinguishable from the Venam's Bight lavas. Locally, there are intensely brecciated and epidotized corridors that contain minor sulphides (pyrite > chalcopyrite > bornite), and strongly epidotized and hematized felsic dykes.

Mafic Sills (OSAm)

They are up to 150 m thick, with shallowly discordant contacts, and may be composite. Fine-grained, locally amygdaloidal and micro-porphyritic margins grade into diabasic, gabbroic, or ophitic cores. Sills may be aphyric to phenocryst-rich. Plagioclase-porphyritic sills are common, clinopyroxene-porphyritic sills are rare. Phenocryst-rich sills contain up to 45% zoned euhedral plagioclase or clinopyroxene up to 2 cm in size. Skeletal to interstitial magnetite+ilmenite intergrowths (up to 20%) and minor sulphides (pyrite > chalcopyrite) are common. Iron-titanium-oxides are partly converted to pale blue or salmon-coloured leucoxene. Geochemically, these sills resemble Snooks Arm Group basalts, and represent subvolcanic conduits, implying close proximity to the volcanic edifice.

ADJOINING OPHIOLITIC ROCKS.

Nippers Harbour Ophiolitic Massif (ONH)

This massif is composed of gabbros, sheeted dykes, and lavas (Schroeter, 1971). It is separated from the Betts Cove ophiolite by a prominent fault, lined with serpentinite. Preliminary data suggest that the Nippers Harbour lavas and dykes are similar to the more evolved boninitic magmas from the Betts Cove massif, suggesting that the two may be lateral equivalents.

SILURIAN ROCKS.

Cape St. John Group (SCJ)

The lowermost exposed rocks of this unit are boulder conglomerates, containing clasts of red chert, fuchsite, and basalt. Interbedded sandstones and conglomerates are commonly channeled and crossbedded. Associated mudstones may exhibit mudcracks, suggesting subaerial conditions. Thick accumulations of felsic lavas and ignimbrites are laminated to flinty and massive, with a pale green or salmon weathering colour, dark blue-grey to brown on a fresh surface. Red chert and fuchsitic fragments of ophiolitic derivation are present locally in the felsic pyroclastic rocks. Thick magnetite-rich ironstones are locally associated with the pyroclastic rocks. Mafic and intermediate lavas commonly contain large, flattened amygdules filled with buff-coloured iron-carbonate+hematite. Platy hematite and iron-carbonate rhombs 1-3 mm in size are abundant in the groundmass of these lavas.

A Cape St. John felsic ignimbrite was dated at 427 ± 2 Ma by Coyle (1990). Similar ages and petrographic resemblances suggest that these felsic volcanic rocks are correlative to the Cape Brulé Granite (DeGrace, et al., 1976; Hibbard, 1983, p.121; Coyle, 1990). Tremblay et al. (1997) proposed that the Cape St. John Group represents the caldera fill related to eruption of the Cape Brulé Granite/Burlington Granodiorite batholith.

Cape Brulé Granite and Quartz-Feldspar Porphyry Dykes (SCB and Sqfp)

Intrusions of quartz+feldspar+biotite porphyry (Sqfp) occur throughout the Betts Cove ophiolite. They have traditionally been attributed to the Cape Brulé Granite (Hibbard, 1983), which appears to form a marginal facies to a large granitoid batholith (Tremblay et al., 1997). Uranium-lead zircon age data (432 ± 2 Ma and 440 ± 2 Ma on the Burlington Granodiorite; 430 +5/-3 Ma for the Cape Brulé Granite: Cawood and Dunning, 1993; Dunning pers. comm. 1996) support a genetic link, though geochemically, the (Sqfp) intrusions are more similar to the Burlington Granodiorite. In Sqfp dykes, biotite is chloritized, feldspars are completely bleached, hematized, or sericitized, and quartz forms ovoid to euhedral embayed phenocrysts and glomerocrysts. The groundmass is either sericitized, hematized, or epidotized. Inclusions of fuchsite are locally abundant. Locally, bodies of Sqfp have a very chaotic, brecciated appearance and may represent subvolcanic breccias or phreatomagmatic deposits. The (Sqfp) intrusions are commonly associated with normal faults and these are strongly sheared. It is possible that the faults acted as conduits for magma ascent and eruption.

DEFORMATION

The first episode of deformation at Betts Cove reflects intra-oceanic extension. A large number of northwest- to southwest-trending faults offset the stratigraphy (up to 1 km) with apparent normal paleo-motions. Fault breccias may be impregnated with mafic magma, and so are intra-oceanic. Considerable hydrothermal activity occurred along some of these structures. Prominent chlorite+quartz±albite alteration haloes surround the copper deposits (Saunders and Strong, 1986). Many of these faults (particularly the chloritized ones) were reactivated during obduction.

Less common structures with shallow paleo-dips appear to correspond with ductile décollement zones related to oceanic extension. One example is a ductile, amphibolite-grade shear zone, with plagioclase, clinopyroxene, and brown hornblende porphyroclasts. Another shear zone with a similar orientation affects sheet-like gabbroic (Obcg) intrusions, but is truncated by the greenschist-grade normal faults discussed above. Several types of 'sills' cut the sheeted dykes, and may represent tension gashes related to movement along the décollements.

During accretion to the Laurentian margin, rocks of the Betts Cove ophiolitic complex and Snooks Arm Group were imbricated along a west-directed, east-dipping thrust fault, which truncates the stratigraphy of the Betts Head Formation lavas immediately to the north of Betts Cove. No evidence for large-scale structural repetition or thrust faults within the Snooks Arm Group was found, however, although some of the small-scale folds in the OBBb and OSPs units may be obduction related. Obduction-related deformation did reactivate favourably oriented, strongly chloritized, paleo-normal faults in the Betts Cove ophiolitic complex, producing steeply dipping (present orientation) C-S fabrics that indicate southwest-directed reverse motions.

Deposition of the shallowly dipping rocks of the Cape St. John Group onto an angular unconformity over ophiolitic lavas and peridotites shows that by Silurian time, the ophiolite and its cover had been tilted and eroded. A set of northwest-dipping extensional faults marks the northern boundary of the ophiolitic massif, from Long Pond eastward. Along this segment, the Cape St. John/ophiolite contact is a brittle to brittle/ductile fault with a shallow to moderate northwest dip, sub-parallel to bedding in the Cape St. John Group, which has moderate dips to the north. The shear-related fabric exhibits a poorly to moderately developed downdip stretching lineation, with kinematic indicators suggesting normal movement (north side down). A weakly developed cleavage locally overprints the shearing. It is oriented southwest to west and dips shallowly to the north-northwest. Similar extensional faults occur well within the Cape St. John Group further to the north. In many places, intrusions of unit Sqfp seem to have been injected into these extensional shears, and to be deformed by them. Southwest of Long Pond, the contact between the Cape St. John Group and the ophiolitic rocks is a shear zone, locally mylonitic, with a fabric that dips moderately northwest, to steeply northwest or southeast, and contains a poorly developed downdip stretching lineation. Kinematic indicators are equivocal. Domains of typical Snooks Arm Group lithologies occur northwest of the ultramafic cumulates at Kitty Pond. We interpret these to represent downfaulted blocks, implying movement along normal (north-side down) faults.

Another set of extensional faults associated with Sqfp intrusions dips moderately towards the northeast. These are especially prominent northeast of Long Pond and Winser Lake, where successive fault blocks display lithological associations corresponding to higher parts of the stratigraphy. Reconstruction of these displacements suggests that the deposits mined in the Tilt Cove East and West mines were probably originally contiguous (Squires, 1981).

The most obvious (and youngest) deformation recorded in the ophiolitic and cover rocks is a large-scale synclinal structure. A weak slaty cleavage oriented southwest to east-west and dipping moderately northwest to north is axial planar to this regional structure. The intensity of deformation increases towards the hinge area and towards the contact with Silurian rocks, producing mesoscopic folds and transposition of rocks of the Snooks Arm and Cape St. John groups. This is particularly evident in the Beaver Cove and Great Caplin Cove areas, where Silurian extensional faults are refolded by this event. We infer an Acadian age (Tremblay et al., 1997) for this compression.

ECONOMIC INTEREST

The Betts Cove ophiolite massif hosts two large copper deposits, a gold deposit, and many copper and gold prospects (Upadhyay, 1973; Upadhyay and Strong, 1973; Squires, 1981; Strong, 1984; Saunders, 1985; Saunders and Strong, 1986; Hurley, 1982; Hurley and Crockett, 1985; Hudson, 1988; Swinden et al., 1990; Al, 1990; Lavigne, 1993; Sangster et al., 1994, 1995).

The largest of the base-metal occurrences is the past-producing Tilt Cove copper deposit (locations 9 and 10, Cu), which produced about 9 000 000 tons of ore in several periods of operation before closing in 1968. Seven hundred and fifty thousand tons of picked ore averaging 7% Cu and 411 tons of picked nickel ore were shipped from Tilt Cove between 1869 and 1876 (Snelgrove, 1931). The deposit occurs within a hyaloclastite breccia facies near the contact between units OBH and OMM, and consists mainly of pyrite and chalcopyrite with minor pyrrhotite. Magnetite is abundant and locally massive. Chlorite, locally with abundant specular hematite, is the most prominent alteration mineral. Very little ore is visible in place, but available dump rock has ore mineral textures that suggest control by the fragmental character of the host rocks, consistent with an origin of the deposit by subvolcanic replacement of basalt. Gold contents are relatively low, with the highest values between 1 and 2 ppm, in both semimassive sulphides and chlorite-hematite-sulphide rock.

The Betts Cove mine (location 2, Cu, Zn, Pb, Au) produced 130 682 tons of copper ore between 1875 and 1885, before closing due to a cave-in (Snelgrove, 1931). The massive ore occurs near the Obcd/OBH faulted contact and consists of pyrite with chalcopyrite, sphalerite, and native gold. The well developed banding is structural in origin. The ore contains substantial gold, with assays ranging between 1 and 15 ppm. The highest values occur in zinc-rich massive sulphides. Several other occurrences of disseminated and stringer copper mineralization are known in the immediate area of the Betts Cove mine including The Betts Head (location 4, Cu) and Dolphin (location 5, Cu) occurrences.

Several other smaller mineral occurrences are found in sheared and broken rocks at the Obcd/OBH contact. The Joey's Pond occurrence (location 3, Cu) contains disseminated and stringer chalcopyrite about 500 m northwest of the Betts Cove Mine. The Mount Misery (location 6, Cu, Au) and Foot Pond (location 7, Cu) occurrences are very similar, and lie on the same apparent lineation about 1 and 2 km to the northeast of the Betts Cove Mine. At the Mount Misery occurrence, disseminated chalcopyrite, pyrite, and pyrrhotite are found in a 0.5 km long zone of highly sheared and locally silicified basalt. The Nudulama showing (location 8, Cu, As, Co, Ni, Au) consists of two sites. Dumps near an exploration shaft contain breccias of chloritized basalt healed with massive chalcopyrite. One sample containing accessory gersdorffite and cobaltite assayed 24 g/t Au. The hanging-wall basalts are resedimented and brecciated unit OBH and OMM hyaloclastites. In the Nudulama adit area, sparse chalcopyrite is disseminated in basaltic hyaloclastite.

The Burton's pond occurrence (location 1) consists of siliceous shear zones and associated stockwork zones in boninites of the sheeted dyke unit and adjacent gabbronorite. The alteration zone contains mainly quartz with carbonate and submassive to weakly disseminated pyrrhotite, chalcopyrite, and gold (Hudson, 1988).

The Beaver Cove Pond showing (location 11, Cu, Zn, Au, Mgt) consists of chalcopyrite associated with pods of massive magnetite near the top of a bluff north of the access road to Tilt Cove. On the south side of the road at the same location, the Mud Pond occurrence (location 12, Cu) consists of a number of small massive sulphide pods enclosed as rafts in talc carbonate schist. On Red Cliff Pond, chalcopyrite is associated with magnetite (location 13, Cu, Mgt) in the sheared contact of the talc carbonate unit and the Mount Misery Formation.

The principal gold occurrence in the area is the Nugget Pond mine (location 14, Au), found in 1989, which contains about 400 000 tons of ore averaging about 14 g/t. The ore consists of stratabound layers of disseminated megacrystic (1-3 cm) auriferous euhedral pyrite, concentrated near the contact between a lower, brick red, distal turbidite, and interbedded distal to proximal, pale green turbidites (OSPs; Swinden et al., 1990; Sangster et al., 1994). The megacrystic pyrite replaces and overgrows magnetite in the upper part of the red unit, and replaces biogenic pyrite, pyrrhotite, and magnetite in the lower part of the green unit. The mineralization is spatially associated with quartz+feldspar+carbonate veins. Stilpnomelane is the principal alteration mineral. Xenotime from the veins has been dated at 374 Ma (Sangster and Parrish, unpub. data). Numerous pyrite occurrences have been documented along the OSPs unit northeast of the deposit on West Pond (location 15, Py), East Pond (locations 16 and 17, Py) and Red Cliff Pond (locations 18, Py, and 19, Ag, Py) but as yet no significant anomalous gold analyses have been encountered.

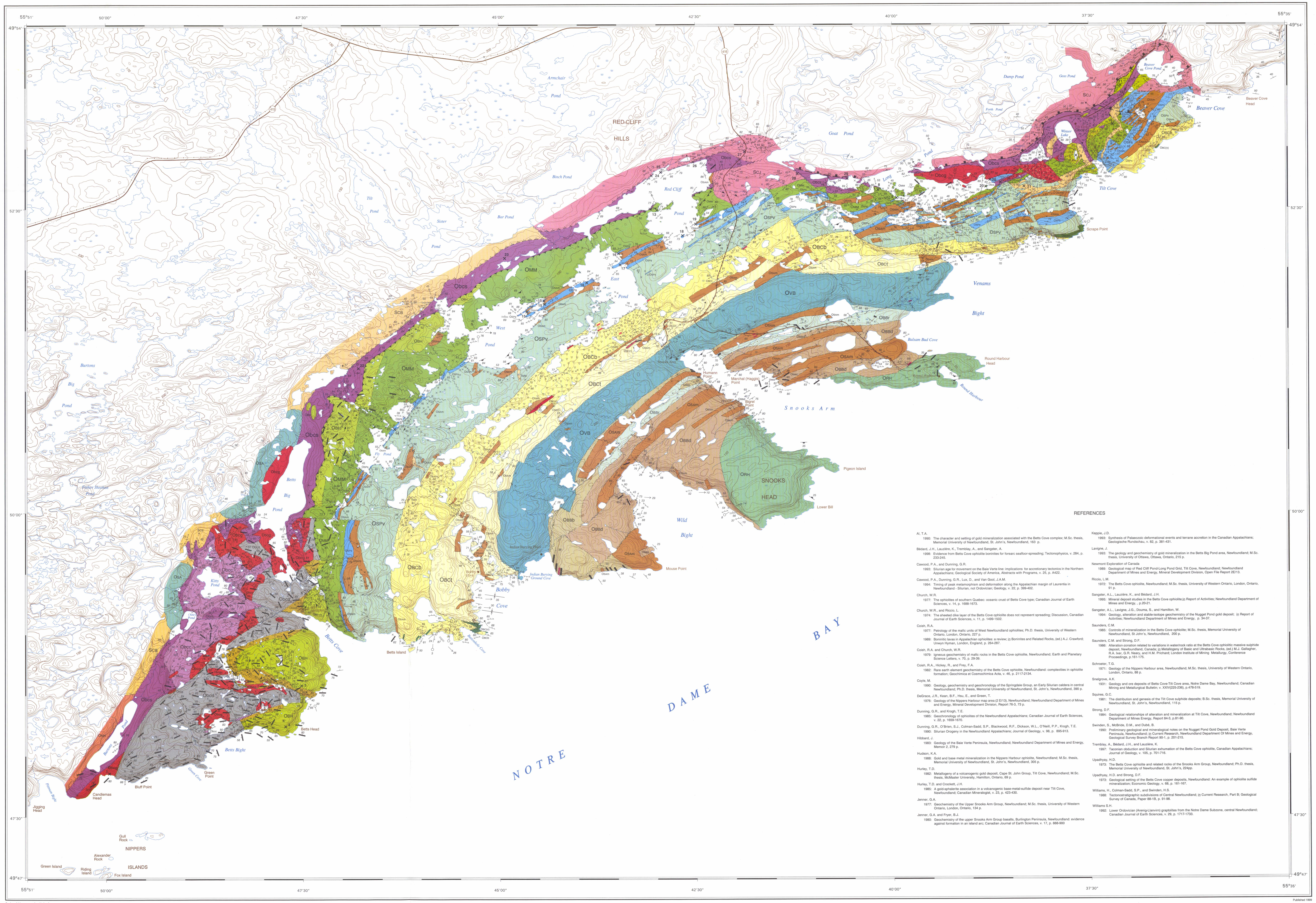
The Castle Rock (location 21, IF, Au) and Long Pond East (location 20, IF, Au) gold occurrences are in stratigraphic sections that resemble the OSPs unit at the Nugget Pond mine. The Castle Rock showing is associated with red hematite-magnetite iron-formation, barren green turbidites, and pyritiferous green sedimentary rocks; all of which are cut by mafic dykes (OSAm), talc-carbonate schist and breccia (Obcs), and quartz-feldspar porphyry (Sqfp). The gold (grades of 20-40 g/t) is in coarse cubic pyrite within large xenoliths of reddish siltstone embedded in the talc-carbonate schist. At the Long Pond East (location 20) occurrence, hematite-magnetite iron-formation, and lithochemically anomalous, pyritic green sediments are also present. The best gold values (near 1 g/t) occur with medium-grained cubic pyrite in white, talc-carbonate schist.

A number of minor occurrences of lithochemically anomalous gold are associated with the basal talc-carbonate schist of the Betts Cove ophiolite and felsic volcanic rocks of the Cape St. John Group. The Long Pond (location 29, Au) occurrence consists of siliceous hematitic carbonate and quartz veins at the sheared northern contact of the ophiolite while at the Boneyard (location 27, Au), Tom (location 28, Au), Melange (location 26, Au), George (location 24, Au) and George extension (location 25, Au) occurrences, gold is associated with minor pyrite or specular hematite/magnetite in highly sheared rocks of the Cape St. John Group at the contact with talc-carbonate of the Betts Cove ophiolite.

At Betts Big Pond (location 22, Au) and Arrowhead Pond (location 23, Au) significant gold assays can be obtained from talc-carbonate schist with or without the presence of trace sulphides.

ACKNOWLEDGEMENTS

The 1994-1995 field seasons and analyses were financed through the Canada-Newfoundland Co-operation Agreement on Mineral Development. The 1996 field season and analyses were financed through an Industrial Partners Program between the Geological Survey of Canada and Ressources Noveder, Exploration Sulliden, and Ressources Dianor, and by FCAR-Équipe grant 95ER2270. Additional fieldwork in 1997 was financed by Pierre Cousineau (Université du Québec à Chicoutimi) and Giff Kessler (Marathon Oil). Scott Swinden provided advice and documentation. Vincent Jourdain (Ressources Noveder), Robert Sansfaçon, Alain Berclaz, David Morin, and Kirsten Oravec (Groupe Conseil GesplAur) provided data, access, and discussion. Benoit Dubé (CGQ) provided valuable comments. S. Douma provided petrographic data. Ginger Rogers, Peter Frampton, Joel Hickey, Barbara Fortin, and Mark Piasecki assisted in the field. Don Collins and Terry Rideout of Tilt Cove; Ray Wimbleton and Bob Jacobs of Snooks Arm; and Ralph and Vida Short of LaScie assisted with logistical and other problems and made our stay especially memorable.



REFERENCES

Al, T.A.
1990: The character and setting of gold mineralization associated with the Betts Cove complex; M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 163 p.

Bédard, J.H., Lauzière, K., Tremblay, A., and Sangster, A.
1998: Evidence from Betts Cove ophiolite boninites for forearc seafloor-spreading; Tectonophysics, v. 284, p. 233-245.

Cawood, P.A., and Dunning, G.R.
1993: Silurian age for movement on the Baie Verte line: implications for accretionary tectonics in the Northern Appalachians; Geological Society of America, Abstracts with Programs, v. 25, p. A422.

Cawood, P.A., Dunning, G.R., Lux, D., and Van Gool, J.A.M.
1994: Timing of peak metamorphism and deformation along the Appalachian margin of Laurentia in Newfoundland - Silurian, not Ordovician; Geology, v. 22, p. 399-402.

Church, W.R.
1977: The ophiolites of southern Quebec: oceanic crust of Betts Cove type; Canadian Journal of Earth Sciences, v. 14, p. 1688-1673.

Church, W.R., and Riccio, L.
1974: The sheeted dike layer of the Betts Cove ophiolite does not represent spreading; Discussion, Canadian Journal of Earth Sciences, v. 11, p. 1499-1502.

Coish, R.A.
1977: Petrology of the mafic units of West Newfoundland ophiolites; Ph.D. thesis, University of Western Ontario, London, Ontario, 227 p.
1989: Boninitic lavas in Appalachian ophiolites: a review; in Boninites and Related Rocks, (ed.) A.J. Crawford; Unwyn Hyman, London, England, p. 264-287.

Coish, R.A. and Church, W.R.
1979: Igneous geochemistry of mafic rocks in the Betts Cove ophiolite, Newfoundland; Earth and Planetary Science Letters, v. 70, p. 29-39.

Coish, R.A., Hickey, R., and Frey, F.A.
1982: Rare earth element geochemistry of the Betts Cove ophiolite, Newfoundland: complexities in ophiolite formation; Geochimica et Cosmochimica Acta, v. 46, p. 2117-2134.

Coyle, M.
1990: Geology, geochemistry and geochronology of the Springdale Group, an Early Silurian caldera in central Newfoundland; Ph.D. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 390 p.

DeGrace, J.R., Kean, B.F., Hsu, E., and Green, T.
1976: Geology of the Nippers Harbour map area (2 E/13), Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Report 76-3, 73 p.

Dunning, G.R., and Krogh, T.E.
1985: Geochronology of ophiolites of the Newfoundland Appalachians; Canadian Journal of Earth Sciences, v. 22, p. 1659-1670.

Dunning, G.R., O'Brien, S.J., Colman-Sadd, S.P., Blackwood, R.F., Dickson, W.L., O'Neill, P.P., Krogh, T.E.
1990: Silurian Orogeny in the Newfoundland Appalachians; Journal of Geology, v. 98, p. 895-913.

Hibbard, J.
1983: Geology of the Baie Verte Peninsula, Newfoundland; Newfoundland Department of Mines and Energy, Memoir 2, 279 p.

Hudson, K.A.
1988: Gold and base metal mineralization in the Nippers Harbour ophiolite, Newfoundland; M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 305 p.

Hurley, T.D.
1982: Metallogeny of a volcanogenic gold deposit, Cape St. John Group, Tilt Cove, Newfoundland; M.Sc. thesis, McMaster University, Hamilton, Ontario, 69 p.

Hurley, T.D. and Crockett, J.H.
1985: A gold-sphalerite association in a volcanogenic base-metal-sulfide deposit near Tilt Cove, Newfoundland; Canadian Mineralogist, v. 23, p. 423-430.

Jenner, G.A.
1977: Geochemistry of the Upper Snooks Arm Group, Newfoundland; M.Sc. thesis, University of Western Ontario, London, Ontario, 134 p.

Jenner, G.A. and Fryer, B.J.
1980: Geochemistry of the upper Snooks Arm Group basalts, Burlington Peninsula, Newfoundland: evidence against formation in an island arc; Canadian Journal of Earth Sciences, v. 17, p. 888-900

Keppie, J.D.
1993: Synthesis of Palaeozoic deformational events and terrane accretion in the Canadian Appalachians; Geologische Rundschau, v. 82, p. 381-431.

Lavigne, J.
1993: The geology and geochemistry of gold mineralization in the Betts Big Pond area, Newfoundland; M.Sc. thesis, University of Ottawa, Ottawa, Ontario, 215 p.

Newmont Exploration of Canada
1989: Geological map of Red Cliff Pond-Long Pond Grid, Tilt Cove, Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Open File Report 2E/13.

Riccio, L.M.
1972: The Betts Cove ophiolite, Newfoundland; M.Sc. thesis, University of Western Ontario, London, Ontario, 91 p.

Sangster, A.L., Lauzière, K., and Bédard, J.H.
1995: Mineral deposit studies in the Betts Cove ophiolite; in Report of Activities; Newfoundland Department of Mines and Energy, , p.20-21.

Sangster, A.L., Lavigne, J.G., Douma, S., and Hamilton, W.
1994: Geology, alteration and stable-isotope geochemistry of the Nugget Pond gold deposit; in Report of Activities; Newfoundland Department of Mines and Energy, p. 34-37.

Saunders, C.M.
1985: Controls of mineralization in the Betts Cove ophiolite; M.Sc. thesis, Memorial University of Newfoundland, St John's, Newfoundland, 200 p.

Saunders, C.M. and Strong, D.F.
1986: Alteration-zonation related to variations in water/rock ratio at the Betts Cove ophiolitic massive sulphide deposit, Newfoundland, Canada; in Metallogeny of Basic and Ultrabasic Rocks, (ed.) M.J. Gallagher, R.A. Ixer, G.R. Neary, and H.M. Prichard; London Institute of Mining Metallurgy, Conference Proceedings, p.161-175.

Schroeter, T.G.
1971: Geology of the Nippers Harbour area, Newfoundland; M.Sc. thesis, University of Western Ontario, London, Ontario, 88 p.

Snelgrove, A.K.
1931: Geology and ore deposits of Betts Cove-Tilt Cove area, Notre Dame Bay, Newfoundland; Canadian Mining and Metallurgical Bulletin; v. XXIV(225-236), p.478-519.

Squires, G.C.
1981: The distribution and genesis of the Tilt Cove sulphide deposits; B.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 115 p.

Strong, D.F.
1984: Geological relationships of alteration and mineralization at Tilt Cove, Newfoundland; Newfoundland Department of Mines Energy, Report 84-3, p.81-90.

Swinden, S., McBride, D.M., and Dubé, B.
1990: Preliminary geological and mineralogical notes on the Nugget Pond Gold Deposit, Baie Verte Peninsula, Newfoundland; in Current Research, Newfoundland Department Of Mines and Energy, Geological Survey Branch Report 90-1, p. 201-215.

Tremblay, A., Bédard, J.H., and Lauzière, K.
1997: Taconian obduction and Silurian exhumation of the Betts Cove ophiolite, Canadian Appalachians; Journal of Geology, v. 105, p. 701-716.

Upadhyay, H.D.
1973: The Betts Cove ophiolite and related rocks of the Snooks Arm Group, Newfoundland; Ph.D. thesis, Memorial University of Newfoundland, St. John's, 224pp.

Upadhyay, H.D. and Strong, D.F.
1973: Geological setting of the Betts Cove copper deposits, Newfoundland: An example of ophiolite sulfide mineralization; Economic Geology, v. 68, p. 161-167.

Williams, H., Colman-Sadd, S.P., and Swinden, H.S.
1988: Tectonostratigraphic subdivisions of Central Newfoundland; in Current Research, Part B; Geological Survey of Canada, Paper 88-1B, p. 91-98.

Williams S.H.
1992: Lower Ordovician (Arenig-Llanvirn) graptolites from the Notre Dame Subzone, central Newfoundland; Canadian Journal of Earth Sciences, v. 29, p. 1717-1733.

LEGEND

SILURIAN

SCB,Sqfp — Cape Brulé Porphyryl Quartz +two feldspar +mica porphyritic granitoid: fuchsite clasts locally abundant; locally heterolithic, very chaotic subvolcanic breccia facies; commonly sheared and altered

CAPE ST. JOHN GROUP

SCJ — Fluviatile sandstone, conglomerate (channeled and cross-bedded) and mudstone; felsic lavas and ignimbrites, amygdaloidal mafic lavas (hematized and carbonated)

ORDOVICIAN

ONH — Nippers Harbour Massif: gabbro, sheeted dykes, and lavas

SNOOKS ARM GROUP (OSAm-OSA)

OSAm — Mafic Sills: includes plagioclase-and/or clinopyroxene-phyric aphyric, gabbroic and diabasic facies; commonly rich in Fe-Ti-oxides (partly altered to leucoxene) and sulphides; commonly amygdalodial near contacts

OSA — Undifferentiated Snooks Arm Group

ROUND HARBOUR FORMATION

ORH — Clinopyroxene+plagioclase-phyric pillow lavas and sheet flows; commonly amygdaloidal; thin red siliceous mudstone interbeds; locally intense brecciation and epidotization

BALSAM BUD COVE FORMATION (OBBr-OBB(r))

OBB(r) minor thin rhyolitic 'tuffs'

OBB(v) mafic lavas

OBBd — Debrite Member: thick-bedded mass-flow conglomerate and volcanogenic sandstone debrites; large fragments of pillow basalt similar to Venam's Bight lavas, leucoxene-diabase, breccia and felsic tuff. Some debrites capped by turbiditic sandstones, siltstones and mudstones; grades up to interbedded turbidites and pelagites, with rare felsic tuffs

OBBb — Basal Member: basal disturbed pelagites and volcaniclastic turbidites, interbedded with mafic volcanics. Thick sequence of massive, to brecciated, to thin-bedded rhyolitic tuffs, interbedded with black, sulphidic graptolitic shales

OBBr — Rhyolite-dominated domain

VENAM'S BIGHT FORMATION

OVB — Pillow lavas and sheet flows; clinopyroxene+plagioclase ±magnetite-porphyritic and vesicular; thin red siliceous mudstone layers

BOBBY COVE FORMATION (OBCb-OBC(r))

OBC(r) minor thin rhyolitic 'tuffs'

OBC(v) mafic lavas

OBCt — Turbidite Member: volcanogenic turbidites interbedded with purpulish pelagic siliceous mudstones; subordinate felsic tuffs

OBCb — Basal Member: dominantly subaqueous pyroclastic andesite tuffs deposited on a low-relief erosonial unconformity. Characteristic thick-bedded, crudely stratified, graded, block and lapilli tuffs; dominantly pumaceous andesitic clinopyroxene+plagioclase± hornblende clasts: locally abundant dacite, sandstone, siltstone, hornblendite or metabasalt clasts; interbedded with sequences of graded, crystal tuffs. Subordinate clinopyroxene-phyric andesitic to basaltic lava flows, dacitic crystal tuffs, and rhyolitic tuffs

D — dacitic tuffs

coarse fragmental facies

SCRAPE POINT FORMATION (OSPs-OSPv)

OSPv — Volcanic Member: amygdaloidal, sparsely to abundantly plagioclase+clinopyroxene-phyric tholeiitic basalt to ferrobasalt pillow lavas and massive flows

OSPs — Sedimentary Member: laterally discontinuous basal boulder conglomerate with basalt-chert fragments cemented by magnetite. Thin-bedded turbiditic sandstones, red siltstones, and magnetic-hematite ironstones (locally with abundant coarse cubic pyrite and stilpnomelane), grading up into green turbiditic sandstones/siltstones and crystal to lapilli tuffs; contact-metamorphic black slates and purple-silver phyllites

magnetic facies

MOUNT MISERY FORMATION

OMM — Spherulitic, amygdalodial, sparsely olivine-phyric tholeiitic pillow lavas and pillow breccias, grading up to plagioclase+pyroxene-phyric lavas. Uppermost lavas commonly hematized and/or strongly magnetic; locally prominent fault and talus breccia zones

C — conglomerate and breccia facies

BETTS COVE OPHIOLITIC COMPLEX (Obcs-OBH)

BETTS HEAD FORMATION

OBH — Spherulitic, amygdaloidal, sparsely olivine+chromite+ orthopyroxene-phyric boninitic pillow lavas. Several breccia types occur, including primary pillow breccia, fault breccia, heterolithic talus breccia impregnated by evolved boninites or gabbro, hyaloclastite and hydraulic breccias cemented by quartz+calcite+hematite +epidote+sulphides

Obcm — Mixed Dykes and Lavas: dyke swarms with 2-10m wide septa of spherulitic pillow lavas

Obcd — Sheeted Dyke Complex: typically 100% dykes. Includes several types: recessive-porphyritic chromite+olivine+orthopyroxene-phyric boninitic; sparsely porphyritic red-weathering boninitic, blue-green-weathering diabasic (boninitic affinity); pink-weathering microgabbroic (boninitic affinity); basal and upper contacts are gradational or faulted

Obcg — Late Intrusive Suite: dominantly massive gabbro-gabbronorite, subordinate hornblende diorite and trondhjemite, locally plagioclase-phyric or layered; pyroxenitic intrusions in (Obcd) probably related

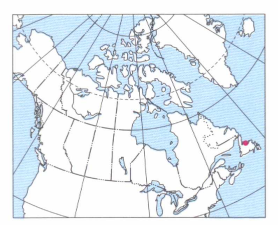
brecciated facies

Obcc — Layered Cumulates: cumulate peridotites (dominant poikilitic lherzolite, subordinate harzburgite and dunite), pyroxenites (orthopyroxenite, clinopyroxenite, and websterite) and foliated gabbronorite sequences; size and modally graded rhythmic beds, loading structures. Cut by pyroxenite and gabbro dykes and sills (Obcg) and dykes of (Obcd)

Obcs — Talc-Serpentinite Schists: altered and deformed peridotites; includes phacoidally cleaved serpentinites, matrix-supported peridotite conglomerate, clast-supported peridotite breccia with carbonate veining, and talc+magnetite+magnesite+ankerite ±sulphide schists

Geological boundary (defined, approximate)
Fault, shear sense unknown (defined, approximate)
Syn-obduction reverse fault
Siluro-Devonian reverse fault
Silurian Extensional fault
Syncline
Bedding, top known (inclined, vertical, overturned)
Bedding, top known (inclined, vertical)
Lava flows and Pillows, top known (inclined, overturned)
Lava flows and Pillows, top unknown (inclined)
Compositional layering (inclined, vertical)
Dyke (inclined, vertical)
Foliation, main fabric (inclined, vertical)
Foliation, second generation (inclined, vertical)
Shear zone (inclined, dip unknown)
Axial plane of minor fold (inclined)
Fold axis
Stretching lineation
Mineral lineation
Crenulation lineation
Intersection lineation
Slickenslide striae
Outcrop
Mineral occurence (adit, mine or showing) numbers explained in descriptive notes
Magnetic facies
Brecciated facies

Copies of this map may be obtained from the Geological Survey of Canada:
601 Booth Street, Ottawa, Ontario K1A 0E8
2535, boulevard Laurier, C.P. 7500, Sainte-Foy (Québec) G1V 4C7
3303-33rd Street, N.W., Calgary, Alberta T2L 2A7
101-605 Robson Street, Vancouver, B.C. V6B 5J3


LOCATION MAP

ESIC CIST
OCT 1 1999
Earth Sciences Sector   Secteur des sciences de la Terre

COOPERATION
COOPERATION AGREEMENT ON MINERAL DEVELOPMENT
ENTENTE DE COOPÉRATION SUR L'EXPLOITATION MINÉRALE
Contribution to Canada-Newfoundland Cooperation Agreement on Mineral Development (1990-1994), a subsidiary agreement under the Economic and Regional Development Agreement.
Contribution à l'Entente de coopération Canada-Terre-Neuve sur l'exploitation minérale (1990-1994), entente auxiliaire négociée en vertu de l'Entente Canada/Terre-Neuve de développement économique et régional
Canada   Newfoundland Terre-Neuve

Geology by J.H. Bédard, 1994 to 1997; K. Lauzière, 1994 to 1996; A. Sangster, 1994 to 1996; M. Tellier, 1994 to 1995; A. Tremblay, 1994 to 1995; T. Dec, University of Calgary 1994

Geological compilation by J.H. Bédard 1994 to 1999

Digital cartography by É. Boisvert, K. Lauzière, GSC Québec and S.J. Frohberg, Geoscience Information Division

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

MAP 1969A

GEOLOGY

BETTS COVE OPHIOLITIC COMPLEX AND ITS COVER ROCKS

NEWFOUNDLAND

Scale 1:20 000 - Échelle 1/20 000

Metres 500 0 500 1000 1500 2000 Mètres

Universal Transverse Mercator Projection
© Her Majesty the Queen in Right of Canada, 1999

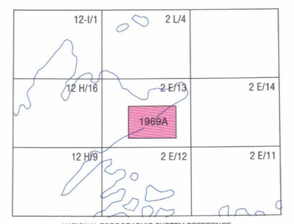
Projection transverse universelle de Mercator
© Sa Majesté la Reine du chef du Canada, 1999

Digital base map from data compiled by Geomatics Canada, modified by the Geoscience Information Division

Some geographical names subject to revision
Local names are in brackets

Mean magnetic declination 1999, 23°45'W, decreasing 7.8' annually

Elevations in metres above mean sea level



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

Published 1999

Recommended citation:
Bédard, J.H., Lauzière, K., Sangster, A., Tellier, M., Tremblay, A., and Dec, T.
1999: Geology, Betts Cove ophiolitic complex and its cover rocks, Newfoundland; Geological Survey of Canada, Map 1969A, scale 1:20 000.

1969 A

Canada

This map has been produced from a scanned version of the original map
Reproduction par numérisation d'une carte sur papier