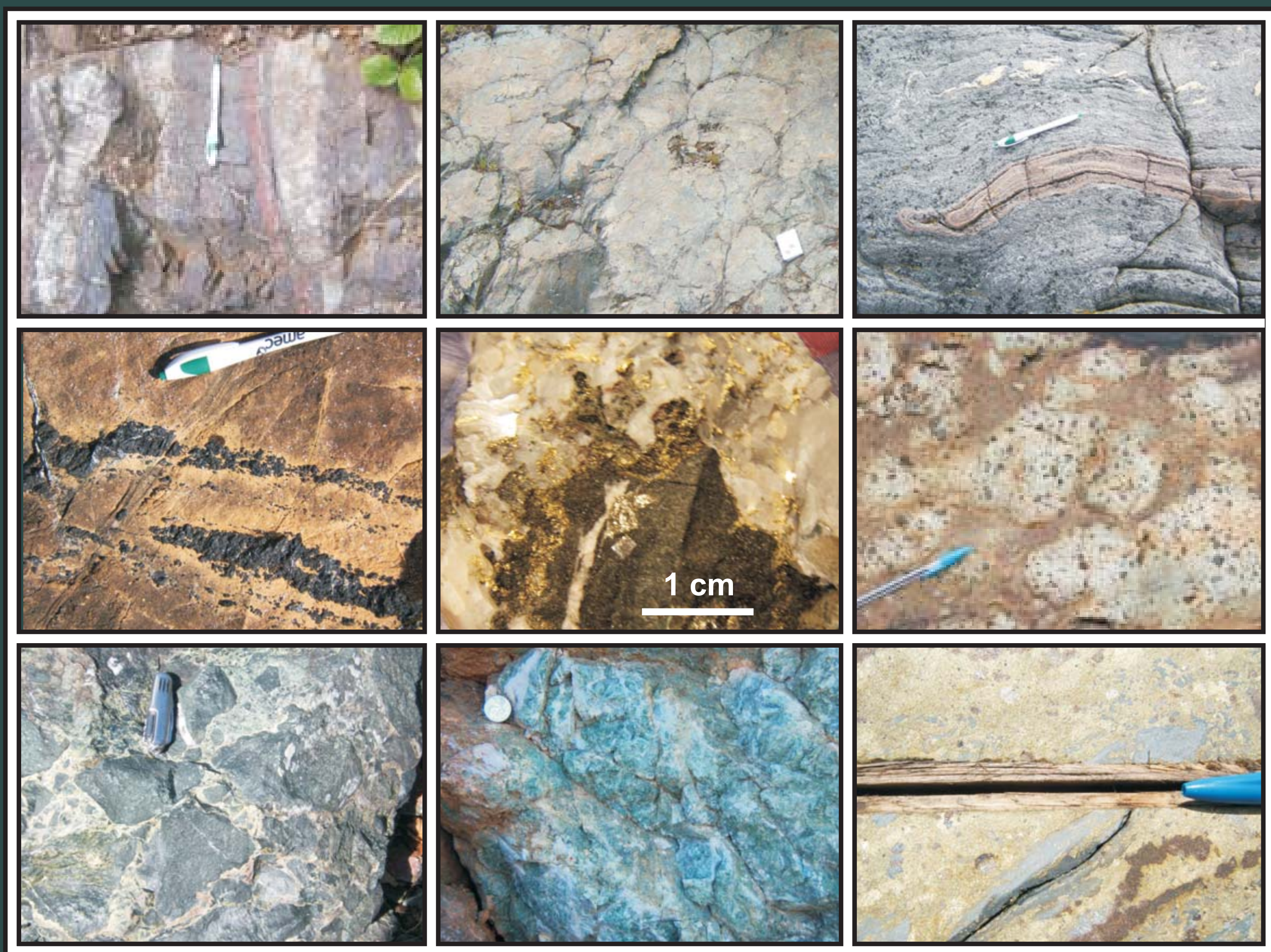
GEOLOGICAL ASSOCIATION OF CANADA
NEWFOUNDLAND AND LABRADOR SECTION

ANNUAL FALL FIELD TRIP
October 2-5, 2009



BAIE VERTE PENINSULA:
AN EVOLVING GEOLOGICAL STORY

Thomas Skulski, Sébastien Castonguay, Cees van Staal,
Neil Rogers, Vicki McNicoll, Andrew Kerr and Monica Escayola

www.gac-nl.ca

BAIE VERTE PENINSULA:
AN EVOLVING GEOLOGICAL STORY

Thomas Skulski[1], Sébastien Castonguay[2], Cees van Staal[3], Neil Rogers[1],
Vicki McNicoll[1], Andrew Kerr[4] and Monica Escayola[1]

Edited by Neil Rogers[1] and Andrew Kerr[4]

(1) Geological Survey of Canada, 601 Booth Street, Ottawa, ON, K1A 0E8

(2) Commission géologique du Canada, 490 rue de la Couronne, Québec, QC G1K 9A9

(3) Geological Survey of Canada, 625 Robson Street, Vancouver, BC, V6B 5J3

(4) Geological Survey of Newfoundland and Labrador, Department of Natural Resources, P.O. Box 8700, St. John's, NL, A1B 4J6

Front Cover Photos (all photos by Andrew Kerr)

TOP: *Left - Nugget Pond horizon marker unit; Centre – Pillow lavas, Snooks Arm; Right - Refolded folds, Coachmans Cove.*

MIDDLE: *Left – Chromite seams, Advocate Complex; Centre – Gold at Nugget Pond; Right – Tuff-breccia marker unit, Snooks Arm.*

BOTTOM: *Left – Pillow breccia, Tilt Cove; Centre – Virginite, Advocate Complex; Right – Copper ore, Rambler footwall zone.*

TABLE OF CONTENTS

FIGURE AND PLATE LOCATIONS IN DOCUMENT

Note that the pages containing the figures in this document are not paginated individually. The listing below indicates the page in the text immediately BEFORE the noted Figure.

OVERVIEW OF THE FIELD TRIP

The 2009 Geological Association of Canada (Newfoundland and Labrador Section) field trip takes us to the Baie Verte Peninsula of northeastern Newfoundland. This is not the first excursion to this area, for it has long been critical in the development of modern tectonic models for Newfoundland and the Appalachian Orogenic belt in general. Like all "classic" areas in the geology of mountain belts, the peninsula reserves as many questions as it answers. In the light of recent work conducted through the TGI-3 Appalacahians Project of the Geological Survey of Canada (GSC), and related work completed by the Geological Survey of Newfoundland and Labrador (GSNL) and mineral exploration companies, new insights into these problems have emerged. At the same time, new ideas and concepts, coupled with new data, lead to unexpected new questions!

The purpose of our field trip is to provide a forum for presentation and discussion of ideas developed over the last few years. These relate particularly to correlations amongst the ophiolite complexes and their volcanosedimentary cover sequences that host most of the peninsula's mineral resources. The field trip does not emphasize visits to the mineral deposits themselves, but rather emphasizes their geological framework and its relevance to exploration. This guidebook is in many respects a preliminary document assembled within a short time-frame, and it may contain some unavoidable inconsistencies and deficiencies. Nevertheless, it is a valuable first step in a new synthesis of potentially important geological relationships in a key area for both tectonics and mineral exploration, and we hope that this field trip will move us closer to this objective.

ACKNOWLEDGEMENTS

We would like to acknowledge the support of geologists and exploration companies that have worked in the Baie Verte Peninsula and that have generously shared their maps and various datasets, and for numerous fieldtrips and discussions. In particular, J. Hibbard, J. H. Bédard, W.S.F. Kidd, W.R. Church, S.J. Piercey, S.D. Anderson, L. Pilgrim and the geologists of Rambler Metals & Mining PLC, Altius Minerals Corp., and GeoScott Exploration Consultants. We thank our partners at McMaster University, W.A. Morris, W. Spicer and H. Ugalde for their collaboration during geophysical surveys, data interpretation and modeling. The capable field assistance and mapping of I. Kerr, J. Duff, Y. Moussallam, S. Hinchey, K. Shweridan, L. Hartree, M. Tucker, and Ian Ames was greatly appreciated. We acknowledge T. Sacrey, R. Wimbledon, R. Bowers, and J. Sacrey for their boat support. We also thank the people of Pacquet for their hospitality. Chris Pereira at GSNL is thanked for editorial assistance, and Heather Rafuse for helping to produce the guidebook. This field trip is supported the Geological Survey of Canada Targeted Initiative Program (TGI3 Appalachians project), and by the Geological Survey of Newfoundland and Labrador.

SAFETY CONSIDERATIONS

The Geological Association of Canada (GAC) recognizes that its field trips may involve hazards to the leaders and participants. It is the policy of the Geological Association of Canada to provide for the safety of participants during field trips, and to take every precaution, reasonable in the circumstances, to ensure that field trips are run with due regard for the safety of leaders and participants. GAC recommends steel-toed safety boots when working around road cuts, cliffs, or other locations where there is a potential hazard from falling objects. GAC will not supply safety boots to participants. Some field trip stops require sturdy hiking boots for safety. Field trip leaders are responsible for identifying any such stops, making participants aware well in advance that such footwear is required for the stop, and ensuring that participants do not go into areas for which their footwear is inadequate for safety. Field trip leaders should notify participants if some stops will require waterproof footwear.

Field trip participants are responsible for acting in a manner that is safe for themselves and their co-participants. This responsibility includes using personal protective equipment (PPE) when necessary (when recommended by the field trip leader or upon personal identification of a hazard requiring PPE use). It also includes informing the field trip leaders of any matters of which they have knowledge that may affect their health and safety or that of co-participants. Field Trip participants should pay close attention to instructions from the trip leaders and GAC representatives at all field trip stops. Specific dangers and precautions will be reiterated at individual localities.

Stops on this field trip include coastal localities and roadside outcrops. Participants should be in good physical condition and accustomed to exercise. The coastal sections contain saltwater pools, seaweed, mud and other wet areas; in some cases it may be necessary to cross brooks or rivers. There is a strong possibility that participants will get their feet wet, and we recommend waterproof footwear. We also recommend footwear that provides sturdy ankle support, as localities may also involve traversing across beach boulders or uneven rock surfaces. Coastal localities present some specific hazards, and participants MUST behave appropriately for the safety of all. High sea cliffs are extremely dangerous, and falls at these localities would almost certainly be fatal. Participants must stay clear of the cliff edges at all times, stay with the field trip group, and follow instructions from leaders. Coastal sections elsewhere may lie below cliff faces, and participants must be aware of the constant danger from falling debris. Please stay away from any overhanging cliffs or steep faces, and do not hammer any locations immediately beneath the cliffs. In all coastal localities, participants must keep a safe distance from the ocean, and be aware of the magnitude and reach of ocean waves. Participants should be aware that unusually large "freak" waves present a very real hazard in some areas. If it is necessary to ascend from the shoreline, avoid unconsolidated material, and be aware that other participants may be below you. Take care descending to the shoreline from above. At roadside stops, participants should make sure that they stay off the roads, and pay careful attention to traffic, which may be distracted by the field trip group. Roadcut outcrops present hazards from loose material, and should be treated with the same caution as coastal cliffs. The mine access roads at Nugget Pond and Rambler may have heavy truck traffic. Within the confines of mining properties, participants must follow safety procedures required by the operators at all times.

Weather is unpredictable in this area and participants should be prepared for a wide range of temperatures and conditions. Always take suitable clothing. A rain suit, sweater, sturdy footwear are essential at almost any time of the year. The hammering of rock outcrops, which is in most cases completely unnecessary, represents a significant "flying debris" hazard to the perpetrator and other participants. For this reason, we ask that outcrops not be assaulted in this way; if you have a genuine reason to collect a sample, inform the leaders, and then make sure that you do so safely and with concern for others. Our preference is that you leave hammers at home or in the field trip vans.

Subsequent sections of this guidebook contain the stop descriptions and outcrop information for the field trip. In addition to the general precautions and hazards noted above, the introductions for specific localities make note of specific safety concerns such as traffic, water, cliffs or loose ground. Field trip participants should read these cautions carefully and take appropriate precautions for their own safety and the safety of others.

PART 1: GEOLOGY OF THE BAIE VERTE PENINSULA

Introduction

The Baie Verte Peninsula (Figure 1) is host to a rich mineral endowment and has long been the focus of mining and exploration for copper, gold, asbestos and other commodities. These diverse mineral resources are mostly hosted by Lower Ordovician submarine volcanic rocks of the Baie Verte oceanic tract (BVOT) of the Notre Dame subzone of the Dunnage zone (Williams et al., 1988; van Staal et al., 2007), which includes ophiolite suites generated in a suprasubduction zone environment (e.g., Betts Cove Complex; Bédard et al., 1998) and their volcanic cover sequences. The ophiolite sequences host asbestos in hydrothermally-altered ultramafic cumulate (± mantle) sections, VMS-style copper ± gold mineralization in mafic and bimodal mafic-felsic volcanic sequences, and gold mineralization in hydrothermally altered mafic and ultramafic rocks. In contrast, the volcanic cover sequences to the ophiolites host epigenetic gold deposits associated with banded iron formation, and in quartz veins or related replacement deposits, mostly hosted by altered and deformed mafic rocks (Evans, 2004). Until recently, understanding the metallogeny of the Baie Verte Peninsula was hampered by uncertainties in the age of volcanic units, their subdivision into individual and potentially unrelated ophiolite complexes, and uncertainties in the tectonic setting of the cover sequences. Further complexity arises from the large contrast in structural style and geometry across the peninsula (Hibbard, 1983). In the east, the Betts Cove Complex is folded into a relatively simple, large-scale, doubly-plunging northeast-trending syncline (Tremblay et al., 1997; Spicer, 2008), whereas in the west (along the Baie Verte line), similar ophiolite sequences and cover rocks are complexly folded and segmented by multiple generations of tightly spaced, northeast-striking faults and shear zones. In contrast, the poorly-exposed central part of the peninsula is dominated by east-trending structures and fabrics. The rocks in this region are gently folded into upright structures in the south, but are polydeformed in the north, where they are affected by recumbent fold structures and associated with both thrusts (Hibbard, 1983) and extensional faults (Anderson, 1998, 2001).

The Baie Verte Peninsula has an extensive history of mineral exploration dating back to the 1850s, and has been the focus of numerous lithological and structural studies including those of Hibbard (1983), Waldron et al., (1998), Bédard et al., (1999; 2000) and Evans (2004). As part of the Geological Survey of Canada’s Appalachian TGI-3 Program, an integrated geoscience study of the Baie Verte Peninsula was initiated in 2006 to aid in the search for base-metal mineralization by resolving problems in the tectonostratigraphy and structural history of the peninsula. This was approached by combining the extensive body of literature and mapping in this area with new focused bedrock mapping in key areas. In conjunction with regional geophysics, geochronology, lithogeochemistry and remote sensing data, this approach has now identified key stratigraphic markers and structural relationships. Key stratigraphic units have been traced across poorly exposed areas with the aid of a high resolution regional

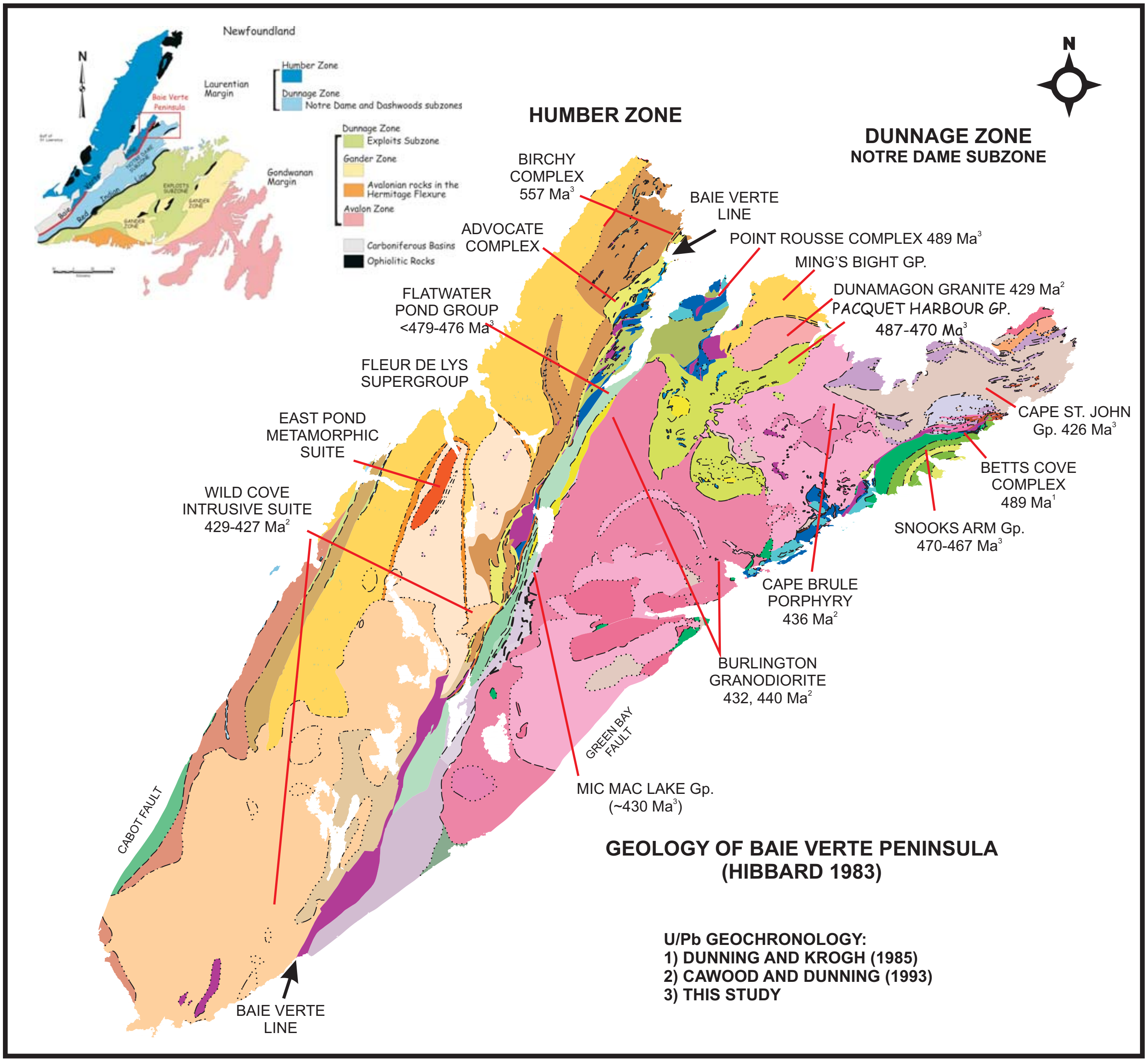


Figure 1. Geology of the Baie Verte Peninsula modified after Hibbard (1983). Insert shows the Baie Verte area in relation to the main tectonic divisions of Newfoundland (Williams, 1995). The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

aeromagnetic survey (Coyle and Oneschuk, 2008a; b), locally augmented by detailed aeromagnetic surveys flown for mineral exploration companies. Detailed petrology and geochemistry, coupled with precise geochronology, was used to ascertain if the sequence defined from the relatively well-exposed and least-deformed Betts Cove area, as described by Bédard et al. (1999; 2000), can be extrapolated westward across the peninsula. The initial results from this work indicate that the various cover sequences to the ophiolite complexes can be correlated at various scales. A detailed report of the structural geology of the central part of the peninsula is presented in Castonguay et al. (2009). This work provides new information on the complex deformational history of this key area, and provides a better understanding of the structural controls on both Ordovician VMS-style Cu-Au deposits and Silurian epigenetic gold deposits.

Geological Setting

The Baie Verte Peninsula straddles the boundary between the Humber zone (representing the ancient continental margin of Laurentia) and the diverse oceanic rocks formed with a region of the Iapetus Ocean that lay proximal to Laurentia; the latter now occupy the Notre Dame Subzone of the Dunnage zone (Figure 1; Williams et al., 1988). The regional geology of the peninsula is illustrated in Figure 1. The Baie Verte oceanic tract (BVOT) is interpreted to represent the vestiges of a narrow oceanic tract (the "Humber Seaway") that developed between Laurentia proper and ribbon-like zones of continental crust of Laurentian affinity, which are collectively termed the "Dashwoods microcontinent" (Waldron and van Staal 2001). This rifted ribbon of continental crust eventually formed the substrate for island-arc terranes represented by younger volcanic sequences now preserved within the Buchans-Roberts Arm Belt. The tectonic boundary between the Humber zone and Notre Dame subzone is the Baie Verte Line (BVL), a complex zone of reactivated shear zones and faults that separate obducted ophiolite crust and underlying mantle from the Laurentian continental margin. West of the BVL, the Humber zone comprises migmatitic gneisses of the East Pond metamorphic suite (interpreted to represent Grenvillian basement) and the overlying Fleur de Lys Supergroup comprising psammites, pelite, marble, graphitic schist and amphibolite derived from continental margin sedimentary rocks (de Wit, 1974; Hibbard, 1983). The Ming's Bight Group comprises pelite, psammite, conglomerate and amphibolite that lie to the east of the BVL, and is correlated with the Fleur-de-Lys Supergroup.

The Fleur de Lys Supergroup is separated from the Baie Verte Line by a narrow, tectonically disrupted zone of graphitic schist, quartzite, pelite, metabasalt, metagabbro and serpentinite melange comprising the Birchy Complex (Hibbard, 1983; Winchester et al., 1992; Figure 1). A metagabbro in the lower part of the Birchy Complex from Coachman's Cove has yielded a U/Pb zircon age of 558 Ma (unpublished data, V. McNicoll, 2007) and is interpreted to record the opening of the Humber Seaway. Faults along the BVL separate serpentinite melange and pelitic (locally graphitic) schists of the Birchy Complex from the Advocate Ophiolite Complex (BVOT) to the east. The pelitic rocks include "coticules", which are distinctive units representing metamorphosed Mnrich cherts of possible exhalative origin). The Advocate Complex consists of serpentinized mantle harzburgite and dunite, and dismembered crustal ultramafic cumulates, gabbro, trondhjemite, sheeted dykes and mafic volcanic rocks. The volcanic and sedimentary cover sequence that overlies the Advocate Complex contains mafic tuffs, basalt, argillite, ophiolite-derived megaconglomerate and cobble-size conglomerate with an argillaceous matrix.

The Dunnage zone east of the BVL comprises several ophiolite complexes including the ca. 489 Ma (Dunning and Krogh, 1982) Betts Cove Complex (Bédard et al. 2000a; b), rocks within the southern (lower) Pacquet Harbour Group, and the Point Rousse Complex (Hibbard, 1983). These collectively define the BVOT (van Staal et al., 2007) and are overlain by volcano-sedimentary cover sequences including the Snooks Arm Group (cover to the Betts Cove Complex), the upper Pacquet Harbour Group, and the Point Rousse cover sequence (Figure 1). These ophiolite sequences and their volcanic cover are discussed in detail below.

The BVOT of the Baie Verte Peninsula is intruded by several large Silurian granitoid plutons including the ca. 434-430 Ma Burlington granodiorite, ca. 430 Ma Cape Brulé porphyry and ca. 429 Ma Dunamagon granite (Hibbard, 1983; Cawood et al., 1993). These plutons are early synvolcanic with respect to early Silurian, bimodal, continental tholeiitic volcanic rocks of the Cape St. John Group that lie unconformably on the Snooks Arm Group (Bédard et al., 2000a; b). To the southwest, the Micmac Lake Group comprises similar bimodal subaerial volcanic rocks. Silurian volcanic rocks and their shallow intrusive equivalents are also present within the Kings Point Complex in the south-central part of the peninsula; these include a prominent ring-dyke that has topographic expression.

Early Ordovician Rocks of the Eastern Baie Verte Peninsula

Betts Cove Complex

The stratigraphy of the Bett’s Cove Complex (Figures. 2, 3a,b) was defined and presented in detail by Bédard et al. (2000a; b). The Betts Cove ophiolite comprises a lower ultramafic cumulate section, overlain by layered gabbros, massive gabbro (transitional to sheeted dykes), sheeted dykes, and pillowed boninites of the Betts Head Formation (Bédard et al., 1999b; 2000a). “Boninites” are distinctive primitive mafic volcanic rocks that typically have high MgO contents compared to other basaltic lavas. Boninites in the Betts Head Formation are subdivided into low $Ti0_2$ (0.1-0.3%) boninites and overlying, intermediate TiO_2 types (0.3-0.5%; Coish and Church, 1979; Bédard et al., 1999a). Low TiO_2 boninites are aphyric or contain small phenocrysts of olivine and pyroxene , and are commonly variolitic. The pillows are generally small with wide, diffuse pillow margins containing small varioles, with partly coalesced, larger varioles in pillow interiors. Intermediate TiO_2 boninites are either aphyric or contain small

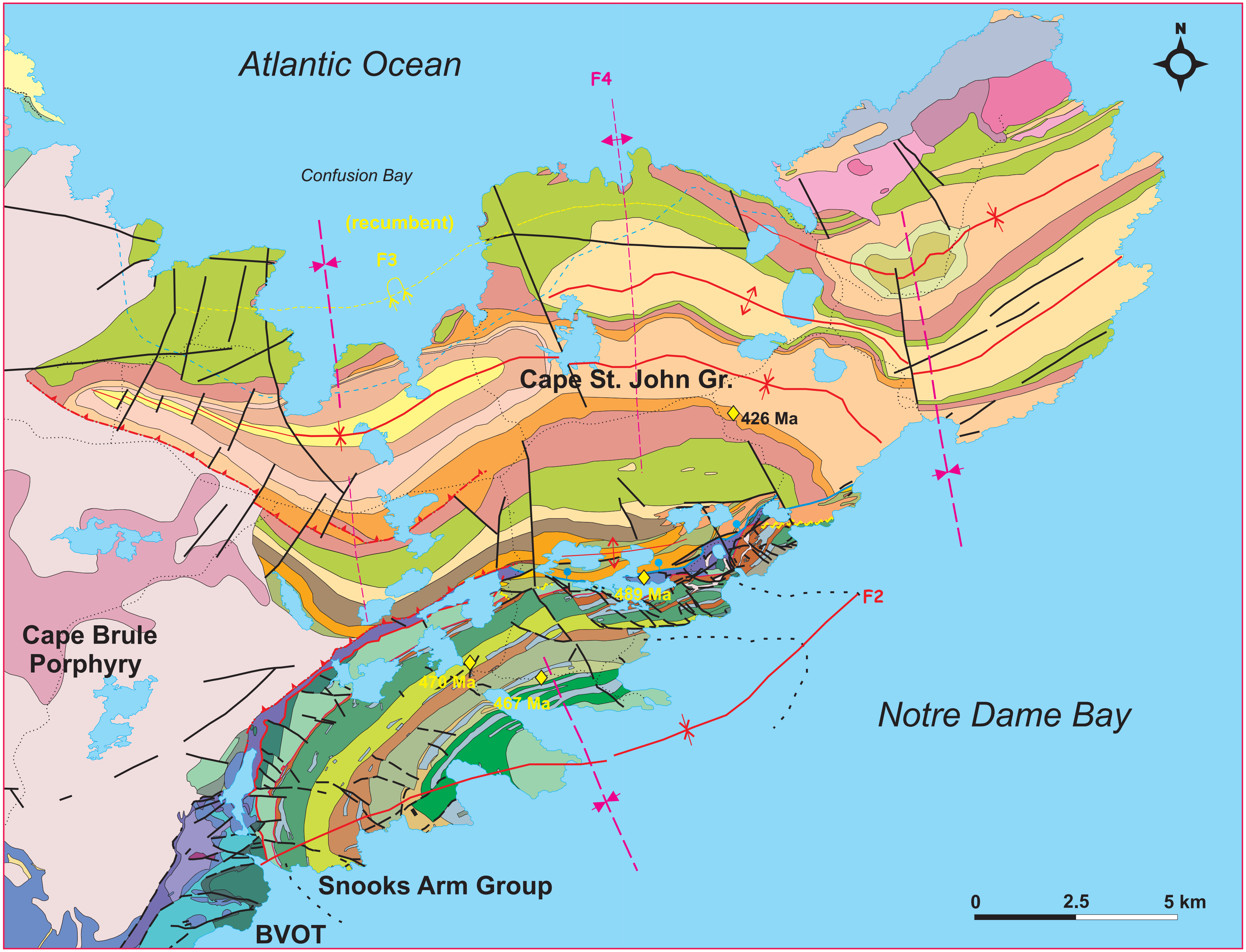


Figure 2. Detailed geology of the Betts Cove/La Scie area. Geology of the Betts Cove Complex and Snooks Arm Group is modified after Bédard et al. (1999b), with the Cape St John Group from Moussallum (2007). The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

DUNNAGE ZONE

Ophiolite Cover Sequence

Late Ordovician

Yak Lake formation

- Rhyodacite (457 Ma), basalt

Middle- to Early Ordovician

Snooks Arm Group / upper Pacquet Harbour Group / Pointe Rousse cover sequence

- Round Harbour Formation, pillow basalt
- Balsam Bud Cove Formation, pillow basalt, debrite
- Balsam Bud Cove Formation, rhyolite (c. 467 Ma) and felsic tuff (c. 470 Ma)
- Balsam Bud Cove Formation, mafic epiclastic rocks, black shale
- Venam's Bight formation, pillow basalt
- Bobby Cove Formation, mafic tuff, epiclastic rocks, turbidites
- Bobby Cove Formation, cpx-phyric mafic tuff breccia, volcanic conglomerate, felsic crystal tuff (c. 471 Ma)
- Scrape Point Formation, pillow basalt, gabbro (c. 483 Ma)
- Scrape Point Formation, mafic volcaniclastic rocks, epiclastic rocks and rare pillow basalts
- Scrape Point Formation, Nuggett Pond member / Goldenville horizon, jasper iron formation, conglomerate

Flatwater Pond Group

- Flatwater Pond Group, undifferentiated
- Venam's Bight formation, pillow basalt
- upper Bobby Cove formation, mafic tuff and epiclastic rocks
- lower Bobby Cove formation, Prairie Hat member, cpx-phyric mafic tuff
- Scrape Point formation, pillow basalt
- Scrape Point formation, argillite, mafic volcaniclastic rocks, banded iron formation
- Six Mile Brook formation, rhyodacite (c. 476 Ma) and felsic volcaniclastic rocks
- Kidney Pond conglomerate formation, black slate matrix gabbro, quartzite, basalt, granodiorite and c. 479 Ma felsic volcanic clasts
- Boudin Pond formation, ophiolite-derived mega conglomerate with black shale matrix

Baie Verte Oceanic Tract

Early Ordovician

Betts Cove Ophiolite complex / Pointe Rousse Complex

- Mt. Misery Formation, intermediate Ti boninite, island arc tholeiitic pillow basalt, pillow breccia
- Rambler Rhyolite formation, rhyodacite, rhyolite masiive flows, tuff breccia (c. 487 Ma)
- Betts Head Formation, Pillowed boninite. aphyric, variolitic
- Sheeted gabbro dykes
- Late gabbro intrusive
- Ophiolite gabbro, layered gabbro, gabbro pegmatite (c. 489 Ma) /sheared gabbro
- Layered ultramafic cumulates
- Serpentinized ultramafic rock, locally listwanite, talc schist

Early Ordovician

Advocate Complex

- Unseparated mafic volcanic and volcaniclastic rocks, black slate, conglomerate with gabbro clasts
- Basalt and mafic schist, island arc tholeiite
- Ophiolite gabbro, metagabbro
- Serpentinized ultramafic rock, locally talc-carbonate-fuchsite alteration

HUMBER ZONE

Laurentian Continental Margin

Proterozoic

East Pond Metamorphic Suite

- High strain zone in psammite and semipelite
- Middle Arm conglomerate
- Psammite, semipelite schist and gneiss
- Migmatite gneiss

Neoproterozoic

Fleur de Lys Supergroup

- Unseparated psammite, semipelite, pelite, graphitic and mafic schist
- Birchy Complex, amphibolite, minor gabbro (c. 557 Ma), psammite, calcareous schist, and graphitic schist
- Rattling Brook Group, semipelite, pelite, psammite and marble
- Old House Cove Group, psammite, semipelite
- Old House Cove Group, feldspar porphyroblastic mica schist

Ming's Bight Group

- Unseparated psammite, semipelite, pelite, and mafic schist

Figure 3a. Provisional lithostratigraphy of the Ordovician and older sequences in the Baie Verte Peninsula. Note that some unit names are informal and correlations indicated are in part derived from unpublished data. U/Pb zircon geochronology is unpublished data from V. McNicoll (2007; 2008; 2009).
(This legend applies to detailed geological maps used elsewhere in the guidebook)

Continental Cover Sequence

Silurian

Seal Island Bight syenite (427 Ma)

La Scie granite

Reddit gabbro

Early Silurian

Cape St. John Group

Undifferentiated Cape St. John Group

Upper aphyric, flow-banded rhyolite

Upper massive, amygdaloidal, tholeiitic basalt

Pumice-bearing lapilli tuff

Magnetite-phyric rhyolite

White massive rhyolite

Aphyric, flow-banded rhyolite (426 Ma)

Beige lapilli tuff

Black lapilli tuff

Massive amygdaloidal, tholeiitic basalt

Fine grained felsic tuff

Heterolithic volcanic breccia, highly magnetic, mafic matrix

Felsic tuff breccia, lapilli tuff with jasper and ultramafic clasts

Lower welded tuff

Massive tholeiitic basalt, amygdaloidal

Reddish-brown arkose, conglomerate

Mic Mac Lake Group

Undifferentiated Mic Mac Lake Group

Upper sequence, red sandstone

Upper sequence, quartz feldspar porphyritic ash flow tuff

Upper sequence, mafic lava and conlgomerate

Lower sequence, rhyolite and welded ash flow tuff (~430 Ma)

Lower sequence, crossbedded sandstone and conglomerate, minor mafic lava and welded tuff

Early Silurian

King's Point Complex

Upper volcanic unit, amphibole porphyritic ash flow tuff

Upper Volcanics, quartz-feldspar porphyritic ash flow tuff, breccia and ring dykes

Upper Volcanics, sparsely porphyritic to aphyric ash flow tuff

Upper Volcanics, sparsely porphyritic quartz-feldspar ash flow tuff

Middle felsic volcanic unit, aphyric to sparsely porphyritic ash flow tuff

Gull Pond formation

Mafic tuff breccia and lapilli tuff (430 Ma)

Dunamagon granite

Granite (429 Ma)

CapeBrule Porphyry

Porphyritic granodiorite, quartz feldspar porphyry (436 Ma)

Diorite, equigranular granodiorite

Burlington Intrusive Suite

Granodiorite (432, 440 Ma)

Wild Cove Pond Igneous Suite

Undifferentiated, granite, granodiorite, diorite and migmatite

Granite

Granodiorite 429 Ma

Migmatite gneiss

Figure 3b. Provisional lithostratigraphy of the Silurian sequences in the Baie Verte Peninsula.
Note that some unit names are informal and correlations indicated are in part derived from unpublished data.
U/Pb zircon geochronology is unpublished data from V. McNicoll (2007; 2008; 2009).
(This legend applies to detailed geological maps used elsewhere in the guidebook)

phenocrysts of pyroxene and plagioclase. Underlying layered cumulates include dunite, harzburgite and their serpentinized equivalents, overlain by pyroxenite and gabbro. These have compositions that are calculated to have equilibrated with low TiO_2 boninitic magmas (Bédard et al., 1999b). A relatively late gabbroic intrusive suite found as intrusive sheets in the dyke section and cutting layered gabbros, is dated at ca. 489 Ma (Dunning and Krogh, 1982) and is calculated to have equilibrated with an intermediate TiO_2 boninitic magma (Bedard et al., 1999b). The ca. 489 Ma age provides the only constraint on the formation of the Betts Cove Complex.

Contrary to the stratigraphy defined by Bédard et al. (1999b) we also include the volcanic rocks of the Mt. Misery Formation in the Betts Cove Complex, rather than in the Snooks Arm Group. (Figures. 3a, 4). The Mt. Misery Formation comprises plagioclase-phyric, pillowed island arc tholeiitic basalts that are chemically transitional to, and interbedded with, intermediate TiO_2 boninites. The top of the Mt. Misery Formation locally contains mafic- and ultramafic-derived breccia and conglomerate. Pillow breccias of the Mt. Misery Formation host Cyprus-style, Cu (± Au)-rich volcanogenic massive sulphide (VMS) deposits at the Tilt Cove Mine. In light of the local interbedding of Mt. Misery lavas with boninites and the presence of distinctive conglomerate and banded iron formation in the immediately overlying rocks of the Scrape Point Formation, it seems reasonable to conclude that the base of the Snooks Arm Group should be redefined as the boundary between the Mt. Misery and Scrape Point formations, rather than at the base of the Mt. Misery Formation. This interpretation is expected to be formalized in the near future.

Snooks Arm Group, Betts Cove area

The stratigraphy of the Snooks Arm Group (Figs. 2, 3a,b) was defined and presented in detail by Bédard et al. (2000a; b). This sequence represents the ophiolitic cover sequence in the vicinity of Bett's Cove. However, as outlined above, the Mt. Misery Formation is herein included within the upper part of the ophiolitic sequence, rather than with the cover sequence. Consequently, the Scrape Point Formation becomes the stratigraphically lowest part of the Snooks Arm Group (Figure 4).

The Scrape Point Formation is locally separated by an angular unconformity from the underlying Mt. Misery Formation (Bédard et al., 1999a). The stratigraphy of the Scrape Point Formation is important in understanding proposed correlations amongst the cover sequences to the ophiolites. Its lowermost unit (the Nugget Pond horizon) comprises a local basal conglomerate or breccia of basalt clasts cemented by jasper, overlain by red siltstones and jasper-magnetite iron formation. These rocks host the Nugget Pond gold deposit, where they are affected by an epigenetic albite-carbonate-quartz-pyrite alteration that contains gold associated with pyrite (Sangster et al., 1994). The Nugget Pond horizon is overlain by (and interbedded with) coarser, green siltstone and tuffaceous wacke. These clastic rocks are in turn overlain by, and locally

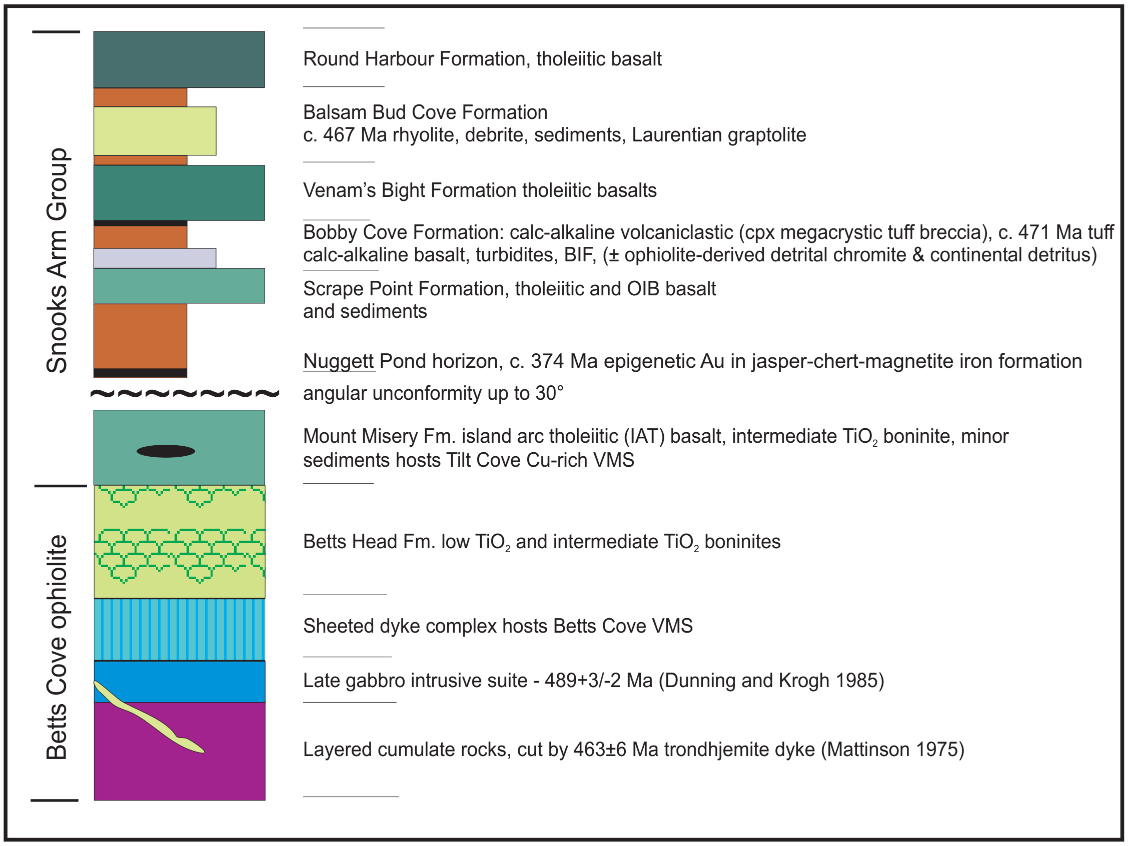


Figure 4. Detailed stratigraphy of the geology in the Betts Cove area; modified after Bédard et al. (1999b). The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

Plate 1. Examples of the distinctive marker units that are proposed for correlations amongst the cover sequences to BVOT ophiolites.
Left: Part of the Nugget Pond horizon. Right: The distinctive clinopyroxene-phyric tuff-breccia.

interbedded with, mafic tuffs and tholeiitic, high TiO_2 (1.5-3.0%), plagioclase-phyric pillow basalts.

The Bobby Cove Formation overlies the Scrape Point Formation and includes a lower, calc-alkaline member (termed the "Prairie Hat" member by Kidd, 1974) comprising distinctive, green-grey, clinopyroxene megaphyric tuff breccia, lapilli tuff and volcanic conglomerate. Basaltic to andesitic lava flows, pillows and dykes are present locally. These are overlain by felsic crystal tuff (locally a lapilli tuff) that yielded a U/Pb zircon age of ca. 470 Ma (unpublished data, V. McNicoll, 2007). The clinopyroxene-phyric tuff-breccia was recognized as a potential marker horizon by Hibbard (1983), and is an important in regional correlations outlined by more recent work.

The upper Bobby Cove Formation comprises green volcanic-derived turbiditic wacke and siltstone, interbedded with purplish pelagic mudstone with rare, thin felsic tuff beds. Locally, a thin jasper iron formation and red shale defines the top of the Bobby Cove Formation.

The overlying Venam's Bight Formation comprises pillowed, amygdaloidal tholeiitic, high TiO_2 (>1.5%) basalts. The basalts are plagioclase-phyric, to glomerophyric, with rare aphyric flows. The pillowed basalts are locally interbedded with pillow breccia, hyaloclastite and mafic agglomerate, and layers of red siliceous mudstone or ironstone.

The Balsam Bud Cove Formation includes a basal member consisting of interbedded red and green siltstone, shale and sandstone, volcaniclastic turbidite, tuffaceous sandstone and basaltic lavas similar to the underlying Venam's Bight Formation basalts. These are succeeded by a sequence of quartz- and feldspar-phyric felsic tuffs, crystal tuffs and black sulphidic shale. The shales contain Laurentian graptolite fossils belonging to the lower *Didymograptus bifidus* Zone (early Llanvirn). A sample of felsic tuff overlying the graptolitic shale yielded a zircon U/Pb age of ca. 467 Ma (unpublished data, V. McNicoll, 2007). The upper member consists of thick-bedded debris-flow deposits ("debrites") comprising large fragments (to 20 m) of massive and pillowed basalt, and smaller clasts of felsic tuff, pyroxenite, tuffaceous sandstone and microgabbro (Bédard et al., 2000a).

The top of the Snooks Arm Group is the Round Harbour Formation. This is dominated by sheet and pillowed flows of tholeiitic basalt similar to the Venam's Bight basalts, interbedded with thin chert units. Pillows are large (up to 2m in diameter), are well-preserved, and may contain pillow shelves.

Early Ordovician rocks of the Central Baie Verte Peninsula

Paquet Harbour Group

Deformed and metamorphosed volcanic and sedimentary rocks of Ordovician age in the north central portion of the Baie Verte Peninsula have been assigned to the Pacquet Harbour Group (e.g., Hibbard, 1983; Figure 5). These are spatially separated from the Betts Cove complex and the Snooks Arm Group by the Silurian Cape Brulé

Porphyry and Cape St. John Group (Figure 1). The Pacquet Harbour Group is gently folded in the south, but more tightly folded in the north and it shows an overall east to northeast younging. Stratigraphic, geochemical and geochronological data reveal that the southern portion of the Pacquet Harbour Group contains correlatives of the Betts Head and Mt. Misery formations of the Betts Cove Complex, as defined by Bédard et al. (2000a; b; Figures. 3a, 6). These are overlain to the north and east by volcanic and sedimentary rocks that have similar petrological and geochemical characteristics to the Snooks Arm Group. This portion of the Pacquet Harbour Group is thus considered to correlate directly with the Snooks Arm Group (Figures 3a, 6). It is expected that this interpretation will be formalized in the near future.

Boninites (low TiO_2 variety) occur with rare, thin cogenetic felsic tuffs and rhyodacitic flows in the south (c.f. Hibbard, 1983). These are cut by tholeiitic gabbro dykes that potentially feed overlying tholeiitic pillow basalts similar to those of the Scrape Point Formation in the Snooks Arm Group. South of the Rambler mine site, there are pillowed boninites (low- and intermediate-TiO_2) and a thin dacitic tuff, which host the Big Rambler Pond stringer massive sulphide deposit. These rocks are interpreted herein to be equivalent to the Betts Head Formation in the Betts Cove Complex. This sequence is overlain by black chert and magnetite iron formation, and by tholeiitic basalts similar to those of the Scrape Point Formation in the Snooks Arm Group. The distinctive sedimentary facies is believed herein to correlate with the Nugget Pond horizon. Locally, these are overlain by a polymict conglomerate and breccia that contains boninite, felsic volcanic and mafic plutonic clasts in a green, chloritic matrix. This conglomerate may be correlated with the Kidney Pond conglomerate in the Flatwater Pond area (see below).

To the north, the Rambler Brook fault contains a hanging wall sequence of boninitic, quartz-phyric, rhyodacite, felsic tuff and tuff breccia commonly referred to as the Rambler rhyolite. The upper parts of the Rambler rhyolite host the volcanic massive sulphide deposits of the Rambler and Ming mines. A sample of Rambler rhyolite sampled immediately below the mineralization yielded a U/Pb zircon age of ca. 487 Ma (unpublished data, V. McNicoll, 2008; Figure 5). The Rambler and Ming massive sulphide deposits are locally capped by black chert and iron formation that may be similarly correlated with the Nugget Pond horizon. This distinctive sedimentary facies is in turn overlain by epiclastic wacke, siltstone and tholeiitic basalts, all of which can be logically correlated with the Scrape Point Formation (Figure 6). Northeast of the Ming mine site, there is a sequence of calc-alkaline basalt and pyroxene-phyric tuff breccia, overlain by mafic turbiditic wacke, siltstone and magnetite iron formation. This sequence is interpreted herein to correlate with the Bobby's Cove Formation of the Snooks Arm Group in the Betts Cove area. The distinctive pyroxene-phyric tuff is believed to represent the marker horizon discussed in the previous section (Prairie Hat member of Kidd, 1974). These rocks are overlain by tholeiitic pillow basalts that are believed herein

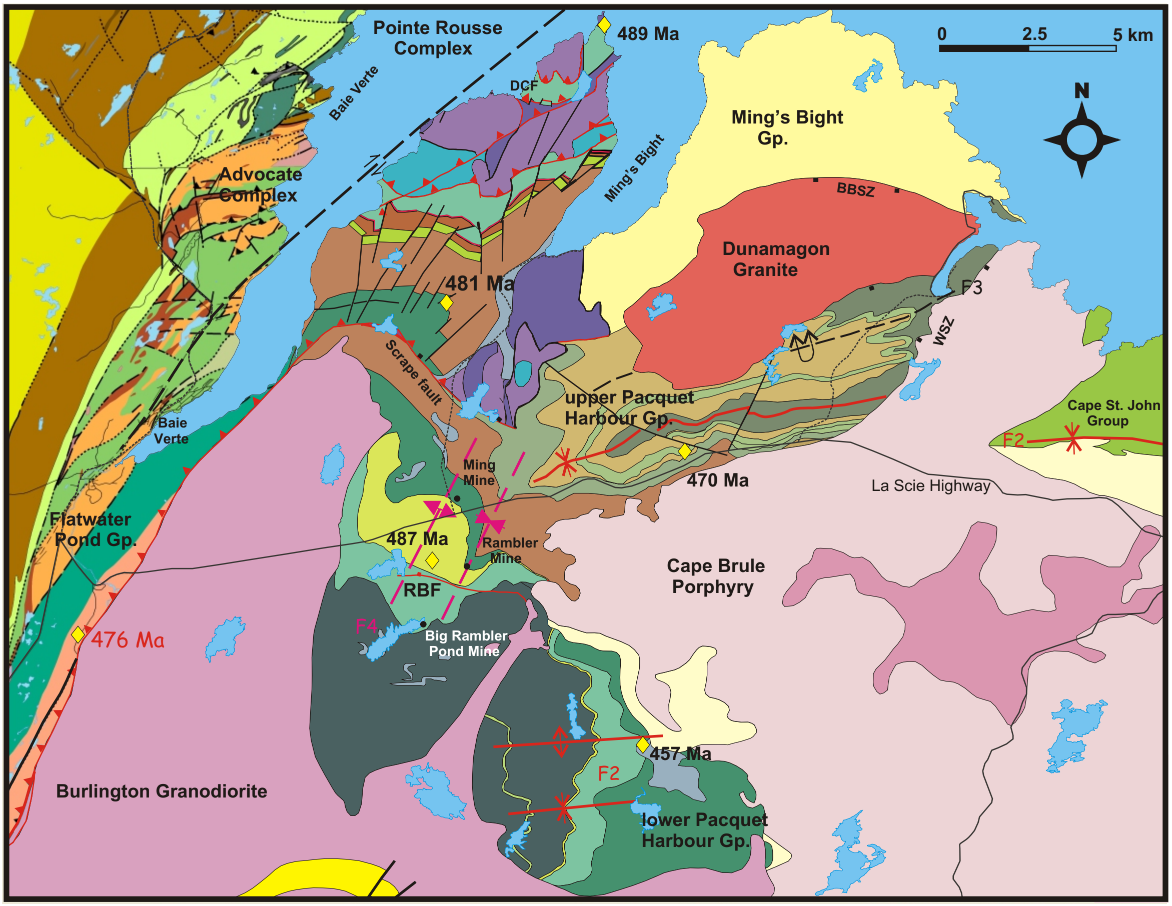


Figure 5. Geology of the Pacquet Harbour Group, Point Rousse and Advocate complexes and adjacent units, north-central Baie Verte Peninsula. Geology modified after Hibbard (1983). The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

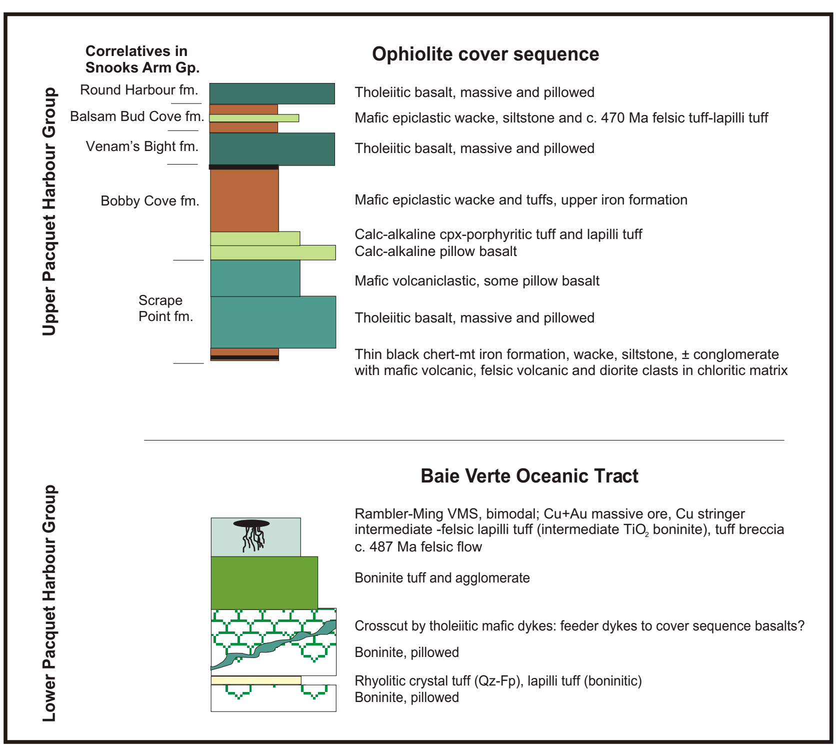


Figure 6. Detailed stratigraphy of the Pacquet Harbour Group. Correlative formations from the Snooks Arm Group based on the stratigraphy of Bédard et al. (1999b). The U/Pb zircon geochronology should be considered approximate.

to be equivalent to the Venam's Bight Formation, in turn overlain by shale, wacke, felsic tuff and lapilli tuff that are likely equivalent to the Balsam Bud Cove Formation. This part of the sequence includes a felsic tuff that gave a U/Pb age of ca. 470 Ma (unpublished data, V. McNicoll, 2008). The top of the volcanic sequence comprises pillowed tholeiitic basalts and mafic epiclastic rocks that are similar to those of the Round Harbour Formation.

In summary, the Pacquet Harbour Group (as previously defined by Hibbard, 1983) is herein considered to include two sequences of different age and affinity. The rocks in its lower (older) portion are interpreted to correlate with the upper section of the Betts Cove Complex. The strong stratigraphic similarities between the largely volcanic rocks of the upper Pacquet Harbour Group and those of the Snooks Arm Group in the Betts Cove area are suggestive of a correlation between these two cover sequences to the BVOT rocks (Figs. 3a, 4, 6). It is expected that these relationships will be defined and formalized in the near future.

Point Rousse Complex

The Point Rousse complex comprises serpentinized mantle harzburgite and dunite, structurally overlain by a fragmented ophiolite complex and a volcanic cover sequence (Figure 5). The overall stratigraphy, lithogeochemistry and geochronology of the ophiolite and its volcanic cover are similar to those defined in the Betts Head and Mt. Misery formations and overlying Snooks Arm Group in the Betts Cove area.

The lower ophiolite comprises boninitic ultramafic cumulates, pyroxenite, layered gabbro, anorthosite gabbro, and thin segregations of trondhjemite. A sample of trondhjemite hosted by layered gabbro yielded a zircon U/Pb age of ca. 489 Ma (unpublished data, V. McNicoll, 2009). Although the sheeted dyke unit includes numerous low TiO_2 boninite dykes, only a thin thrust-bound sliver of mafic boninite is actually preserved in the ophiolite. The core of an anticline in the southern half of the Point Rousse Peninsula exposes boninitic dacite associated with massive sulphide mineralization. However, there are thick, structurally imbricated (and folded) panels of pillowed basalts of tholeiitic affinity that are petrographically and chemically similar to those of the Mt. Misery Formation rocks in the Betts Cove area. These tholeiitic volcanic rocks are present throughout the Point Rousse Peninsula.

The cover sequence to the ophiolitic rocks on the Point Rousse peninsula (Figure 5) comprises a lower banded magnetite and jasper iron formation (termed the Goldenville horizon), overlain by mafic tuffs and tholeiitic basalts that are likely correlative with the Scrape Point Formation. These are overlain by calc-alkaline basalt, clinopyroxene-phyric tuff and tuff-breccia, and thin unit of mafic epiclastic rocks capped by iron formation. As in the case of the Pacquet Harbour Group, the pyroxene-phyric tuff-breccia is interpreted as the marker horizon near the base of the Bobby Cove Formation, forming a direct connection to the stratigraphy of the Snooks Arm Group.

The youngest volcanic rocks exposed in the cores of folds in the southern Point Rousse peninsula are tholeiitic pillow basalts similar to those of the Venams Bight Formation in the Snooks Arm Group.

Flatwater Pond Group

The volcanic cover sequence extending along the east side of the BVL from the town of Baie Verte to Micmac Lake (Figure 7) was thought to be the youngest ophiolite cover sequence on the Baie Verte Peninsula and was named the Flatwater Pond Group by Hibbard (1983). Unpublished stratigraphic, lithogeochemical and geochronological data now indicate that the Flatwater Pond Group has many similarities to the lower part of the Snooks Arm Group. However there are also significant lithological differences between the two sequences. These differences may be related to paleogeography; the Flatwater Pond Group likely formed in close proximity to the Laurentian continental slope, whereas the time-equivalent sequences in the east were removed from such influences.

The base of the Flatwater sequence is not exposed; however abundant coarse grained conglomerate and megabreccia occur at the lowest observed stratigraphic position (Kidd, 1974). A unit informally named the "megaboudin conglomerate" by Kidd (1974) contains clasts of gabbro up to 100 m in diameter surrounded by a dark grey-green chloritic matrix. Banded chert, and magnetite iron formation, associated with mafic volcaniclastic rocks and tholeiitic basalt occurs in the lower parts of the Flatwater Pond Group north of its type locality, and may be correlative with the Scrape Point Formation of the Snooks Arm Group (Figure 3a). The overlying Kidney Pond conglomerate (informal name after Kidd, 1974) is polymict and contains ophiolite-derived gabbro, flaser gabbro, boninite (rare) and basalt, as well as quartzite and limestone (rare), and locally derived granite, jasper and felsic volcanic clasts. The most obvious source for quartzite and limestone clasts is the Laurentian platformal sequence. The conglomerate is clast-supported and typically has a shale to sand-size, grey-black matrix. U/Pb dating of granitoid clasts, previously thought to be derived from the Burlington granodiorite, yielded an age of ca. 479 Ma (unpublished data, V. McNicoll, 2008) and provides a maximum age for deposition of the conglomerate. The source of these granitoid clasts is now unclear, but their sources may have been related to contemporaneous felsic volcanism in the Flatwater Pond area. A fault-bounded panel along the northeastern margin of the Flatwater belt comprises dacite, felsic lapilli tuff and sericitized tuff. Dacite within this unit has an age of ca. 476 Ma (unpublished data, V. McNicoll, 2008).

Immediately overlying the Kidney Pond conglomerate are pillowed basalts of tholeiitic affinity and mafic tuff. The lower conglomerates, the felsic volcanic rocks and the tholeiitic basalts are believed to represent the same stratigraphic sequence defined by the the lower Snooks Arm Group in the Betts Cove area.

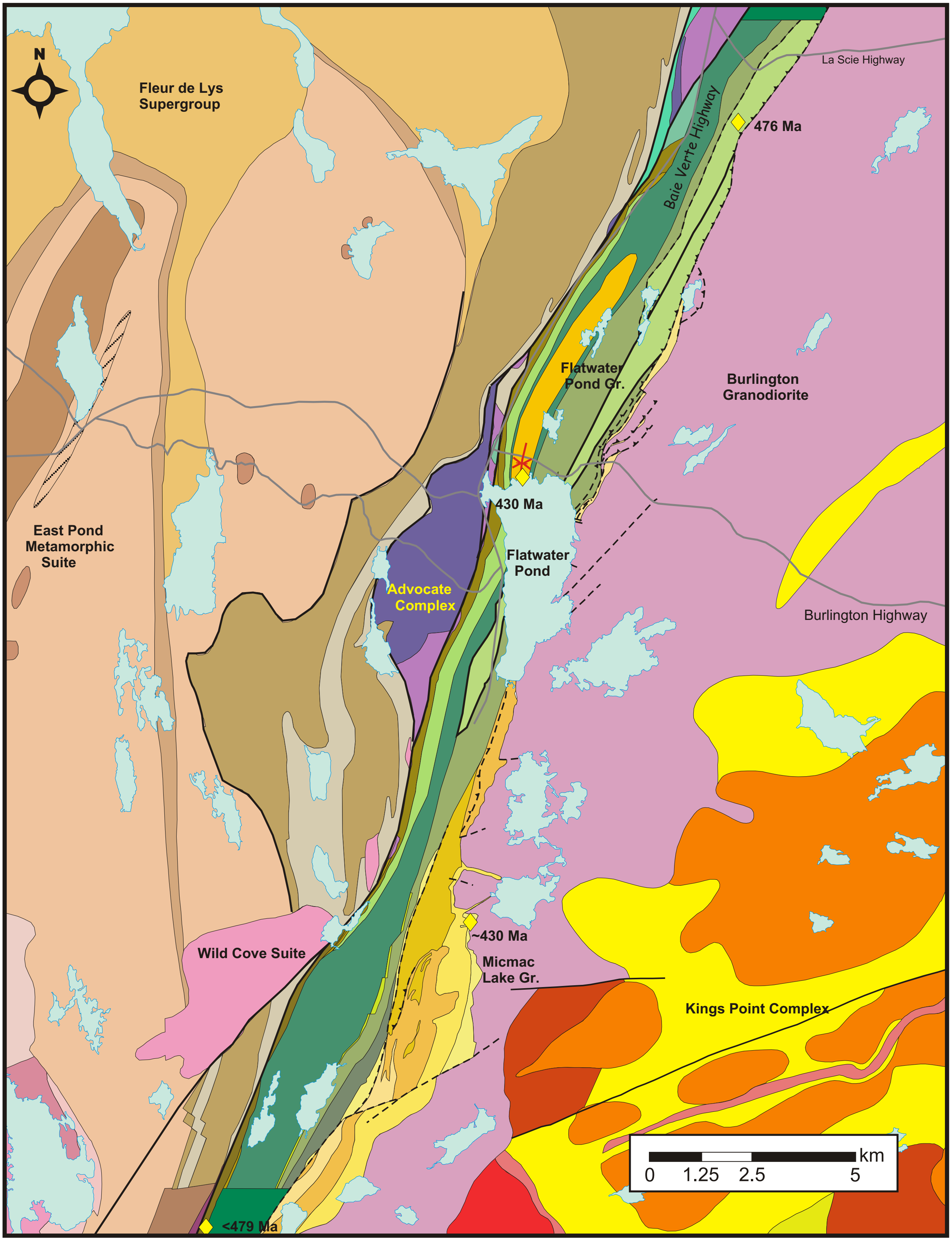


Figure 7. Detailed geology of the Flatwater Pond area. Geology is modified after Kidd (1974), and Hibbard (1983). The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

Immediately overlying the tholeiitic basalts is a thin sequence of calc-alkaline clinopyroxene-phyric lapilli tuff and crystal tuff, that is correlated with similar pyroxene-bearing mafic volcaniclastic rocks in the Bobby Cove Formation, including the distinctive marker horizon described by Kidd (1974). These rocks are overlain by black shale, limestone (rare), mafic volcaniclastic rocks, pillowed basalt and an oxide-facies banded iron formation, the latter found north of Flatwater Pond. The uppermost unit in the Flatwater Pond Group consists of high TiO_2, tholeiitic pillow basalts that are logically correlated with the Venam's Bight Formation.

Although the geochronological controls available elsewhere on the peninsula are not present to the same extent within the Flatwater Pond Group, and it contains somewhat different sedimentary facies, the overall stratigraphy has a marked resemblance to that of the Snooks Arm Group. It is expected that the stratigraphic links discussed above will be formalized in the near future.

Advocate Complex

The Advocate Complex is the westernmost fragment of ophiolite crust on the Baie Verte Peninsula (Figure 5). As discussed previously, the Advocate Complex is separated from the ancient continental margin rocks by a thin unit termed the Birchy Schist. The Advocate Complex includes serpentinized mantle harzburgite with discordant dunite pods and dykes, in mostly tectonic contact with boninitic, serpentinized ultramafic cumulates, layered gabbro, boninitic anorthositic gabbro (clinozoisite-quartz rock), gabbro, sheeted dykes and rare, tectonic slices of mafic volcanic rocks. Most of the pillowed volcanic section of the ophiolite (presumed herein to be equivalent to the Betts Head Formation of the Betts Cove Complex) is missing either through faulting or erosion. Pillowed island arc tholeiitic basalts similar to those of the Mt. Misery Formation occur in tectonic slivers along the Baie Verte Highway and are locally associated with massive sulphide mineralization (e.g., at the old Terra Nova Mine). Gabbro dykes of island arc tholeiitic affinity cut ophiolitic gabbro in the town of Baie Verte, and may represent feeders to these volcanic rocks.

The Advocate volcanic cover sequence was named the Shark Point Group by Bursnall (1972). Stratigraphic younging is rare and numerous faults disrupt the stratigraphy along the Baie Verte line; these factors complicate subdivision and interpretation. The ophiolite southeast of the Advocate pit is adjacent to ophiolite-derived conglomerate, megabreccia containing gabbro rafts and argillite. These units are now covered in mine tailings, but are described by Bursnall (1972). They appear to be similar to the "megaconglomerates" and shales found within the Flatwater Pond Group (see above). At Shark Point itself, located southeast of the old Advocate wharf, island arc tholeiitic basalt lies structurally beneath high TiO_2, tholeiitic basalt.

Alteration of Ultramafic Cumulates

Ultramafic and ophiolitic rocks of the Baie Verte Peninsula are locally carbonatized, and termed listvenite (also known as listwaenite, and locally as "virginite"). Listvenites from two localities, on the Baie Verte road and on the Point Rousse Peninsula, have been recently studied (Escayola et al., 2009). Listvenite, *sensu stricto*, consists mostly of quartz, carbonate and chromium-rich mica that formed in response to the carbonatization of ultramafic and/or ophiolitic rocks. They are commonly associated with other metasomatic rocks, including quartz–carbonate rocks, talc–silica–carbonate-rich rocks and serpentine–talc–chlorite–carbonate rocks.

The Baie Verte road and Point Rousse listvenites are exposed adjacent to shear zones through which hydrothermal fluids were apparently channelled. There is still some uncertainty whether the listvenite is associated with dunite or harzburgite cumulate in the area. These listvenites are chiefly composed of carbonate (ankerite, magnesite and/or dolomite) with talc, chlorite and/or fuchsite together with disseminated pyrite and other accessory minerals such as chalcopyrite and magnetite. Chromite (the most refractory primary mineral in ultramafic rocks) is locally preserved within these metasomatic mineral assemblages. Hydrothermal alteration transformed the rock to talc-carbonate schist (listvenite) through interaction with Ca-CO2-S and possibly As-rich solutions, liberating important quantities of silica. The silica likely formed quartz vein networks that also characterize these rocks.

Listvenites have possible economic significance. During this type of alteration Au originally present in trace amounts in the ultramafic andmafic rocks can be mobilized and concentrated during hydrothermal alteration in sulphide and arsenide phases, and then reprecipitated in late stage structures and metallic mineral assemblages. Preliminary chlorite geothermometry (Escayola et al., 2009) indicates that the alteration history of the Baie Verte Road and Point Rousse listvenites is consistent with the development of this type of Au mineralization and further investigation and exploration of these rocks are warranted.

Late Ordovician— Early Silurian Rocks

Cape St. John Group

North of Betts Cove, an angular unconformity separates tilted Snooks Arm Group rocks from overlying basal conglomerate of the early Silurian Cape St. John Group (Figure 2). The Cape St. John Group has been subdivided into a number of distinctive mappable volcanic units, the details of which are given in Moussallam (2007). The following sequence of mappable lithological units will form the basis for a formalized stratigraphy for the Cape St. John Group that is currently under development (Figs 2, 3b). These mappable units include a basal conglomerate, and continental red bed arkose and siltstone, which are overlain by a welded tuff and then by a heterolithic crystal tuff containing small jasper and ultramafic fragments. These are in turn overlain by a pyroclastic breccia and conglomerate made up of dark basalt fragments, purple rhyolite clasts and large pumice fragments, a fine beige ash tuff and amygdaloidal, massive

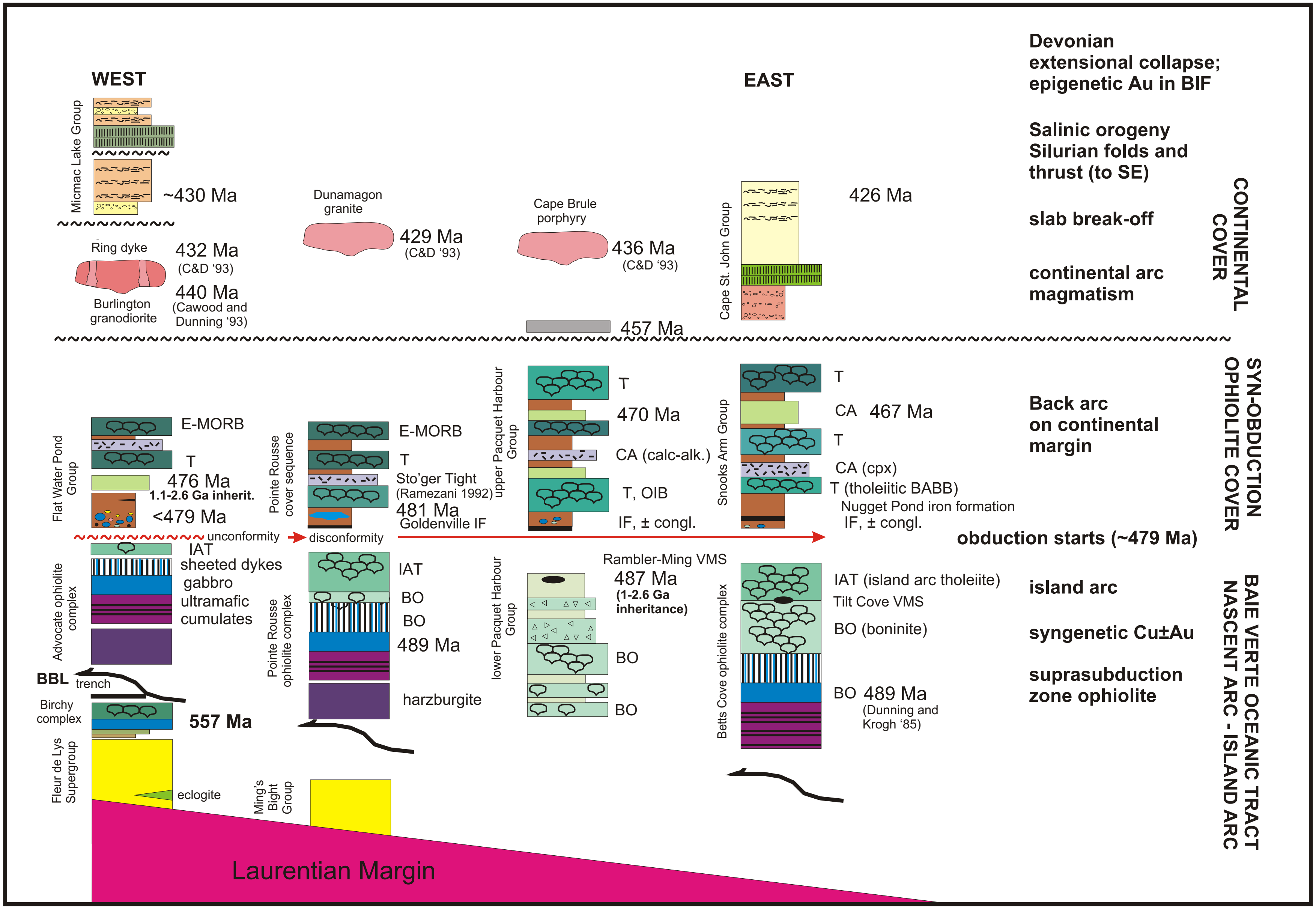


Figure 8. Tectonstratigraphic summary of the Baie Verte Peninsula, indicating a provisional association of units across the region. The U/Pb zircon geochronology presented from this study are from provisional, unpublished data (V. McNicoll, 2007; 2008; 2009) and should be considered approximate.

continental tholeiitic basalt. Above this unit is a fine-grained, white crystal tuff with black elongate lapilli and fiamme, a beige tuff with elongate lapilli and fiamme in a dark aphanitic matrix, and an autoclastic rhyolite with large purple blocks in a flow-banded, K-feldspar-phyric groundmass. These units are overlain by white, flow banded, plagioclase and quartz-phyric rhyolite and ash tuff with quartz, K-feldspar and magnetite (to 0.5mm) phenocrysts. The youngest unit in the Cape St. John Group comprises white, pumice lapilli tuff with abundant altered K-feldspar phenocrysts. A flow banded rhyolite towards the stratigraphic top of the Cape St. John Group has yielded a zircon U/Pb age of ca. 426 Ma (unpublished data, V. McNicoll, 2008). The lower Cape St. John Group is likely the extrusive equivalent to the adjacent ca. 430 Ma (Cawood et al., 1993) Cape Brulé Porphyry, which it in part closely resembles.

Micmac Lake Group

The Micmac Lake Group is located near to the BVL, to the west of the Burlington Granodiorite (Figure 7). It may be correlative with the lower Cape St. John Group, as it contains a somewhat similar stratigraphy containing continental red bed sandstone and conglomerate (Figure 3b). These are overlain by basalt and welded rhyolite lapilli tuffs and tuff breccia. A sample of mafic tuff breccia on northern Flatwater Pond yielded a zircon U/Pb age of ca. 430 Ma (unpublished data, V. McNicoll, 2008), and this may date the lower part of the Mic Mac Lake Group.

Other Areas

Small isolated exposures of late Ordovician rhyolite and clastic sedimentary rocks of indeterminate map extent are found on Baie Verte Peninsula. A small outcrop of flow banded rhyolite south of the Rambler area near the Brass Buckle gold showing was dated at ca. 457 Ma (unpublished data, V. McNicoll, 2008) and a quartzite south of Micmac Lake (Figure 7), previously thought to belong to the Flatwater Pond Group (Hibbard, 1983), contains detrital zircons of similar age, which provide an upper limit for its deposition (unpublished data, V. McNicoll, 2008).

Plutonic Rocks

Plutonic rocks underlie large parts of the Baie Verte Peninsula, notably in its south-central region. The most extensive plutonic unit on the peninsula is the Burlington Granodiorite, which displays significant compositional and textural variation, and likely includes several phases. This was previously considered to of Ordovician age, based on old U-Pb and Ar-Ar data, but has more recently given dates of ca. 430 and ca. 434 Ma (Cawood et al., 1993). However, the presence of significantly older plutonic rocks within this body cannot be ruled out. The Burlington Granodiorite differs from most other plutonic rocks on the peninsula, in that it is relatively calcic and sodic, with a geochemical signature that broadly corresponds to that expected for calc-alkaline ("arc-type") plutonic suites.

The medium to coarse grained K-feldspar porphyritic Dunamagon Granite has a an age of c. 429 Ma (Cawood et al., 1993), which resembles that obtained from the partially subvolcanic Cape Brulé porphyry (ca. 434 Ma; Cawood et al., 1993). Most other plutonic suites in the eastern part of the peninsula remain undated, but are considered to be Silurian on the basis of limited deformation and contact relationships. Several of these plutonic units are geochemically evolved, with compositions that are transitional to alkaline or peralkaline varieties. The Seal Island Bight syenite and the Kings Point Complex are the best-known examples, and the layered mafic rocks of the Reddits Cove gabbro are also of alkaline affinity. There is a significant disparity between the compositional traits of the Burlington Granodiorite and most of the other Silurian plutonic suites east of the BVL (e.g., Kerr, 1996).

Plutonic rocks are less abundant in the area west of the BVL, but large areas in the southeast of the peninsula are underlain by diorite, granodiorite and granite of the Wild Cove Pond Igneous Suite (as defined by Hibbard, 1983). These rocks are not known in detail, but outcrops examined by AK over the years are coarse-grained biotite- and biotite-hornblende granitoid rocks, commonly containing enclaves of metasedimentary parentage. K-feldspar megacrystic granites are also abundant, and biotite-muscovite leucogranites are also present locally. In general, the plutonic rocks of this area most closely resemble those developed within the Gander Zone and parts of southeastern Newfoundland, where metasedimentary rocks of broadly similar composition also occur (e.g, Kerr, 1997). Cawood and Dunning (1993) obtained ages of ca. 427 Ma from two phases of the Wild Cove Pond Suite. The small Partridge Point Granite is a garnetiferous biotite-muscovite granite interpreted to record anatexis of the Fleur-de-Lys Supergroup. It has been linked to Pb and Mo mineralization in adjacent areas (Hibbard, 1983), but there is no real proof of such a relationship.

Nd isotope data from plutonic rocks across the BVL were reported by Fryer et al. (1992) in general terms, although the data remain unpublished. Not surprisingly, they indicate contrasts in the nature of underlying crust. Intrusions west of the BVL have negative εNd (-4 to -8; 420 Ma) consistent with the involvement of Laurentian basement or metasedimentary rocks derived from such sources. The Fleur-de-Lys Supergroup and the Mings Bight Group have ancient sources, as indicated by εNd of -11 to -16 (at 420 Ma). Intrusive rocks to the east of the BVL have neutral to positive εNd (-1 to +2; 420 Ma) aside from the Cape Brulé Porphyry (-3). The further investigation of regional isotopic patterns is an interesting avenue for continued research building on the results of the current TGI3 project.

Regional Structural Geology

The Baie Verte Peninsula has been the focus of numerous local to sub-regional studies and theses that included components of bedrock mapping and description of the structural geology (see Hibbard, 1983, and Anderson, 1998, for a review). At least four phases of regional deformation have affected the rocks of the Baie Verte Peninsula (Hibbard, 1983). Most deformation phases are domainal, as structures vary in orientation, style and in intensity. In addition, structural correlations across the Baie Verte Line (BVL) are difficult due to intense and long-lived strain along this complex fault zone, which has juxtaposed rock units of different origins and structural levels. East of the BVL, the rocks show a general increase in strain and metamorphic grade from east to west and from south to north across the peninsula. However, the Point Rousse Complex exhibits a significantly lower grade of metamorphism than that seen in the neighbouring units of the Ming's Bight and northern Pacquet Harbour groups. Mesoscopic and regional-scale structural features of each phase are summarized below.

Deformational History

Structures related to D_1 (D_e of Hibbard, 1983) have been strongly overprinted by subsequent deformation. The D_1 fabrics have been observed in the Fleur de Lys Supergroup where an S_1 micaceous schistosity is preserved in areas of low post-D_1 strain and/or in the hinges of F_2 folds. The latter locally were refolded into fold interference patterns during D_3 (Hibbard, 1983). East of the BVL, the D_1 structures are poorly preserved. A relict S_1 fabric is deduced in some localities of less intense S_2 transposition and where F_2 folds have folded an earlier bedding/layering parallel foliation. The D_1 phase is interpreted to be related to obduction of the ophiolite complexes and arc collision during the main stages of the Ordovician Taconic orogeny (Hibbard, 1983; Waldron et al., 1998; van Staal et al., 2007). The ophiolites of the Baie Verte Peninsula constituted the upper plate during the Taconic orogeny and were thus less tectonized than the Laurentian margin units of the lower plate, which were rapidly buried and experienced high pressure metamorphism (Jamieson, 1990). Preliminary $^{40}Ar/^{39}Ar$ ages from the Birchy Complex in the footwall of the Advocate Complex suggest that this event occurred between 465-460 Ma (Castonguay et al., unpublished data) and suggest that the area underwent a late Middle Ordovician metamorphic cooling.

The D_2 event represents the main tectonometamorphic phase of most parts of the Baie Verte Peninsula, corresponding to D_m of Hibbard (1983), D_1 of Gale (1971) and Anderson et al. (2001), and D_2 of Tuach and Kennedy (1978). The intensity of D_2 fabrics and the nature of accompanying metamorphic mineral assemblages varies regionally: Although the correlation of fabrics across the BVL remains difficult, and the ages of fabrics are still being resolved, the dominant fabric in the Humber zone (S_2 in the Fleur de Lys Supergroup and Birchy Complex) is tentatively correlated with the main regional foliation observed east of the BVL (hence also called S_2 herein). In most of the central and northeastern part of the peninsula (Pacquet Harbour and Cape St. John groups), D_2 shows an overall increase in intensity deformation and metamorphic grade from south to north. In the southern part of the peninsula, D_2 is weak and S_2 is a northeast- to northwest-dipping spaced cleavage. Mesoscopic F_2 folds are rarely observed, but reversal of pillow tops and the map-scale distribution of marker horizons suggest that F_2 folds are present. In the Rambler-Ming mines area, D_2 is characterized by a strong L>S fabric, that is manifested as a northeast-plunging mineral or a stretching lineation defined by extended clasts and pillows. The long axes of the Rambler and Ming ore bodies are parallel to the L_2 lineation (Tuach and Kennedy, 1978). In the northern part of the peninsula, the S_2 fabric varies from weak to a penetrative schistosity; S_2 is axial planar to nearly isoclinal, northeast-plunging F_2 folds. The trace of a major east-northeast-trending F_2 syncline is recognized roughly 500 m north and parallel to the La Scie Highway; its southern limb is generally steep, whereas dips are progressively shallower along the northern limb, most probably due to the influence of F_3 recumbent folding (see below). Based on comparable style and geometry, this fold correlates with similar large-scale folds to the east affecting much of the Silurian Cape St. John Group and the Betts Cove Complex.

The D_2 fabrics are interpreted to be associated with ductile to brittle-ductile, moderately north-dipping, south-directed shear zones, such as the Rambler Brook fault and the Scrape fault in the Pacquet Harbour Group (Hibbard, 1983). In the hanging wall of the Scrape fault, D_2 second-order thrust and high-angle faults divide the Point Rousse Complex into several fault-bounded panels or 'thrust sheets' (Hibbard, 1983; Gower et al., 1990; Kirkwood and Dubé, 1992; Dubé et al., 1993). The Scrape fault juxtaposes the greenschist-facies mafic and ultramafic rocks of the Point Rousse Complex to the northeast, against the amphibolite-facies gabbros and mafic volcanic rocks of the Pacquet Harbour Group to the southwest. The footwall of the shear zones comprises a ca. 200-m-wide mylonite zone with consistent south-directed reverse shear-sense indicators. However, the contrasting and sharp upward decrease of metamorphic grade across the Scrape fault (low grade over higher grade) and the southward decrease of M_2 metamorphic grade across structurally deeper levels (an apparent inverted metamorphic gradient) within the Pacquet Harbour Group indicate post-D_2 structural juxtaposition (see below). Similar south-directed faults occur eastward in the Cape St. John Group and at the contact with the Betts Cove Complex. Along the BVL, D_2 structures are associated with SSW-trending sinistral and east-directed faults, some of which juxtapose units of the Flatwater Pond Group against the Burlington granodiorite (Hibbard, 1983).

The D_2 regional deformation of the Baie Verte Peninsula is associated with an overall Silurian sinistral transpressive deformation regime localized along the BVL and subsidiary faults. This deformation quickly follows peak Salinic metamorphism in the Fleur de Lys Supergroup (Humber zone) and contributes to north-to-south burial and metamorphism of the eastern part of the peninsula. Previously determined and and recent age constraints on metamorphic cooling and D_2 deformation fall mainly in the range of 432-422 Ma.

Structures formed during the third phase of deformation (D_3) are inhomogeneously developed, east of the BVL, they are mainly recognized north of the

La Scie Highway. They are particularly well developed in the northeastern part of the Baie Verte Peninsula where they become the dominant structure in the Ordovician Pacquet Harbour and Ming's Bight groups and the Silurian Cape St. John Group. These structures also correspond to the third phase (D_3) of most previous studies (i.e., Gale, 1971; Tuach and Kennedy, 1978; Pacquet Harbour area D_2 of Anderson, 1998, and part of D_L of Hibbard, 1983). In the Pacquet Harbour Group, D_3 structures comprise shallowly inclined to recumbent, open to tight southeast-plunging F_3 folds. An axial-planar S_3 fabric is locally observed. It dips shallowly to the southeast or south and ranges from a weakly developed spaced or crenulation cleavage, to a well defined composite foliation mainly formed by transposition of S_2, northward, near the contact with the Dunamagon granite. In the northeastern Pacquet Harbour Group, Anderson (1998) and Anderson et al. (2001) interpreted the contacts with the Dunamagon granite and Cape Brulé porphyry as shallowly south-dipping, brittle-ductile, D_3 extensional shear zones, such as the Woodstock shear zone. D_3 is well-developed (and locally the dominant structure) in the Ming's Bight Group, where it is associated with an amphibolite-facies assemblage overprinting D_2 fabrics (Anderson, 1998). Similar shallow-dipping to flat-lying structures are present eastward in the northernmost part of the Cape St. John Group, where the dominant S_2 fabric is progressively affected by F_3 recumbent folding. In the Point Rousse Complex, the main fabric (S_2) is locally cut by a younger sub-parallel but steeper crenulation cleavage. This moderately to steeply north-dipping S_3 crenulation is associated with asymmetric folds and kink-bands. However, recumbent folds and low-angle structures are absent. In D_3 high-strain zones, foliations become sub-parallel creating a composite $S_{2\text{-}3}$ fabric. Kinematic indicators and D_3 kinks suggest north-side-down motion. In the Point Rousse Complex, several of these D_3 high-strain zones appear to reactivate D_2 thrusts and reverse faults as extensional faults, as tentatively suggested by Kidd et al. (1978). Post D_2 (probably D_3) extensional shear bands in the immediate footwall wall of the Scrape fault suggest that it was affected by normal sense reactivation, as previously postulated by Jamieson et al. (1990). This reactivation of the early thrusts as extensional faults may have contributed to the apparent low over high grade relationship across the Scrape fault.

The D_3 regional deformation of the Baie Verte Peninsula is associated with an overall dextral strike-slip (transpressive and transtensional) deformation regime attributed to the Acadian Orogeny. Strain was localized along the BVL and subsidiary faults, often reactivating older D_2 fault zones. Dextral transtensional deformation was coeval with exhumation and rapid cooling of the Ming's Bight Group and surrounding areas during the Devonian (Anderson et al., 2001).

The D_4 deformation (D_4 of Tuach and Kennedy, 1978, and part of D_L of Hibbard, 1983) is characterized by undulating to open, upright F_4 cross folds, although styles and plunges of these folds vary depending on the orientation of earlier fabrics. These folds are locally associated with a sub-vertical fracture or weakly developed crenulation axial-planar cleavage. The F_4 folds trend to the north-northeast in the Pacquet Harbour Group, especially in the Rambler Mines area, and trend to the north or north-northwest in the Cape Brulé Porphyry and Cape St. John Group, where they are conspicuous at the map scale through their effects on both regional F_2 and F_3 axial planes. These folds have not been recognized in the Point Rousse and Advocate complexes, or in the Flatwater pond area. The age of D_4 is not constrained, beyond being post-Silurian.

Structural Controls on Mineralization

The relationships observed between fabrics of different ages, regional structure, and the various mineral deposits of the study area have important implications for base-metal and gold exploration on the Baie Verte Peninsula. The economically important sulphide deposits in the Pacquet Harbour Group have been strongly modified during D_2 as evidences by the cigar-like shapes of the Rambler and Ming deposits, which is co-linear with the strong northeast-plunging L_2 lineation. Hence, the sulphide deposits may have been dismembered and translated by thrusting related to D_2, and the sulphides may be structurally thickened in hinge zones of regional F_2 folds. Post-D_2 deformation is best developed in the northern Pacquet Harbour Group and may also have modified the orientation and geometry of prospective horizons and ore deposits at depth. For example, the recumbent F_3 folding north of the Ming deposits may have changed the shape of ore bodies down-plunge by refolding and reorientation. Hence, potential also exists for structural thickening at depth.

Most mesothermal gold mineralization in the Point Rousse Complex is spatially and genetically associated with D_2 shear zones. Consequently, D_2 tear and transpressional faults may also be prospective themselves or may have caused lateral displacements of mineralized zones. Similar D_2 shear zones also occur in the southern Pacquet Harbour Group (e.g., Rambler Brook fault) and may also be prospective for gold. The potential for presence or remobilization of mineralization during inversion of thrust faults and in late extensional shear zones may represent additional exploration targets.

Economic Geology

The principal focus of this excursion is on the regional stratigraphy and structure of the Baie Verte Peninsula, rather than the details of individual mineral deposits; however, these two topics are intimately linked, and the new insights into regional geological relationships have metallogenic implications. This section is not intended to provide a detailed geological discussion of deposits and their origins, but rather to place them in the context of the geological evolution of the peninsula. It is drawn from review articles and survey reports, notably Hibbard (1983), Swinden et al. (1990), Evans (2004), Evans and Kerr (2001), Kerr et al. (2005) and Sangster et al. (2008), and also from exploration company websites relevant to recent activity. Figure 9 illustrates the locations of selected mineral deposits and prospects on the Baie Verte Peninsula, including examples discussed below. For a complete inventory, readers are referred to the Mineral Occurrence Data System (MODS) maintained by the Geological Survey of Newfoundland and Labrador.

Historical Background

The Baie Verte Peninsula has a history of base-metal exploration stretching back over 150 years to the discovery of the Terra Nova and Tilt Cove deposits. These were actually some of the first volcanogenic massive sulphide (VMS) deposits discovered in North America. However, the exploitation of mineral resources on the peninsula dates back thousands of years to the soapstone quarry established near Fleur-de-Lys by the Dorset Palaeoeskimos (see later stop descriptions).

Copper was first extracted from the Tilt Cove and Betts Cove mines around 1864, and the latter stayed in operation through to 1917. For part of this period Newfoundland was one of the world's largest producers of copper. Both deposits are hosted in the upper sections of the Betts Cove ophiolite complex. Mining resumed at Tilt Cove between 1957 and 1967, and exploration elsewhere subsequently led to new operations in the central part of the peninsula. The Rambler, Ming, East, and Big Rambler Pond mines are also VMS-style deposits, in this case spatially associated with the Rambler rhyolite, within the lower part of the Pacquet Harbour Group (herein correlated with the Betts Cove Complex). The deposits were initially discovered shortly after the turn of the century, but mining commenced in the 1960's and 70's, when larger resources were proved. Production from the Rambler deposits was fairly short-lived, although the original Ming Mine operated until 1982. The VMS deposits of the peninsula tend generally to be Au-rich, and the Rambler ores were known for locally spectacular concentrations of free gold. Historic information from Tilt Cove is scanty, but the deposits produced significant amounts of gold (55,000 ounces). The most recent review of the Betts Cove – Tilt Cove area is by Sangster et al. (2008). Almost 150 years after the initial discoveries and the first mines, interest in VMS base-metal deposits remains strong on the Baie Verte peninsula. Current activity is focused again in the Rambler area, where mineral tenure issues for many years impeded the downdip (and downplunge) exploration of the prospective Ming Mine horizon. Rambler Metals and Mining Pty. has now defined a substantial Cu-Au resource through deep drilling, and recently completed refurbishment of the underground workings. The strong structural control of the known orebodies by the D_2 lineation (see above) was an important component of this predictive exploration.

The ultramafic rocks of the Baie Verte Peninsula are also of economic importance. Asbestos mining was centred in the Advocate Complex, where the first open-pit mine was established in 1955. Aside from a short period of closure in 1981, these deposits remained in production for 35 years, finally closing in 1990. The deposits provided the economic foundation for the town of Baie Verte.

Gold mining also has a long history on the peninsula, and the Goldenville deposit was one of the first gold mines to operate in Newfoundland, albeit briefly. An adit excavated on the shore of Ming's Bight in the 1860s has the distinction of being perhaps the first attempt to exploit gold in our province, but these efforts were interrupted by French warships. However, there was limited exploration for gold prior to the late 1970s and early 1980s, when reform of our mineral tenure system, coupled with tax incentives for exploration, led to more widespread prospecting. Numerous gold-bearing zones, typically associated with relatively late structures and veins in mafic host rocks, were discovered over this period, and the gold mineralization of the area is summarized in detail by Evans (2004). The Nugget Pond deposit was one of these discoveries, and eventually became the first modern gold mine to operate on the Peninsula. The deposit was small, but high-grade (about 0.5 Mt at over 10 g/t Au) and renowned for its spectacular pockets of free gold. The establishment of a small mill at Nugget Pond was an important incentive for further exploration as it served other deposits following exhaustion of the Nugget Pond orebody. Ore from the Hammerdown deposit near Springdale was eventually processed at the facility and in more recent times it handled ore from the Nalunaak Deposit in south Greenland.

Other significant gold deposits discovered in the 1980s include the Deer Cove, Pine Cove, and Stog'er Tight deposits, all located in the Mings Bight – Point Rousse area (Figure 9). Attempts at mining Stog'er Tight in the late 1990s were frustrated by continuity problems in the ore zone, and development of Pine Cove was impeded by its generally low grades (< 3 g/T Au). The Deer Cove deposit has good grades (5 to 9 g/T Au), but a relatively small tonnage (less than 0.2 Mt). However, sustained exploration at the Pine Cove deposit eventually brought tonnages to economic levels at prevailing prices, and open-pit mining commenced in early 2007. Following problems with gold recovery at the Pine Cove mill, some ore will now be processed at the Nugget Pond facility, again underlining the long-term value of this infrastructure to the local economy. In the light of high commodity prices, there is now renewed interest in both Stog 'Er Tight and Deer Cove, and in many other smaller prospects that remain incompletely explored.

Although base metals and gold have always been the bread-and-butter of the peninsular mining economy, they are not the only commodities of interest. There was an historical attempt at mining a molybdenum deposit near Fleur-de-Lys (the Parrell Prospect) and also small deposits of vein-style Pb (+/- Ag). There are also defined resources of industrial minerals such as talc (at Deer Cove) and silica (at La Scie). In recent times, Silurian felsic volcanic rocks have become targets for uranium exploration, and an interesting discovery was made in the Kings Point Complex in 2007. In the last year or so, there was an interesting discovery of PGE-enriched zones within ultramafic rocks of the Betts Cove Complex, concerning which few geological details are yet available.

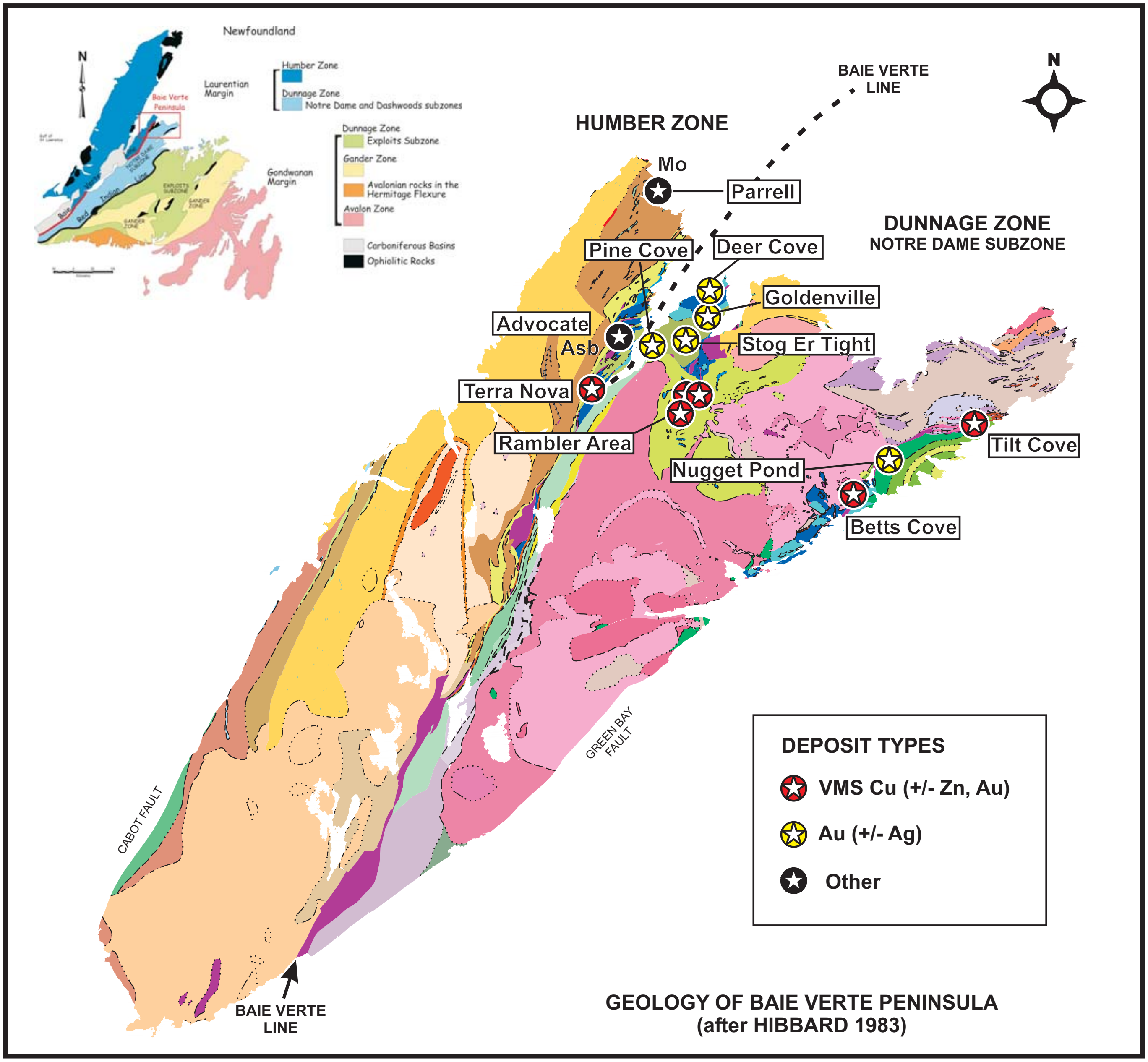


Figure 9. The major mineral deposits of the Baie Verte Peninsula, subdivided according to commodity and type. Note that the map shows only current and past-producing mines, and prospects that have defined resources that may support future production.

Metallogeny of the Ophiolite Sequences of the BVOT

The rich history of mining and exploration across the Baie Verte Peninsula is in large part a reflection of its geological diversity. It hosts a wide variety of "metallotects" recording different tectonic settings, structural and igneous events. A detailed geological review of known mineralization, and the economic potential of this area, is beyond the scope of this report, but this section attempts to place important deposits in the context of new geological insights that are the focus of this field trip.

The ophiolitic complexes that constitute the BVOT have long been known as important targets. The Advocate asbestos deposits represent the most important resource associated directly with the ultramafic rocks, and these host rocks are the dominant compositional control on their genesis. The asbestos deposit is located within a tectonically emplaced ultramafic body in the Advocate Complex (Figure 9). The asbestos consists of stockworks of chrysotile cross-fibre veins which average 5-8 mm in width; collectively, these make up about 3% of the ore by volume. Serpentinization and related alteration of the host rocks have destroyed and replaced most of the original plutonic textures and mineral assemblages, but the protoliths were originally harzburgite with minor dunite and rare lherzolite. In hand sample the ultramafic rocks range from blue-black and green-black to very dark grey. Serpentinization is ubiquitous in ultramafic rocks of the Advocate Complex and varies in extent in individual bodies. The location of this ophiolite complex within the structurally complex zone of the BVL is undoubtedly a factor in the development of the asbestos resource. Riordan (1975; in Hibbard 1983), suggested that the formation of asbestos ore is dependent upon an extensive fracture system to act as a conduit for serpentinizing fluids, with ore formed by both wall rock replacement along fractures and fracture filling. Additionally, ultramafic rocks are potentially important source components for hydrothermal Au and PGE mineralization (e.g., in listvenites) and the Advocate Complex and associated rocks may have potential in this regard.

The ophiolitic rocks of the BVOT also host most of the significant base-metal deposits on the peninsula, of which the largest and best-known is at Tilt Cove (e.g., Sangster et al., 2008). The host rocks are highly chloritized, sheared, and brecciated basaltic to andesitic (tholeiitic) pillow-lavas and pillow breccias of the Mt. Misery Formation. Individual ore bodies at Tilt Cove include massive sulphides dominated by fine-grained pyrite, and disseminated to stockwork-type deposits, where sulphides mostly form veins. The grades of the latter are naturally lower than the massive zones, and their contacts are usually gradational into the wall-rocks. Native silver occurs in minute amounts, and gold is present as gold-silver alloys; no native gold has been observed. One of the peculiar features of Tilt Cove was a small high-grade zone of nickel mineralization, including some unusual minerals (e.g., millerite; NiS). Its origins are unclear, but a ready source of Ni is available in nearby ultramafic rocks, and it is likely hydrothermal in origin.

The Betts Cove deposit has many similarities to Tilt Cove, but is hosted mostly in sheeted dykes rather than in extrusive rocks. It contains significant Zn and Ag in addition to Cu and Au, and is interpreted as part of a footwall hydrothermal system associated with possible exhalative mineralization (Sangster et al., 2008).

The deposits of the Rambler area, in the centre of the peninsula, are spatially associated with the felsic volcanic rocks colloquially known as the Rambler rhyolite, traditionally assigned to the Pacquet Harbour Group. The stratigraphic correlations outlined by recent work, and new geochronological results, indicate that this VMS cluster is essentially time-equivalent to the Tilt Cove and Betts Cove deposits, i.e., mineralization is hosted by volcanic rocks in the upper section of the BVOT, rather than within its cover sequence. The Rambler deposits are strongly deformed and locally strongly attenuated VMS (exhalative?) deposits and associated footwall alteration zones. The metal associations are subtly different to those of the Tilt Cove and Betts Cove deposits. The primary ore minerals consist of chalcopyrite, sphalerite and bornite, along with gangue of magnetite, pyrite and pyrrhotite. Most mineralization occurs within strongly lineated, weakly pyritic, sericitic, rhyolite, or at its contact with an overlying more massive medium- to fine-grained pillowed basalt unit. The local presence of a thin zone of well-bedded volcaniclastic greywacke and/or magnetite-bearing iron formation immediately above the sulphide zone is particularly important from a stratigraphic perspective, as it indicates that the prospective horizon sits below the probable equivalent of the Nugget Pond horizon. The grade and tonnage for Rambler rhyolite deposits include the Main Mine with 0.4 Mt at 1.3% Cu, 2.16% Zn, 29 g/t Ag, 5.1 g/t Au, the East Mine with 1.9 Mt at 1.04 % Cu, Big Rambler Pond at 45,000 tonnes at 1.2% Cu and Ming West with 0.15 Mt of 4.5% Cu. The deposits all contain significant amounts of Au and Ag. The recent exploration of the downdip and downplunge extension of the Ming Deposit and its footwall suggests significant additional resources of some 5 Mt at about 2% Cu, 8 g/t Ag and 1.5 g/t Au (all resource categories; Rambler Metals and Mining press release, 2009). In rough terms, this newly-defined resource is equivalent to all of the previous production from the Rambler area. Clearly, the old adage that “the best place to find a new mine is next to an old mine” remains as true as ever!

The Terra Nova mine, located near the town of Baie Verte, was one of the earliest discoveries in Newfoundland. The deposit was suggested by Hibbard (1983) to represent large blocks within a “megaconglomerate” or olistostrome possibly developed during obduction of the ophiolites of the Advocate Complex. The original deposit was inferred to have been a VMS accumulation similar in general terms to the Tilt Cove and Betts Cove deposits. The deposit is estimated to have produced as much as 0.25 Mt at a grade of some 2% Cu, with associated Au and Ag (Hibbard, 1983).

Metallogeny of the Volcanic Cover Sequences to the BVOT

The cover sequences to the ophiolitic rocks of the BVOT, namely the Snooks Arm Group, the upper Pacquet Harbour Group, parts of the Point Rousse Complex, and the Flatwater Pond Group, are best known for their gold mineralization, rather than for base-metals. Several styles of gold mineralization are documented in these rocks, including deposits hosted in sedimentary rocks and/or iron formations affected by quartz-albite-carbonate alteration and veining (e.g., Nugget Pond and Goldenville), disseminated deposits hosted by mafic intrusive or volcanic rocks affected by chlorite-carbonate-quartz-pyrite (+/- albite) alteration (e.g., Stog'er Tight and Pine Cove), and "classic" auriferous quartz veins with or without associated base-metal sulphides (e.g., Deer Cove, Romeo and Juliet, and Dorset prospects). Evans (2004) provides the most comprehensive discussion of local gold metallogeny, and most of this section is drawn from this source.

The Nugget Pond Deposit was the first gold mine to operate on the peninsula in modern times, and it is also one of the most interesting and unusual of its gold deposits. There are relatively few public-domain accounts of the deposit, which contained 488,000 tonnes at an exceptional grade of 12.3 g/t Au; the following summary is drawn from Sangster et al. (2008). The deposit is hosted within the thin sequence of volcaniclastic and sedimentary rocks termed the Nugget Pond horizon, itself forming part of the Scrape Point Formation of the Snooks Arm Group. The mineralized zone is broadly stratiform in geometry, which led to some initial speculation that it was of syngenetic origin, but in detail the gold is associated with extensive quartz-albite-carbonate-pyrite veins that are partially discordant to the stratigraphy. The mineralization consists of coarse pyrite and minor galena, with traces of native silver and Ag-telluride minerals. The pyrite commonly overgrows earlier diagenetic or syngenetic pyrite in the host rocks, and also appears to have replaced magnetite in the original oxide-facies iron formation. Spectacular native gold occurs locally, and these pockets have intrinsic value far above that of their contained metal; luckily, some of the better examples were rescued from processing in the mill. The run-of-the-mill gold occurs mostly as small inclusions in the pyrite. The deposit is considered to be a stratigraphically-controlled, epigenetic, hydrothermal replacement deposit (sometimes termed a "manto") in which pyritic beds and magnetite-rich zones acted to trap gold from the fluids via reduction. The age of mineralization was suggested to be 374 +/- 8 Ma, based on U-Pb dating of xenotime recovered from a quartz-albite-carbonate vein. Recent attempts at direct dating using the Re-Os system on pyrite separates proved inconclusive, due to generally low Re and Os contents and locally high proportions of common Os (D. Selby and A. Kerr, unpublished data). The presence of earlier (syngenetic) sulphides in the ore horizon may contribute to problems in interpretation.

Some other lesser gold deposits in the area may have similar origins to Nugget Pond, but have neither the tonnage nor the grade. The Castle Rock gold showing (see later stop descriptions) is also hosted by the Nugget Pond horizon, and shows many parallels, including locally high grades and replacement of magnetite (Sangster et al., 2008). The Goldenville deposit, near Ming's Bight, is hosted by an iron formation within the Point Rousse Complex, referred to as the Goldenville horizon. The gold is typically associated with pyritiferous quartz veins and as disseminated gold hosted by bedded magnetite and ferruginous cherts. The host rocks are considered to be equivalent to the Nugget Pond horizon, and the deposit is considered to have similar epigenetic origins, despite its broadly stratiform geometry.

The Stog'er Tight deposit, located within the cover sequence of the Point Rousse Complex near Ming's Bight, exemplifies a different style of gold mineralization that sits somewhere between replacement-style deposits such as Nugget Pond, and "classic" vein-hosted gold prospects such as Deer Cove (see below). This deposit was explored in the late 1980s and early 1990s, and a total resource of 650,000 tonnes at 6.7 g/t Au was outlined, contained within several discrete zones. The deposit was eventually brought into production by Ming Minerals in 1996-97, but this venture proved unsustainable. The deposit, which was thought to have continuity, proved instead to be a series of higher-grade mineralized lenses within a larger shear zone, and mining efforts were complicated by dilution problems. However, there is now renewed interest in the deposit in the light of high commodity prices. The geology of the deposit is discussed by Huard (1990), Ramezani (1992) and Evans (2004). The following summary is derived from these sources.

The mineralization is hosted by one of three gabbroic sills, which intrude a sequence of mafic volcanic and volcaniclastic rocks, of both arc-type and oceanic-island-type affinity. The host gabbro is dated at ca. 483 Ma (Ramezani, 1992). The best mineralization is associated with red albite—pyrite alteration and replacement of the gabbro, which passes outward into chlorite—magnetite, ankerite—sericite and chlorite—calcite alteration. The gold is associated with the pyrite, within which it forms microveinlets and blebs; it is only very rarely visible to the naked eye. The pyrite locally forms spectacular cubes akin to those seen in the Nugget Pond deposit, but there is no indication that the host rocks originally contained syngenetic sulphides. Abundant quartz veins occur within the mineralized zones, and the strongest alteration and mineralization is typically seen adjacent to these. Kirkwood and Dubé (1992) conducted a structural study of quartz veining and alteration, and discussed the structural controls on mineralization. The altered mafic rocks at Stog'er Tight contain "hydrothermal" zircon, dated by Ramezani (1992) at ca. 420 Ma, which was inferred to be the age of the gold mineralization. Direct dating using the Re-Os method on pyrite separates indicates an age between 419 Ma and 404 Ma, based on samples that are essentially devoid of common Os (D. Selby and A. Kerr, unpublished data, 2009). This is broadly consistent with the earlier result.

The Pine Cove Deposit is the only current gold producer on the Baie Verte Peninsula, and it has some similarities to the Stog 'Er Tight deposit, in that it is dominated by disseminated mineralization where gold is closely associated with epigenetic pyrite. The average grade is significantly lower than Stog 'Er Tight, but the zones exhibit greater consistency and continuity. The Pine Cove Mine is a small open-pit operation, with probable reserves of about 2.4 Mt at 2.8 g/t Au. The host rocks at Pine Cove are dominantly volcanic, rather than plutonic, and likewise form part of the cover sequence to the Point Rousse ophiolite. Structural controls are important, and the deposit is spatially associated with the Scrape Thrust and related fault zones. The main ore zones are termed the Thunder and Lightning zones, and there are also several smaller satellite zones. Gold mineralization is associated with pyrite in quartz veins and with disseminated pyrite in sheared and altered host rocks. The alteration is dominated by quartz, chlorite, carbonate and albite, and visually resembles some of the lower-grade sections of the Stog'er Tight deposit, although the distinctive red albite is rare. Gold mineralization is developed in basalt and hematitic arenite, indicating that host rock composition played an important role in concentrating the gold. Gabbroic rocks have also been identified as important hosts on a local scale, but in many areas the exact nature of the original host rock is obscure. The broad similarities to Stog 'Er Tight are supported by the results of recent Re-Os geochronology on sulphide separates. A Re-Os isochron on pyrite separates containing virtually no common Os indicates an age of ca. 419 Ma, within error of the U-Pb and Re-Os ages obtained from Stog 'Er Tight (D. Selby and A. Kerr, unpublished data, 2009).

The Deer Cove deposit is the best known of the numerous vein-hosted gold deposits on the Baie Verte Peninsula. It is hosted by largely mafic volcanic rocks of the cover sequence to the Point Rousse Complex ophiolite. The vein system is developed in the hanging wall of a south-directed thrust fault that brings these rocks above talc-carbonate schists and other rocks derived from ultramafic precursors (Evans, 2004). Gold mineralization occurs in a series of quartz veins and quartz-breccia veins, and there are several discrete zones defined by exploration work, including a high-grade, near-surface zone containing almost 0.1 Mt at 6 g/t Au (uncut). Similar quantities of lower-grade material (around 2.5 g/t Au) are also defined. The mineralization consists of free gold within quartz veins and altered wall-rocks, and gold inclusions within base-metal sulphides, mostly pyrite. There is a strong correlation between gold grade and pyrite content within the veins.

Numerous other smaller gold prospects and showings are known on the peninsula, but these are far too numerous to discuss in this guidebook; details of most of are provided by Evans (2004). Although minor gold showings are known within the ophiolitic rocks of the BVOT, the majority of known occurrences are situated within the cover sequences to these ophiolites, commonly in proximity to major structures, some of which juxtapose these rocks with ultramafic rocks. In the structural synthesis of the peninsula (Castonguay et al., 2009), gold-bearing structures are considered to have developed during the main deformation event (D_2), which affected Silurian rocks and is thus attributed to the Salinic Orogeny (see earlier discussion). However, there are relatively few Au showings in the extensive granitic rocks of Silurian age, or in Silurian volcanosedimentary sequences such as the Cape St. John and Micmac Lake groups. Available information on the timing of mineralization, from U-Pb studies (e.g., Ramezani, 1992) and preliminary Re-Os geochronology (D. Selby and A. Kerr, unpublished data) suggests that mineralization occurred ca. 420 to 400 Ma ago, except possibly for Nugget Pond. Such inferences suggest that the Silurian sequences should at least in part be prospective for gold, but they have not been explored to the same extent (see below).

Empirical evidence suggests that the older ophiolitic rocks are most prospective for base-metals, but less so for epigenetic gold mineralization, and that the reverse applies to the overlying cover sequences. However, the ophiolite sequences (notably the ultramafic rocks) and the syngenetic Au-rich VMS zones developed within them may be a critical element in the development of later (epigenetic) vein-style gold mineralization, by acting as sources for precious metals.

Metallogeny of Silurian Volcanic and Plutonic Rocks

The Silurian sedimentary and volcanic rocks that underlie much of the peninsula are generally seen as less prospective for base-metals and gold than their Ordovician counterparts, but they do contain scattered indications and showings. These are not discussed further in this report, and Evans (2004) considers that many previously assigned to the Micmac Lake Group are more likely hosted by the Flatwater Pond Group. There are no known occurrences of epithermal-style gold mineralization in the Silurian sequences, but some of these define caldera structures (e.g., Coyle and Strong, 19xx), which are characteristically associated with such systems.

Silurian plutonic rocks host some minor indications of pyrite and locally molybdenite, notably in the Dunamagon Granite and the Burlington Granodiorite. The peralkaline igneous rocks of the Kings Point Complex in the south of the peninsula have recently attracted attention as a target for uranium, and also host some zones rich in rare metals (e.g., Zr, Y, REE). The Wisker Valley uranium showing, explored by Bayswater Resources in 2008, contains some high-grade mineralization (details) associated with a sequence of welded and non-welded ash deposits; observations by AK in 2008 suggest that the highest radioactivity is associated with non-welded to fragment-rich horizons. Drilling did not intersect any significant uranium mineralization at the site, but prospecting activity continues in the area.

Other Mineralization

Aside from industrial minerals (mostly talc and silica) which are not discussed here, most other styles of mineralization on the Baie Verte Peninsula presently have limited economic importance. The area west of the Baie Verte Line contains few mineral occurrences; the most significant is the Hodder Prospect, where copper, zinc and lead sulphides occur as stringers and veinlet in marble of the Fleur-de-Lys Supergroup. Other small vein-style occurrences are also present in this area, and in one location within the Mings Bight Group. The Parrell Prospect, also located near Fleur-de-Lys, is a curious zone of molybdenite in which significant mineralization is restricted to a friable fault zone, and is therefore likely late in timing (Fuller, 1941; Kerr et al., 2009).

PART 2: FIELD TRIP STOP GUIDE

Introduction

This section of the guide contains descriptions of specific stops to be visited on the field trip. Outcrop location is given in UTM coordinates using NAD 83, zone 21. In the event that topographic maps are registered to the previous NAD 29 coordinate system, the conversion factors for easting and northing are X and Y metres, respectively (these are approximations only). Directions for locating roadside stops are given using odometer readings in kilometres. Readers should note that odometers in vehicles range in accuracy by as much as +/- 10%; for this reason, distances are generally quoted from the nearest known landmark. If you are using the guide independently, we recommend testing your odometer against the distance from the Trans-Canada to the first stop of Day 1 (virginite outcrops on Route 410) – This should be 44.1 km – and correct your readings accordingly. The distribution of field trip stops is shown in Figure 10.

Note that the listing of stops in this section is idealized, and it is likely that some will be omitted during the field trip because of time constraints. Weather concerns may also affect the ordering of stops or perhaps even cause field trip days to be switched. Participants should read the safety information section at the start of the guidebook and also pay attention to specific safety notes for each stop.

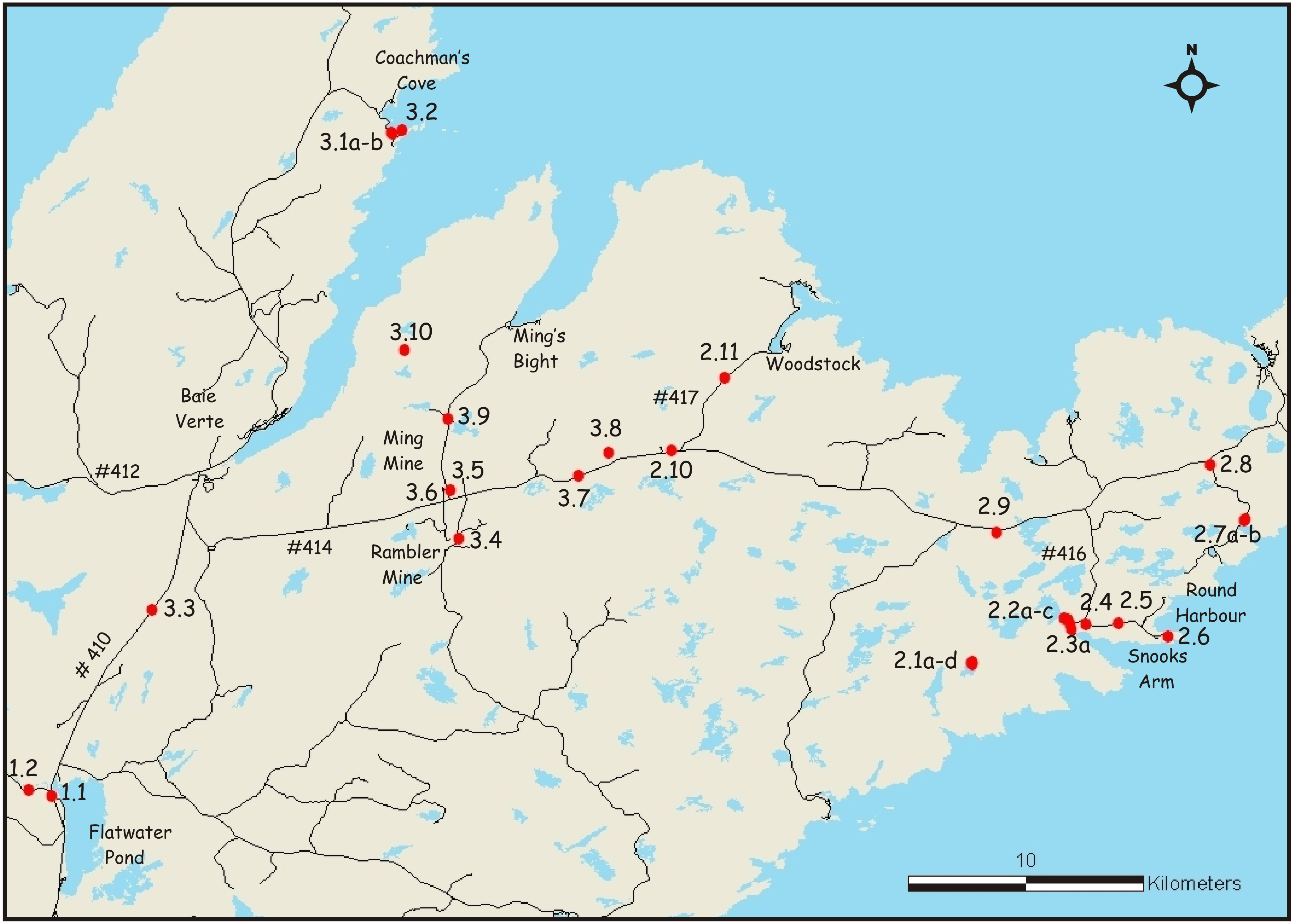


Figure 10. Distribution of field stops. Note that alternate field stops and those of an optional nature are not indicated.

Day One Stops

Day one field trip stops are mostly of general interest, and focus on ultramafic rocks along the Baie Verte line and their alteration products.

Stop 1.1: "Virginite" outcrops, near Flatwater Pond

Directions: From the TCH junction with the Dorset Trail (Route 410) drive to a point just south of the junction for Westport. The distance from the TCH junction is approximately 44.1 km. The outcrops are easily spotted on the left (west) side of the highway, because they are bright green *(easting: 548981; northing: 5516370 NAD83)*. **Participants should be aware of traffic at this locality !**

Description: These are the famous "virginite" outcrops, from which ornamental stone has been extracted over the years for craft purposes. The mineral rights to this locality are held by Meyer's Minerals of Pasadena, and for this reason we request that no large-scale sampling be attempted. However, small pieces of virginite may be taken freely. The following description is adapted from a previous guidebook by Kerr et al. (2005), which is itself derived from earlier descriptions.

These exposures consist of quartz-magnesite-fuschite rocks that represent metasomatized ultramafic rocks. The ultramafic rocks form part of the string of dismembered ophiolites (Baie Verte oceanic tract) that define the Baie Verte Line, which is the boundary between the Notre Dame Subzone and the Humber Zone. The ultramafic protolith has been transformed by the introduction of CO_2, SiO_2 and minor K_2O. The green colour is imparted by chromium-bearing mica (fuchsite), which contains 4% to 8% Cr_2O_3. These outcrops are the source for ornamental stone used widely in the local craft industry.

Rocks of this general type have a number of names around the world. They are sometimes called "listwaenites" or "listvenites", and are also known as "mariposites" in California. In Newfoundland, they are generally known as "virginites". This informal name was coined by Norman Peters, a well-known prospector and geologist who discovered many mineral deposits in this area. The derivation of this unusual name is best preserved for verbal discussions. It is, however, a credit to the influence of Newfoundland geology that this name is increasingly used elsewhere in the world for quartz-magnesite-fuschite rocks.

On a more serious note, metasomatized ultramafic rocks of this type elsewhere in the world are known to be auriferous, or to be associated with gold mineralization, and those on the peninsula are being studied as part of the TGI-3 project (Escayola et al., 2009). These particular examples do not contain any gold or sulphides, which is probably a good thing, because the latter would oxidize and render the material useless for stonecraft.

Stop 1.2 (optional): Less-altered ultramafic rocks, Westport road

Directions: From the virginite outcrops, continue north for 0.2 km, and then turn left on the road towards Westport. Drive for 1.0 km, to a point just beyond where the road comes closest to the river. The rounded outcrops that make up this stop can easily be seen here between the road and the river - to get to them requires a short walk through some alders and brush. **The ground underfoot may be wet and slippery. Be cautious on the outcrop above the river, as there are steep drops to the water.**

Description: The outcrops provide examples of relatively unaltered, well-foliated ultramafic rocks (harzburgite and dunite) that are believed to represent mantle tectonites of the Baie Verte oceanic tract. In the area located about half way between the road and the larger outcrop *(easting: 547975; northing: 5516643 NAD83)*, the ultramafic rocks contain thin chromite seams. The larger outcrop above the river consists of brown-weathering peridotites, of harzburgitic type, cut by networks of serpentine veins. The hydrothermal alteration that produced the virginite seen at Stop 1.1 evidently did not affect this area. A penetrative fabric is widely developed in the outcrop but is not always easy to see, and the outcrop as a whole displays crude compositional banding parallel to this fabric. Younger ductile shear zones also affect the outcrop locally.

Stop 1.3: The Dorset Eskimo Soapstone Quarry

Directions: From Stop 1.2, continue for about 1 km to a straight stretch of road to turn around, and return to the Dorset Trail (Route 410). Turn left, and drive northward through Baie Verte, and continue to the community of Fleur-de-Lys, following the signs for the "Dorset Soapstone Quarry Historic Site", which is located on the north side of the harbour.

Description: From a geological perspective, this stop represents one of several altered ultramafic units that are contained within pelitic to psammitic metasedimentary rocks of the Fleur-de-Lys Supergroup. These have traditionally been considered to be of Paleozoic (likely Ordovician) age, and to have been structurally interleaved with the metasedimentary rocks during the obduction of Taconic allochthons. However, the recent age of ca. 558 Ma (unpublished data, V. McNicoll, 2006) obtained from gabbroic rocks associated with ultramafic lenses at Coachman's Cove (See stop 3.2) raises questions about the age and origin of this and other ultramafic slivers west of the Baie Verte Line. This problem is being pursued by further study of these rocks (M. Escayola and C. van Staal, in progress)

The historical significance of this site outweighs these geological uncertainties, because it is one of the oldest known mining excavations in North America; the summary below is drawn from an article by O'Driscoll (1998) available on the Newfoundland and Labrador Heritage website.

The quarry was known for many years, but field investigations of the site did not commence until the 1980s. Archeological evidence suggests that it was used by the Maritime Archaic peoples about 4,000 years ago and subsequently by the Middle Dorset Paleoeskimo from 1,800 to 1,200 years ago. The strongest connection is to the Middle Dorset period, because finished vessels assigned to these sources correspond closely with unfinished vessels and extraction scars in the faces. The stone tools found at the site include material made from chert and quartz crystal, presumably used for shaping and extraction. The soapstone from the quarry was mostly used for functional purposes, such as cooking pots and lamp vessels, rather than for artistic carving. The large number of extraction scars at the site implies that it was an active quarrying operation for centuries. The soapstone vessels were to a large extent carved in situ. The removal of the first round or ovoid soapstone "preform" created the inner surface for the next vessel, and the process continued. However, not every attempt was successful, and some partially finished vessels were left in place when they were abandoned. The partially finished vessels were presumably removed from the quarry site, and the final stages of manufacture were completed elsewhere.

This is a protected archaeological site, and no sampling, hammering or other disturbance is permitted. If time permits, there is a short loop trail that leads to a ridge above the site, from which there are spectacular views.

Stop 1.4: Parrel Molybdenum Prospect

Directions: From Stop 1.3, this site is located in a roadcut a short distance west of the parking area, and is easily located by the extensive rusting and staining. **Watch for traffic.**

Description: Closely adjacent to the Dorset soapstone quarry is one of the early attempts at mining in Newfoundland. The prominent rusty zone is located along the contact between the ultramafic rocks and adjacent metasedimentary rocks. This is the site of the Parrell Prospect, where a shaft and some crosscuts were excavated in an attempt to exploit a high-grade concentration of molybdenite (MoS_2) around 1915. The prospect was described in some detail in the 1940s (Fuller, 1945), and recently summarized in an article by Kerr et al. (2009). Molybdenite can be found in the clay-like gouge along the faulted contact, and is locally high-grade. It was of very limited extent, and mining attempts were soon abandoned. The construction of the road later destroyed the shaft and removed waste dumps. The origin of the deposit is unknown, although it has sometimes been described as skarn-like due to its location at a contact between compositionally different rock types. However, it could equally represent the effects of late fluids moving through this faulted zone. There is not a great deal of molybdenite left at the site, so we ask participants to refrain from sampling.

Day Two Stops

The field trip stops for this day focus on several different aspects of the geology of the Peninsula, with an emphasis on the stratigraphy of the upper section of the Betts Cove ophiolite and the overlying Snooks Arm Group. The morning commences with an examination of the distinctive marker unit sequence of the Nugget Pond horizon, which sits above the ophiolitic rocks of the Betts Cove Complex and below the volcanic and sedimentary rocks of the Snooks Arm Group. Remaining stops for the morning excursion examine the stratigraphy of the Snooks Arm Group, which is the least deformed of the Ordovician volcanosedimentary sequences examined on the trip. The afternoon stops for Day 2 commence with an examination of Silurian rocks of the Cape St. John Group, mostly to emphasize the important role of Salinic (Silurian) deformation. Later stops are in rocks assigned to the upper part of the Pacquet Harbour Group, which is herein correlated with the Snooks Arm Group. These later stops emphasize aspects of regional structural development that apply to both the Ordovician rocks and the younger Silurian sequences. The stratigraphic aspects of correlation between the Snooks Arm Group and the Pacquet Harbour Group will be examined on Day Three.

Stop 2.1: Transition from the upper Betts Cove ophiolite into the Snooks Arm Group

Directions: Drive 2 km south from Baie Vista Inn to the junction with the La Scie Highway (Route 414). Proceed 39.2 km east on La Scie Highway to the junction for Snooks Arm and Round Harbour (Route 416). Turn right (south) on Route 416 and drive 5.7 km to the junction of the Nugget Pond mine access road, and continue to the security gate. **Permission to enter the Nugget pond site must be obtained in advance from the operators and/or site manager. If there are no arrangements for access, see the alternate stops near Tilt Cove, which are accessible at all times.**

After passing through the gate proceed 5 km west to the Nugget Pond mine site. After signing in at the office, drive 375 m northwest and west around mill to the tailings pond. Continue 90 m northwest along the tailings pond road, then walk 40m southwest to a small outcrop by the lake *(easting: 588145; northing: 5522039 NAD83)*.

Within the Nugget Pond mine site, participants should be aware of machinery and trucks, and follow all safety procedures required by the operators, which will be outlined at the time of the visit.

Stop 2.1a

Description: This outcrop belongs to the upper part of the Mt. Misery Formation and comprises pillow basalts of island-arc tholeiite affinity. The pillows are pale green coloured, generally small (20-30 cm in diameter) and contain abundant quartz, jasper, and epidote alteration that is preferentially concentrated on pillow margins. Underlying basalts are northeast striking, steeply dipping (~80 degrees) and young to the southeast.

The Mt. Misery Formation represents juvenile island arc crust that developed on a substrate of boninitic volcanic rocks. Both volcanic sequences form part of an ophiolite developed above a subduction zone, rather than in a purely oceanic setting. At Tilt Cove, Mt. Misery Formation basalts are interbedded with intermediate-TiO_2 boninites, and host Cyprus-style VMS mineralization. The island-arc tholeiites and intermediate TiO_2-boninites are both depleted in light rare earth elements (LREE) relative to chondrite. Intermediate-TiO_2 boninites (and by inference the Mt. Misery Formation), are considered to be of ca. 489 Ma age, based on the date obtained by Dunning and Krogh (1985) from a geochemically-similar gabbro on Long Pond, near Tilt Cove (Bédard et al., 2000).

Stop 2.1b

Directions: Return to Tailings Pond road and proceed to small outcrop on north side of road *(easting: 588180; northing: 5522070 NAD83*).

Description: This outcrop contains massive and vein-style jasper alteration with quartz veining, developed in the uppermost Mt. Misery Formation pillow basalts. This style of alteration is consistent with alteration associated with relatively low-temperature hydrothermal fluids, associated with the cooling of the submarine volcanic pile.

Stop 2.1c

Directions: Proceed 55m southeast and south along Tailings Pond road to outcrop on east side of road *(easting: 588206; northing: 5522024 NAD83)*.

Description: This outcrop of the Nugget Pond horizon of the Scrape Point Formation comprises iron formation with red jasper beds, interbedded with red shale and overlain by green, volcanic-derived sandstone and siltstone. The jasper unit at this outcrop is LREE-enriched and shares a geochemical affinity with surrounding LREE-enriched Scrape Formation basalts. At the Nugget Pond Mine, quartz-albite carbonate epigenetic veins cut the Nugget Pond horizon and contain gold mineralization associated with pyrite. There is also widespread development of pyrite cubes in the sedimentary host rocks, which host a stratiform zone of replacement-style gold mineralization (Sangster et al., 2008). The mine access roads that we are walking on here contain numerous examples of pyrite-bearing material developed in and around the ore zone, which make excellent display specimens.

The Nugget Pond horizon is a regionally significant stratigraphic marker that demarcates the base of the Lower to Middle Ordovician cover sequence to the Betts Cove ophiolite, i.e., the Snooks Arm Group. It is correlated herein with the Goldenville horizon on the Pointe Rousse Peninsula. Drill holes at the Nugget Mine have intersected conglomerate cemented with jasper at the base of the Nugget Pond horizon, that is overlain by jasper iron formation and red shale. To the west in the Flatwater Pond area, the base of the ophiolite cover sequence comprises proximal conglomerates and megabreccia (see Stop 3.3) that are likely time-equivalents of the Nugget Pond horizon. These conglomerates are constrained to have been deposited at ca. 476 Ma (unpublished data, V. McNicoll, 2007; see discussion in part 1).

Stop 2.1d

Directions: Continue 32m south from last stop to outcrop on east side of road *(easting: 588202; northing: 5521991 NAD83)*.

Description: This outcrop comprises interbedded grey-green epiclastic greywacke, siltstone, and shale. Graded bedding in the greywacke is oriented 055/58E and indicates younging to the southeast. Note the gradual change in the style of sedimentation between stops 1c and d. Conglomerates at the base of the Scrape Point Formation (not exposed in this area) give way to clastic-starved, iron-rich chemical sedimentary rocks of the Nugget Pond horizon. The thickness of chert and red shale beds decreases up section at the expense of green siltstone and greywacke (upward-coarsening), reflecting increased input of coarse volcanic-derived detritus. A sample of the green greywacke was collected from this site for U/Pb geochronology but did not yield any detrital zircon.

Stop 2.1 (Alternate): Nugget Pond Horizon at the Castle Rock gold showing

Directions: The alternative location for viewing the Nugget Pond horizon is located just south of the community of Tilt Cove, and requires a steep hike of approximately 1 km. From the La Scie Highway (Route 414) continue to the Tilt Cove junction, and drive down the road into the community for about 5.7 km, and park. Walk up the steep road that leads to the Catholic Cemetery and "Castle Rock"; the latter is clearly visible as a large pinkish outcrop surrounded by scree slopes. The hike should take 10 to 15 minutes, depending on how many stops are made for resting and admiring the view. Castle Rock is accessible via a short side trail; it consists of an intensely cleaved talc-carbonate-magnetite rock that represents an intensely altered ultramafic component of the Betts Cove Complex. **The rock has steep cliffs all around it, and care must be taken on surrounding loose scree slopes.**

Follow the main trail around the northwest side of the pond to the Castle Rock gold showing and adjacent outcrops. The first part of the stop is marked by large blocks of pillow breccia *(easting: 597798; northing: 5526098 NAD83)*

Description: The large blocks of pillow breccia (and subjacent outcrops) at this locality represent the Mount Misery Formation of the Betts Cove Complex, and are equivalent to the host rocks of the Tilt Cove Copper mine. The breccias are altered and the matrix to the fragments locally contains disseminated chalcopyrite. From this outcrop, walk another 50 metres along the track and turn left; there is a large partially bedded and rusty outcrop at this locality. The bedding is overturned here; the right hand side of the outcrop consists of mafic pillow breccias akin to the first outcrop, and the left hand side of the outcrop consists of mafic volcanic and/or volcaniclastic rocks of the Scrape Point Formation. The rusty bedded unit that separates these contrasting sections of the outcrop is the basal Nugget Pond horizon, which is here a condensed sequence compared to its type locality. Elsewhere on the peninsula, thin sequences of this type are the norm for this marker unit. The following description is in part adapted from information in an earlier guidebook (Sangster and Pollard, 2001).

The rock types at this spot are best exposed on a stripped outcrop exposed on a skidder trail at the top of this exposure. Silicification and related alteration in the lowermost pillow breccias is not seen in the sedimentary sequence, suggesting (but not proving) that there is a time interval or hiatus between volcanism and sedimentation. The Nugget Pond horizon consists of argillites (locally sulphide-bearing), cherts and thin siltstone beds. The sequence commences with a massive green argillite, associated with sulphide bands, which passes upwards into a red hematite – magnetite-bearing silicate facies iron formation, locally overlain by breccias with a talc-carbonate matrix (Sangster and Pollard, 2001). Tight folding is visible in these rocks in several parts of the outcrop. These rocks contain gold mineralization, which is associated with pyrite cubes and albite alteration in a red chert unit. The best gold mineralization is associated with a thin (10 cm) band of heavily disseminated pyrite cubes within a red argillite bed in the iron formation. The grades from surface sampling were locally spectacular, including assays of up to 100 g/t over narrow widths (Sangster et al., 2008). The Castle Rock showing is surrounded by Silurian porphyry, and local outcrops are cut by porphyry dykes. Although described in previous guidebooks as a “huge xenolith”, there is no indication that these rocks have been moved from their original position, and the relationships are interpreted as original.

Stop 2.2: Clinopyroxene-phyric tuff-breccia marker unit, Bobby Cove Formation

Stop 2.2a

Directions: Return to Crew Gold office and drive 5 km east to the gate on Nugget Pond Mine road, and park off the road about 50 m beyond the gate. Walk 25m up the dry stream bed on north side of road towards the dam; the first outcrop is exposed along stream bed *(easting: 592106; northing: 5523957 NAD83)*. **Note that vehicles must be kept well off the mine access road to provide room for passing trucks, and participants must be wary of truck traffic.**

Description: This portion of the outcrop is dominated by a very distinctive submarine pyroclastic rock, in which fragments showing a wide size range contain euhedral phenocrysts of clinopyroxene. There are small numbers of other fragment types, which range from fine-grained aphyric igneous rocks to amygdaloidal rocks. The overall composition of the rock unit is basaltic to andesitic, and the outcrop did not contain any zircon for dating purposes. However, a felsic tuff slightly higher in the stratigraphy was successfully dated (see stop 2c, below). The fragments in this distinctive rock type vary widely in size and morphology, but most are rounded, suggesting that they may have been hot and plastic upon accumulation; in places, larger fragments appear to have “disaggregated” into smaller blobs. The ubiquitous clinopyroxene phenocrysts suggest that the unit was erupted from a large mafic to intermediate magma chamber that was a mixture of crystals and magma. The textures in the breccia, notably the moulding and disaggregation of clasts, and the flattening of amygdules locally within them, suggest that they accumulated whilst still relatively hot and plastic. The wide distribution of this unit across the peninsula implies that this was a large eruptive event, but the greater thickness and coarser nature of the marker unit at this locality suggests that it was closer to the eruptive centre. The rock type is interpreted as a composite subaqueous pyroclastic flow complex, within which individual units grade up into lapilli tuff and eventually volcaniclastic turbidites.

Stop 2.2b

Directions: This section of the stop is located in the same diverted river channel as Part 2.2a, but below (downstream) of the Nugget Pond mine road, a distance of about 50 m. **Watch for traffic when crossing the mine access road.**

Description: From a stratigraphic perspective, the outcrop sits immediately above the marker horizon described in Part 2.2a, and grades downward into lapilli tuffs with similar clast types. The outcrop consists of well-bedded tuffaceous and volcaniclastic rocks.

Stop 2.2c

Directions: Return to road and walk 145m east and southeast; outcrop is located on north side of road *(easting: 592269; northing: 5523893 NAD83)*. **Watch for traffic when crossing the mine access road.**

Description: The outcrop consists of a massive felsic crystal tuff with a few lithic fragments, representing a stratigraphic level above that of Part 2.2b. This outcrop provided a U-Pb zircon age of ca. 470 Ma (unpublished data, V. McNicoll, 2007), which provides a minimum age for the marker horizon at Part 2.2a of the outcrop. By inference, it provides a minimum age for other outcrops of this distinctive marker horizon identified in other parts of the peninsula, within the Point Rousse Complex, Pacquet Harbour Group, and Flatwater Pond Group.

Optional stop: Volcaniclastic sedimentary rocks containing breccia units

Directions: From Stop 2.2, return through the gate on the Nugget Pond mine road, and drive to a cabin on the left side of the road. At the time of writing, the cabin was marked by gateposts with two open hands. The outcrops are located adjacent to the cabin, at *(easting: 591641; northing: 5523651 NAD83)*. Note that this is private property, and permission should be obtained to look at the outcrops if the owners are in residence.

Description: This interesting outcrop consists largely of a mafic to intermediate tuff unit, possibly of volcaniclastic origin, that is broadly equivalent to the dated crystal tuff locality visited at the last stop. The outcrop contains two discrete horizons of an angular breccia including dominantly felsic fragments. In places, individual clasts can be fitted back together in a jigsaw-like manner. Although most of the clasts are the same rock type, there are several clasts that represent the clinopyroxene-phyric tuff breccia used as a marker unit.

Stop 2.3: Sedimentary rocks of the upper Bobby Cove Formation

Stop 2.3a

Directions: From the Nugget Pond mine road, rejoin the Snooks Arm road. Turn right (south) and drive for about 200 m to a long roadcut outcrop on the east side of the road *(easting: 592381; northing: 5523672 NAD83).* **Watch for traffic.**

Description: This outcrop exposes volcanic-derived turbiditic sedimentary rocks of the Snooks Arm Group, specifically the Bobby Cove Formation, which also includes the distinctive marker horizon exposed at Stop 2.2. The outcrop is well-bedded and the beds are subvertical. It contains abundant sedimentary structures (including way-up indicators), and some delicately laminated units at the tops of some Bouma sequences.

Stop 2.3b

Directions: From Stop 2.3a, walk south for less than 200 m to the junction of the road heading south to Snooks Arm and the road heading east to Round Harbour. The outcrop is on the east side of road *(easting: 592412; northing: 5523490 NAD83)*. **Watch for traffic.**

Description: This is near the top of the Bobby Cove Formation. It consists of a thin unit of red shale, and jasper (silicate-facies iron formation) capping turbidites similar to those of Stop 2.3a. On the coast, this unit is two to three meters thick.

Stop 2.4: Venam's Bight Formation

Directions: Turn onto the road to Round Harbour, and continue 275m to road cut on northeast side of road *(easting: 593022; northing: 5523660 NAD83)*. **Watch for traffic.**

Description: These outcrops display a sequence of well-formed pillow lavas containing interstitial red chert, passing upward into a sequence of pillow breccias. The rocks are assigned to the Venam's Bight Formation of the Snooks Arm Group. The pillows are locally well-formed, but the shapes are not in all areas diagnostic of facing directions. Some thin sedimentary units of red and cream chert define the orientation of bedding, which is steep; facing directions are thought to be to the southeast. The pillows display widespread alteration, dominated by hematization, which is interpreted to be seafloor or subseafloor hydrothermal alteration. Epidote-rich alteration is most noticeable in the centres of pillows, where higher temperatures were likely maintained. Cross-cutting epidotized zones are also apparent. The transition from well-preserved pillows into the pillow breccias is marked by a sudden increase in the volume of red cherty material. The red chert is not simply the matrix to the breccias for it occurs also as fragments. The pillow breccias are thus likely debris flows rather than true hyaloclastites developed through quenching and in-situ fragmentation. The well-developed pillow lavas visible in the distant cliffs are stratigraphically above the pillow breccias and presumably represent the start of another volcanic cycle.

Stop 2.5: Felsic volcanic rocks of the Balsam Bud Formation

Directions: From Stop 2.4, continue for about 1.4 km southeast and east along Round Harbour road, to a roadcut on north side of road *(easting: 594459; northing: 5523716 NAD83)*. **Watch for traffic.**

Description: This outcrop represents rhyolitic rocks of the Balsam Bud Formation of the Snooks Arm Group, although this is not immediately obvious upon initial examination. The larger outcrop is a featureless obsidian-like rock, although some have suggested that it could be a chert. The smaller outcrop contains some chaotic banding and lamination locally, which is interpreted as flow-banding rather than bedding. The origin of this rock (igneous versus sedimentary) has also been keenly discussed at times. However, a geochronology sample contained a small number of tiny magmatic zircons, which yielded a SHRIMP U-Pb age of ca. 467 Ma (unpublished data, V. McNicoll, 2007). This result suggests that it is very unlikely to be a chert, and provides the youngest age constraint currently available for the Snooks Arm Group.

Stop 2.6: Mafic volcanic rocks of the Round Harbour Formation - and Lunch!

Directions: From Stop 2.5 continue to Round Harbour and park near the government wharf. There are two choices for outcrops at this locality. If the weather is poor, visit the outcrop on the small hill above the harbour by the powerline *(easting: 596547; northing: 5523162 NAD83)*. This represents the Round Harbour Formation, the uppermost unit of the Snooks Arm Group. Bedding is at N250/76, and the pillows are overturned. In the rain, lunch can be eaten in the shed by the wharf.

If weather permits, a better outcrop is to be found on the coast. From the government wharf continue along path and boardwalk on the northern shore of the harbour for about 300 m. The outcrop is past the green and yellow house and occurs on a small hill overlooking the sea**.** The wooden boardwalk and path passes over private property, and over the front deck of the green and yellow house. The outcrop is steep and can be slippery when wet. *(easting: 596745; northing: 5523122 NAD83).* **Do not climb down to the shore.**

Description: The outcrop on the point exposes some superb pillow lavas, with white cherty interpillow material, and locally quartz-epidote concentrations. Some of the pillows are very large, and many are plagioclase-phyric. A curious feature of this outcrop is the presence of large "voids" in the centres of pillows. These have undoubtedly been created by modern coastal erosion processes, but the preferential erosion of the pillow centres likely reflects some original features. If these were tube-like features through which hot basalt flowed, perhaps there were voids left following extrusion, which have subsequently been excavated by modern processes? Or were pillow centres altered and less resistant?

Stop 2.7 The Silurian Cape St. John Group

Stop 2.7a: Sheared contact with the Ordovician sequence

Directions: Return to the La Scie Highway (Route 414). Continue east on La Scie highway for 5.9 km to the junction with the Tilt Cove road. Turn south on Tilt Cove road and continue 3.7 km south to gate and cottage. Walk around gate and continue 80m along northern edge of property to the small cliff overlooking stream. Outcrop is on private property, so ask permission before entering *(easting: 599817; northing: 5528138 NAD83)*. If the Alternate Stop 2.1 above Tilt Cove was visited, this outcrop and Stop 2.8 are best visited on the way back to the La Scie Highway (Route 414).

Description: Outcrops in a small cliff face on the west side of the stream expose strongly foliated, siliciclastic sedimentary rocks of the Cape St. John Group, in this case sitting structurally above the Ordovician Snooks Arm Group. In a nearby coastal locality, there is a preserved angular unconformity between similar (but less deformed) equivalents of these rock types. The fabric at this locality indicates the importance of Silurian orogenic events across the Peninsula, and their potential effects upon Ordovician sequences. Here, the shear fabric is dipping shallowly to moderately to the northwest; shear sense indicators and the present-day orientation of the fabric suggest normal sense of motion (Tremblay et al., 1997). However, if the fabric was rotated subsequent to shearing, it may also be consistent with thrust motion, possibly as an out-of-sequence structure. Further up the stream, shear fabric is overprinted by a very steep cleavage, which may correspond to the regional S_2 foliation.

Stop 2.7b: Tholeiitic basalt of the lower Cape St. John Group

Directions: Return to road and walk a short distance north on Tilt Cove road to an outcrop on the west side *(easting: 599768; northing: 5528115 NAD83)*. **Watch for traffic.**

Description: This outcrop reveals massive basaltic rocks considered to be of subaerial origin, which are visibly amygdaloidal, and much less deformed than the rocks by the stream. The mafic rocks in this outcrop are Ti-rich, continental tholeiites that contrast strongly with the submarine boninites and island-arc tholeiites typical of the Ordovician sequences. The massive basalt is overlain by a thin (<1m) flattened flow breccia.

Stop 2.8: Felsic volcanic rocks of the Cape St. John Group

Directions: Drive northward from Stop 2.7, back towards the La Scie Highway. About 200 m south of the highway junction there is a road cut on the east side of the road. There is a large exposure on the top of this outcrop (*easting: 598336; northing: 5530486 NAD83)*. **Be extremely careful of an overhead power line which is only 7 feet above the ground on the top of the outcrop. Stay well away from this area!**

Description: The outcrops consist of homogeneous felsic volcanic or hypabyssal intrusive rocks that locally display flow-banding. These are interpreted to be some of the younger felsic volcanic rocks within the Cape St. John Group. A sample from this outcrop provided a U-Pb zircon age of ca. 426 Ma (unpublished data, V. McNicoll, 2007). The fabric in this rock is dipping moderately to the north, and is interpreted to represent the regional S_2 foliation.

Stop 2.9: Cape St. John Group, mafic tuff breccia and transposed bedding

Directions: Rejoin the La Scie Highway (Route 414), and then drive west 9.7 km east to a large quarry on southwest side of road. Enter the quarry along the gravel access road and head to the road ascending the south wall, walking up it to an east-facing outcrop overlooking the quarry *(easting: 589218; northing: 5527599, NAD83)*. **Be careful of loose rock on the quarry face, and stay clear of loose soil on the cliff edge.**

Description: The outcrop reveals coarse-grained mafic tuff-breccia and other pyroclastic and epiclastic rocks of the Cape St. John Group, in which individual clasts (locally up to 70 cm in length) and fragments are strongly deformed. The fabric (regional S_2) in these rocks is moderate to strong (S_2 N286/52; L_2 N030/55) and primary bedding and other features are transposed along it. F_2 folds are also present (fold axis N030/51, axial plane N241/62).

Stop 2.10: Incipient recumbent folds in metasedimentary rocks

Directions: Continue west on La Scie Highway (Route 414) for 14.5 km to the junction with the road to Woodstock and Pacquet (Route 417), and proceed west on La Scie Highway for 350 m beyond the junction, to a large road quarry on north side. The area of interest is on the north wall of the quarry *(easting: 575373; northing: 5531111 NAD83)*. **Be careful of loose rock in the quarry face, and do not approach it too closely.**

Description: These outcrops reveal metasedimentary rocks that have traditionally been assigned to the Pacquet Harbour Group. These rocks are now considered to be broadly the metamorphosed equivalents of the sedimentary rocks of the lower Balsam Bud Cove Formation in the type section of the Snooks Arm Group, visited earlier today. The deformation here is intense, but relict primary structures including crossbedding are observed in outcrops at the top of the rear wall. However, it seems that expansion of the quarry face has removed the best examples of primary features. The remaining rocks retain few original features, but are interpreted to have originally been volcaniclastic turbidites. Magnetite porphyroblasts are developed locally, and foliation surfaces commonly display randomly-oriented late porphyroblasts of prismatic amphibole ("garbenscheifer texture"), which have yielded $^{40}Ar/^{39}Ar$ cooling ages of ca. 350-355 Ma (Hibbard, 1982).

In the back wall of the quarry, the dominant high-angle S_2 fabric is affected (folded) by open F_3 folds with flat-lying axial planes. This is the initial manifestation of an important phase of deformation that dominates the area to the north, throughout which both Ordovician and Silurian rocks exhibit recumbent tight to isoclinal folds that verge towards the south. The next stop illustrates a more intense and striking development of this structural pattern.

Stop 2.11: Axial zone of recumbent fold structure

Directions: Return to junction of La Scie Highway and road to Woodstock and Pacquet (Route 417), and proceed north on Route 417 for 3.9 km, to a road cut on the west side of the road *(easting: 577631, northing: 5534180 NAD83)*. **Watch for traffic.**

Description: These outcrops consist of metasedimentary rocks that are also correlated with the Balsam Bud Cove Formation of the Snooks Arm Group type section. The rocks consist of well-bedded mafic volcaniclastic rocks, locally including graded medium- to fine-grained greywacke, and some beds of lapilli tuff or tuff-breccia. The most obvious feature is a strong flat-lying foliation, representing a composite $S_{2\text{-}3}$ fabric. However, S_2 is locally preserved in hinge of S_3 crenulations. Bedding (or at least an earlier compositional layering) is visible in several places, where it is subvertical in attitude. The outcrop is thus considered to be part of the closure (hinge) of a large-scale recumbent F_3 fold. Minor folds visible in several parts of the outcrop are viewed as parasitic structures. This flat-lying fabric, and evidence for recumbent folding, is typical of the northeastern part of the peninsula. These structures have been interpreted as genetically related to extensional faults that resulted in the exhumation of the Ming's Bight Group during the Middle Devonian (Anderson et al., 2001; see part 1 for more details).

If time permits, walk south for a short distance and then up a branch road that leads to a cabin. Smooth, low-lying outcrops in the road bed do not obviously display the subhorizontal fabric, but this largely reflects their orientation. The outcrop does display some original features, including graded beds and possible cross-bedding; however, some might argue that truncation surfaces associated with the latter might actually reflect transposition associated with D_2 deformation.

Day Three Stops

The stops on Day Three of the field trip begin with some well-known outcrops located west of the Baie Verte Line, for which new data and interpretations are presented. Later stops east of the Baie Verte Line are within Ordovician volcanosedimentary sequences that are now correlated with the Betts Cove Complex and the Snooks Arm Group. These include parts of the Pacquet Harbour Group (previously considered to host the Rambler VMS deposits, although this interpretation is here revised) and the Point Rousse Complex, which includes both ophiolitic rocks and a cover volcanic sequence. The day will also include a brief examination of two outcrops in the Flatwater Pond Group, a package of rocks now also believed to correlate with the Snooks Arm Group.

Stop 3.1: The Birchy Complex

Stop 3.1a: Neoproterozoic ophiolitic gabbro within the Birchy Schist

Directions: From Baie Verte drive northeast on the Dorset Trail (Route 410) to the junction for Coachman's Cove, and turn right on this road. Drive 2.3 km to a road junction, and then continue straight for 1.2 km along the coastal road. Park near the last house, which has a white wooden garage. Walk 80 m east-southeast across the green lawn in front of small cottage to a coastal outcrop *(easting: 563485; northing: 5544599 NAD83)*. **The rocks in the coastal outcrops may be wet and slippery.**

Description: This locality shows the contact zone between greenish schistose rocks interpreted to be of metavolcanic origin, and a strongly sheared, coarse-grained, leucocratic to anorthositic metagabbro. The contact relationships here are not clear because there is no obvious discordance. Relict igneous textures are preserved in the gabbro, and it contains a greater abundance of quartz veins, reflecting its more competent character during deformation.

The gabbro at this locality gave a U-Pb zircon age that was unexpected - it is latest Neoproterozoic (ca. 558 Ma – unpublished data, V. McNicoll, 2007), rather than Cambro-Ordovician, as previously supposed. This result raises questions about its relationship with the adjoining metasedimentary rocks - does their spatial association reflect tectonic juxtaposition, and/or are parts of the metasedimentary rocks also late Precambrian in age? The gabbro outcrop does contain some enclave-like zones that resemble adjacent metasedimentary rocks, suggesting that these might be older than the gabbro. However, relationships remain equivocal!

The revised interpretation of the gabbro (and by inference associated ultramafic rocks) is that they record the generation of oceanic crust during development of the "Humber Seaway" by late Precambrian rifting of the so-called "Dashwoods microcontinent" from Laurentia. This enigmatic and unexposed piece of Grenvillian basement is interpreted to have formed the basement to arc systems developed on the peri-Laurentian margin during the Ordovician closure of Iapetus. For more discussion, see the first part of this guidebook, and the numerous references cited therein.

Stop 3.1b: Metasedimentary Rocks

Directions: Walk 60m northwest across grass to outcrop on beach (*easting: 563443; northing: 5544649 NAD83*).

Description: The outcrop consists of complexly folded and internally disrupted metasedimentary rocks, derived from graphitic shale, siltstone, greywacke and iron formation, and also mafic volcaniclastic rocks, all of which form part of the Birchy complex.

Stop 3.2: Polyphase deformation, coticules and other delights

Directions: Continue east along coastal road for 600 m until parking lot in front of "Petit Nord" park. The first part of this stop is located on the shoreline outcrops to the west of the park (*easting: 563899; northing: 5544748 NAD83*). **Participants should be careful of slippery wet rocks, and of ocean waves if the water is rough.**

Description: These outcrops are classic field trip localities that reveal metasedimentary rocks of the Birchy Complex, and their polyphase deformation. The Birchy Complex contains a mixture of strongly deformed metasedimentary and metamorphosed volcaniclastic rocks, generally correlated with the Fleur-de-Lys Supergroup, and also mafic and ultramafic rocks previously considered to be equivalent to the Baie Verte ophiolites. The outcrop is well-known for complex fold interference structures, representing Type 2 and Type 3 patterns as defined by J. G. Ramsay. Three phases of folding are readily demonstrated in these outcrops: The dominant foliation, S_2, is axial-planar to isoclinal fold affecting an older S_1 fabric. Some F_1 closures are preserved along limbs of F_2 folds. A steep S_3 cleavage is superimposed on earlier fabrics and is associated with open to close F_3 folds.

These structures are best outlined by reddish-brown manganese-rich layers rich in pink spessartine-rich garnet. These layers are commonly known as "coticules". Coticules in the Appalachian-Caledonian orogen were generally deposited during the Middle Cambrian to Early Ordovician on the slopes of both margins of the Iapetus Ocean. Coticule deposition may have been coeval with a period of intense island arc volcanism in the peri-Laurentian realm, representing a distal product of sea-floor hydrothermal activity associated with massive sulfide deposition near volcanic centres. , If the Birchy Complex coticule layers are also of this general age, there must be a disconformity or structural discontinuities within the Birchy Complex, considering the Neoproterozoic age of the gabbro at Stop 3.1.

Early interpretations of structure in these outcrops attributed most structural elements to deformation associated with the Taconic orogeny, during the Early to Middle Ordovician. The current interpretation, following the recognition of the importance of Silurian (Salinic) deformation across the Newfoundland Appalachians, is that all but the earliest (D_1) fabrics are thought to be Salinic and younger. Preliminary $^{40}Ar/^{39}Ar$ analyses from this locality give amphibole and white mica ages of ca. 465-460 Ma, tentatively interpreted as the imprint of Taconic metamorphism. Muscovite in a psammite, from a locality 1.2 km to the west, yielded an $^{40}Ar/^{39}Ar$ age of ca. 422 Ma, interpreted as a Salinic metamorphic cooling age (Castonguay et al., unpublished data).

The apparent absence of the Taconic fabrics in ophiolites and their cover rocks to the east of the Baie Verte Line is one of the main contrasts across this structure, reflecting localization of the ductile deformation and associated metamorphic effects of the Taconic Orogeny mainly to west of the line, in continental margin rocks of the Humber zone.

Stop 3.3: Kidney Pond conglomerate

Directions: Return from Coachman's Cove to Baie Verte. From the junction of Route 410 and the La Scie Highway (Route 414), continue 4.3 km south on Route 410 to a small road quarry on the east side of road, which is badly overgrown (*easting: 575373; northing: 5531111 NAD83*). The outcrops require penetrating the alders to the old quarry face. **Be careful of traffic on Baie Verte Highway. There is very limited parking space on a steep road embankment. The alders are very thick and difficult to penetrate.**

Description: These outcrops reveal intensely flattened and stretched matrix-supported polymictic conglomerate traditionally assigned to the Flatwater Pond Group. The clasts are mostly cobbles and boulders, and include quartzites, mafic intrusive rocks, granites (?), volcanic rock types and (rarely) ultramafic rocks. The traditional view of this unit, termed the Kidney Pond conglomerate, is that it is a late Ordovician or Silurian rock reflecting uplift and erosion of older units. This was largely based on inference, notably the presence of granodiorite cobbles that were correlated on the basis of lithology with the Burlington granodiorite. However, this requires revision in the light of new geochronological information indicating that the Flatwater Pond Group is in fact of lower Ordovician age (see below). The provenance of the large granodiorite cobbles, which yielded a surprising age of ca. 479 Ma (unpublished data, V. McNicoll, 2007) is problematic, because a local source rock of this age is unknown. However, they may have been sourced from uplifted parts of the Notre Dame arc (built upon the Dashwoods microcontinent to the east) or perhaps from cryptic older phases within the Burlington Granodiorite. Correlation of the Flatwater Pond Group with the Snooks Arm Group is supported also by the recognition of the distinctive clinopyroxene-phyric tuff breccia marker unit. However, outcrops of the latter are unfortunately not accessible for the purposes of the field trip.

The revised interpretation of the Kidney Pond conglomerate is that it records the initial uplift of and development of west-directed thrust wedges related to collision and emplacement of the Baie Verte oceanic tract and its trailing arc terrane (Notre Dame arc?) across the Humber margin. The sedimentary clasts were probably derived from the Laurentian margin, whereas mafic and rarer ultramafic debris came from the advancing ophiolite slices. The conglomerate is thus viewed as the time-equivalent of the iron formations and chemical sediments of the Nugget Pond horizon, which represent a period of volcanic quiescence. The Nugget Pond horizon was deposited in deep water in a more distal location with respect to the ancient continental margin and the westward-advancing leading edge of the Baie Verte oceanic tract.

Optional Stop: Felsic rocks of the Flatwater Pond Group

Directions: from Stop 3.3, turn around (it may be necessary to drive on for a short distance for a safe location) and return to the La Scie highway (Route 414) junction, and turn right towards La Scie. Drive for a short distance (1.8 km) and stop by a small outcrop on the right (north) side of Route 414 *(easting: 555744; northing: 5527012 NAD83)*.

Description: This is not a very spectacular outcrop, but it is important. It is a recrystallized, felsic lapilli tuff, assigned to the Flatwater Pond Group. U-Pb zircon geochronological studies of this outcrop yielded an age of ca. 476 Ma (unpublished data, V. McNicoll, 2007), indicating that it is early Ordovician in age, and thus broadly correlative with the Snooks Arm Group.

Stop 3.4: The Rambler Rhyolite

Directions: Continue eastward on the La Scie highway (Route 414). From the junction for the road to Ming's Bight, continue east for about 0.7 km to a crossroads with a gravel road. Turn right (south) and continue south on the Rambler Mine road for 2 km, passing the junction to the abandoned Rambler mine site, to an outcrop on the east side of road *(easting: 566323; northing: 5527313 NAD83)*. This outcrop provides the best illustration of structural features, but a second (located about 50 m down the road) preserves original textures better. **Note that the gravel road is rough and poorly-maintained and may not be suitable for low-clearance vehicles. The Abandoned Rambler mine site should not be entered, as demolition and rehabilitation work is currently in progress.**

Description: Both outcrops represent the "Rambler Rhyolite", a general term applied to an area of deformed felsic volcanic rocks that is spatially associated with virtually all the mineralized zones in this area. These particular outcrops were originally coarse volcanic breccias containing rhyolitic clasts. These tuff-breccias are interpreted to occur mostly on sides of the "Rambler" felsic dome. There is a strong L-fabric developed in the outcrops, with elongation of clasts ranging up to at least 10:1. This same elongation lineation is present in and around all of the sulphide zones at Rambler; it provides an important guide to the distribution of high-potential areas downplunge from existing deposits. This L-fabric is interpreted as part of the second and dominant phase of regional deformation (D_2), which is also related to early deformation along the Scrape

Thrust, an important structure that will be visited at a later stop. The D_2 fabrics predate the recumbent folding and related subhorizontal cleavage (D_3) examined yesterday.

There have been many attempts to date the Rambler rhyolite with a view to establishing the timing of related mineralization. The unit typically has a low Zr content, and was likely originally glassy, and it contains virtually no zircon. A more homogeneous extrusive variant from a nearby outcrop was the subject of the most recent attempt, and 3 full buckets of material ultimately yielded a small number of magmatic zircon needles. Dating was possible using the SHRIMP and a crystallization age of ca. 487 Ma (unpublished data, V. McNicoll, 2007) was obtained. This age, significantly older than those typical of the Snooks Arm Group, confirms that the Rambler rhyolite and associated ore deposits are temporally linked to the older ophiolitic rocks, correlated with the Betts Cove Complex. The Rambler deposits may thus be time-equivalent (broadly) to the VMS system at Tilt Cove, which occupies a similar stratigraphic position. The implication of this result is that the package of rocks termed the Pacquet Harbour Group is in fact composite; its lower section correlates with the Betts Cove and other ophiolites of the Baie Verte oceanic tract, whereas the upper section is broadly correlative with the Snooks Arm Group. The remainder of today's stops examine the linkages and correlations with this type section.

Stop 3.5: Iron Formations above the Rambler VMS deposits (Nugget Pond horizon equivalents?)

Directions: From Stop 3.4, return along the dirt road to Route 414, and then to the junction for Ming's Bight. Turn towards Ming's Bight for a short distance, and then turn right on the Ming mine access road, which leads to the abandoned open pit of the Ming East deposit. **Permission to access the site should be obtained in advance from Rambler Metals and Mining Canada Ltd.** The outcrops of interest are located on the edge of the pit *(easting: 565964; northing: 5529370 NAD83)*. **Note that the pit itself is a dangerous locality, and includes openings into disused workings and stopes. Under no circumstances should participants venture beyond the earth dykes that protect the open pit.**

Description: The footwall of the pit contains sericitized felsic schist representing the Rambler Rhyolite in an altered state, overlain by pyrite-rich, banded, massive sulphide ore. Immediately overlying the ore is a shallow-dipping sequence of north-younging graded greywacke, siltstone, and thin iron formations containing 5-8 mm chert beds and 2-3 cm magnetite beds. This is considered to be a condensed equivalent of the Nugget Pond horizon, examined at the first stops on Day Two. An equivalent sequence of chert and iron formation sits above the sulphide deposits at the "Old Rambler" and "East Mine" localities, suggesting that all these represent the same stratigraphic horizon. The footwall rocks (best seen in large blocks in this area) contain the strong L_2 fabric characteristic of all areas in and around the Rambler camp. The attitude of this fabric in outcrops is the same as that seen in the Rambler rhyolite at Stop 3.4.

Stop 3.6: Rambler Metals and Mining Exploration Project and Lunch!

Directions: Return to the Ming's Bight road, and drive across it, to the Rambler Metals and Mining Property.

Description: This active exploration project has defined substantial copper resources associated with the former Ming Mine, within a zone of strong stringer-style footwall mineralization. Cu-Zn mineralization has also been defined by following the known deposits down the plunge defined by the strong L-fabric seen at the previous two stops. This stop provides an opportunity to eat lunch in the relative comfort of the Rambler Metals property. An update on the exploration and development project will be available. If time permits, some of the drill core from recent exploration will be available for a brief examination.

Optional Stop: Volcaniclastic rocks (Scrape Point Formation equivalents)

Directions: From the Rambler Metals and Mining property, return to the Ming's Bight road, and then to the La Scie Highway (Route 414). Turn eastward, and drive for 1.2 km, to a small outcrop on the left (north) side of the road *(easting: 567088; northing: 5529354 NAD83)*. **Watch for traffic.**

Description: These outcrops consist of volcaniclastic sedimentary rocks, including a tuffaceous unit in the stratigraphically lowest part of the outcrop. These rocks are traditionally considered as part of the undivided Pacquet Harbour Group, and sit stratigraphically above the iron formations of the previous stop. It is now suggested that they correlate specifically with the Scrape Point Formation of the Snooks Arm Group, which occupies an equivalent stratigraphic position, i.e., immediately above the chemical sedimentary rocks of the Nugget Pond horizon.

Stop 3.7: Mafic volcanic rocks (Venam's Bight Formation equivalents)

Directions: From the Rambler Metals and Mining property, return to the Ming's Bight road, and then to the La Scie Highway (Route 414). Turn eastward, and drive for 5.8 km, to outcrops located on the left (north) side of the road *(easting:* 571433*; northing:* 5530025 *NAD83)*. These outcrops are 4.6 km from the optional stop described above. Note that this is the second outcrop of mafic volcanic rocks on the roadside; there is an inferior outcrop located about 150 m before this location. **Watch for traffic.**

Description: This is the last outcrop of pillow lava to be examined on the field trip, which may come as a relief to some participants. However, it is a very nice outcrop, with some well-preserved pillow shapes, which are upward-facing. The pillow tubes dip into the outcrop face, towards the north. These submarine mafic rocks are correlated with the Venam's Bight Formation of the Snooks Arm Group. The intervening units, including the distinctive clinopyroxene-phyric tuff-breccia marker horizon, are also recognized within this part of the Pacquet Harbour Group, but are not readily accessible for the field trip.

Stop 3.8: Felsic pyroclastic and/or volcaniclastic rocks (Balsam Bud Formation equivalents)

Directions: From Stop 3.7, continue eastward on the La Scie Highway (Route 414) for about 1.4 km, to a junction with a dirt road that leads northward up a gentle hill. The road is passable by high-clearance vehicles, but there is limited space for turning at the stop. Drive or walk for 250m to scattered outcrops on west side of road near a powerline. There are three or four outcrops *(easting:* 572701*; northing:* 5530975 *NAD83)*.

Description: This is a white-weathering, granular rock that displays a strong lineation. Relict bedding is visible locally, as are lithic fragments. These outcrops are interpreted as quartz-feldspar rhyolite crystal tuff to lapilli tuff, locally interbedded with grey-green epiclastic rocks. The lapilli tuff has been dated at ca. 470 Ma (unpublished data, V. McNicoll, 2008); an age that is closely similar to that obtained from the glassy, featureless rhyolites of the Balsam Bud Formation (see Stop 2.5). Although the rock types are lithologically distinct, it seems reasonable to correlate them as part of the same sequence.

Stop 3.9: The Scrape "Thrust"

Directions: From Stop 3.8, turn around and drive west on the La Scie highway (Route 414), returning to the Ming's Bight junction. Turn right for Ming's Bight, and drive 3.3 km to prominent white-weathering outcrops on the right (east) side of the road *(easting:* 565860*; northing:* 5532435 *NAD83)*. **Watch for traffic.**

Description: These outcrops mark the location of the Scrape Thrust, a regionally important fault zone that marks the southern limit of the Point Rousse Complex. Like the other sequences examined in this field trip, the Point Rousse Complex includes both ophiolitic rocks and a younger volcanosedimentary sequence. However, it is not as easily accessible as the other sequences examined on this trip.

The Scrape Thrust is a complex and long-lived shear zone that juxtaposes talc-carbonate schists derived from ultramafic rocks of the Point Rousse Complex (hanging wall) against deformed amphibolitic-grade metasedimentary rocks and gabbros previously included as part of the undivided Pacquet Harbour Group (footwall). The latter are now viewed as equivalents of the Scrape Point Formation of the Snooks Arm Group. The original kinematic sense of the fault is interpreted to be south-directed, during the second phase of regional deformation (D_2). The fault zone is associated with a well-developed, locally mylonitic, foliation and a strong lineation in the footwall, which correlates with the elongation lineation that defines mineralized trends at the Rambler deposits. Re-examination of these outcrops (Jamieson et al., 1990; Anderson et al., 2001; this study) suggests that the most recent episode of motion along the fault zone is normal as shown by extensional shear bands and north-side-down C-S fabrics. This fault reactivation, possibly related to the regional D_3 phase, may be responsible for the present-day juxtaposition of the lower-grade Point Rousse complex structurally above the higher-grade Pacquet Harbour Group.

Stop 3.10: The clinopyroxene-phyric tuff breccia makes its final appearance

Directions: The final stop for Day 3 may be deferred until the morning of Day 4 due to timing constraints. From Stop 3.9, continue northward on the Ming's Bight road for 1.4 km, and take the road on the left signposted for the Pine Cove Mine. This is unpaved, but passable by all vehicles. Drive to the gate for the mine property. Park outside the gate. A power and phone line runs a short distance on the left hand side of the road. Cross the cleared area towards the pole line, and walk a short distance northward to the outcrops (*easting:* 56399*; northing:* 5535346 *NAD83)*. **Vehicles must be kept well off the road to allow mine trucks to pass. Watch for traffic when crossing the access road.**

Description: These small outcrops are the only easily accessible location within the Point Rousse Complex where the distinctive clinopyroxene-phyric tuff-breccia marker horizon can be seen. This unit is found in several other places, and affirms the correlation between these rocks and the type section of the Snooks Arm Group. The other key correlation between the Point Rousse Complex and the Snooks Arm Group is provided by the iron formation that hosts the Goldenville gold deposit; this is considered to correlate with the Nugget Pond horizon.

DAY FOUR, MONDAY OCT 5

The final day of the field trip will include a visit to the Pine Cove mine of Anaconda Mining. The details of this visit were not available prior to completion of this guide, and will thus be provided onsite.

Stop 4.1: The Pine Cove Gold Mine

Directions: The Pine Cove gold mine is located a short distance from Baie Verte but must be accessed via a gravel road that leads from the road to Ming's Bight. **Prior permission is required to visit the site. Participants must follow all safety procedures required by the operator.**

Description: The visit to the mine will include a brief overview of the local geology, followed by a visit to the open pit and the processing mill. There will be an opportunity to see typical gold ore – although no gold can be seen, this material is visually spectacular. The general geology of the Pine Cove gold deposit is described in the first part of the guidebook. The following description is drawn from an earlier reports and field trip guides that were written prior to development of the present operation (Evans, 2004; Kerr et al., 2005).

The Pine Cove deposit is located in the same general area as Goldenville, Deer Cove, Stog'er Tight and several other important gold deposits (Figure 9). The deposit entered production in early 2008. Anaconda Gold Corporation conducted extensive delineation drilling and feasibility studies over several years prior to production. The deposit has a long history of exploration, which is recounted in detail by Evans (2004), and summarized here. The initial stages involved surficial geochemistry surveys and geophysics, which led to the discovery of gold-bearing quartz veins containing 6-10 g/t Au in 1988, by geologist and prospector Charlie Dearin. Subsequent drilling by Varna Resources and Corona Corporation defined two main gold prospects, which are termed the Thunder Zone and the Lightning Zone. The resource at the time was estimated at 2.75 million tonnes at 3 g/t Au, and the deposit was assessed for mining by NovaGold Resources in the early 1990s. Feasibility studies were positive, but the project did not proceed at the time due to other factors, notably the falling price of gold.

The property was eventually transferred to New Island Minerals Incorporated, who then optioned it to Anaconda Gold Corporation. Following two years of assessment work, bulk sampling, mill testing, and a positive feasibility study, Anaconda Gold announced a production decision in late 2004. The current resource total quoted by Anaconda Gold prior to production was 2.2 million tonnes at 2.9 g/t Au (indicated) with an additional 800,000 tonnes of inferred resource at slightly lower grades. The diluted reserves for open pit development were quoted at 1.87 million tonnes at 2.9 g/t (Anaconda Gold, press release, 2004). Anaconda Gold continues to explore around the deposit and at nearby zones (e.g., Romeo and Juliet, see below) in search of additional tonnage and potential high-grade zones.

The Pine Cove deposit is within the Point Rousse Complex, which comprises dismembered ophiolitic rocks, conformably overlain by mafic volcanic and volcaniclastic rocks (Hibbard, 1983; see Part 1). The geology in, and around, the Pine Cove deposit is described by Hibbard (1983) and Evans (2004). The latter account is based to a large extent on unpublished assessment and consultant reports, and forms the basis for the following summary.

In the vicinity of the deposit, the host rocks are dominated by mafic flows and tuffs, which are intruded by gabbro and diabase. Gabbroic rocks are typically fine-grained, and are locally strongly altered, to the point where they can be hard to recognize. The dominant host rock at Pine Cove is inferred to have been gabbro (see below). The Pine Cove deposit lies close to the Scrape Thrust (see earlier stops), along which the Point Rousse Complex has been thrust southward over the mafic volcanic rocks of the Pacquet Harbour Group. The Pacquet Harbour Group in this area is polydeformed, and metamorphosed to amphibolite facies; it is also possibly structurally imbricated with the Point Rousse Complex along, and beneath, the main thrust plane (Hibbard, 1983). A related structure, called the Pasture Pond thrust, lies north of the deposit and structurally above it.

The Pine Cove deposit belongs to the carbonate-quartz-sulphide replacement subclass of Evans (2004). The following description of gold mineralization is summarized from Evans (2004), in part compiled from unpublished assessment reports. The Thunder Zone and the Lightning Zone are each hosted by a variety of rock types, including gabbro, mafic volcanics and hematitic volcanogenic arenites, and mineralization is confined to a structural slice between the Scrape Thrust and the Pasture Pond Thrust The rocks are structurally complex and four phases of deformation were identified by Calon and Weicke (1990). Early deformation is largely responsible for the distribution of rock units, which reflect reclined tight to isoclinal folds. These early structures are affected by later deformation, which appears to be related to the southward emplacement of the Point Rousse Ophiolite Complex over the Pacquet Harbour Group, likely during the Silurian. The gold mineralization occurs in two forms, i.e., in quartz veins and quartz-breccia zones that contain pyrite, and as disseminated auriferous pyrite in strongly altered wall rocks. The predominant host for economic mineralization appears to be an intensely altered gabbro sill, now completely altered to iron carbonate, albite and pyrite. Duncan and Graves (1992) believed that the primary controls on the distribution of mineralization were lithological, rather than structural, and that most mineralization actually predated southward thrusting linked to the Scrape Thrust and related structures.

The gold is associated with pyrite, which occurs in quartz veins, marginal to quartz veins, and as disseminated material. Gold occurs as inclusions and fracture systems grains in the sulphides, and gold grains are small, typically 1 to 50 microns in size. The grades reported from the deposit range up to 11 g/t Au over 8 m, and 10 g/t Au over 36 m, but gold values in the 2 to 6 g/t Au range are more typical on a deposit-wide scale (Evans, 2004; Anaconda Gold, press releases, 2004).

REFERENCES

Anderson, S.D., 1998. Structure, metamorphism, and U-Pb and 40Ar/39Ar geochronology of the Ming's Bight Group, and the Paleozoic tectonic evolution of the Baie Verte Peninsula, Newfoundland. Unpublished Ph.D. thesis, Dalhousie University, Dartmouth, Nova Scotia. 452 p.

Anderson, S.D., R.A. Jamieson, Reynolds, P.H., 2001. Devonian extension in northwestern Newfoundland: $^{40}Ar/^{39}Ar$ and U/Pb data from the Ming's Bight area, Baie Verte Peninsula. Journal of Geology, v. 10, p. 191-211.

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

Bédard, J.H., 1999a. Petrogenesis of boninites from the Betts Cove ophiolite, Newfoundland, Canada: identification of subducted source components. Journal of Petrology, v. 40, p. 1853-89.

Bédard, J.H., Lauziere, K., Boisvert, E., Sangster, A.L., Tellier, M., Tremblay, A., and Dec, T., 1999b. Geological map of the Betts Cove Ophiolite and its cover rocks, 1:20,000 scale: Geological Survey of Canada, A-series Map 1969A.

Bédard, J.H., Lauziere, K., Tremblay, A., Sangster, A.L., Douma, S., and Dec, T., 2000a, The Betts Cove ophiolite and its cover rocks: Geological Survey of Canada, Bulletin 550, 76 p.

Bédard, J.H., Lauzière, K., Boisvert, É., Deblonde, C., Sangster, A., Tremblay, A., Dec, T. 2000b. Betts Cove geological dataset for GIS applications, Geological Survey of Canada, Open File D3623

Bursnall, J. T., 1979. Geology of part of the Fleur-de-Lys map area. Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey, Report 79-1., p.68-74.

Bursnall, J. T., and de Wit, M. J. 1975. Timing and development of the orthotectonic zone in the Appalachian Orogen of northwest Newfoundland. Canadian Journal of Earth Sciences, v. 12, p. 1712–1722.

Castonguay, S., Skulski, T., van Staal, C., Currie, M. 2009. New insights on the structural geology of the Pacquet Harbour Group and Point Rousse Complex, Baie Verte Peninsula, Newfoundland: Current Research (2009) Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 09-1, pages 147-158

Calon, T. J., and Weicke, J., 1990: Structural study on the Pine Cove deposit area. Unpublished report for Corona Corporation. Newfoundland Department of Mines and Energy, Geological Survey File Number 12H/16 (1272).

Cawood, P.A., van Gool, J.A.M., 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, no.6, p.A422.

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.

Coyle, M; Oneschuk, D. 2008. Residual total magnetic field, Baie Verte aeromagnetic survey, Nippers Harbour, NTS 2 E/13 and part of 2 E/14, Newfoundland and Labrador Geological Survey of Canada, Open File 5633, 1 sheet.

Coyle. M. L., and Strong, D. F., 1987: Geology of the Springdale Group: A newly-recognized Silurian epicontinental-type caldera in Newfoundland. Canadian Journal of Earth Sciences, v. 24, p. 1135-1148.

De Wit, M.J. 1974. On the origin and deformation of the Fleur de Lys metaconglomerate, Appalachian fold belt, northwest Newfoundland. Canadian Journal of Earth Sciences, v. 11, p. 1168-1180.

Dubé, B., Lauziére, K. and Poulsen, H.K., 1993. The Deer Cove deposit: An example of "thrust"-related breccia-vein type gold mineralization in the Baie Verte Peninsula, Newfoundland. Current Research, Geological Survey of Canada, Paper 93-ID, p. 1-10.

Duncan, D. R., and Graves, R. M., 1992: 1992 assessment report (7th year) on geology and diamond drilling at the Pine Cove property, Baie Verte area. Novagold Resources. Geological Survey File Number 12H/16 (1278).

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.

Escayola, M.P., Proenza, J.A., van Staal, C., Rogers, N., and Skulski, T. 2009. The Point Rousse listvenites, Baie Verte, Newfoundland: Altered ultramafic rocks with potential for gold mineralization?: Current Research (2009) Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 09-1, pages 1-12

Evans, D. T. W., and Kerr, A. (eds), 2001: Geology and Mineral deposits of the northern Dunnage Zone, Newfoundland Appalachians. GAC-MAC-CSPG Annual Meeting, St. John's, NL, 2001, Field Trip Guide A2.

Evans, D.T.W. 2004. Epigenetic Gold Occurrences, Baie Verte Peninsula (NTS 12H/09, 16 and 12I/01), Newfoundland. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey. Mineral Resources Report no. 11, 157 p.

Fuller, J. O. 1945. Geology and mineral deposits of the Fleur-de-Lys area. Geological Survey of Newfoundland Bulletin no. 15, 47 pages.

Fryer, B. J., Kerr, A., Jenner, G. A., and Longstaffe, F. 1992: Probing the crust with plutons: regional isotopic geochemistry of granitoid intrusions across insular Newfoundland. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 92-1, p. 119-141.

Gale, G. H., 1971: An investigation of some sulphide deposits in the Rambler area, Newfoundland. Unpublished Ph.D. thesis, University of Durham, Durham England.

Gower, D. Graves, G., Walker, S., and Poulsen, K.H. 1990: Lode gold mineralization at Deer Cove, Point Rousse Complex, Baie Verte Peninsula. In Swinden, H.S., Evans, D.T.W., and Kean, B.F., eds., Metallogenic framework of base and precious metal deposits, Central and Western Newfoundland: 8th IAGOD Symposium Filed Trip Guidebook, Geological Survey of Canada, Open File2156, p.165-172.

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

Huard, A.A. 1990. The Noranda/Impala Stog'er Tight Gold Deposit. *In* Metallogenic framework of base and precious metal deposits of central and western Newfoundland. *Edited by* H.S. Swinden, D.T.W. Evans and B.F. Kean. Eighth IAGOD Symposium Field Trip Guidebook: Geological Survey of Canada, Open File 2156, P. 173-177.

Jamieson, R.A. 1990: Metamorphism of an Early Palaeozoic continental margin, western Baie Verte Peninsula, Newfoundland: Journal of Metamorphic Geology, V.8, P.269-288.

Kidd, W.S.F., 1974. The evolution of the Baie Verte lineament, Burlington Peninsula, Newfoundland. Unpuiblished Ph.D. thesis, University of Cambridge, Cambridge, England, 294 p.

Kidd, W.S.F., Dewey, J.F., and Bird, J.M., 1978. The Ming's Bight Ophiolite Complex, Newfoundland: Appalachian oceanic crust and mantle. Canadian Journal of Earth Sciences, v. 15, p. 781-804.

Kirkwood, D. and Dube, B. 1992. Structural control of sill-hosted gold mineralization: the Stog'er Tight Gold deposit, Baie Verte Peninsula, northwestern Newfoundland. In Current Research, Part D. Geological Survey of Canda, Report 92-1D, pages 211-221.

Kerr, A., 1997: Space-time-composition relationships amongst Appalachian-cycle plutonic suites in Newfoundland. Geological Society of America, Memoir, 191, p. 193-220.

Kerr, A., Wardle, R. J., O'Brien, S. J., Evans, D. T. W. and Squires, G. C. 2005: Gold metallogeny in the Newfoundland Appalachians. GAC-MAC-CSPG-CSSS joint meeting, Halifax, NS, May 2005. Field Trip B9, 91 pp.

Kerr, A., van Nostrand, T., Dickson, W. L., and Lynch, E. P. 2009: Molybdenum and tungsten in Newfoundland: A geological overview and a summary of recent exploration developments. Newfoundland Department of Natural Resources, Geological Survey, Report 2009-1, p. 43-80

O'Driscoll, C. 1998: Prehistoric soapstone mining Newfoundland and Labrador Heritage website (www.heritage.nf.ca/environment/soapstone.html).

Ramezani, J. 1992. The geology, geochemistry and U-Pb geochronology of the Stog'er Tight Gold Prospect, Baie Verte peninsula, Newfoundland: Unpublished M.Sc. thesis, Memorial university of Newfoundland, 256p.

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 1994, Newfoundland Department of Mines, p. 34-37.

Sangster, A.L. and Pollard, D. 2001: Field Guide to mineral occurrences in the Betts Cove and Tilt Cove areas, Newfoundland. In Evans, D. T. W., and Kerr, A. (eds), Geology and Mineral deposits of the northern Dunnage Zone, Newfoundland Appalachians. GAC-MAC-CSPG Annual Meeting, St. John's, NL, 2001, Field Trip Guide A2, p. 37-51.

Sangster, A.L., Douma, S. L., and Lavigne, J. 2008: base metal and gold deposits of the Betts Cove Complex, Baie Verte Peninsula, Newfoundland. Geological Association of Canada, Mineral Deposits Division, Special Publication 5, p. 703-723.

Spicer, W. 2008. Geophysically Supported Geologic Modeling of the Betts Cove Ophiolite. Unpublished Bachelors Thesis. 56.p, McMaster University, Hamilton, Ontario

Swinden, H.S., Evans, D.T.W., and Kean, B.F., eds., 1990: Metallogenic framework of base and precious metal deposits, Central and Western Newfoundland: 8th IAGOD Symposium Field Trip Guidebook, Geological Survey of Canada, Open File 2156.

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

Tuach, J. and Kennedy, M.J. 1978: The Geologic Setting of the Ming and Other Sulfide Deposits, Consolidated Rambler Mines, northeast Newfoundland: Economic Geology, v.73, p.192-206.

van Staal, C.R., Whalen, J.B., McNicoll, V.J., Pehrsson, S., Lissenberg, C.J., Zagorevski, A., van Breemen, O., and Jenner, G.A. 2007: The Notre Dame arc and the Taconic orogeny in Newfoundland: in Hatcher, R.D., Jr., Carlson, M.P., McBride, J.H., and Martínez Catalán, J.R., eds., 4-D Framework of Continental Crust: Geological Society of America Memoir 200, p.511-552.

Van Staal, C.R., McNicoll, V., Hibbard, J., and Skulski, T., 2008. New data on the opening of the taconic seaway in Newfoundland. Abstracts with Program, Northeastern Section of the Geological Society of America, v. 40.

Waldron, J.W.F., and van Staal, C.R. 2001: Taconian Orogeny and the accretion of the Dashwoods Block; a peri-Laurentian microcontinent in the Iapetus Ocean: Geology, v.29; p.811-814.

Waldron, J.W.F., Anderson, S.D., Cawood, P.A., Goodwin, L.B., Hall, J., Jamieson, R.A., Palmer, S.E., Stockmal, G.S., and Williams, P.F. 1998: Evolution of the Appalachian Laurentian margin: Lithoprobe results in western Newfoundland: Canadian Journal of Earth Sciences, v. 11, p.1271-1287.

Williams, H., Colman-Sadd, S. P., and Swinden, H. S., 1988: Tectonostratigraphic divisions of central Newfoundland. Geological Survey of Canada, Paper 88-1B, 91-98.

Williams, H. 1995: Temporal and spatial divisions, in Williams, H., ed., Geology of the Appalachians-Caledonian Orogen in Canada and Greenland. Geological Survey of Canada, Geology of Canada, no. 6 (also Geological Society of America, The Geology of North America, v. F-1), p. 21-44.

Winchester, J.A., Williams, H., Max, M.D., and van Staal, C.R., 1992. Does the Birchy Complex of Newfoundland extend into Ireland? Journal of the Geological Society of London, v. 149, p. 159-162.

OUR THANKS TO THE SPONSORS OF THE 2009 FALL FIELD TRIP

GEOLOGICAL SURVEY OF NEWFOUNDLAND AND LABRADOR (DEPARTMENT OF NATURAL RESOURCES)

GEOLOGICAL SURVEY OF CANADA TARGETED GEOSCIENCE INITIATIVE TGI-3 Appalachians Project

GEOLOGICAL ASSOCIATION OF CANADA NEWFOUNDLAND AND LABRADOR SECTION