

# Mineral Deposits of Newfoundland: A Trans-Island Compilation

Field trip organized by the MUN-SEG and UA-SEG Student Chapters:



**August 1-10, 2016**

**Open File NFLD/3322**

## **Leaders:**

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*Sponsored by:*



# INTRODUCTION

This field trip consists of a compilation of previous field trips focused on regional geology and ore deposits throughout Newfoundland. The trip was organized as a joint effort, by both the Memorial University of Newfoundland and University of Arizona Society of Economic Geologists Student Chapters. Over the course of the ten day, west to east, traverse across Newfoundland participants will observe several major ore deposits on the island and learn the significance of their respective geotectonic setting.

The following outlines the stops for the field trip and the respective source from which each stop was derived. See italicized for sources, and stop numbers in parentheses beside stop titles for the respective source stop location.

## Day 2: Gros Morne

*From: Dunning, G. 2015. Trans-Island Guide Book – A Geologic Cross-Section of the Appalachian Orogen in Newfoundland*

- Stop 2.1 Cow Head Section (Stop 3-1)
- Stop 2.2 Green Point Cambro-Ordovician Boundary Global Stratotype (Stop 3-2)
- Stop 2.3 Lobster Cove Head at Rocky Harbour (Stop 3-3)
- Stop 2.4 Rocky Harbour Beach (Stop 3-4)
- Stop 2.5 Highway outcrop of Forteau Formation (Stop 3-5)
- Stop 2.6 Cambrian - Precambrian (Grenvillian) basement unconformity (Stop 3-6)

## Day 3: Gros Morne

*From: Dunning, G. 2015. Trans-Island Guide Book – A Geologic Cross-Section of the Appalachian Orogen in Newfoundland*

- Stop 3.1 Ophiolitic Cover Sequence (Stop 4-1)
- Stop 3.2 Green Gardens Precambrian Rift volcanic sequence (Stop 4-2)
- Stop 3.3 Bay of Islands Ophiolite – MOHO and mantle section (Stop 4-3)
- Stop 3.4 Virginite and serpentinite, Advocate Ophiolite Complex (Stop 5-1)
- Stop 3.5 Least-altered Ophiolitic Mantle Peridotite (Stop 5-2)

## Day 4: Baie Verte Peninsula

*From: Dunning, G. 2015. Trans-Island Guide Book – A Geologic Cross-Section of the Appalachian Orogen in Newfoundland; and Pilote, J-L. Buschette, M. Lode, S. Dunning, G. 2014. Mineral Deposits and Tectonic Evolution of the Tally Pond and Baie Verte Belts, Newfoundland.*

- Stop 4.1: Fleur de Lys metasediments cut by mafic dykes (Stop 5.3 Dunning, 2015)
- Stop 4.2: Ophiolitic mélange at Coachman's Cove (Stop 5.4 Dunning, 2015)
- Stop 4.3: Iron Formation above the Rambler VMS Deposits
- Stop 4.4: Ming Cu-Au-(Zn-Ag) VMS deposit (Stop 2.1 Pilote et al., 2014)
- Stop 4.5: Nugget Pond (Stop 2.5a-d Pilote et al., 2014)
- Stop 4.6: Tilt Cove (Stop 2.2 Pilote et al., 2014)

## **Day 5: Baie Verte Peninsula**

*From: Dunning, G. 2015. Trans-Island Guide Book – A Geologic Cross-Section of the Appalachian Orogen in Newfoundland; and Pilote, J-L. Buschette, M. Lode, S. Dunning, G. 2014. Mineral Deposits and Tectonic Evolution of the Tally Pond and Baie Verte Belts, Newfoundland.*

Stop 5.1: Scrape Thrust (Stop 5-6 Dunning, 2015)

Stop 5.2: Anaconda orogenic gold properties

Stop 5.2A: Pine Cove

Stop 5.2B: Stog'er Tight

Stop 5.2C: Goldenville

## **Day 6: Buchans**

*From: Piercey, S. J., & Hinchey, J. 2012. Volcanogenic massive sulphide (VMS) deposits of the Central Mineral Belt, Newfoundland. In Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting, Field Trip Guidebook B (Vol. 4)*

Stop 6.1 Ski Hill Buchans (Stop 1.2)

Stop 6.2 Discovery Outcrop from the Buchans Orebodies (Stop 1.3)

Stop 6.3 Arkose of the Sandy Lake Formation (Stop 1.4)

Stop 6.4 Canadian Zinc Corporation core shack

## **Day 7: Twillingate**

*From: Reusch, D. 1987. Silurian stratigraphy and mélanges, New World Island, north central Newfoundland. North-Eastern Section of the Geological Society of America: Decade of North American Geology, Centennial Field Guides Volume 5, 5, 463; and Swinden, H. S., 1991, Metallogenic framework of base and precious metal deposits, central and western Newfoundland, (Field Trip 1)*

Stop 7.1: The Old Sleepy Cove Mine (Stop 1 - 1, Swinden, 1991)

Stop 7.2: The Oldest and Youngest Intrusive Rocks in Notre Dame Bay (Stop 1 - 2, Swinden, 1991)

Stop 7.3: Clarkes Cove—Silurian unconformity (Stop 1, Reusch, 1987)

Stop 7.4: Rogers Cove—Silurian mélange (Stop 2, Reusch, 1987)

Stop 7.5: Reach Run—Dunnage mélange (Stop 3, Reusch, 1987)

Stop 7.6: Beothuck Interpretation Centre

## **Day 8: Burin Peninsula**

*From: Pilote, J-L. 2015. Epithermal Systems of the Avalon Zone.*

Stop 8.1 Musgravetown Group (Stop 2.1)

Stop 8.2 Big Easy Prospect (Stop 2.2)

Stop 8.2A Unaltered Musgravetown Group (Stop 2.2a )

Stop 8.2B Trench 7 (Stop 2.2b )

Stop 8.2C Trench 4 (Stop 2.2c )

Stop 8.2D Trench 6 (Stop 2.2d )

**Day 9: Burin Peninsula**

*From: Pilote, J-L. 2015. Epithermal Systems of the Avalon Zone.*

Stop 9.1 Lodestar prospect (Stop 1.1 )

Stop 9.2 Monkstown Road Shear Zone (Stop 1.2 )

Stop 9.3 Monkstown Lazulite Showing (Stop 1.3 )

Stop 9.4 Tower Zone (Stop 1.4 )

Stop 9.5 Baine Harbour Shear Zone (Stop 1.5)

Stop 9.6 Rattle Brook Prospect (Stop 1.6 )

**Day 10: (Optional)**

*From: Pilote, J-L. 2015. Epithermal Systems of the Avalon Zone.*

Stop 10.1 Steep Nap Prospect (Stop 2.3 )

Stop 10.2 Oval Pit – Pyrophyllite mine (Stop 2.5 )



Date	Itinerary	Overnight
<i>(All distances given are approximate.)</i>		
1-Aug Monday	<b>0615 hours</b> Depart from <b>MUN for Deer Lake Airport</b> (650 km) UA Participants arrive at Deer Lake Airport at 0800 hours 1300 hours Rendezvous with UA group at Deer Lake airport and depart for Shallow Bay Motel (120 km) <b>1700 hours</b> <b>Mandatory Safety and Logistics Meeting for All Participants</b> Introduction to Mine and Deposit Site Visits <u>Lodging:</u> Shallow Bay Motel Tel. (709) 243-2471 193 Main Street, Cow Head, NL A0K 2A0	Gros Morne
2-Aug Tuesday	0800 hours Progress through stops 1 to 5: Gros Morne National Park (80 km) 1700 hours Return to Shallow Bay Motel (80 km) <u>Lodging:</u> Shallow Bay Motel Tel. (709) 243-2471 193 Main Street, Cow Head, NL A0K 2A0	Gros Morne
3-Aug Wednesday	0800 hours Progress through stops 1 to 3: Gros Morne National Park 1700 hours Depart for Baie Verte from Deer Lake (160 km) 1900 hours Arrive at Dorset Soapstone Quarry <u>Lodging:</u> Dorset Soapstone Quarry Museum Tel. (709) 253-2126 24 Dorset Trail, Fleur de Lys, NL A0K 2M0	Baie Verte
4-Aug Thursday	0800 hours Progress through stops 1 to 6: Baie Verte Peninsula 1800 hours Return to Dorset Soapstone Quarry <u>Lodging:</u> Dorset Soapstone Quarry Museum Tel. (709) 253-2126 24 Dorset Trail, Fleur de Lys, NL A0K 2M0	Baie Verte
5-Aug Friday	0800 hours Depart for Anaconda mine tours: Baie Verte Peninsula 1700 hours Depart for Buchans (230 km) <u>Lodging:</u> The Red Ochre Inn Tel. (709) 672-4455 21 Main Street, Buchans, NL A0H 1G0	Buchans
6-Aug Saturday	0800 hours Progress through stops 1 to 5: Buchans 1700 hours Depart for Twillingate (220 km) <u>Lodging:</u> Anchor Inn Hotel & Suites Tel. (709) 884-2777 3 Path End, Twillingate, NL A0G 4M0	Twillingate

<b>Date</b>	<b>Itinerary</b>	<b>Overnight</b>
7-Aug	0800 hours Progress through stops 1 to 5: Twillingate	
Sunday	1630 hours Depart for Clarenville (220 km)	
	<u>Lodging:</u> Wave Hotel & Fitness Centre Tel. (709) 466-7946 11B Blackmore Ave, Clarenville, NL A5A 1B8	Clarenville
8-Aug	0800 hours Progress through stop 1 to 2: Burin Peninsula	
Monday	1700 hours Return to Wave Hotel and Fitness Centre	
	<u>Lodging:</u> Wave Hotel & Fitness Centre Tel. (709) 466-7946 11B Blackmore Ave, Clarenville, NL A5A 1B8	Clarenville
9-Aug	0800 hours Progress through stop 1 to 6: Burin Peninsula	
Tuesday	1700 hours Depart for St. John's (260 km)	
	<u>Lodging:</u> TBD	St. John's
10-Aug	0800 hours Depart for Bell Island (optional)	
Wednesday	1700 hours Return to St. John's	
	<u>Lodging:</u> TBD	St. John's
11-Aug	<b>END OF TRIP</b>	
Thursday	Participant depart on their own schedules	

## GENERAL SAFETY

*(From: Field trip guidebook-Volcanogenic Massive Sulphide [VMS] Deposits of the Central Mobile Belt, Newfoundland- Stephen J. Piercey and John Hinchey).*

This field trip may involve hazards to the leaders and participants. We recommend steel-toed safety boots when working around road cuts, cliffs, or other locations where there is a potential hazard from falling objects. Steel-toe safety boots must always be worn on mine sites. We will not supply safety boots to participants. Long hikes are predicted for this field trip (up to 9 km) and 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.

Weather in Newfoundland is unpredictable, especially near the coasts. Participants should be prepared for a wide range of temperatures and conditions. Always take suitable clothing. A rain suit, sweater, and sturdy footwear are essential at almost any time of the year. Gloves and a warm hat could prove invaluable if it is cold and wet, and a sunhat and sunscreen is recommended. It is not impossible for all such clothing items to be needed on the same day.

Above all, 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 at all field trip stops. Specific dangers and precautions will be reiterated at individual localities.

Some of the stops on this field trip are in coastal localities. Access to the coastal sections may require short hikes, in some cases over rough, stony or wet terrain. 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. On some of the coastal sections that have boulders or weed-covered sections, participants may find a hiking stick a useful aid in walking safely. 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 such 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 you are swept off the rocks into the ocean, your chances of survival are negligible. If possible, stay on dry sections of outcrops that lack any seaweed or algal deposits, and stay well back from the open water. Remember that wave-washed surfaces may be slippery and treacherous, and avoid any area where there is even a slight possibility of falling into the water. 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.

Other field trip stops are located on or adjacent to roads. At these 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. Participants should be extremely cautious in crossing roads, and ensure that they are visible to any drivers. Roadcut outcrops present hazards from loose material, and they should be treated with the same caution as coastal cliffs; be extremely careful and avoid hammering beneath any overhanging surfaces. 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. Many locations on trips contain outcrops that have unusual features, and these should be preserved for future visitors. Frankly, 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 must read these cautions carefully and take appropriate precautions for their own safety and the safety of others.

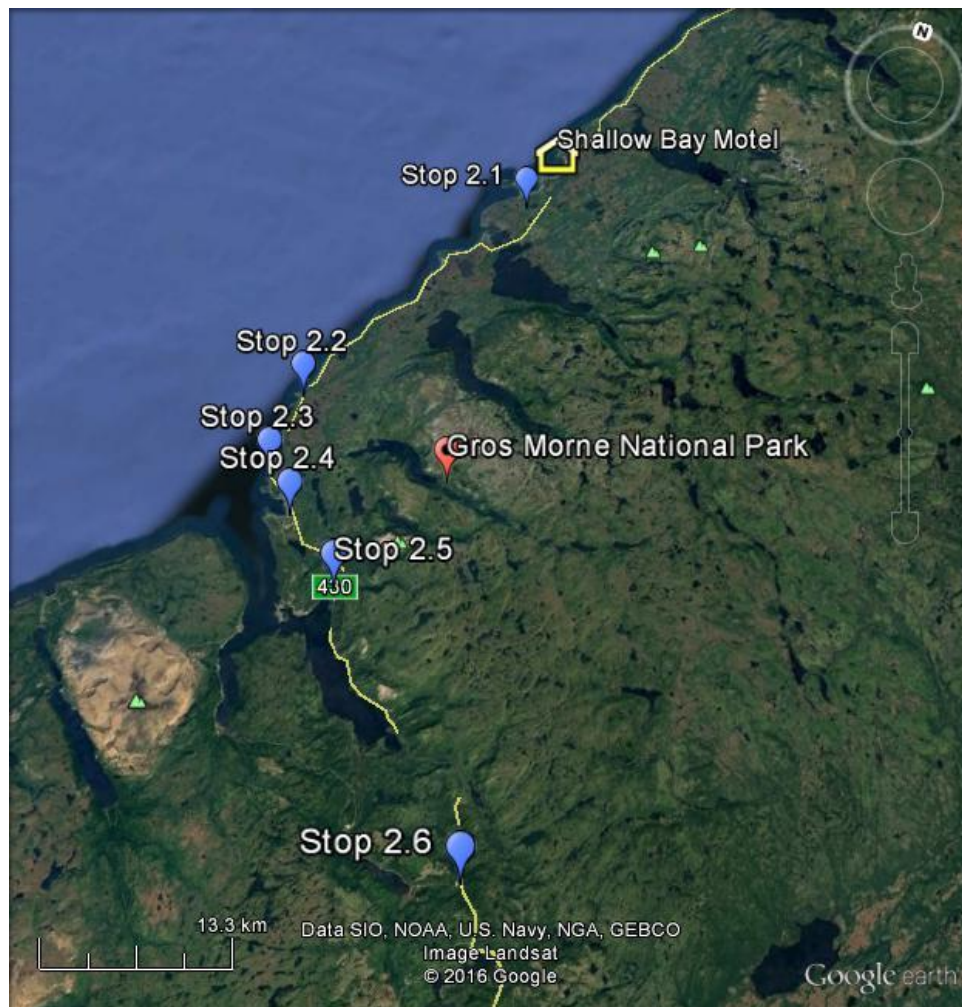
## **ACKNOWLEDGEMENTS**

The Memorial University of Newfoundland and University of Arizona Society of Economic Geologists Students Chapters would like to express their sincere thanks to the respective sources from which the field trip was compiled. A special thanks to Greg Dunning and Jean-Luc Pilote for stimulating discussions and advice during the preparation of the field trip. Financial support was provided by the CIM, SEG and GAC; which made a trip of this scale possible. Printing of the guidebook was done by the Geological Survey of Newfoundland and Labrador.

## DAY 2: GROS MORNE NATIONAL PARK

### DAY 2 — STOP LIST

- Stop 2.1 Cow Head Section
- Stop 2.2 Green Point Cambro-Ordovician Boundary Global Stratotype
- Stop 2.3 Lobster Cove Head at Rocky Harbour
- Stop 2.4 Rocky Harbour Beach
- Stop 2.5 Highway outcrop of Forteau Formation
- Stop 2.6 Cambrian - Precambrian (Grenvillian) basement unconformity



## INTRODUCTION

Day two of the trip will lead us to explore the Precambrian-Cambrian unconformity and the oldest autochthonous sedimentary rocks exposed in Gros Morne National Park. It will also provide an overview of the various components of park geology, and visit important outcrops at Lobster Cove Head, which were critical in the initial understanding of the allochthonous nature of the ophiolite sequences for which the Park is now most famous. We will also visit examples of the melanges that facilitated long-distance transport of the Humber Arm Allochthon.

### Cow Head Group

The Cow Head Group crops out sporadically throughout the Cow Head region of central west Newfoundland. The sequence has been studied since the 1860's and was the subject of intensive, ongoing research in the fields of stratigraphy, sedimentology and paleontology. It comprises a stack of marine sediments 300 to 500 metres thick of late Middle Cambrian to early Middle Ordovician age. Much of the succession consists of shales, silts and thin-bedded limestones, but the characteristic feature of the Cow Head Group is the occurrence of massive limestone breccias or conglomerates. Some exceed 100 metres thick, while one block at Lower Head measures over 200 metres long.

### Lithostratigraphy and depositional environment

Conglomerates can be classified into five facies (A to E), based upon grading, sedimentary structures, matrix content, sorting, fabric, and clast type. Facies A consists of graded- stratified, grainy, cobble to pebble conglomerates that have cross-stratified and ripple-laminated tops. The layers are a maximum of about 1 m thick. Sand-sized grains are dominantly peloids, with minor quartz, ooids, and bioclasts.

Hiscott and James (1985) conclude that Facies B, C, D and E are debris flows. The bases of some facies D and E layers are erosive but most facies B, C, D, and E conglomerates have flat bases showing no more than a few centimeters of downcutting into underlying beds, primarily by plucking of the underlying substrate.

Hubert et al. (1977) suggest a complex paleogeography and current system during the deposition of the Cow Head but recent studies (Hiscott and James, 1985; James and Stevens, 1986) suggest a simple toe-of-the-slope deposit which accumulated on a southeastward-dipping slope.

In general, the breccias become finer and less frequent towards the south; they are considered to have been derived from a north-westerly direction. This forms the basis for dividing the group into two coeval 22 formations; the Shallow Bay Formation in the north-west, and Green Point Formation to the south-east.

Contemporaneous Cambrian and Ordovician rocks outcropping nearby (Fig. 3) are of shallow water origin, typical of the Lower Paleozoic carbonate belt of the Appalachians. Since the lithologies of these shallow water, autochthonous platformal carbonates are no different from those of the entire western Newfoundland platform, there is no evidence that the Cow Head area was close to the platformal edge (James and Stevens 1986). The Cow Head Group is, therefore, considered to be allochthonous. The original site of deposition was probably to the

east of the Long Range Mountains (Rodgers and Neale 1963; James and Stevens 1986) with transport consequently over many tens and possibly more than one hundred kilometres.

Deposition of the Cow Head Group was terminated by a flood of clastic rocks, derived from newly rising tectonic lands to the east during initial stages of the Taconic Orogeny. These are referred to the Lower Head Formation.

## **Structure**

The Cow Head Group and Lower Head Formation occur in a series of east-dipping and east- younging belts repeated across strike by west-dipping thrusts (Cawood and Williams, 1988). Minor folds verge westward. The thrust stack structurally overlies time-equivalent shallow marine shelf carbonates. Assembly of the thrust stack and its emplacement over time-equivalent shallow water segments of the continental margin took place during the early to middle Ordovician Taconian Orogeny. The driving mechanism for this orogenic event was probably the attempted subduction of the continental margin (Humber Zone) beneath an island arc of the Iapetus Ocean (Dunnage Zone).

A second deformational event, linked to the Devonian Acadian Orogeny, is also recognized in this region. Acadian structural elements consist of a series of late-stage faults which overprint the imbricate thrust stack of the Humber Arm Allochthon. These faults are termed the Parsons Pond Thrust and Long Range Thrust, and bound the western margin of the Long Range Mountains. These detachments extend down into Grenville basement and have resulted in west-directed thrusting of Grenville basement and shelf carbonates over the allochthonous Cow Head Group and Lower Head Formation (Cawood and Williams, 1988; Williams and Cawood, 1988). Rocks of the allochthon lie in a footwall syncline. The Green Point section (Stop 3.3) of the Cow Head Group lies on the southeastern limb of this synclinal structure.

## **Biostratigraphy**

The Cow Head Group ranges in age from late Middle Cambrian (*Bathyriscus*-*Elrathina* Zone) to late Canadian, early Whitrockian (*Arenig*). Blocks within the limestone breccias yield shallow water shelly fossils, including trilobites, brachiopods and conodonts. Faunal assemblages indicate that many blocks are only slightly older than the breccia beds within which they are contained. The shale and limestone interbeds yield occasional inarticulate brachiopods and 23 trilobites, but the fauna is dominated by graptolites and deep water conodonts. Other microfossils include radiolaria, scolecodonts, sponge spicules and palynomorphs, but these groups have yet to be studied.

Owing to this varied assemblage, it is possible to correlate zonal schemes established for shallow and deep water sequences in North America. Such correlations are suggested by James and Stevens (1986), but more precise studies have since been attempted (Ross and James, 1987; Williams et al., 1987). The trilobites and graptolites have been described by Kindle and Whittington (1958), Erdtmann (1971), Fortey and Skevington (1980) and Williams and Stevens, (1987). The conodont fauna has been described by Fahraeus and Nowlan (1978), Pohler (1987) and Barnes (in press). Other fossil groups have not yet been systematically investigated.



## **DAY 2 — FIELD STOPS**

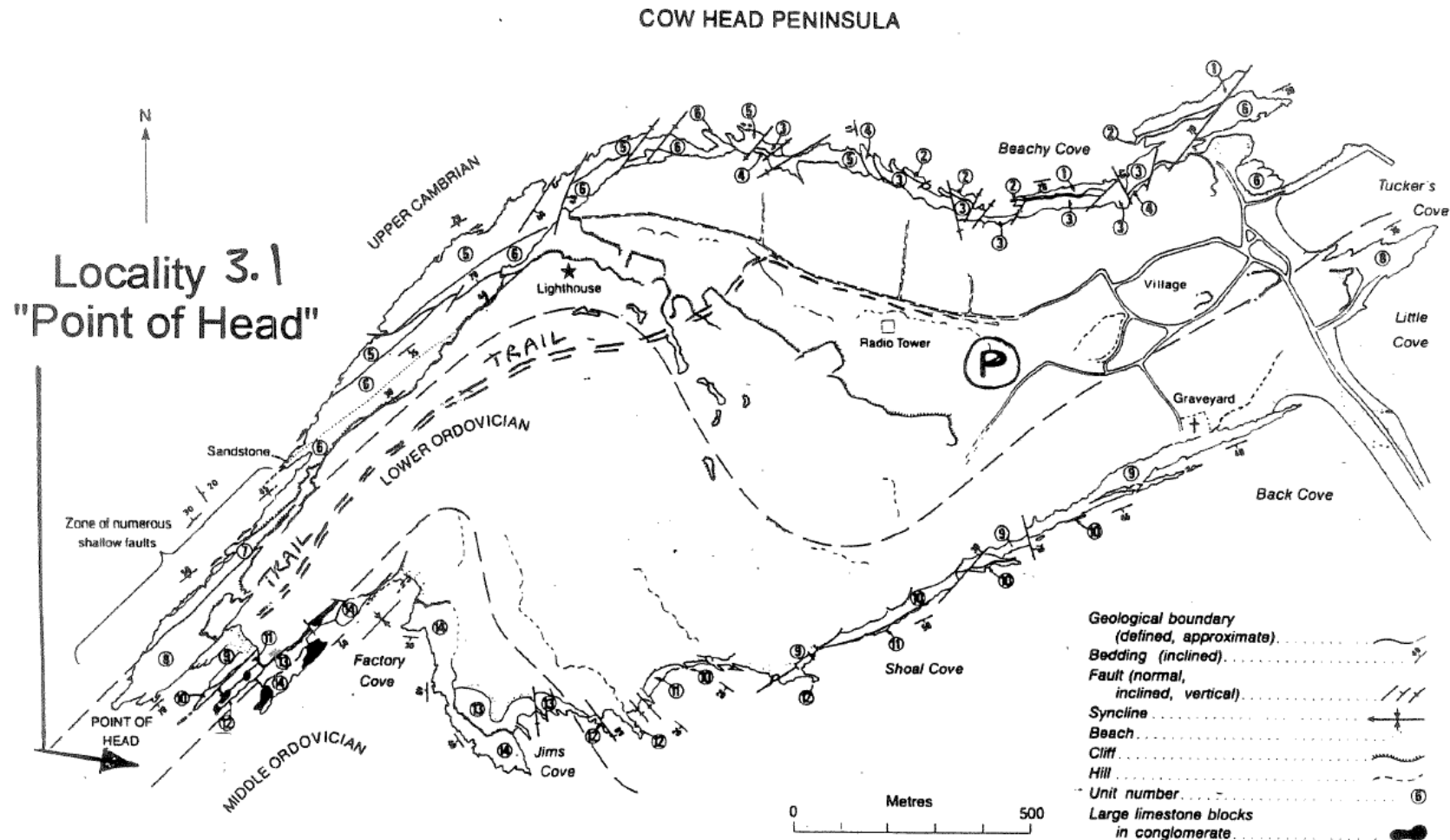
### **Stop 2.1: Cow Head Section (70 myrs of Cambrian-Ordovician sedimentation) (UTM 21 441526E 5529816N—parking)**

#### **Location.**

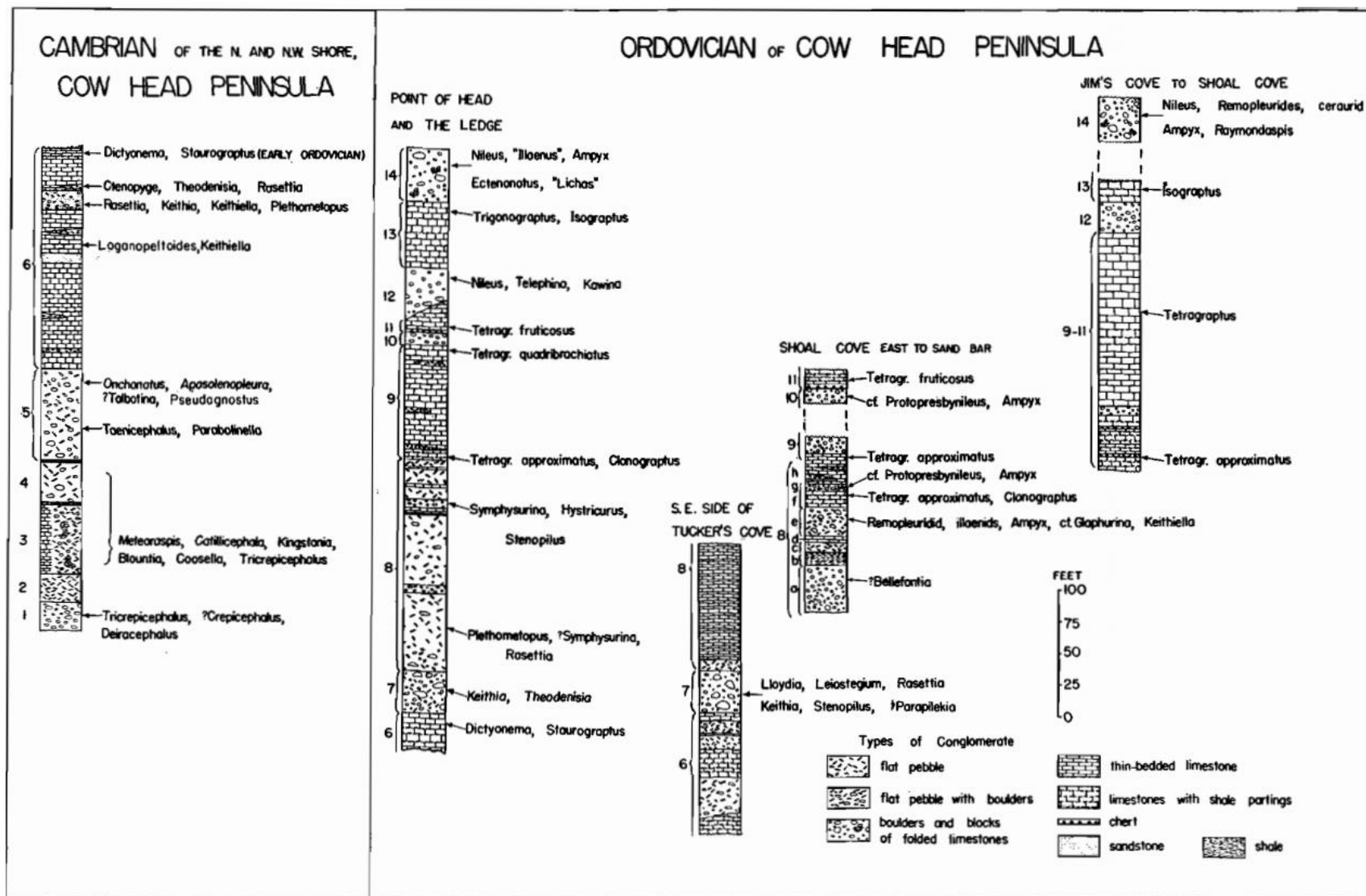
Cow Head Peninsula, Highway 430, 43 km north of Rocky Harbour. Park at the amphitheatre (near radio tower). Walk north to small cemetery (75 metres) then turn west and walk up gravel track for 7- 10 minutes for the alternate location. Point of Head location is approximately 20 minute walk.

#### **Description.**

The section on Cow Head Peninsula (Figs. 1, 2, 3) is virtually continuous and represents some 70 m.y. of deposition. The excursion will walk the section in its entirety. To facilitate observation and discussion, different parts of the sequences are described separately on the following pages beginning with the oldest beds. The bed numbers are those used by Kindle and Whittington (1958) (Fig. 2): the bed descriptions given below are extracted from James and Stevens(1986)..



**Figure 1.** Geological map of the Cow Head Peninsula, showing the area visited on this trip. Other numbers refer to a previous field trip of more detailed character. From James et al. (1988)



**Figure 2.** Cambrian and Ordovician stratigraphy of the Cow Head Peninsula. From Kindle and Whittington (1958)

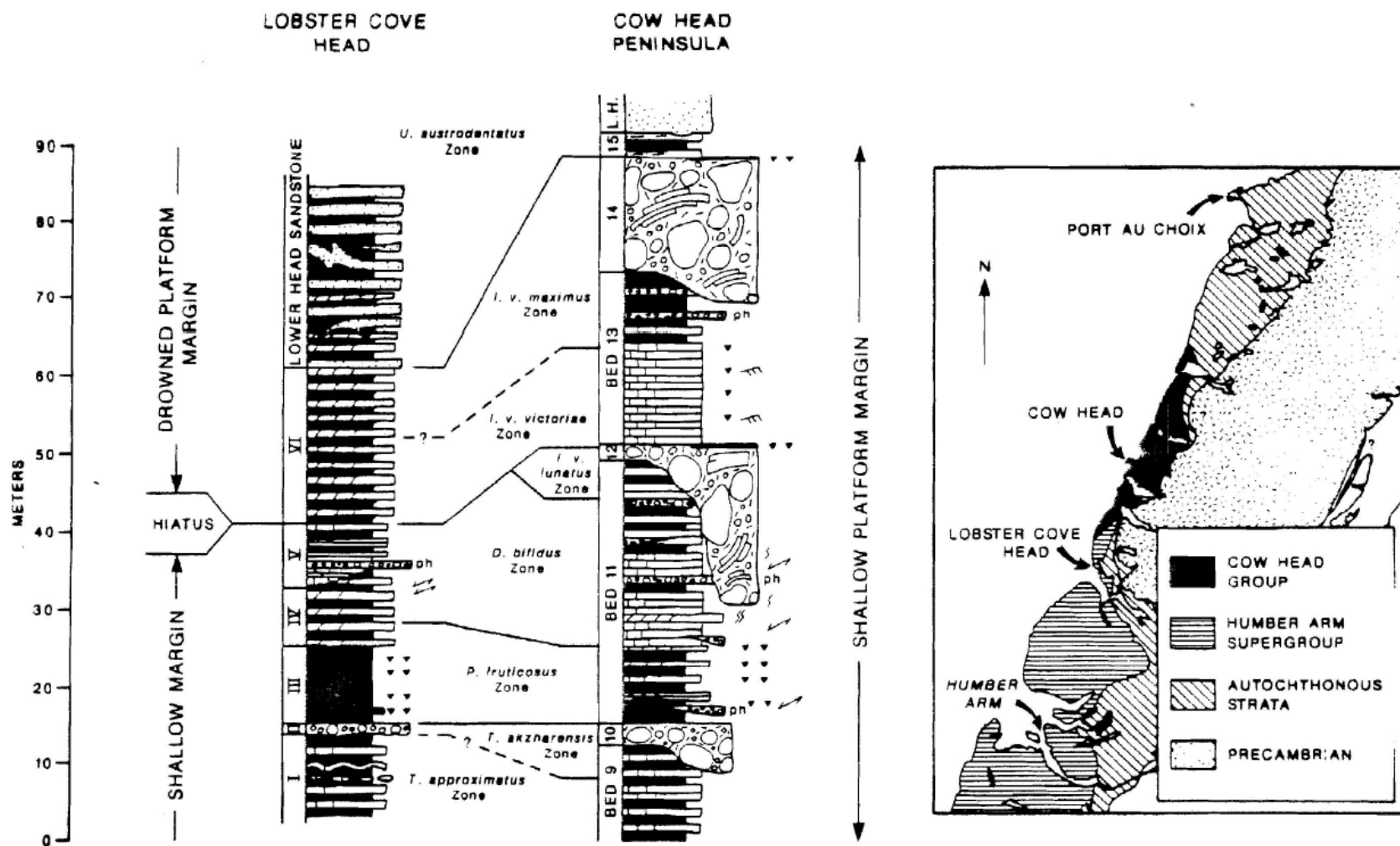


Figure 3. Stratigraphy of the Lobster Cove Head and Cow Head Peninsula. From James and Stevens (1986).

## **Alternate Location—rainy day stop (UTM 21 440900E 5530145N)**

Exit gravel trail at picnic table/outhouse and take short trail north to coast (2 minutes). The outcrop consists of a series of small clast carbonate conglomerates which are sometimes separated by parted mudstone and shale. There are faults in the section and part of the section is repeated to the west. This locale may be a faulted section of bed 6 located further to the southwest.

**Bed 6:** The low platform formed by Bed 6 (Fig. 2), although broken and repeated by faulting, is a continuous section some 70 m thick. It is characterized by a wide variety of lithologies but few massive breccias. Strata are distinguished by abundant quartz sand which reaches a maximum at the center of the bed as sandstone layers. The most common lithologies are quartzose calcarenites with all the characteristics of carbonate turbidites (Facies A; Hiscott and James, 1985). A peculiarity of the thicker small-clast conglomerates or calcarenites is large isolated boulders "floating" in the bed. The upper half of Bed 6, which is cliff-forming, exhibits more thick conglomerates, fewer graded calcarenites and more parted to ribbon mudstones. The age of Bed 6 ranges from mid Upper Cambrian (Aphelaspis-Dunderbergia Zone) to latest Cambrian (Saukia Zone).

## **Locality 2: Point of Head (UTM 21 440297E 5529396N)**

From north to south, bed descriptions are from Williams et al. (1988).

**Bed 7:** Upward in Bed 6 there is a gradual increase in the number of conglomerates containing large boulders of white limestone. These culminate in Bed 7, a cliff-forming mass some 16 m thick, comprising 3 welded conglomerates characterized by conspicuous, large, white limestone boulders. The unit cuts down some 4 m into underlying beds. The white boulders, which occur throughout the Cow Head but are largest here, are composed of Epiphyton and Girvanella together with internal sediment and cement. James (1981) interprets these blocks as fragments of a long lasting upper slope shelf margin facies.

**Bed 8:** The actual Point of Head is formed by Bed 8 which is basal Ordovician in age. This unit is transitional, the lower part composed of graded calcarenites similar to Bed 6, yet punctuated by coarse conglomerates as is Bed 7 while the upper part exhibits many features that characterize subsequent strata. In this bed, for the first time, chert occurs both in beds and as clasts; distinct trace fossils are found in abundance; phosphate (collophane) granules are dispersed throughout many conglomerates and brightly hued shales separate carbonate beds. Shallow-water clasts in this unit appear to have undergone more intensive or extensive diagenesis compared to those in older units. The Tremadoc-Arenig boundary is considered to occur in the thinly bedded, dolomitic unit at the top of Bed 8. Striking faunal differences below and above this unit are exhibited both by graptolites and conodonts.

**Bed 9:** The cove east of the head is formed by an impressive section of parted to ribbon limestones which are medial Early Ordovician in age, equivalent to the Catoche Formation of the St. George Group on the platform. The evenly-bedded, parted to ribbon lime mudstones to wackestones are separated by black to green shale. Within the limestones are abundant

sponge spicules, together with occasional inarticulate brachiopods, hexactinellid sponges and graptolites (*T. approximatus* and *T. akzharensis* zones). Some beds are intensively burrowed and illustrate numerous U-shaped *Arenicolites* (Jansa, 1974) while a few show *Zoophycus*.

## **Stop 2.2: Green Point Cambro-Ordovician Boundary Global Stratotype (UTM 21 430292E 5503643N)**

### **Location.**

Just 200 metres north of the Highway 430 Green Point campground turnoff, drive down to harbour, park and walk on the beach towards the northwest. Ideal at low tide, but accessible anytime.

### **Description.**

This shoreline outcrop is a distal facies of the Cow Head and spans a time period from late Cambrian (Trempealeauan) to middle Ordovician (Arenig/Llanvirn). The excursion will examine the better exposed Upper Cambrian and Lower Ordovician (Tremadoc) strata. The strata are overturned. (Fig. 4)

The section is a distal facies and the Cambrian-Ordovician boundary interval includes the upper Martin Point Member and the lower Broom Point Member. The upper 161.5 m of the Martin Point Member is exposed but only the upper 25 m (units 17-22) is discussed here. The Martin Point Member consists primarily of green and black shale with thin beds of lime mudstone, dolomitic siltstone, and ribbon limestone. Apart from small lenses, the only significant conglomerate bed occurs as unit 19 (1.1 m thick); its base does not down-cut, in fact it lies directly on a thin bed of lime mudstone. The Broom Point Member (82.6 m thick) is fully exposed and consists of ribbon and parted limestone with interbedded grey-green and black shale. A thin (0-0.3 m) lens of *Symphysurina*-bearing conglomerate occurs in unit 25. Higher in the section some local synsedimentary slumped horizons are present (e.g. in units 27,28), but the superb wave platform and cliff exposure allows the complete stratigraphy to be established with confidence.

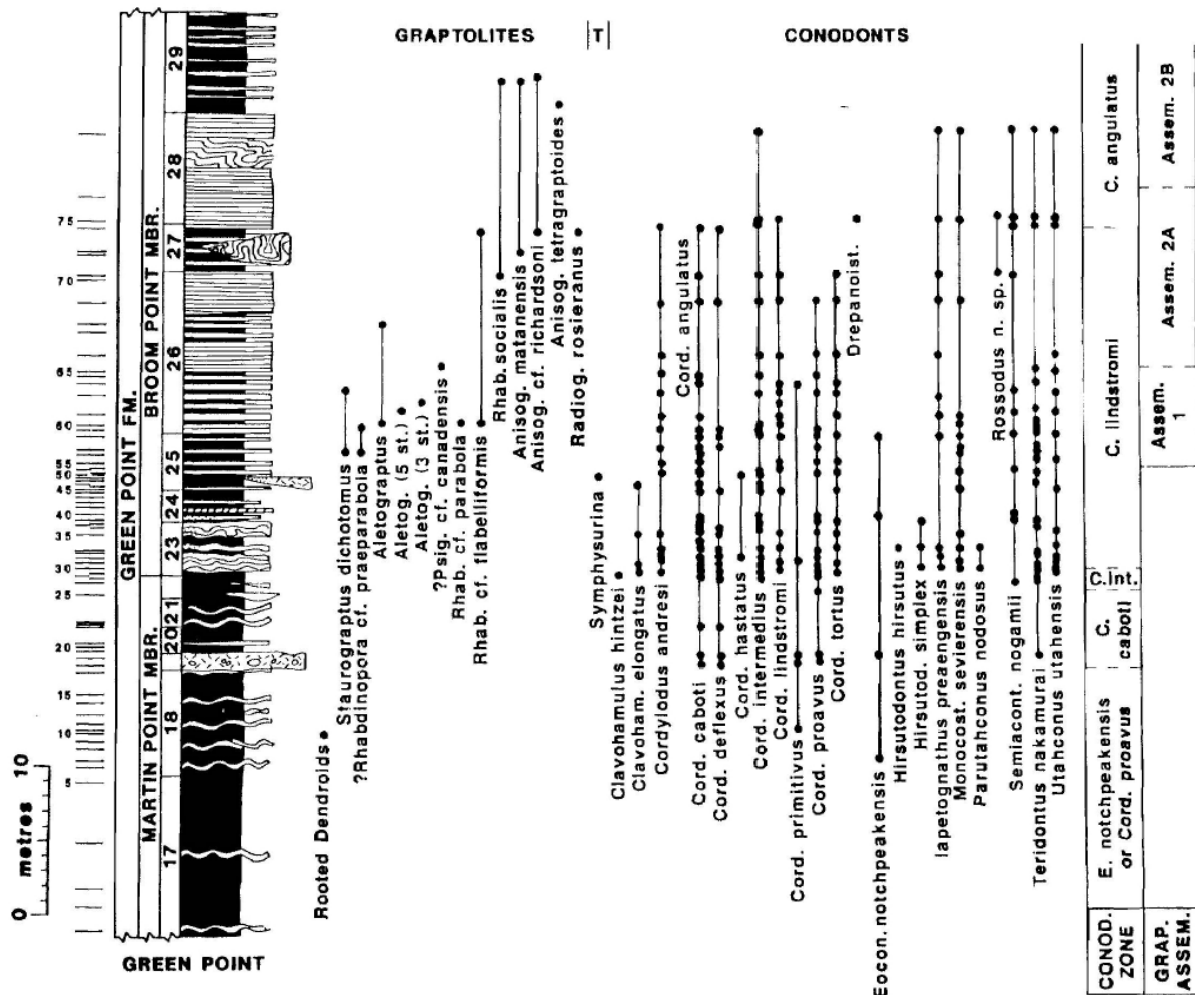
The Green Point section presents possibly the best sequence of early graptolite evolution in the world; preservation is excellent and graptolites occur both in the shales and in three dimensions in the limestones. Erdtmann (1986, pers. comm. to C.R. Barnes 1986) recently sampled, bed-by-bed, through a 41 m interval with rich graptolite faunas. Diminutive nematophorous graptolites first appear in unit 25 (*Rhabdinopora praeparabola*) as initially quadrixradiate forms which extend through 7 m up to unit 26; triradiate forms occur for about 9 m to the top of Bed 27; triradiate plus pseudobiradiate forms occur through 17 m into unit 29; and finally biradiate graptolites occur through an 8 m interval into unit 29. *Psigraptus* cf. *Canadensis* (probably synonymous with *Triograptus canadensis* Bulman) appears only in the lower part of unit 26, about 8 m above the first nematophorous graptolites. This sequence comprises Assemblages 1,2A, and 2B of Cooper (1979). Latest Tremadoc and early Arenig (*T. approximatus* Zone and higher) graptolites have also been discovered in the more poorly exposed upper part of the section (S.H. Williams, pers. obs.).

Several conodont zones can be recognized. Units 17-18 yield too few conodonts for precise assignment, *Eoconodontus notchpeakensis* Zone and/or *C. proavus* Zone is suggested.

Unit 19 conglomerate contains a fauna from the *C. caboti* Zone. Upper unit 22 is from the the *C. intermedius* Zone with the *C. lindstromi* Zone in basal unit 23. The *C. angulatus* Zone is first recognized in basal unit 28. Shelly fossils are rare in the Green Point section but only limited investigations have been undertaken. Fortey discovered *Symphysurina* sp. in the conglomerate 0.9 m above the base of unit 25 and careful collecting may yield more trilobites from the Tremadoc interval.

In summary, nematophorous graptolites first appear directly above the *Symphysurina* conglomerate lens in unit 25. Through the next 40 m and higher a remarkable succession is developed of superbly preserved graptolites including *Rhabdinopora* (quadri- and then triradiate), *Bryograptus* (biradiate), *Staurograptus* (quadriradiate), ?*Radiograptus* (of *flexibilis* type, quadriradiate), *Aletograptus* (quadriradiate), *Anisograptus* (triradiate), true *Radiograptus* (of *R. rosieranus* type, tri- and pseudoradiate) and *Adelograptus* (biradiate) (Erdtmann, pers. 986). Shelly fossils are rare and largely uninvestigated. Units 17-18 appear to lie within the *Eoconodontus notchpeakensis* and/or *Cordylodus proavus* Zones. *C. caboti* first occurs within unit 19. In abundant yielding samples, *C. intermedius* first appears within unit 22 and *C. lindstromi* first occurs at the base of unit 23 together with *Hirsutodontus simplex* and *Iapetognathus preaengensis*. The base of unit 28 contains the first appearance of *C. angulatus* together with *Drepanoistoides* sp, and early colopodans indicative of the *C. angulatus* Zone.

The recommended level for the systemic boundary is at the base of unit 23 (of James and Stevens, 1986, p.142) which forms the base of the Broom Point Member of the Green Point Formation. The level is defined and correlated by the first occurrence of the *Cordylodus lindstromi* Zone, recognized by the nominate species together with *Hirsutodontus simplex* and *Iapetognathus preaengensis*; *Monocostodus sevierensis* and *Parutahconus nodosus* also first appear near the base of this zone with *Clavohamulus hintzei* first occurring higher. This proposed boundary level is 6.9 m below the first appearance of nematophorous graptolites in unit 25.



**Figure 4.** Stratigraphy and associated biostratigraphy of the Green Point section. Graptolite ranges from Cooper et al. (1998) and Erdtmann (1985). Conodont ranges from Barnes (1988).

### Stop 2.3: Lobster Cove Head at Rocky Harbour (UTM 21 431011E 5494721N - parking)

#### Location.

Drive on highway 430 to Lighthouse Parking lot. The lighthouse shore section at Rocky Harbour, accessible by several paths that start at the lighthouse. The northern path leads to the base of the section.

#### Description.

This tectonically deformed yet virtually intact sequence of Lower to Middle Ordovician strata is a large, disrupted raft within the Rocky Harbour Melange (Williams et al., 1986) which structurally underlies the Cow Head thrust complex to the north. The entire section of Cow Head Group and overlying Lower Head Formation here is Arenig (late Canadian or Ibexian to early Whiterockian) in age. The basal part of the section is a proximal facies of the Cow Head Group and can be correlated, both in terms of lithology and biostratigraphy, with beds 9, 10 and part of Bed 11 on Cow Head Peninsula. The upper part of the section consists of interbedded



dolostone and shale and is unlike any other sequence in the Cow Head Group. These upper beds are defined as the Lobster Cove Member of the Shallow Bay Formation (James et al., 1987) and are interpreted to have been deposited downslope from a drowned platform margin as dilute turbidites of mud and detrital dolomite under dysaerobic conditions. Contact between the two sedimentary packages is marked by a faunal break and coincides with emplacement of megaconglomerate Bed 12 at Cow Head.

This break marks the change from a uniform to complex carbonate platform and is interpreted to be the result of synsedimentary faulting. The margin upslope from Cow Head remained in shallow water during the final stages of Cow Head Group deposition whereas that upslope from Lobster Cove Head was drowned and shed little sediment into deep water. The syn-sedimentary faulting, which led to rapid subsidence and platform margin upslope from Lobster Cove Head and probably the deposition of mega-conglomerate Bed 12 at Cow Head, coincides with the onset of the Taconic Orogeny in western Newfoundland.

Upper beds of the Lobster Cove Member grade up section into greywackes of the Lower Head Formation, which are being deposited ahead of the advancing allochthons. Basal beds of the Lower Head sandstone contain bedded intervals of dolostone and shale, as below, locally tilted and rotated as blocks and displaying later injection of sandstone. This sort of disrupted contact is common at the base of the Lower Head sandstone elsewhere in the Humber Arm Allochthon. Sediments above this disrupted zone are graded sandstone with minor shale interbeds.

**Stop 2.4: Rocky Harbour Beach  
(UTM 21 433629E 5493362N)**

**Location.**

In the town of Rocky Harbour, across from Fisherman's Landing Restaurant, take walking path to beach outcrops.

**Description.**

Black Shale matrix mélange, highly cleaved and fractured, with sedimentary shale clasts and disrupted beds. This extensive regional scale melange in the Rocky Harbour area separates allochthon from autochthon.

**Stop 2.5: Highway outcrop of Forteau Fm (Labrador Gp) by East Arm  
(UTM 21 439556E 5488932N) WARNING! WATCH FOR TRAFFIC!**

**Location.**

On highway 430, on the east side of the road on a downhill section just before a small causeway across a lake. The outcrop forms a large west-dipping bedding plane with rock bolts prominent.

**Description.**

The journey from Rocky Harbour passes along strike through outcrops of the Hawke Bay and Forteau Formations (Labrador Group), including sandstones, quartzites, siltstones, shales

and minor limestones. Note the massive steel rock bolts, a precaution against rock slides. These are needed because the rocks dip towards the road.

At this stop, the formation is dominated by shales and siltstones. The outcrop contains the large trilobite *Olenellus thompsonii*, but specimens can be faint and hard to see in poor light.

**Stop 2.6: Cambrian - Precambrian (Grenvillian) basement unconformity  
(UTM 21 452323E 5479003N) WARNING! WATCH FOR TRAFFIC!**

**Location.**

The road cut is about 9.5 km north from the Route 430/431 junction in Wiltondale, just past the sign indicating the hiking trail to Southeast Brook. The long outcrop on the right hand side of the road exposes basement rocks and overlying Lower Cambrian conglomerates, sandstones and carbonate rocks of the Labrador Group.

**Description.**

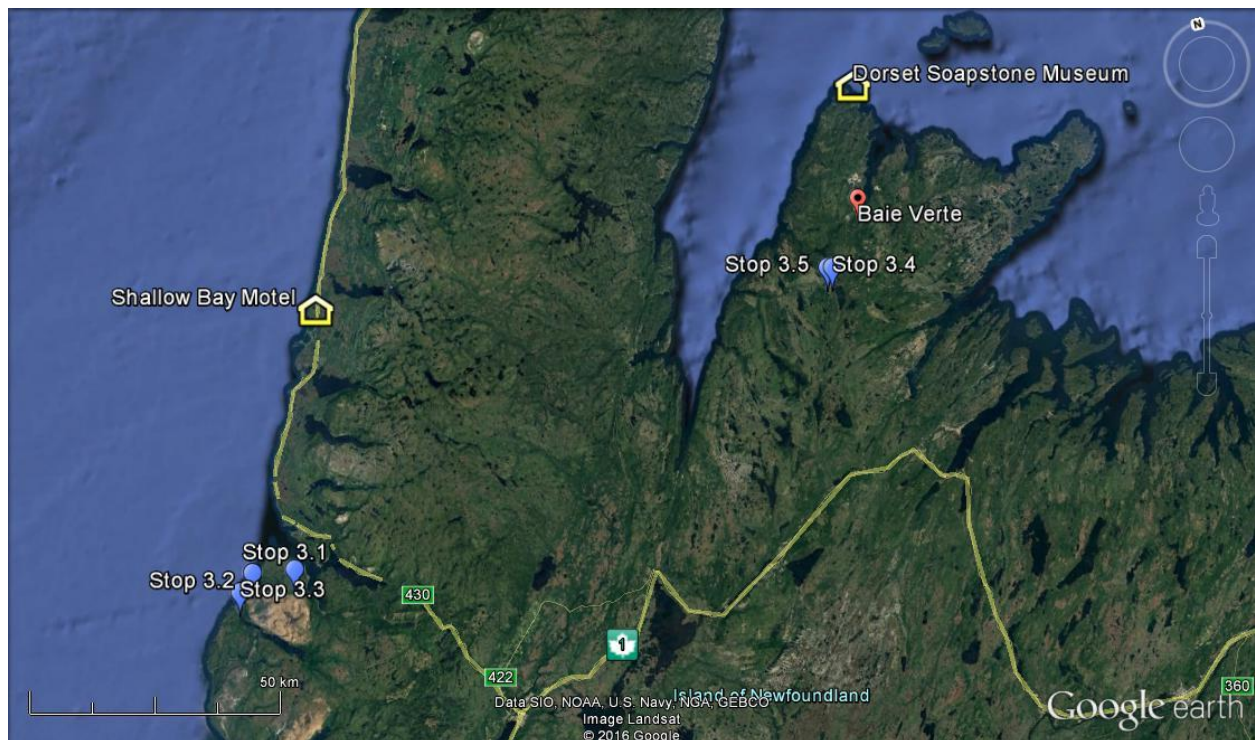
The basal terrigenous clastic rocks of the Bradore Formation (Labrador Group) are thin here (<10 m), and pass upwards into the overlying Forteau Formation. The unconformity surface is rather irregular, and fissures or depressions are filled with coarser grained conglomerate, containing boulder-sized granite clasts. The overlying purplish sandstones of the Bradore Formation are magnetic.

The Precambrian rocks include an epidotized foliated granitic rock, cut by a mafic dyke, possibly of the ca. 620 Ma rift-related Long Range swarm. Locally the unconformity rests on the dyke.

## DAY 3: GROS MORNE NATIONAL PARK

### DAY 3 — STOP LIST

- Stop 3.1 Ophiolitic Cover Sequence
- Stop 3.2 Green Gardens Precambrian Rift volcanic sequence
- Stop 3.3 Bay of Islands Ophiolite – MOHO and mantle section (optional)
- Stop 3.4 Virginite and serpentinite, Advocate Ophiolite Complex
- Stop 3.5 Least-altered Ophiolitic Mantle Peridotite



## **DAY 3 — FIELD STOPS**

### **Stop 3.1: Ophiolitic Cover Sequence (UTM 21 430301E 5481149N)**

#### **Location**

On highway 431 to Trout River opposite scenic lookout parking lot. Distance is 3.6 km west from intersection of turnoff to Woody Point.

#### **Description**

This section includes pillow lava, pillow breccia, red cherty sediment, and the section is cut by faults. These rocks have been assigned to the Little Port Complex, an arc-related plutonic/volcanic complex, to the northwest of Tablelands (Stevens in GAC NF Field Trip Guide 2003). Alternatively, they appear very similar to the cover sequence in the Bay of Islands Ophiolite Complex in the Blow Me Down and North Arm Mountain Massifs to the southwest of Tablelands Massif.

### **Stop 3.2: Green Gardens Precambrian Rift volcanic sequence (UTM 21 421895E 5482299N)**

#### **Location**

Park at the second parking lot to Green Gardens on route 431, located about 9.1 km west of Stop 3.1. Walk following the Park Trail in to the beach at Green Gardens (~4.2 km or a round trip of 8.4 km).

#### **Description**

En route to the volcanic sequence you will cross a high hill that is underlain by small outcrops of white-weathering trondhjemite of the Little Port Complex, a Cambrian arc-related plutonic/volcanic sequence. The section along the beach displays the main rock units of the Skinner Cove Volcanics shown on the cross section and map in the figure (Fig. 5). A promontory of outcrop displays excellent pillow lava, then next to (overlying it) in the cliffs to the south, around the steps to the beach are a series of volcanoclastic tuffs and conglomerates, some with a carbonate-rich matrix.

A major ankaramite flow (ol- and cpx- porphyritic basalt) occurs mainly in shoals that are islands at low tide. Further south, the long cliff along the beach is composed of trachytic flows with variable amounts of feldspar crystals.

#### **Discussion.**

This sequence was for many years considered to be an early Paleozoic allochthonous remnant from the Iapetus Ocean, perhaps a seamount. These rocks took on a whole new significance when the ankaramite lava flow was dated as late Precambrian (551 ± 3/-2 Ma; McCausland B.Sc. thesis, 1995). These rocks are now recognized to be a rift-related sequence related to Laurentian continental break-up and ocean formation, one of many such sequences along the length of the mountain belt (Fig. 5). The paleomagnetic signature of this sequence has been used as an important pin for identifying the paleo-position of North America at 20 degrees

S ( $\pm 10$  degrees) in the southern hemisphere in late Precambrian time, and for identifying the relative position of North America with respect to other cratonic nuclei at this time for plate reconstructions (McCausland and Hodych, 1998).



**Stop 3.3: Bay of Islands Ophiolite – MOHO and mantle section; gabbro (optional)**  
**(UTM 21 418666E 5479095N - parking)=**

**Location.**

Boat trip up Trout River Pond OR a hike along a trail on east side of Trout River Pond.

**Description.**

The pond lies between mantle rocks of the Tablelands to the northeast and ophiolitic dykes and lavas of the North Arm Massif to the southwest. The MOHO is visible up on the hillside, and a down faulted block of gabbro (i.e. MOHO) is exposed near the shore. At the southeastern end of the pond, the metamorphic aureole is clearly visible

**Stop 3.4 Virginite and serpentinite, Advocate Ophiolite Complex**  
**(UTM 21 548912E 5516165N)**

**Location.**

Roadcut along Baie Verte highway (Route 410) by parking lot south of intersection with highway 411.

**Description.**

Ultramafic rocks of the Advocate ophiolite complex along the Baie Verte–Brompton Line everywhere show some degree of alteration, generally to serpentinite, but also to talc-magnesite and quartz- magnesite. A somewhat unusual alteration assemblage of magnesite-quartz-fuchsite is locally referred to as virginite; named by local prospector Norman Peters. Similar rocks elsewhere in the world have been termed maraposite (e.g. California) and listwaenite (e.g. North Africa).

Virginite, on fresh surfaces, is easily recognized by a streaked emerald green and white appearance and abundance of milky white quartz veins. Weathered outcrops are rusty brown instead of emerald green, but the quartz veining readily identifies them.

Virginite consists primarily of pale green breunnerite (a variety of magnesite containing 5-30% iron), with lesser quartz and 1-2% of fuchsite (a chromium-rich muscovite). The variegated green colour of the virginite is largely due to the breunnerite with a contribution from the unusually high Cr content of the fuchsite. Virginite is generally enclosed by a metre wide zone of carbonate serpentine-talc rock which in turn passes into schistose serpentinite.

The formation of talc and carbonate-rich assemblages and virginite is attributed to metasomatic reaction of serpentinite with H<sub>2</sub>O-CO<sub>2</sub> fluids passing along structural zones.

**Stop 3.5 Least-altered Ophiolitic Mantle Peridotite**  
**(UTM 21 541776E 5519007N)**

**Location.**

Roadside outcrop on south side of highway 411 approximately 7.3 km further west from

### Stop 3.4.

#### **Description.**

Semipelitic and psammitic schists are composed of quartz, feldspar, muscovite, biotite and garnet. Quartzitic units, coarse feldspathic units and arkosic metagreywacke are all prominent locally.

Three phases of deformation are recognized regionally. An early schistosity is folded by second phase isoclinal folds containing an axial planar crenulation cleavage. All of these structures are affected by third phase folds with northeast-trending axes and axial planes that dip moderately northwest.

At this locality, the metasediments are cut by multiple mafic dykes up to about 2 metres width. These dykes, now characterized by amphibolite grade mineral assemblages, are known locally to preserve cores of eclogite grade (omphacite + garnet).

#### **Discussion.**

The eclogite is only preserved in the centre or cores of some of the widest dykes and can be quite difficult to recognize. The eclogite grade event (i.e. high pressure) has not clearly been dated but is probably linked to the timing of attempted subduction of the continental margin. The amphibolites are not directly dated but the migmatites in the Fleur de Lys yield U-Pb monazite ages of 427 Ma.

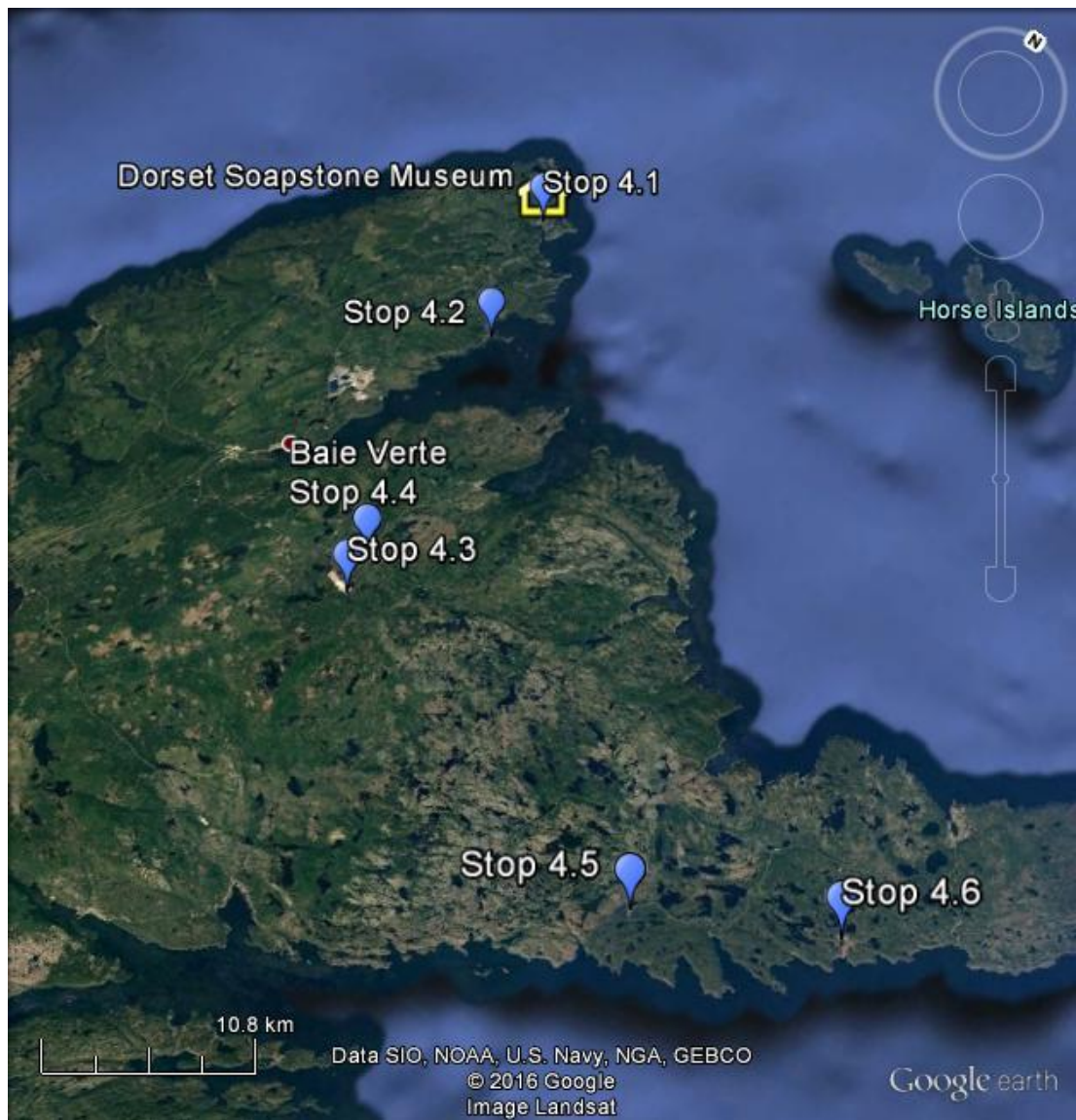
Alternatively, there are many Devonian Ar-Ar ages (ca. 400 Ma) determined regionally in the Fleur de Lys which may record a significant thermal event or be cooling after peak Silurian P-T conditions.



## DAY 4: BAIE VERTE PENINSULA BASE AND PRECIOUS METAL DEPOSITS

### DAY 4 — STOP LIST

- Stop 4.1: Fleur de Lys metasediments cut by mafic dykes
- Stop 4.2: Ophiolitic mélange at Coachman's Cove
- Stop 4.3: Iron Formation above the Rambler VMS Deposits
- Stop 4.4: Ming Cu-Au-(Zn-Ag) VMS deposit
- Stop 4.5: Nugget Pond
- Stop 4.6: Tilt Cove



## GEOLOGIC SETTING

The Baie Verte Peninsula comprises two contrasting tectono-stratigraphic zones separated by the steep, north-northeast trending Baie Verte-Brompton Line, a complex major structural boundary. This structural feature is a major crustal-scale suture zone that separates North American (Laurentian) continental rocks of the Humber Zone from ophiolitic and volcanic rocks of the Dunnage Zone (Figs. 6A and 6B). Melanges and ophiolitic rocks occur along the boundary.

The Humber Zone consists of Grenville basement and an overlying cover sequence (Fig. 6B). Hibbard (1983) describes a basement complex, termed the East Pond Metamorphic Suite, which contains migmatite, banded gneiss and metaclastic rock.

The cover sequence, named the Fleur de Lys Supergroup consists of metaclastic schist, marble, amphibolite and greenschist. Mafic dykes, possibly related to initial continental rifting ca. 610 Ma, are relatively common within the Fleur de Lys metasediments. These dykes are locally deformed and retrogressed to amphibolite, but some still preserve eclogitic facies mineralogy (Jamieson P-T data), reflecting deep burial and uplift of the continental margin. The metaclastic rocks can be equated with similar lower grade rocks of Cambrian to Early Ordovician age in the Humber Arm Allochthon and are considered to represent passive continental slope and basinal deposits. At the top of the cover sequence are greenschists and ophiolitic melanges of the Birchy Complex.

The melanges contain large blocks of serpentinized ultramafic rocks, actinolite-fuchsite alterations of smaller ultramafic blocks, altered gabbro, a variety of clastic sedimentary blocks and marble. The melange shows the same multiple deformational and metamorphic history as the rest of the Fleur de Lys Supergroup. It developed on top of the collapsed continental margin during ophiolite obduction.

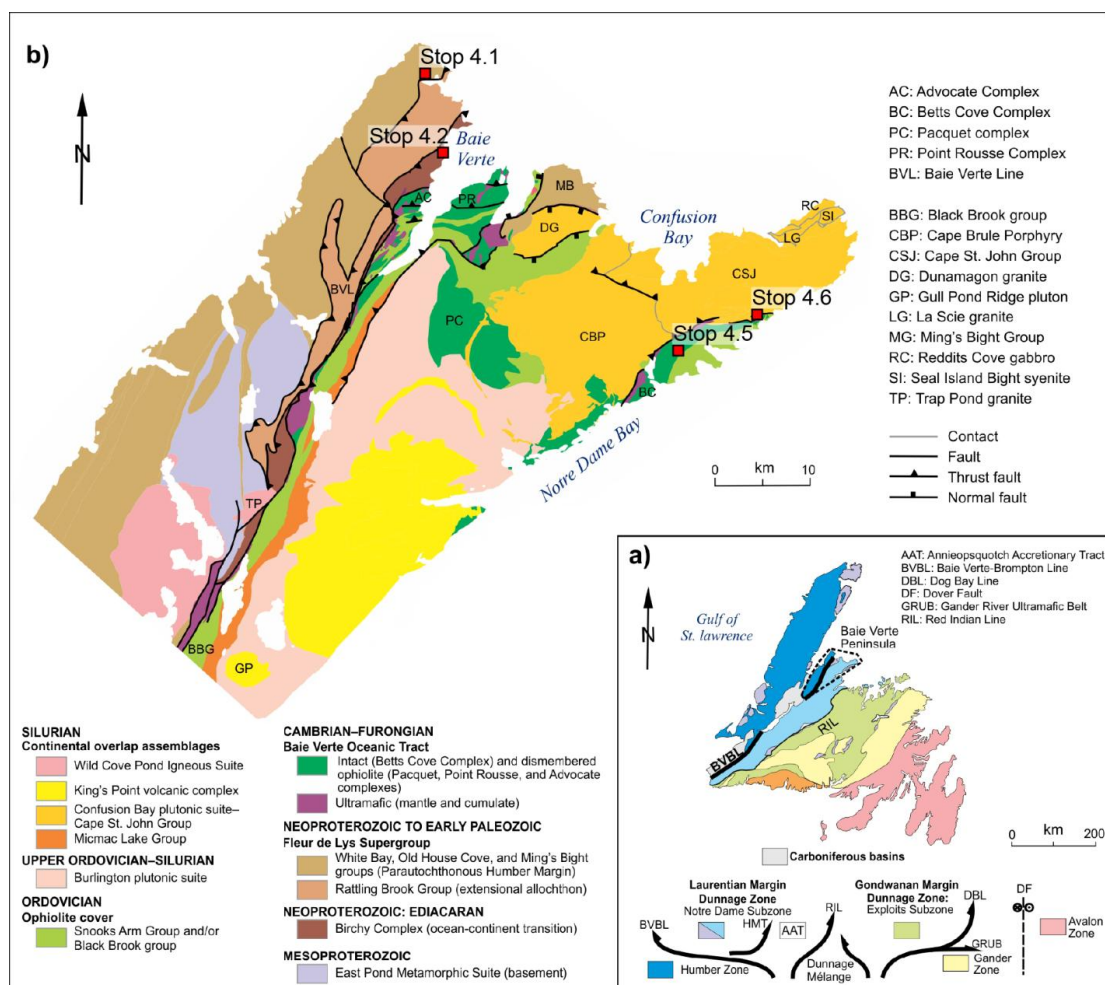
Dunnage Zone rocks to the east of the Baie Verte-Brompton Line consist of ophiolite suites and their volcanic cover sequences. A number of separate ophiolite units are distinguished on the peninsula including the Advocate, Point Rousse, Betts Cove and Pacquet Harbour complexes (Fig. 6B). They have been suggested to be mutually correlative and to represent imbricated oceanic crust (Hibbard 1983). The Advocate Complex is a dismembered ophiolite in the Baie Verte- Brompton Line of probable Early Ordovician age. It marks the most western outcrops of the Dunnage Zone on the peninsula. The occurrence of garnetiferous amphibolite in the western wall of the Advocate open pit asbestos mine indicates the local preservation of a metamorphic sole beneath the Advocate Complex, like that beneath the Bay of Islands Complex. This implies that the rocks along the Baie Verte-Brompton Line were obducted from an initial oceanic environment to their present setting. The Baie Verte-Brompton Line is considered to mark the root zone of the ophiolites within the west Newfoundland Taconic Allochthons.

Three main phases of deformation and upper greenschist to middle amphibolite facies regional metamorphism affect the entire Humber Zone and the northern portion of the Dunnage Zone on the Baie Verte Peninsula. Elsewhere, Dunnage rocks display greenschist or lower grade metamorphism. In general, deformation increases in intensity towards the Baie Verte-Brompton Line. Early deformation may be of Taconic age and related to westward regional

obduction of ophiolites over the Humber Zone, however no Ordovician radiometric ages have been determined that can be related to deformation or metamorphism. Some deformation is cut off by the 432  $\pm$  2 Ma Burlington Granodiorite. As well there is deformation of probable Acadian (Devonian) age that is marked by a reversal in structural vergence to the east, resulting in uplift of the metamorphic rocks to the west of the Baie Verte-Brompton Line. The concentration of deformation and metamorphism along the line reflects its position at the collisional interface between the Humber and Dunnage zones. In northern parts of the peninsula there is clearly a Carboniferous (ca. 355 Ma) metamorphic/melting event to amphibolite grade.

The Baie Verte-Brompton Line represents the eastern surface limit of the Humber Zone. Recent deep seismic reflection profiling has revealed that the Grenville basement of the Humber Zone extends east under the Dunnage Zone (Fig. 6A).

A number of base and precious metal deposits occur in mafic volcanic rocks of the ophiolite sequences on the peninsula, including the Tilt Cove and Rambler deposits. The Advocate asbestos deposit, developed along the Baie Verte Line near the town of Baie Verte, is now abandoned. Recent exploration has revealed many gold prospects and the Nugget Pond past-producing mine.



## DAY 4 — FIELD STOPS

### **Stop 4.1: Fleur de Lys Metasediments Cut by Mafic Dykes (UTM 21 548912E 5516165N)**

#### **Location.**

Roadside outcrop on south side of highway 410 approximately 200 m west from the Dorset Soapstone Quarry site.

#### **Description.**

Semipelitic and psammitic schists are composed of quartz, feldspar, muscovite, biotite and garnet. Quartzitic units, coarse feldspathic units and arkosic metagreywacke are all prominent locally. Three phases of deformation are recognized regionally. An early schistosity is folded by second phase isoclinal folds containing an axial planar crenulation cleavage. All of these structures are affected by third phase folds with northeast-trending axes and axial planes that dip moderately northwest.

At this locality, the metasediments are cut by multiple mafic dykes up to about 2 metres width. These dykes, now characterized by amphibolite grade mineral assemblages, are known locally to preserve cores of eclogite grade (omphacite + garnet).

### **Stop 4.2: Ophiolitic mélange at Coachman's Cove (UTM 21 563799E 5544468N)**

#### **Location.**

Ophiolitic melanges are exposed at a number of coastal localities around Coachman's Cove. We shall visit the Picnic site locality. Coachman's Cove is located at the end of a branch road leading east off the Baie Verte 410 highway, approximately 25 km north of the community of Baie Verte (Fig 6b).

#### **Description.**

Here, you are at the northern termination of the Baie Verte – Brompton Line in North America. This locality shows intense deformation. The melange displays the same structural and metamorphic history as the surrounding schists. The dominant schistosity is a regional second-phase fabric, locally associated with second-generation tight to isoclinal folds.

At the picnic site locality (Fig. 6b), the ophiolitic melange is up to 20 m wide and is infolded with greenschist and blocks of gabbro and metasediment.

### **Stop 4.3: The Rambler Deposit and Overlying Snooks Arm Group (UTM 21 565996E 5527185N)**

#### **Location.**

This stop is located south of highway 414, approximately 15 km east of Baie Verte (Figs. 7 and 8) From Baie Verte, drive east onto Highway 414, pass the intersection for Ming's Bight (and Ming mine), continue for 700 m and turn right onto a gravel road. Continue south on the

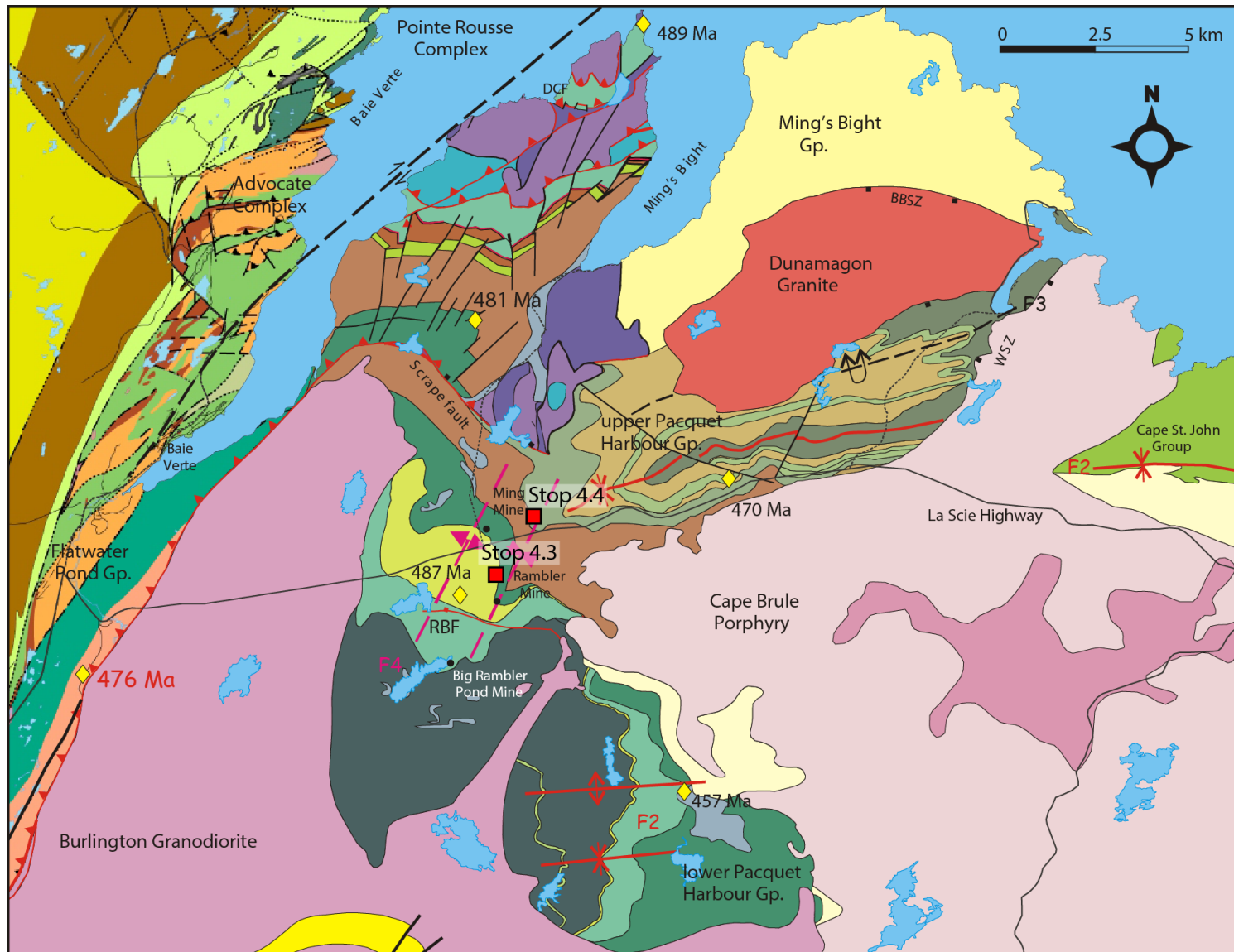
gravel road for 2.4 km (you will pass a *major* intersection on your left and a gate on your right) until you see a clearing and the tailings on your right. Park the vehicles on the side of the road without blocking potential incoming traffic (there are cottages up the road). Walk northwest for 130 m towards the tailings and cross the small brook. You are now walking on altered felsic rocks of the immediate footwall of the historic Rambler mine. **PLEASE stay away from the steep slopes and cliffs around the pond. It can be very slippery, even on a dry day. The pond is very acid and deep. NO HAMMERING on this outcrop.**

#### **Description.**

The outcrop consists of strongly sericite-altered quartz-bearing felsic crystal tuff, overlain by stratiform pyrite-rich massive sulphide—both dipping north-northeast (30-35°). These rocks form the uppermost portion of the Pacquet Complex (ophiolite). The massive sulphide is cut by a 4-5 m thick mafic sill (that feeds some of the Snooks Arm mafic volcanic rocks), locally forming two separate lenses. The felsic tuff and massive sulphide occur at the same stratigraphic horizon as the Ming deposit. The alteration assemblages stratigraphically below the Rambler massive sulphide predominantly consist of sericite-quartz-fuchsite-sulphide±chlorite, whereas pervasive chlorite alteration occurs at greater depths (>30-50 m). Concordantly overlying the massive sulphide is a 1-2 m thick sedimentary sequence that consists of a dark grey magnetite-rich volcanogenic mudstone to siltstone; despite strong deformation, grading can still be resolved. This sedimentary unit represents the base of the Snooks Arm Group and can be traced across the Baie Verte Peninsula (equivalent to the Nugget Pond horizon). Overlying the sedimentary sequence are mafic flows and volcanoclastic rocks of the Snooks Arm Group. The Rambler deposit, much like the Ming deposit, is located at the hinge of a regional scale northeast plunging fold. At least four phases of deformation have affected rocks of the Pacquet Complex (and Snooks Arm Group) and peak metamorphism reaches upper-greenschist to lower-amphibolite facies. A strong penetrative foliation can be observed throughout the Rambler and Ming areas. This foliation is attributed to be related to D<sub>2</sub>, during which most of the sulfide stringers have been transposed parallel to S<sub>2</sub>.

The Rambler orebody is 30 to 100 m wide, can reach up to 15 m in thickness, and has been traced for more than 1 km down-dip (via drilling) from its surface exposure. The massive sulphide predominantly consists of a pyrite-chalcopyrite-sphalerite assemblage with subordinate precious metals. Rambler produced, between 1961 and 1967, 440 000t of ore with grades averaging 1.3% Cu, 2.16% Zn, 26.44 g/t Au, and 4.67 g/t Ag. It is important to note that the ore was hand-cobbed, which increased production grade.





**Figure 7.** Regional geology of north-central Baie Verte Peninsula. Map after Skulski et al. (2010) and references therein. See legend in Figure 8.



**Figure 8.** Legend to accompany Figure 7. Legend after Skulski et al. (2010).

#### Stop 4.4: Ming Cu-Au-(Zn-Ag) VMS deposit

##### Location.

From the Dorset Museum in Fleur-de-Lys, drive south on HWY 410 for 32 km and turn east onto HWY 414 direction La Scie. Continue for 14 km and turn left onto HWY 418 (direction Ming's Bight). Continue for 300 m, the Rambler Metals and Mining PLC-Ming operation will be on the left. **Permission to access the site should be obtained in advance from Rambler Metals and Mining PLC. Stop locations and summary of the stratigraphy of the peninsula are illustrated in Figures 7-9.**

##### Description.

The past and currently producing bimodal-mafic Ming volcanogenic massive sulphide deposit (Figs. 7 and 10) is host to elevated concentrations of Au and Cu, and with local

enrichments of Ag and Zn. The Ming deposit has a NI43-101 compliant total reserves of 1.51 Mt at 1.70 wt% Cu, 2.09 g/t Au, 9.48 g/t Ag, and 0.37 wt% Zn and combined measured and indicated resources estimated at 2.47 Mt at 2.27 wt% Cu, 2.15 g/t Au, 9.08 g/t Ag, and 0.44 wt% Zn (recalculated from Pilgrim, 2009). The deposit contains four elongated Cu-Au-(Zn-Ag) massive to semi-massive sulphide lenses, all gently plunging north-northeast (Fig. 10) and separated 30 to 50 metres from each other along the same stratigraphic horizon. One of the zones, the 1806 zone, is very precious metal-rich and contains 487 000 tonnes of 3.4 g/t Au and

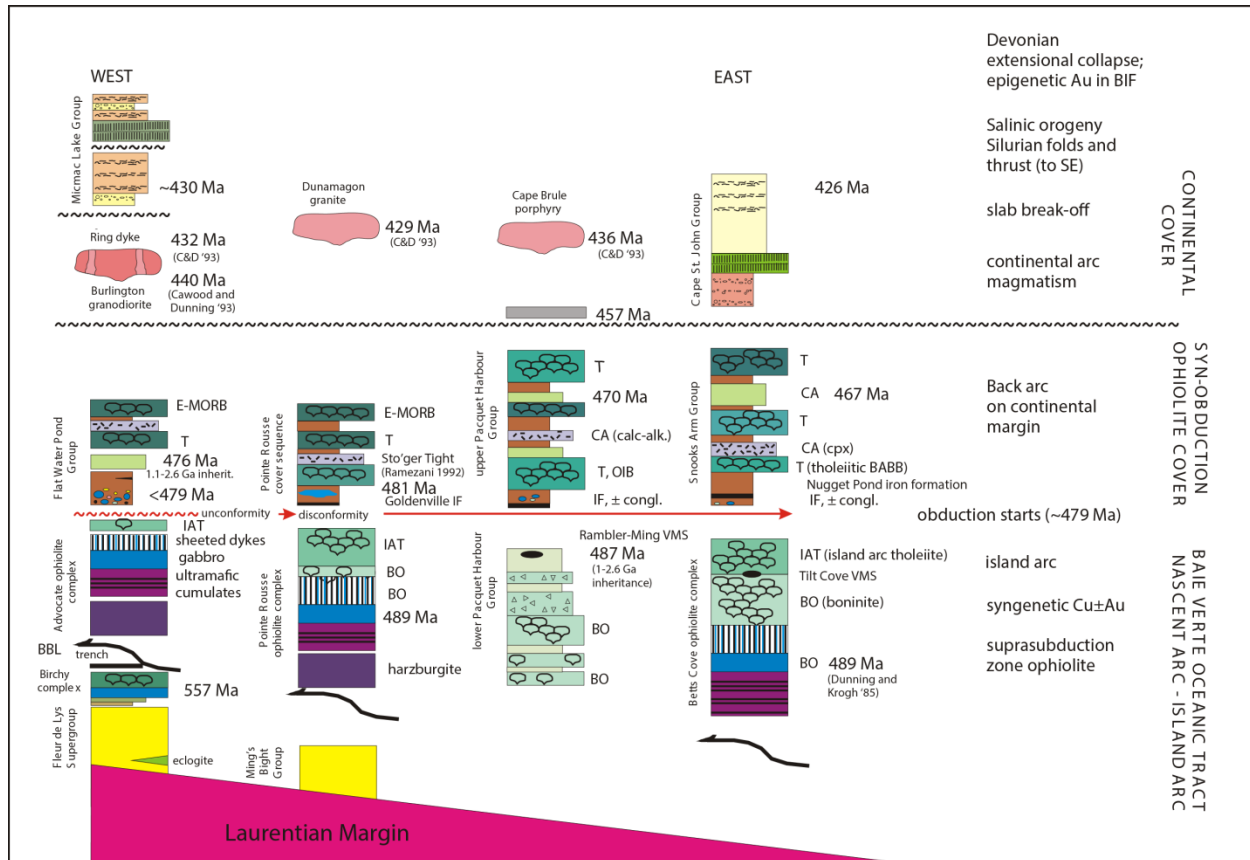
22.31 g/t Ag (Pilgrim, 2009). The deposit is underlain by a northeast-dipping sequence dominated by felsic volcanic and volcanoclastic rocks of the lower Pacquet Harbour Group (Hibbard, 1983). The felsic rocks are regionally referred to as the “Rambler rhyolite”. South of the Rambler Camp, the lower PHG is dominated by mafic pillowed lavas and volcanic breccia of boninitic affinity and gabbro that is believed to represent an incompletely preserved ophiolitic sequence (Piercey et al., 1997). Macroscopically, the sulphide consists of chalcopyrite, pyrite, sphalerite, pyrrhotite and minor galena (Tuach and Kennedy, 1978; Brueckner et al., 2011, in press). Electrum (Au-Ag alloy) can also be visible to the naked eye in some areas.

The lenses are spatially associated with several metamorphosed hydrothermal alteration mineral assemblages developed in the footwall including sericite, chlorite, quartz, biotite, tremolite, manganiferous garnet and calcite, green mica, epidote, magnetite, and pyrite (Pilote et al., 2015). A Cu-rich zone consisting primarily of chalcopyrite, pyrrhotite, and pyrite with minor Bi-Te sulfosalts and sphalerite in a strongly chlorite-epidote altered felsic volcanic rock occurs 50 to 100 metres below the main sulphide lens, representing the high-temperature discharge zone of the Ming hydrothermal system (e.g. Pilote and Piercey, 2013). An overprint of metamorphic biotite is ubiquitous throughout the felsic footwall rocks and represents metamorphosed K-Fe-(Mg) alteration to upper greenschist facies.

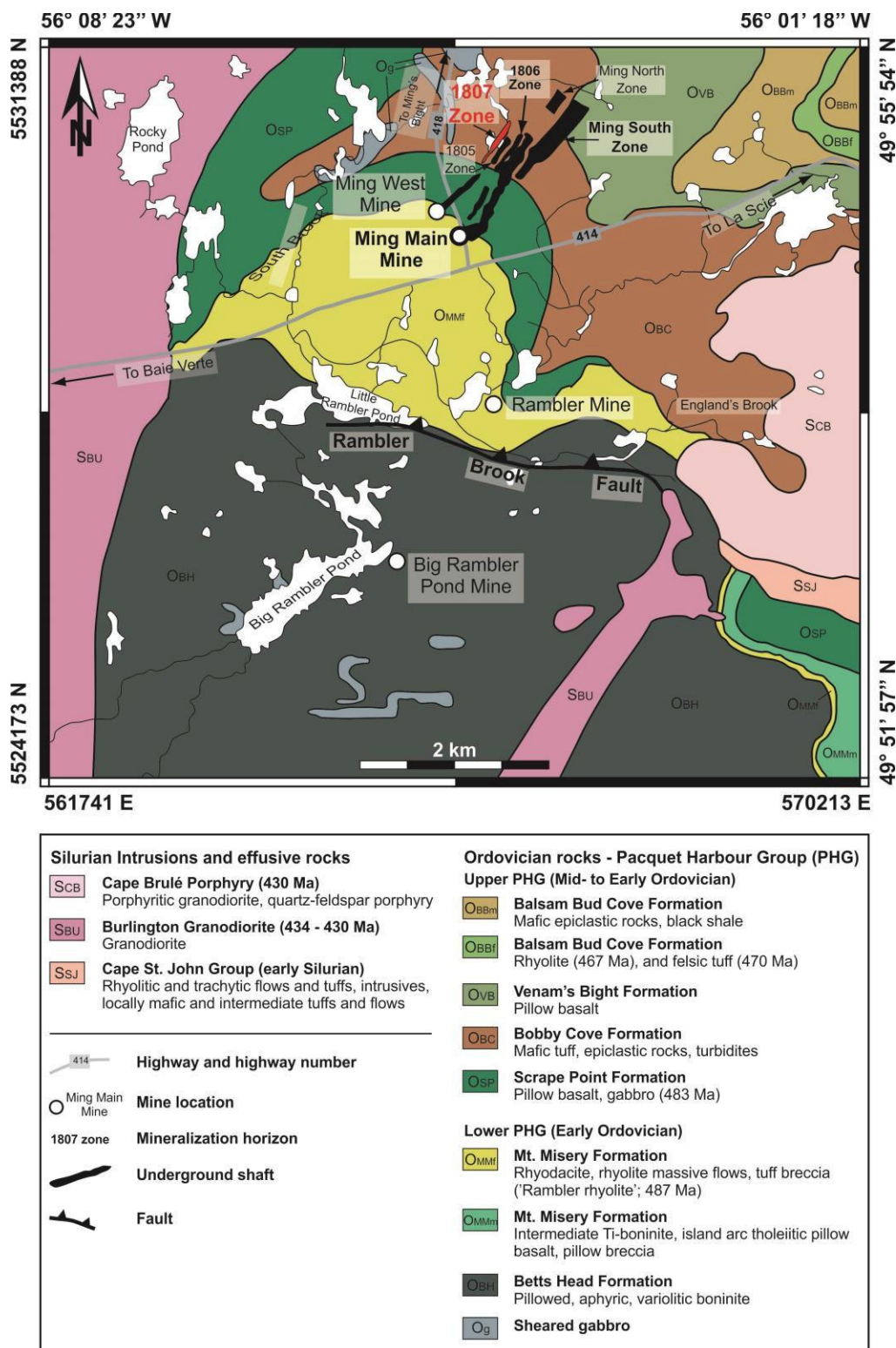
The immediate hanging wall is lithologically heterogeneous; varying from a highly silicified volcanoclastic rock to a magnetite-rich volcanogenic siltstone, locally structurally removed, juxtaposing the massive sulfide with mafic volcanic rocks of the overlying syn- obduction ophiolite cover sequence. The siltstone is correlated with the Nugget Pond horizon, host to orogenic Au mineralization elsewhere in the Baie Verte Peninsula (Skulski et al., 2009, 2010). The entire stratigraphic package is crosscut by at least three generations of mafic to intermediate sills and that have distinctive lithogeochemical signatures; they are interpreted to be genetically related to the mafic rocks of the ophiolitic cover sequence (Pilote and Piercey, 2013, Pilote et al., 2015).

The relationship between the stratigraphy, spatial distribution and styles of alteration, and the mineralization strongly favor a syngenetic origin for the ore zones and Au-enrichment (Brueckner et al., 2011, in press; Pilote and Piercey, 2013; Pilote et al., 2015; Brueckner et al., 2016; Pilote et al., 2016). Despite local chemical and mechanical remobilization of the massive sulfide in the westernmost zone of the deposit (1807 zone) due to subsequent deformation events (Pilote and Piercey, 2013, 2015), the sulfide bulk composition for all zones, including the precious metals, has not been changed by deformation and metamorphism, suggesting formation from intrinsically Au-enriched VMS ore-forming fluids (Brueckner et al., 2011, in press)





**Figure 9.** Tectonostratigraphy of Baie Verte Peninsula. After Skluski et al. (2010).



**Figure 10.** Regional geology map of the Rambler camp, Baie Verte Peninsula with projected to surface Ming VMS orebodies in black. Map modified after Pilgrim (2009), Tuach and Kennedy (1978), Castonguay et al. (2009), and Hibbard (1983). Ages are from Castonguay et al. (2009) and Cawood et al. (1993).

#### **Stop 4.5: Nugget Pond** (*Modified after Skulski et al., 2009*)

These 4 stops will examine (much closer this time) rocks of the upper Betts Cove Complex and cover sequence of the Snooks Arm Group (**Figured 11 and 12**). In addition, a tour of the Nugget Pond facility may possibly be given by one of the mill operators. **Please wear the proper safety gear and follow all safety procedures required by the operators outlined at the time of the visit. Also, be aware of machinery and trucks.**

##### **Stop 4.5A: (UTM 21 588145E 5522039N)**

This stop is located 40 m southwest of the tailings pond road (**Fig. 11**), 90 m northwest of the road that surrounds the mill. This outcrop comprises pillow basalt with pale green pillows (20-30 cm in diameter) and contains abundant quartz, jasper and epidote preferentially concentrated on pillow margins. These rocks belong to the upper Mount Misery Formation and have an island-arc tholeiite affinity, intermediate-TiO<sub>2</sub> composition, and depleted in REEs relative to chondrite (Skulski et al., 2009). Based on a geochemically-similar coarse-grained quartz gabbro sample from Long Pond, near Tilt Cove, which yielded a U-Pb zircon (TIMS) age of 488.6 Ma  $\pm$  3.1/-1.8, the Mt. Misery is thought to be of Late Cambrian/Early Ordovician age.

##### **Stop 4.5B: (UTM 21 588180E 5522070N)**

Return to the Tailings Pond road, the outcrop located north of the road (**Fig. 11**) consists of pillow basalt with massive and vein-style jasper alteration and quartz veining. This style of alteration is more likely a result of relatively low-temperature hydrothermal fluids associated with the cooling of the submarine volcanic rocks.

##### **Stop 4.5C: (UTM 21 588206E 5522024N)**

Continue 50-60 m southwest on the road (**Fig. 11**). This outcrop comprises iron formation with red jasper beds interbedded with red shale and overlain by green volcanogenic sandstone and siltstone. The jasper unit is geochemically similar to the surrounding mafic volcanic rocks of the Scrape point Formation (both are LREE-enriched). The horizon is also a regionally significant stratigraphic marker that marks the base of the Snooks Arm Group. It is correlative with the Goldenville horizon on the Pointe Rousse Peninsula, the Flatwater Pond area, and overlying the massive rhyolite in the Rambler Camp (Skulski et al., in preparation).

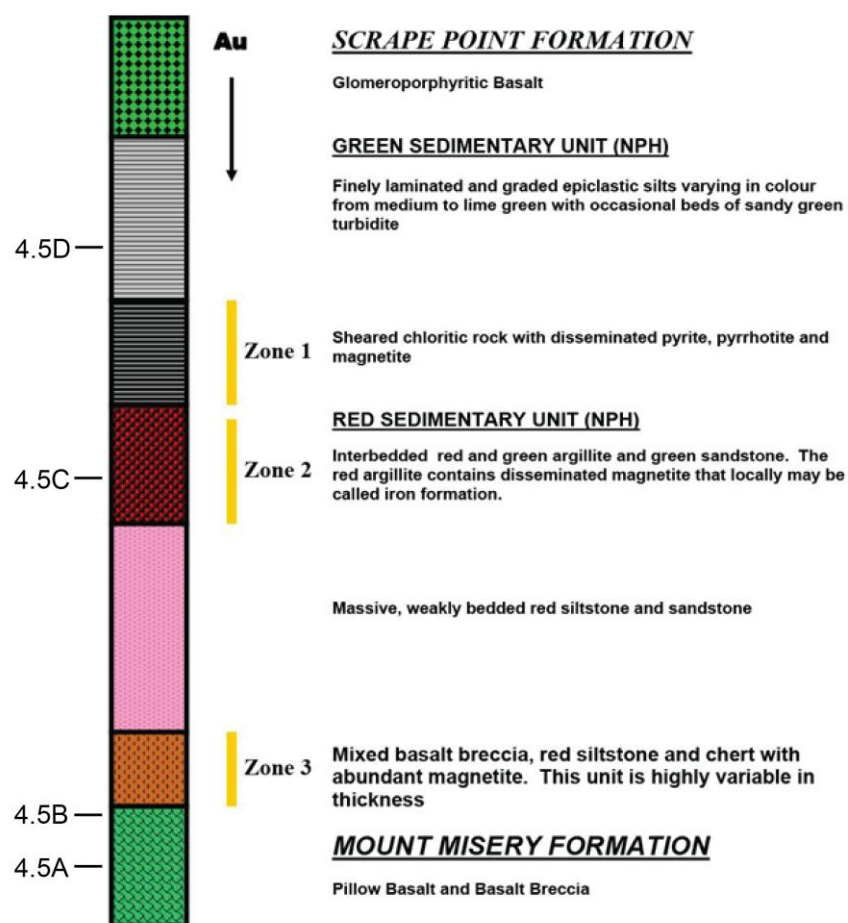
The Nugget Pond horizon is host to significant gold mineralization with a defined reserve of 488 000 tonnes at 0.357 oz/t (Sangster et al., 2008). The iron-rich sedimentary rocks are affected by an epigenetic albite-carbonate-quartz-pyrite alteration with gold occurring as free grains of native gold filling fractures in pyrite, coating pyrite grains, or small irregular-shaped grains within stilpnomelane altered rocks (Sangster et al., 2008).

##### **Stop 4.5D: (UTM 21 588202E 5521991N)**

Continue 30 m south to an outcrop east of the road (**Fig. 11**). The rocks at this location consist of interbedded grey-green graded volcanogenic greywacke, siltstone, and shale. As we move south, the rocks are getting finer-grained to gradually get coarser with green siltstone and greywacke which indicate an increase of coarse volcanogenic detritus input. **Can you determine the younging direction of the rock sequence?**



**Figure 11.** Location of stops near the Nugget Pond Mill. These stops will examine rocks of the upper Betts Cove complex and lower Snooks Arm Group.



**Figure 12.** Generalized and simplified stratigraphic column of the host rocks at the Nugget Pond. Also shown is the stratigraphic location of the mineralization (*modified from Sangster et al., 2008*).

**Stop 4.6: Tilt Cove**  
**(UTM 21 598707E 5526573N)**

**Location.**

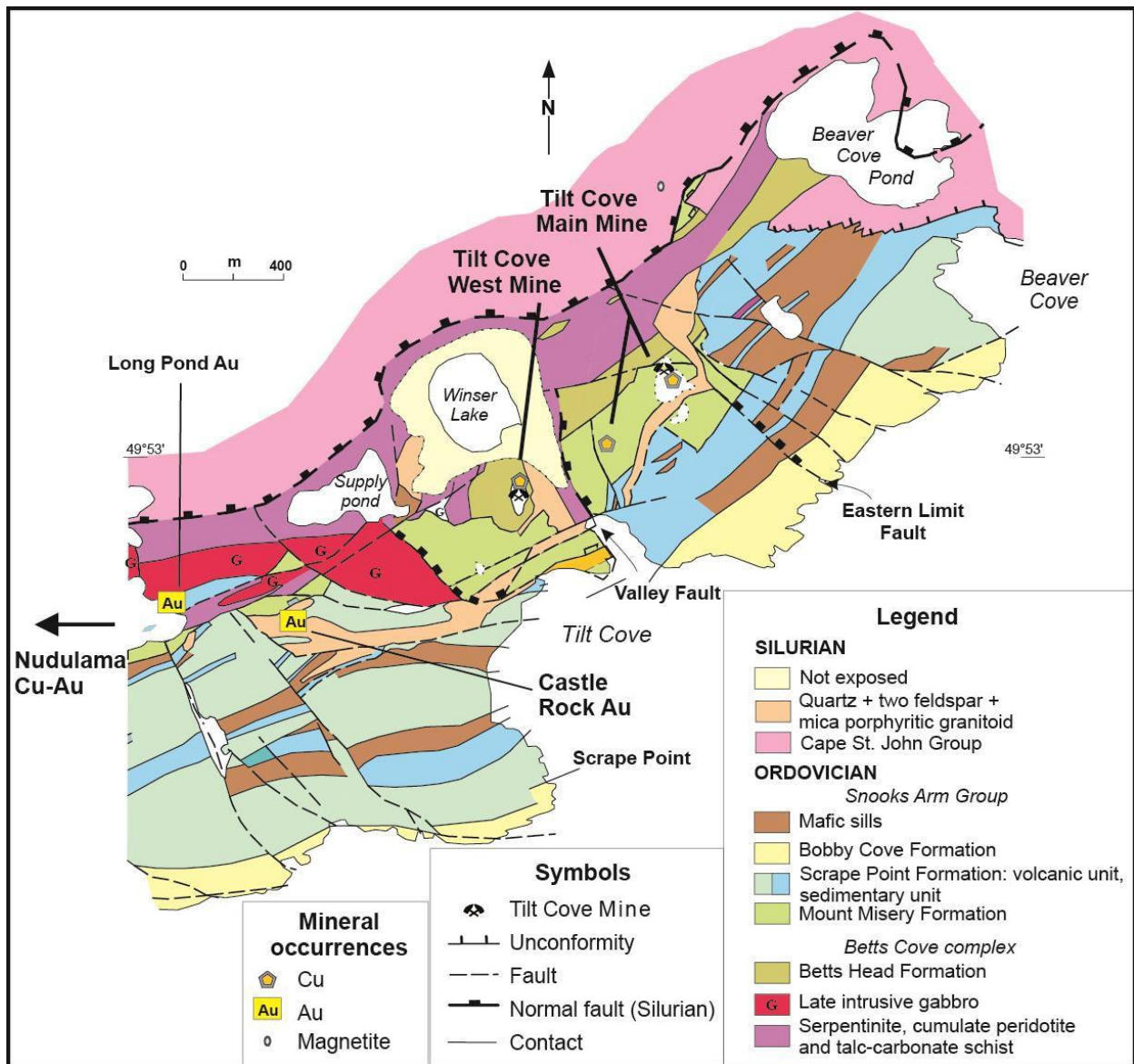
From Stop 4.5, leave from the ore processing facility at Nugget Pond. Continue northeastward to the triple junction and stay left through the triple junction onto hwy 416. Continue northward to the next triple junction and turn right onto hwy 414. After ~6 km turn right at the junction for Tilt Cove Road. Continue South for 5.7 km and turn left at the Tilt Cove village, keep east side of the Winsor Lake.

**Description.**

Tilt Cove is predominantly underlain by rocks of the Betts Cove Ophiolitic Complex, disconformably overlain to the southeast by the ophiolite cover sequence Snooks Arm Group, and structurally overlain to the northwest by the Silurian continental cover sequence Cape St. John Group (**Fig 13**; Bédard et al., 1996). The rocks surrounding the Winsor Lake (note that this is one of the very few lakes on the island) consist of talc-serpentinite peridotite, locally altered to talc+magnetite+magnesite+ankerite±sulphide. Rocks at the northern ridge of the valley varies (from west to east) from boninitic volcanic breccia to pillow lavas of the Betts Head Formation to olivine-phyric tholeiitic pillow lavas and pillow breccias of the Mount Misery Formation. These are overlain by the Scrape Point Formation which consists of a laterally discontinuous basal boulder conglomerate with basalt-chert fragments cemented by magnetite, thin-bedded turbiditic sandstone, and magnetic-hematite banded iron formation (Nugget Pond member equivalent). South of the valley, the rocks are intruded by Silurian two-mica quartz- feldspar porphyry dykes (possibly related to the Cape Brulé porphyry).

The Betts Cove Complex was an important contributor to the Newfoundland economy. Copper was first discovered at Tilt Cove in 1857 (West Mine) and production first began in 1864 (Hibbard, 1983). In the case of the East Mine, it was discovered in 1886 and produced until 1917. Production resumed in 1957 until 1967 when both mines closed. In total, approximately 8.2 Mt were mined at Tilt Cove with 7.4 Mt of ore grading 1.24% Cu and 42,500 oz of Au were extracted between 1957 and 1967 (Strong, 1984; Sangster et al., 2008). Ore consisted mainly of disseminated and stringer chalcopyrite-pyrite-pyrrhotite mineralization forming a steeply dipping pipe-like body in massive and pillowed basalt and basalt breccia belonging to the Betts Head and Mount Misery formations (Squires, 1981). Associated alteration minerals are dominantly chlorite, carbonate and minor stilpnomelane (Sangster et al., 2008).





**Figure 13.** Location and geological setting of the Tilt Cove Mine (modified after Bédard et. al., 2000).]

## DAY 5: BAIE VERTE PENINSULA — ANACONDA MINE TOURS

### DAY 5 — STOP LIST

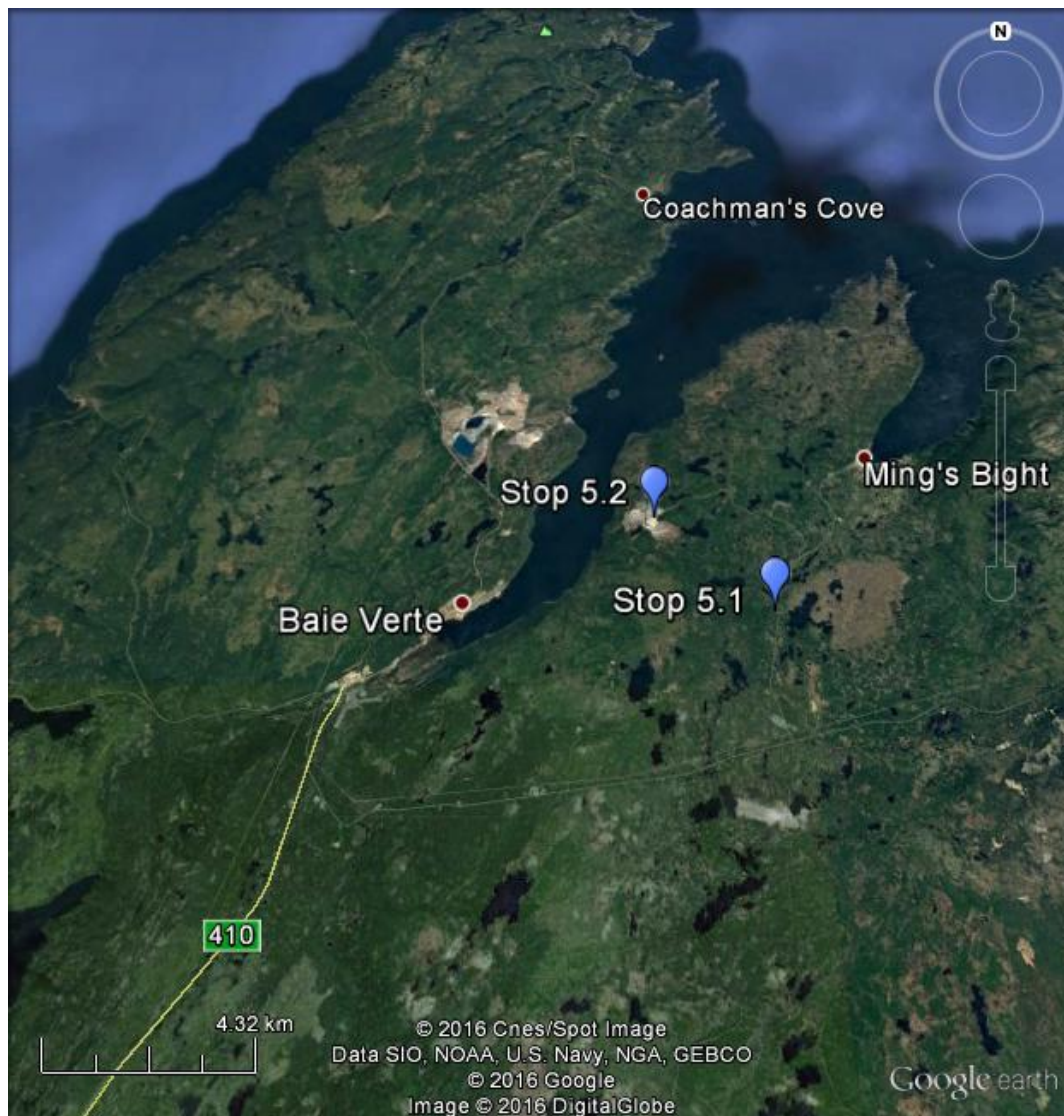
Stop 5.1: Scrape Thrust

Stop 5.2: Anaconda Mine Tours

Stop 5.2A: Pine Cove

Stop 5.2B: Stog'er Tight

Stop 5.2C: Goldenville



*The following introduction is an excerpt from the Ni 43-101 Technical Report: Mineral Resource And Mineral Reserve Update On The Pine Cove Mine And Mineral Resource Estimate On The Stog'er Tight Deposit, Point Rousse Project. Prepared by David Copeland, P.Geo and Catherine Pitman, P.Geo. December 5, 2015*

## **HISTORY**

What is now the Pine Cove Mining Lease 189, was staked in 1985 and the Pine Cove gold deposit was discovered in June 1987 South Coast Resources Ltd. In November 1988, Corona Corp. ("Corona") optioned the property from Varna Resources Inc. ("Varna") and conducted detailed geological, geophysical and soil geochemistry surveys, followed by trenching and diamond drilling in 24 holes. In the fall of 1991, NovaGold Resources Inc. ("NovaGold") optioned Corona's 70% interest in the Pine Cove property with the view to mine the deposit by open pit after definition drilling. Other work by Electra Mining Consolidated/Electra Gold/Raymo Processing ("Electra/Raymo") in 1996, New Island Resources Inc. ("New Island") in 2000 lead to further definition and development of the resource.

In 2003, Anaconda acquired an exclusive option form New Island to earn up to an undivided 60% interest in the Pine Cove project. In the fall of 2004 a 5,000-tonne bulk sampling program was successful and a NI 43-101 compliant technical report and feasibility study was completed and released by Anaconda 2005. A production decision followed and construction was initiated in 2007 and production commenced in 2008. Start-up issues resulted in reconfiguring the mill with a flotation circuit to produce a gold-pyrite concentrate. Commercial production was achieved in September enabling Anaconda to earn a total of 60% of the project, per the terms of the exclusive option agreement with New Island. In January 2011, Anaconda acquired New Island's remaining 40% interest.

The Stog'er Tight area was staked in 1986 by Pearce Bradley and optioned to International Impala ("Impala"). Impala formed a 50/50 joint venture arrangement on the Bradley North Property with Noranda Exploration Company Ltd. ("Noranda") and in 1987, an extensive soil geochemistry survey and trenching resulting in the discovery several mineralized zones. Noranda conducted geochemical, geological and geophysical surveys, trenching and diamond drilling outlining more mineralized zones through this work and an 8,000 m diamond drill program. In 1996, Ming Minerals Inc. ("Ming") purchased the Stog'er Tight property from Noranda and extracted a 30,735 tonne bulk sample grading 3.25 g/t Au from the Stog'er Tight deposit and processed the material at the former Consolidated Rambler mill which was located approximately 7.5 km south of Stog'er Tight. For a variety of reasons, including poor mill recoveries, head grade was less than anticipated and the project was shelved. In following 2006 Tenacity Gold Mining Company Ltd. carried out additional trenching and drilling and estimated an indicated resource of 96,000 tonnes grading 7.04 g/t Au and an inferred resource of 53,000 tonnes grading 5.75 g/t Au which included a mineral reserve of 65,200 tonnes grading 4.96 g/t Au at a cut-off grade of 1.9 g/t Au. Tenacity began mining and toll milling at the Rambler Metals and Mining ("Rambler") PLC's Nugget Pond mill located 47 km by road to the east. A total of 29,695 tonnes of material with an estimated average grade of 4.8 g/t Au was trucked to the mill. The actual mill head grade was 1.92 g/t Au. The difference between the estimated grade and the actual head grade was attributed to mining dilution. No further work was undertaken and the



Stog'er Tight Mining Lease was subsequently acquired by 1512513 Alberta Ltd. ("Alberta") and optioned by Anaconda in 2012. 16

## **GEOLOGICAL SETTING, MINERALIZATION AND DEPOSIT TYPES**

The Point Rouse Project area is underlain by Cambro-Ordovician ophiolitic Betts Cove complex and Snooks Arm Group cover rocks. The Betts Cove complex includes ultramafic cumulates, gabbros, sheeted dykes and pillow basalts. The Snooks Arm Group consists of a lower banded magnetite and jasper iron formation referred to as the Nugget Pond Horizon (Goldenville Horizon within the Point Rouse Complex) overlain by tholeiitic basalts overlain by calc-alkaline basalt, clinopyroxene-phyric tuff, mafic epiclastic wackes and conglomerates, iron formation and tholeiitic basalts. Four phases of regional deformation termed D1 thru D4 are evident with gold related to D1 - D2 deformation potentially synchronous with the emplacement of the Taconic allochthons.

Mineralization is typical of orogenic greenstone-hosted gold. Gold appears to be associated with secondary structures near larger faults interpreted to be larger first order structures. These structures are generally pre- or syn- D2, and typically the variation in rocktype, and resultant rheological contrast during deformation, may play an important role in mineralization since it is commonly the more competent of the rocks present which host gold. Mineralization is intimately associated with disseminated and massive pyrite within the host rock or within quartz-carbonate veins closely associated with mineralization. Alteration within mafic volcanic and gabbroic rocks can be characterized by albitization and carbonitization. Titaniferous host rocks are also characterized by the presence of leucoxene commonly observed as a broad halo around the mineralized zone.

### **DAY 5 — FIELD STOPS**

#### **Stop 5.1: Scrape Thrust (UTM 21 565778E 5532244N)**

##### **Location.**

The locality is 3.7 km north from hwy 414 along road 418 to Ming's Bight. The stop is a large (50 m long) roadside outcrop on the east side of the road.

##### **Description.**

The main feature of this locality is the Scrape Thrust, a south- directed thrust, which juxtaposes ultramafic rocks of the Point Rouse ophiolite over gabbro and other sheared mafic rocks of the Pacquet Harbour Group. At the southern end of the outcrop, a coarse gabbro is cut by mylonite zones. The deformation increases northwards towards the Scrape Thrust. Some rock layers below the thrust contain abundant coarse amphibole. The ultramafic rocks above the thrust are strongly altered to talc-magnesite assemblages and locally contain serpentine- filled fractures and quartz veins.

##### **Discussion.**

The Scrape Thrust is of regional importance and has been considered a splay off the Baie Verte - Brompton Line. The ophiolitic rocks of the Point Rouse and Pacquet Harbour are both

Ordovician in age (Stog'er Tight Gabbro, Point Rousse dated at 483  $\pm$  3/-2 Ma by U-Pb zircon). The coarse amphiboles nearby the thrust are dated at 355 Ma by Ar-Ar (Early Carboniferous). The Carboniferous age is unusual for the Baie Verte Peninsula as a whole but is common in this immediate northern area of the peninsula.

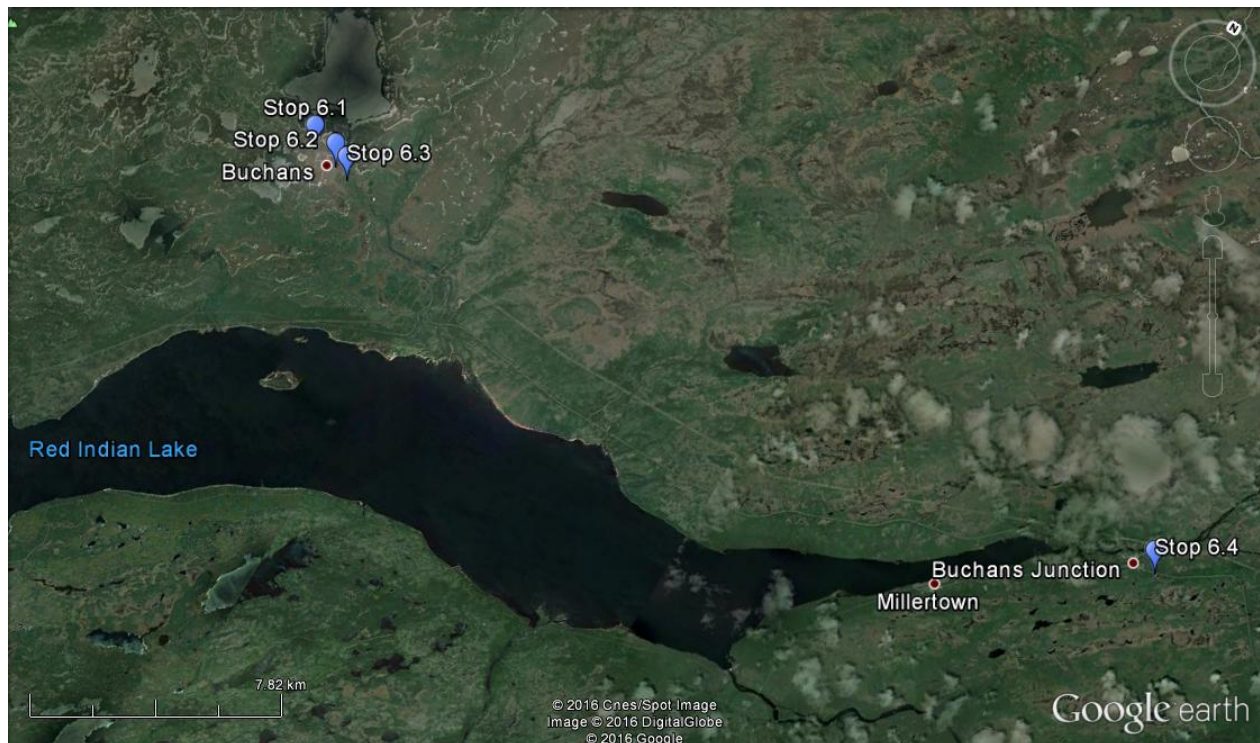
#### **Stop 5.2:       Anaconda Mine Tours**

**During the mine tours please adhere to all safety regulations instated by Anaconda Mining.** A safety induction and overview meeting will take place prior to the mine tours. A total of three properties will be vistied: Pine Cove, Stog'er Tight, and Goldenville.

## DAY 6- VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS OF THE CENTRAL MOBILE BELT

### DAY 6 — STOP LIST

- Stop 6.1 Ski Hill Buchans
- Stop 6.2 Discovery Outcrop from the Buchans Orebodies
- Stop 6.3 Arkose of the Sandy Lake Formation
- Stop 6.4 Candian Zinc Corporation core shack



## GEOLOGIC SETTING

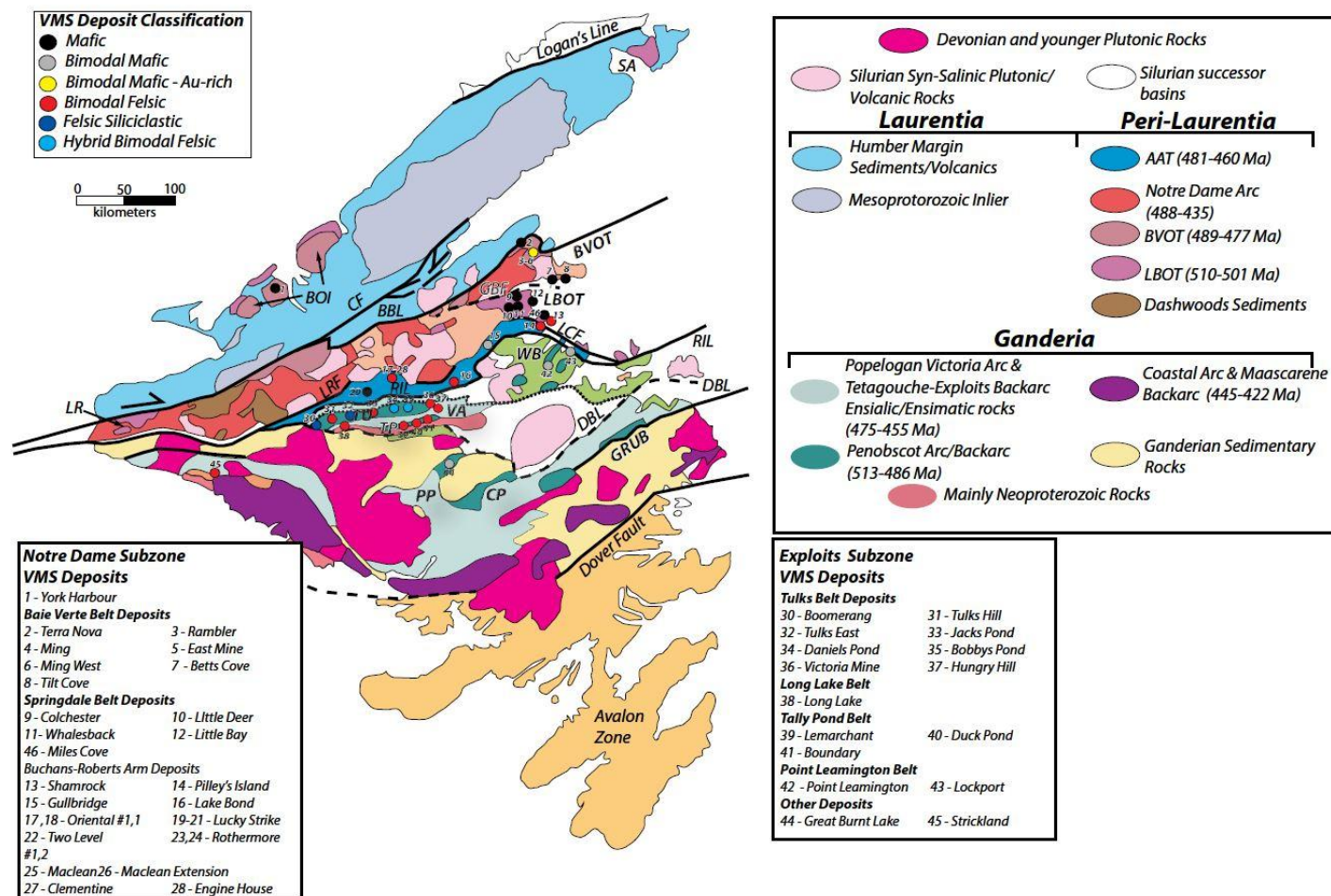
The Newfoundland Appalachians is divided into four tectonostratigraphic zones from west to east (e.g., Williams, 1979): 1) Humber Zone; 2) Dunnage Zone; 3) Gander Zone; and 4) Avalon Zone (Fig.14). The Humber Zone represents predominantly Cambrian and Ordovician ancient passive margin rocks that were deposited upon the Laurentian craton (Williams and Hiscott, 1987; Lavoie *et al.*, 2003) (Fig. 14). The Avalon and Gander zones represent Gondwana-derived microcontinental blocks with Neoproterozoic to Ordovician geological histories (O'Brien *et al.*, 1991; van Staal, 1994, 2007; van Staal and Barr, 2012) (Fig. 14). The Dunnage Zone, which is the focus of this trip, is the main host to volcanogenic massive sulphide (VMS) mineralization in Newfoundland and throughout the Appalachians in other parts of Canada and the United States (Swinden and Kean, 1988; Goodfellow *et al.*, 2003; Goodfellow, 2007). The Dunnage Zone is subdivided into two subzones: the Notre Dame and Exploits subzones (Williams *et al.*, 1988) (Fig. 14). The Notre Dame subzone consists of Cambrian to Ordovician arc and back-arc rocks that formed along the margin of Laurentia (peri-Laurentian), whereas the Exploits subzone contains arc and back-arc rocks that formed along the margin of Gondwana (peri-Gondwana) (O'Brien *et al.*, 1997; Swinden *et al.*, 1997; Zagorevski *et al.*, 2006; van Staal, 2007; Zagorevski *et al.*, 2007; Zagorevski *et al.*, 2010; van Staal and Barr, 2012) (Fig. 14). The two subzones are associated with distinctive rock assemblages and associations.

The Notre Dame subzone contains rocks that range from Cambrian to Ordovician. The Lushs Bight Group of the Lushs Bight Ocean Tract (LBOT) consists of Cambrian ophiolitic rocks that host Cu-rich VMS deposits in the Springdale area and are interpreted to have formed within a primitive arc environment (Kean *et al.*, 1995; Swinden *et al.*, 1997; van Staal, 2007; van Staal and Barr, 2012) (Fig. 14). The Lushs Bight Group rocks were obducted onto the Dashwoods Block, a rifted continental fragment from the Laurentian margin (Waldron and van Staal, 2001), in the early Ordovician (~500–490 Ma) (Szybinski, 1995; Swinden *et al.*, 1997; van Staal, 2007; van Staal and Barr, *in press*). Obduction of the LBOT was coincident with the closure of the Humber Seaway, the oceanic tract that formed between the Dashwoods Block and the Laurentian margin (Waldron and van Staal, 2001), and the closure of this ocean resulted in the formation of the rocks of the Baie Verte belt: the Baie Verte Oceanic Tract (BVOT) (Hibbard, 1983; Bedard *et al.*, 1999; van Staal, 2007; Skulski *et al.*, 2009; Skulski *et al.*, 2010; van Staal and Barr, 2012). The BVOT contains ophiolitic rocks (e.g., Pacquet Harbour Group) that are ~490–488 Ma (Dunning and Krogh, 1985; Skulski *et al.*, 2009; Skulski *et al.*, 2010), and have primitive arc affinities, including rhyolitic rocks (Piercey *et al.*, 1997; Bedard *et al.*, 1999; Bailey, 2002) (Fig. 14). The ophiolitic rocks are host to both Cu-rich VMS deposits (e.g., Tilt Cove) and Au rich bimodal mafic deposits (e.g., Rambler-Ming; see below) (Fig. 14). These ophiolitic rocks formed the basement to younger ~487–470 Ma arc-back-arc rocks of the Snooks Arm Group and equivalents (Skulski *et al.*, 2009; Skulski *et al.*, 2010). Obduction of the BVOT in the Ordovician, coupled with extension, resulted in ophiolite emplacement onto the Humber

Zone (van Staal, 2007; van Staal and Barr, *in press*), some of which host ophiolite hosted Cu-rich VMS deposits (e.g., York Harbour) (Duke and Hutchinson, 1974) (Fig. 14). The Notre Dame subzone also contains later Ordovician rocks of the Anniepsquotch Accretionary Tract (AAT) that includes ~480–473 Ma ophiolitic rocks (e.g., Anniepsquotch Ophiolite), and ~473–

462 Ma arc and back-arc rocks of the Buchans–Roberts Arm belt that host the deposits of the Buchans and Pilley's Island districts (Dunning and Krogh, 1985; Dunning *et al.*, 1987; Lissenberg, 2005; Zagorevski *et al.*, 2006) (Fig. 14).

The Exploits subzone also contains abundant VMS deposits of Cambrian to Ordovician age (Fig. 14). The deposits of the Victoria Lake supergroup are some of the oldest deposits within the Exploits subzone and formed within arc and arc-rift complexes associated with the Penobscot and Popelogan–Victoria arc systems (Dunning *et al.*, 1991; Evans and Kean, 2002; Rogers *et al.*, 2006; van Staal, 2007; Zagorevski *et al.*, 2007; van Staal and Barr, 2012; Fig. 14). The Tally Pond group (~514–509Ma) hosts some of the oldest VMS systems, including Duck Pond, Boundary, and Lemarchant, and consists of a bimodal assemblage of calc-alkalic to transitional rhyolitic and basaltic rocks with lesser carbonaceous sedimentary rocks (Evans and Kean, 2002; Rogers and van Staal, 2002; Rogers *et al.*, 2006) (Fig. 14). The Tally Pond group contains inherited zircon of Neoproterozoic age, and is underlain by Neoproterozoic (~563Ma) arc rocks of roughly similar age (*e.g.*, Sandy Brook Group; Fig. 14) and are interpreted to have formed a peri-continental/continental arc that developed upon a Neoproterozoic basement (Rogers *et al.*, 2006; McNicoll *et al.*, 2010). The Tally Pond group is in thrust contact with the Long Lake group, which consists of bimodal volcanic rocks that are late Cambrian (~505 Ma) and host the Long Lake deposit and other showings (Evans and Kean, 2002; Rogers and van Staal, 2002; Rogers *et al.*, 2006) (Fig. 14). The younger belts in the Victoria Lake supergroup include the Tulks group (~498 Ma), the Pats Pond group (~488 Ma) (Rogers and van Staal, 2002; Rogers *et al.*, 2006), the Sutherlands Pond group (*ca.* 462 – 457 Ma; Zagorevski *et al.*, 2008; Dunning *et al.*, 1987), and the Wigwam Brook group (~453 Ma; van Staal *et al.*, 2005; Zagorevski *et al.*, 2007), which are parts of the classically described Tulks Volcanic Belt (TVB), a terminology we use herein (McKenzie *et al.*, 1993; Evans and Kean, 2002; Hinchey, 2011). The TVB lies in fault contact with the Long Lake group (Fig. 14). The TVB has varying styles of mineralization ranging from shale- and rhyolitic volcanoclastic-rich deposits (*i.e.*, Bathurst-like) in the south of the belt (*e.g.*, Tulks East, Boomerang), ranging to hybrid VMS epithermal-type deposits in the north of the belt (*e.g.*, Bobby's Pond, Daniel's Pond; Hinchey, 2011; Fig. 14). The northeastern portion of the Exploits Subzone also hosts VMS mineralization within primitive arc rocks of the lowermost portion of the Wild Bight Group (Swinden *et al.*, 1990; MacLachlan and Dunning, 1998; MacLachlan *et al.*, 2001; Fig. 14). The Glovers Harbour Formation of the Wild Bight Group is the host to the VMS mineralization in the group, and consists of a ~486 Ma mafic dominated, bimodal assemblage of boninite and low-Ti arc tholeiites (Swinden *et al.*, 1990; MacLachlan and Dunning, 1998; MacLachlan *et al.*, 2001). The Glovers Harbour Formation is host to the Point Leamington and Lockport deposits (Walker and Collins, 1988) (Fig. 14).



**Figure 14.** Geological map of the Newfoundland Appalachians with tectonostratigraphic zones, accretionary tracts, VMS deposits, their classifications and associated belts. Map tectonostratigraphy modified from van Staal (2007) and van Staal and Barr (in 2012). Volcanogenic massive sulphide (VMS) deposit classification from Piercey (2007) and Hinchey (2011). Abbreviations: BBL=Baie Verte Brompton Line; BOI=Bay of Islands; BVOT=Baie Verte Oceanic Tract; CF=Cabot Fault; CP=Coy Pond Complex; DBL=Dog Bay Line; GBF=Green Bay Fault; GRUB=Gander River Ultramafic Belt; LBOT=Lushs Bight Oceanic Tract; LCF=Lobster Cove Fault; LR=Long Range; LRF=Lloyds River Fault; PP=Pipestone Pond Complex; RIL=Red Indian Line; SA=St. Anthony; TP=Tally Pond Belt; TU=Tulks Volcanic Belt; VA=Victoria Arc; B=Wild Bight Group.

## VMS DEPOSIT CLASSIFICATION AND SETTING

Volcanogenic massive sulphide (VMS) deposits form as a result of the syngenetic exhalation of metalliferous hydrothermal fluids upon or near the sea floor. These deposits are classified in numerous manners (e.g., metal content, type locality), but the most robust and widely accepted classification involves the utilization of host lithostratigraphy and geodynamic setting (Barrie and Hannington, 1999; Franklin *et al.*, 2005; Galley *et al.*, 2007). Under the lithostratigraphic classification deposits are classified into six groups, including (Fig. 15): 1) mafic; 2) mafic-siliciclastic (or pelitic-mafic); 3) bimodal-mafic; 4) bimodal felsic; 5) felsic siliciclastic; and 6) hybrid bimodal felsic. With minor exception, all of these various sub-types of the VMS clan are found in Newfoundland. The details of each of these deposit classifications are as follows (*op. cit.*):

1. **Mafic** – these are VMS deposits hosted by mafic/ophiolitic rocks where the deposits are typically Cu-(Zn)-rich and hosted within basaltic flows or sheeted dykes. These are the Cyprus-type deposits and the deposits of the Springdale Peninsula, Betts Cove Complex, and the ophiolitic rocks of the Bay of Islands are Newfoundland examples (Figs. 14 and 15).
2. **Mafic Siliciclastic** – these are VMS deposits hosted in sequences rich in sedimentary rocks, often carbonaceous or turbiditic in nature, and interlayered with abundant basaltic intrusive and extrusive rocks, with or without ultramafic rocks. These deposits are the Besshi-type deposits, are typically Cu-Co-Au-enriched, and there are no bona fide examples of this deposit type in the Newfoundland Appalachians (Fig. 15).
3. **Bimodal Mafic** – these are VMS deposits hosted in belts that are mafic dominated, but where the deposits are often hosted by felsic rocks. Often these environments are primitive arc terranes, they are often polymetallic, but with abundant Zn and Cu. These are the VMS deposits that are common to the Noranda and Flin Flon districts, and Newfoundland Appalachian examples include deposits such as Ming, Rambler, and Point Leamington (Figs. 14 and 15).
4. **Bimodal Felsic** – these are VMS deposits hosted in belts that are bimodal, but felsic dominated, and in which the deposits are typically hosted by felsic volcanic and volcanoclastic rocks. They are the polymetallic (Zn-Pb-Cu-Au-Ag-Ba) Kurokotype deposits. The Buchans, Duck Pond, and Lemarchant deposits are examples of this type of deposit in the Newfoundland Appalachians (Figs. 14 and 15).
5. **Felsic Siliciclastic** – these are VMS deposits that are hosted within volcanic and sediment-rich belts, where there are abundant siliciclastic sedimentary rocks, often graphitic, iron formation, and the volcanic rocks are often volcanoclastic. This deposit type is typical of the Brunswick-type deposits in the Bathurst Mining Camp, they are polymetallic, and the Tulks East and Boomerang deposits of the Newfoundland Appalachians are examples of this sub-group (Figs. 14 and 15).
6. **Hybrid Bimodal Felsic** – these deposits are those that are like bimodal felsic deposits, but they contain additional features, including aluminous alteration attributes, precious metal enrichments, and enrichments in epithermal suite elements (e.g., Bi-Te-Hg-Sb-As). They are interpreted to be shallow water VMS systems with features hybrid between epithermal and VMS deposits. They are similar to the deposits at Eskay Creek and in the Bousquet-LaRonde camp; the Daniel's Pond deposit represents an example of this sub-type (Fig. 15).



The various deposits types above are found in different VMS belts within Newfoundland.

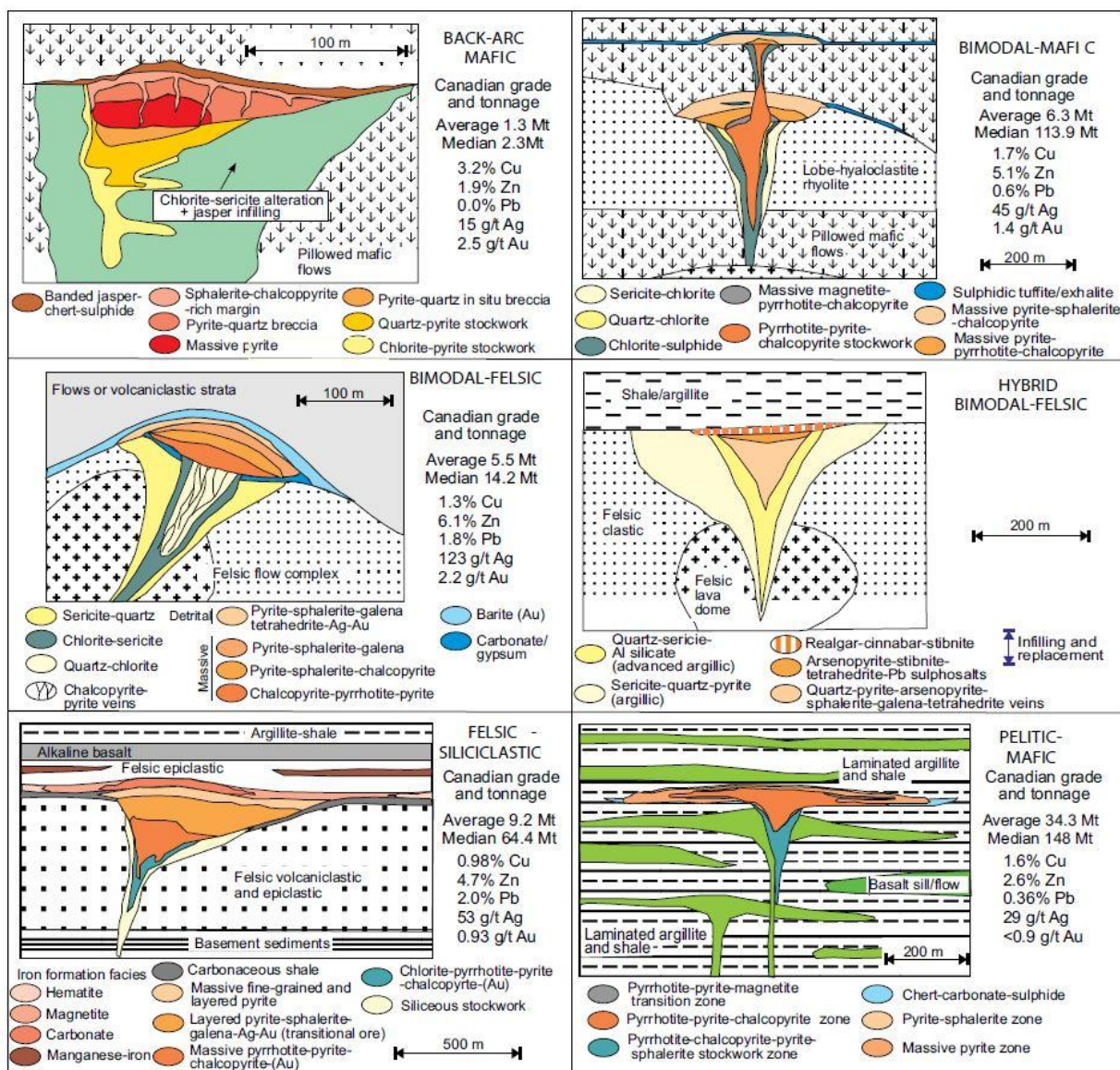
In the Exploits subzone, the belts include (Fig. 14):

1. **Tally Pond Belt** – this belt is hosted by the ~514–509 Ma Tally Pond group, and contains the bimodal felsic Duck Pond, Lemarchant, and Boundary deposits;
2. **Long Lake Belt** – this belt is hosted by the bimodal, yet felsic dominated ~505 Ma Long Lake group, and it contains the bimodal felsic Long Lake deposit;
3. **Tulks Belt** – this belt hosted by the bimodal, yet felsic volcanoclastic-dominated ~498–453 Ma Tulks Volcanic Belt. The belt has highly variable deposits, ranging from felsic siliciclastic deposits (Boomerang, Tulks East), bimodal felsic deposits (Tulks Hill, Victoria Mine), and hybrid bimodal felsic deposits (Bobby's Pond, Daniel's Pond).
4. **Point Leamington Belt** – this belt is hosted by the ~486 Ma primitive arc rocks of the Glovers Harbour Formation of the Wild Bight Group in the northeastern Notre Dame Bay area. The belt contains bimodal mafic deposits, including Point Leamington and Lockport.

In the Notre Dame subzone the belts include (Fig. 15):

1. **Springdale Belt** – this belt is hosted by the ~505 Ma ophiolitic rocks of the Lushs Bight group and consists of mafic-type deposits, including Little Deer, Whalesback, Little Bay, and Colchester.
2. **Baie Verte Belt** – this belt consists of deposits hosted by ~489 Ma ophiolitic rocks of the Betts Cove ophiolite complex and ~487 Ma rocks of the Pacquet Harbour Group. In both sequences the deposits are hosted by primitive arc rocks, with mafic-type deposits hosted within boninitic and tholeiitic pillow lavas in the Betts Cove complex, whereas precious metal-rich bimodal mafic deposits are hosted by rhyolitic rocks within the Rambler Camp, including the Ming, Rambler Main, East, and Big Rambler Pond mines.
3. **Buchans–Roberts Arm Belt** – this belt is hosted by ~471–465 Ma calc-alkalic to much lesser tholeiitic rocks of the Anniopsquotch Accretionary Tract. Deposits of the Buchans area are bimodal felsic deposits hosted by the Buchans Group. Deposits in the Roberts Arm/Pilley's Island area are bimodal felsic deposits hosted by the Roberts Arm Group. The Skidder Formation of the Red Indian Lake Group hosts the mafic dominated Skidder deposit.





**Figure 15.** Lithostratigraphic classification of volcanogenic massive sulphide (VMS) deposits. Classification based on Barrie and Hannington (1999), Franklin et al. (2005), and Galley et al. (2007). Diagram modified from Galley et al. (2007).

## DAY 6 — FIELD STOPS

Where available, all stops are given in universal transverse mercator (UTM) coordinates using North American Datum 1927 (NAD27). All are in UTM zone 21.

### Stop 6.1: Ski Hill Buchans (UTM 21 509824E 048260N)

#### Location.

This stop is located behind the core storage facility and the vehicles should be parked either at this facility or along the Sandy Lake Road (location GB-5 on Figure 16). Participants

should follow field trip leaders and walk to the top of Ski Hill. Please be careful walking on the trail up the ski hill and the general area and terrane around the core storage facility.

### Description.

This area contains an outstanding regional view of the Buchans and surrounding area. Ski Hill itself contains basaltic to andesitic volcanic and volcanoclastic rocks of the Ski Hill Formation, the deeper footwall basaltic rocks to the Buchans deposits. Towards the southeast and in the distance south of Red Indian Lake, one can see Harpoon Hill and Hungry Hill which are intrusions into the rocks of the Victoria Lake supergroup. Red Indian Lake and rocks in the foreground represent the Red Indian Line and peri-Laurentian rocks. Also present in the immediate Buchans area one can see the relict pits from old mine operations, including the glory hole from the Lucky Strike pit. Towards the north, west, and east are the rocks of the younger Silurian Topsails Igneous Suite.

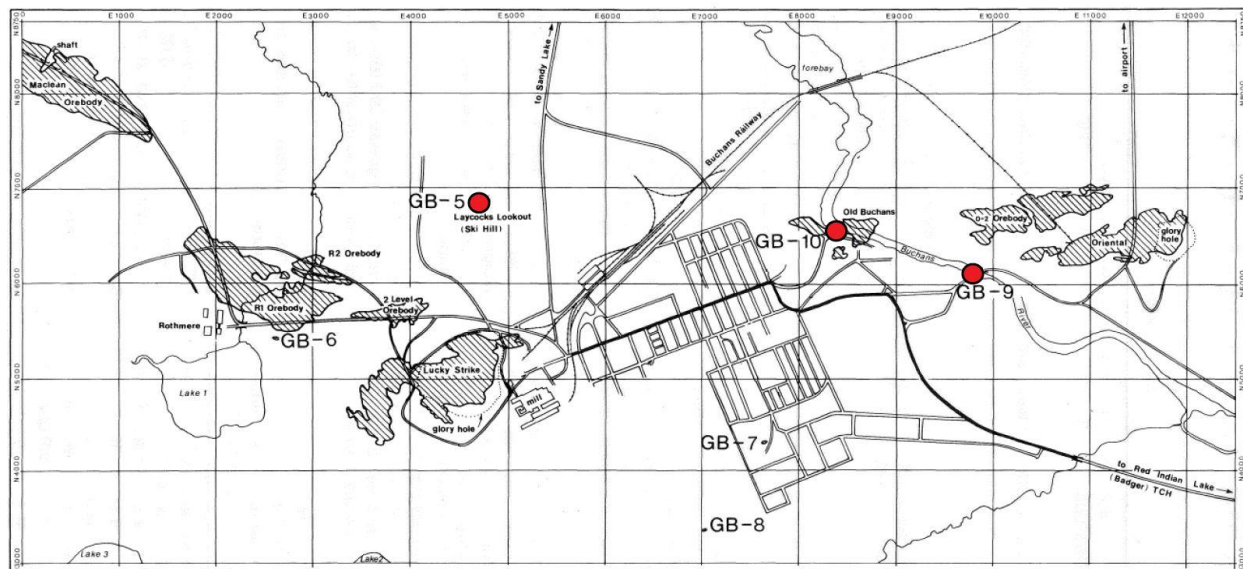
## Stop 6.2: Discovery Outcrop from the Buchans Orebodies (UTM 21 510886E 5408118N) NO HAMMERING PLEASE!

### Location.

This stop is located near the Buchans River and easily accessible just off the main street of Buchans (location GB-10 on Figure 16). Park vehicles near the building just off of Main Street and walk towards the Buchans River. Be careful of slippery rocks and ensure your footing.

### Description.

This is the location of the original prospector's discovery and what became the Old Buchans Orebodies (Swinden *et al.*, 1988). The outcrops consist of barite breccias with sulphide clasts, and grey to white rhyolitic clasts that are angular with interstitial pyrite. The outcrop contains a fault, Buchans River Thrust of Swinden *et al.* (1988), with some of the rhyolitic fragmental rocks being potentially rounded by the fault. At the west end of the outcrop are granitic cobbles potentially representing the Feeder Graniodiorite with basalt, rhyolite/dacite, and sulphides.



**Figure 16.** Field trip stops for the Buchans region. Diagram from Swinden *et al.* (1988).



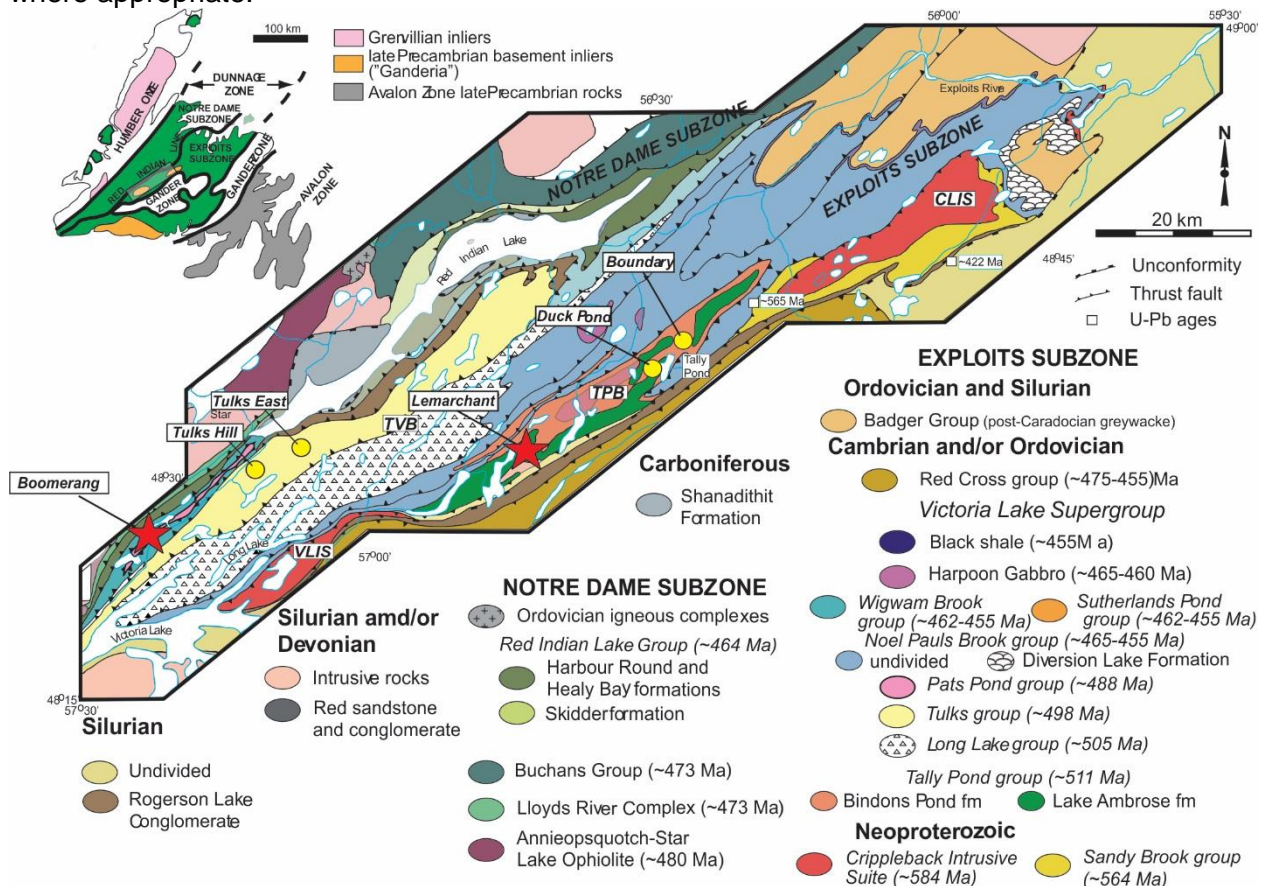
**Stop 6.3: Arkose of the Sandy Lake Formation**  
**(UTM 21 511399E 5407944N)**  
*(Modified from Swinden et al., 1988)*

This stop is within walking distance from the previous stop and consists of thick sections of arkose that are typical of the Buchans Group (location GB-9 on Figure 16). The rocks contain varying amounts of quartz, plagioclase, and rhyolitic clasts, and under the bridge there are matrix-supported conglomerates with rhyolitic clasts and large quartz phenocrysts. These likely represent the weathering products of rhyolitic rocks of the Buchans Group and the hosts to mineralization.

*Participants will drive from STOP 6.3 to the core storage facility in Buchans Junction (6.4).*

**Stop 6.4: Canadian Zinc Corporation core shack**

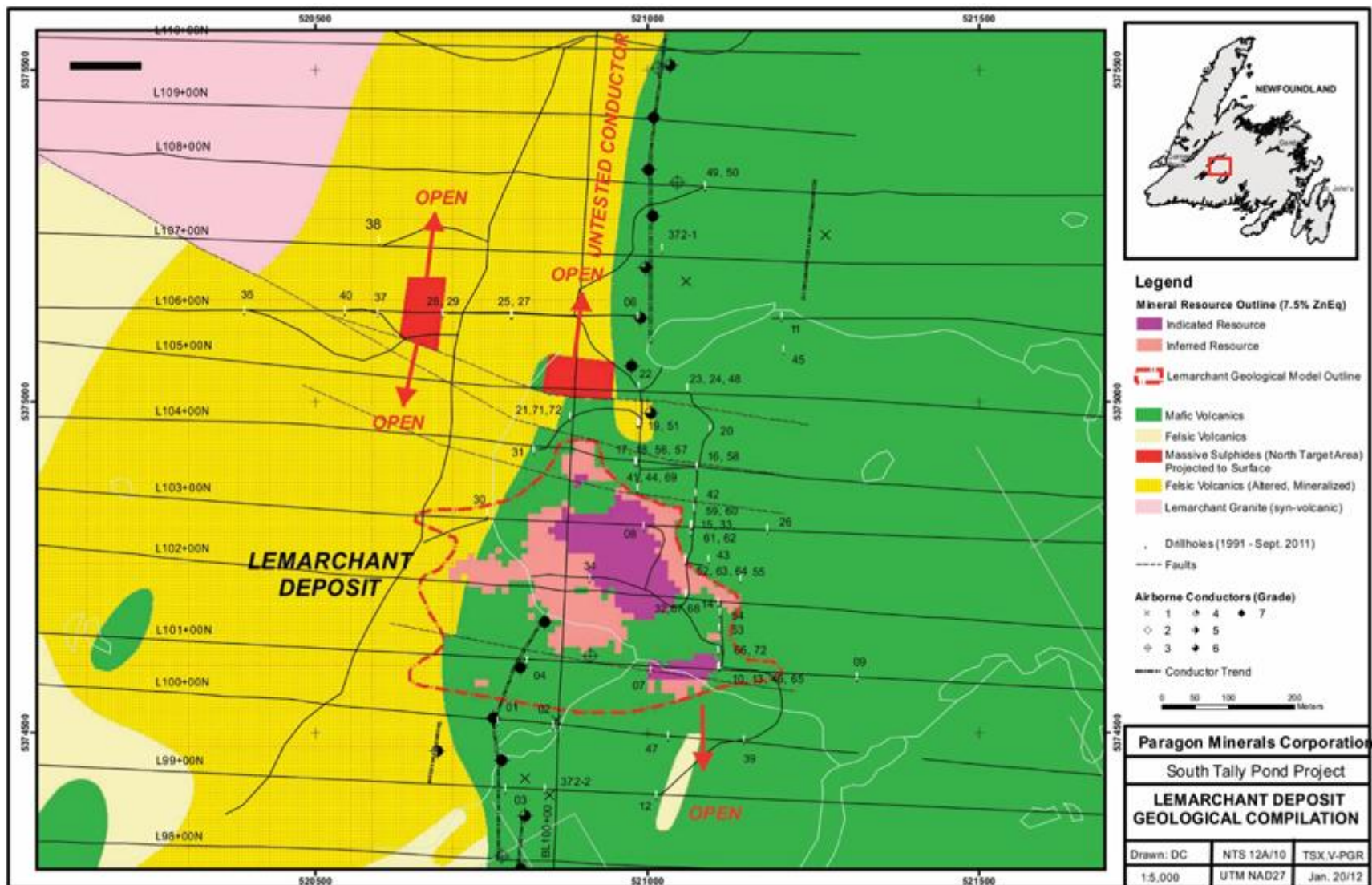
This stop will examine drill core from the Lemarchant and Boomerang deposits (Fig. 17). The drill core facility is located at Buchans Junction and all participants must adhere to all safety regulations of Canadian Zinc Corp., including wearing proper personal protective equipment, where appropriate.



**Figure 17.** Geological setting of the Victoria Lake supergroup, outlining the different VMS deposits in the Tully Pond group and Tullys volcanic belt. Diagram modified from McNicoll et al. (2010).

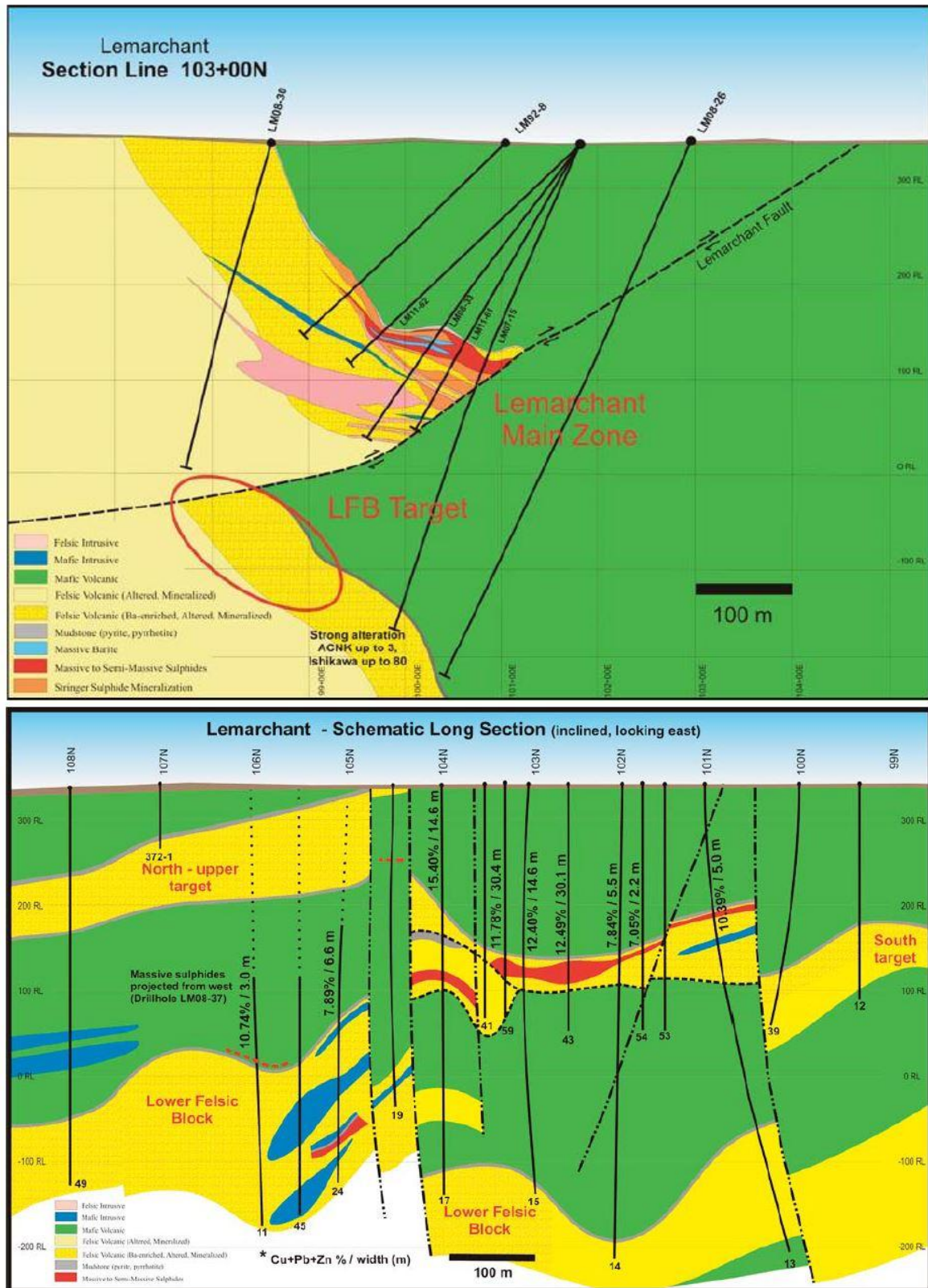
### **Lemarchant Deposit.**

The Lemarchant VMS deposit is located approximately 10km to the southwest of the Duck Pond deposit and is also hosted by the Tally Pond group (Figs. 18 and 19). A recent NI-43-101 resource was completed and yielded an indicated resource of 1.24 million tonnes @ 5.38% Zn, 0.58% Cu, 1.19% Pb, 1.01 g/t Au and 59.17 g/t Ag and an inferred resource of 1.34 million tonnes @ 3.70% Zn, 0.41% Cu, 0.86% Pb, 1.00 g/t Au and 50.41 g/t Ag (Paragon Minerals Corp., press release, March 8, 2012 and Fraser *et al.*, 2012). The deposit is hosted within a bimodal assemblage of basalts and rhyolitic rocks that have been variably dissected by thrust faults (Copeland *et al.*, 2008; Copeland *et al.*, 2009; Fraser *et al.*, 2012; Figs. 18 and 19). The deposit's hanging wall is dominated by pillowed and massive basalt flows with lesser interflow chert and hydrothermal sedimentary rocks (Figs. 18 and 19). The footwall and the host rocks to the mineralization contain blocky rhyolitic flows and associated volcaniclastic rocks very similar to those present in the Mineralized Block at Duck Pond. However, mineralization at the Lemarchant deposit is dominated by massive sulphide intergrown with barite, interpreted to have formed on the seafloor rather than by subseafloor replacement (Copeland *et al.*, 2008, 2009; Fraser *et al.*, 2012; Figs. 18 and 19). The mineralization is dominated by Zn–Pb rich sulphides with abundant galena, sphalerite, tetrahedrite and much lesser pyrite, chalcopyrite, bornite, covellite, digneite, cubanite, and trace amounts gold and stromeryite; all of which is associated with barite (Copeland *et al.*, 2009). The deposit has been interpreted to represent a classic Kuroko-type VMS system that formed from low temperature fluids.



**Figure 18.** Surface geology, drill hole locations, and resource classifications for the Lemarchant VMS deposit (Piercey and Hinchey, 2012).



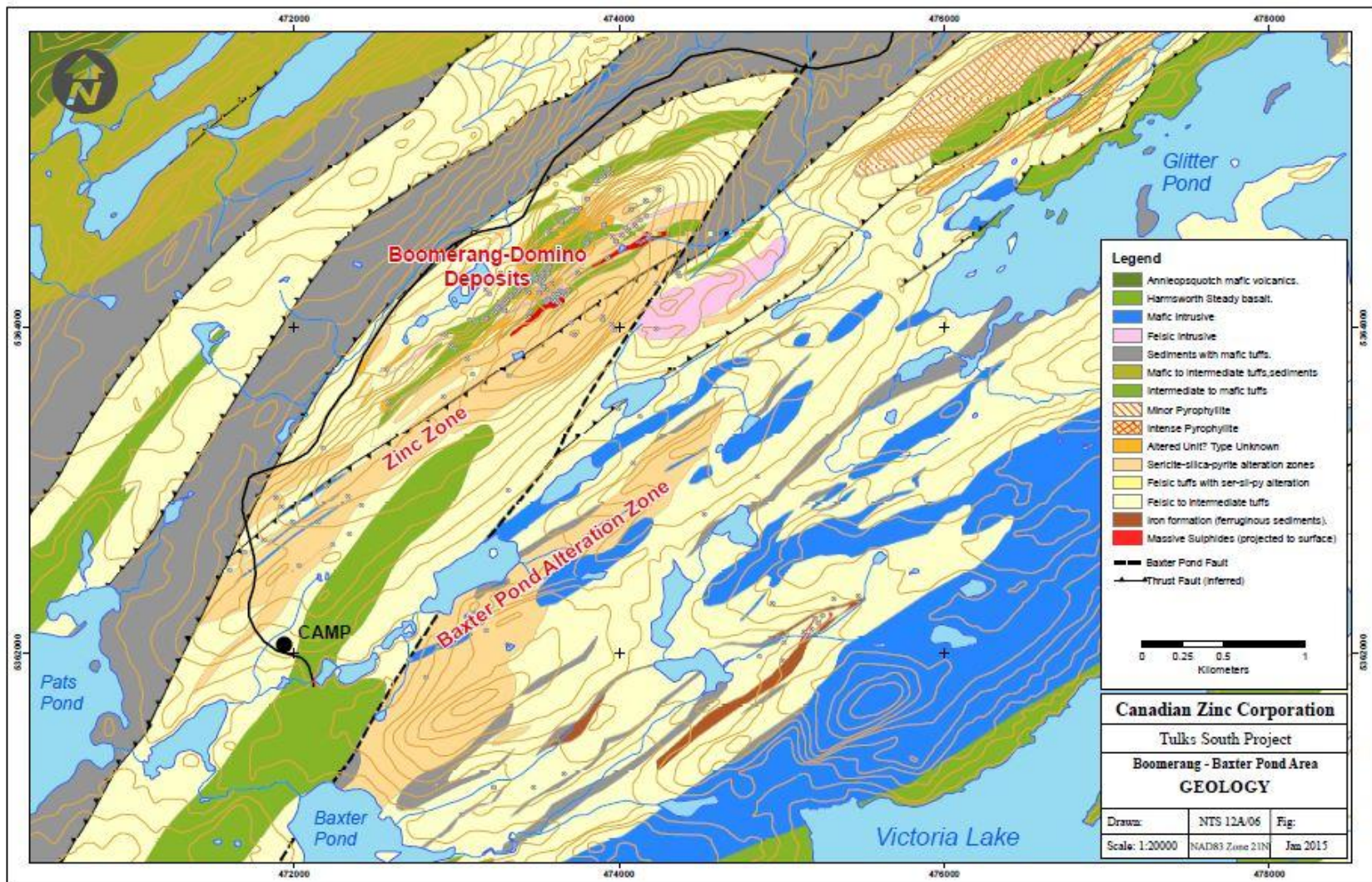


**Figure 19.** Schematic cross section and long section through the Lemarchant VMS deposit (Piercey and Hinchey, 2012).

### **Boomerang Deposit.**

The Boomerang Deposit is located approximately 17.5 km southwest of the southern tip of the Red Indian Lake and is hosted in the Tulks volcanic belt (Figure 17, Hinchey, 2007; 2011). The Boomerang deposit consists of three lenses from southwest to northeast are: Boomerang, Domino and Hurricane. The Hurricane is located 500 m northeast and along strike with Boomerang; whereas Domino lens is approximately 200 m northeast and 100 m deeper than the Boomerang deposit and is interpreted to lie in a different stratigraphic horizon (Figure 20). A NI-43-101 report completed in 2007 yielded indicated resources at Boomerang estimated at 1.36 Mt grading 7.09 wt. % Zn, 3.00 wt. % Pb, 0.51 wt. % Cu, 110.43 g/t Ag, and 1.66 g/t Au with inferred resources at 0.69 Mt grading 6.5 wt. % Zn, 2.8 wt. % Pb, 0.4 wt. % Cu, 95 g/t Ag, and 0.9 g/t Au (De Mark and Dearin, 2007). The inferred resources at Domino are estimated at 411,200 tonnes grading 6.3 wt. % Zn, 2.8 wt. % Pb, 0.4 wt. % Cu, 94 g/t Ag, and 0.6 g/t Au (De Mark and Dearin, 2007). The Hurricane has non-NI-43-101 compliant resources estimated at 55,100 tonnes grading 13.40 wt. % Zn, 7.0 wt. % Pb, 1.20 wt. % Cu, 159.0 g/t Ag and 2.90 g/t Au (A. Marcotte, personal communication, 2015). The Boomerang deposit is considered to be a felsic-siliciclastic type VMS deposit and consists dominantly of felsic volcanoclastics with lesser intercalated sedimentary and mafic volcanics. The deposit's hanging wall consists of undifferentiated locally fining upwards, felsic to intermediate volcanoclastic and epiclastic rocks dominated by ash- and quartz-feldspar crystal tuff, black shale, argillite, greywacke, chert, volcanoclastic conglomerates/breccias and bimodal, locally amygdaloidal, sills (Figure 21; Hinchey, 2007; 2011). The footwall and the host rocks to the mineralization consist of strongly altered fine-grained, crystal-ash tuffs with local lapilli tuffs and fine-grained sedimentary rocks, such as black shales, argillite and chert (Figure 21). The mineralization is dominated by fine- to medium-grained banded and wispy intergrowths of red and honey sphalerite, galena, chalcopyrite and pyrite with lesser gold and silver. The deposit is interpreted to have formed via sub-sea floor replacement which is evident by the relic quartz crystals and altered lapilli fragments which occur within the bedded sulphides.





**Figure 20.** Geological map of the Boomerang VMS deposit (Canadian Zinc Corp website, 2016).



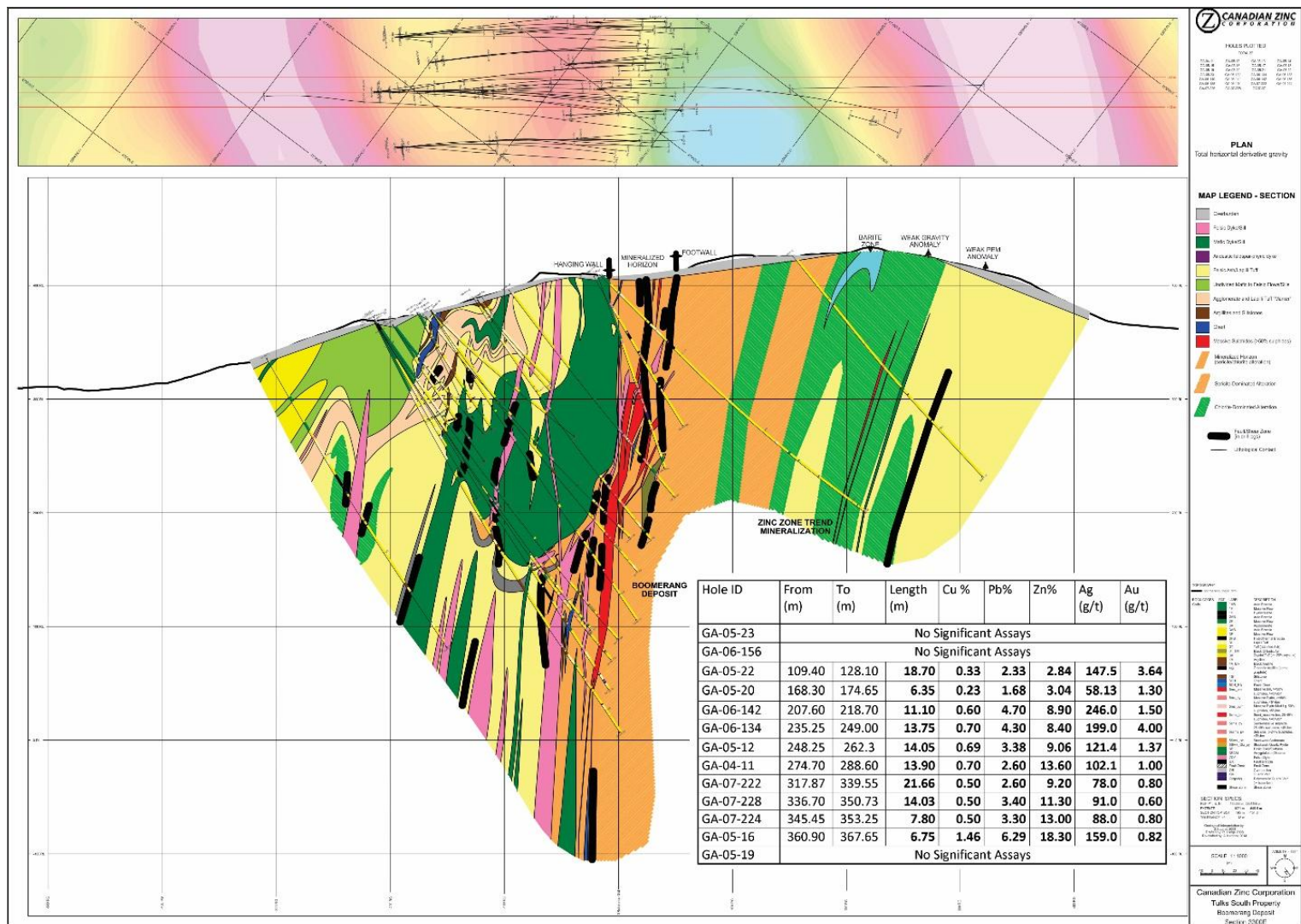
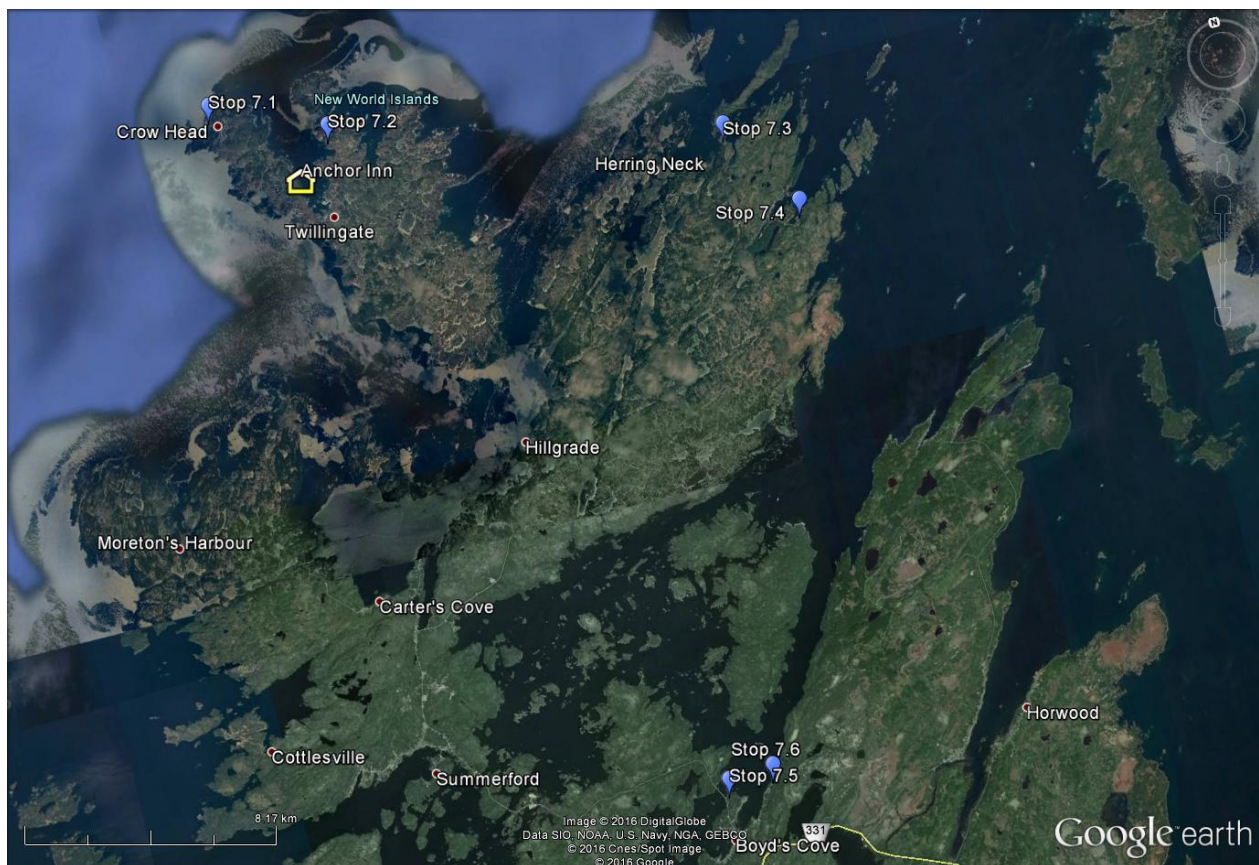


Figure 21. Cross section through the Boomerang VMS deposit (Canadian Zinc Corp website, 2016).

## DAY 7: GEOLOGY OF EASTERN NOTRE DAME BAY

### DAY 7 — STOP LIST

- Stop 7.1: The Old Sleepy Cove Mine
- Stop 7.2: The Oldest and Youngest Intrusive Rocks in Notre Dame Bay
- Stop 7.3: Clarkes Cove—Silurian unconformity
- Stop 7.4: Rogers Cove—Silurian mélange
- Stop 7.5: Reach Run—Dunnage mélange
- Stop 7.6: Beothuck Interpretation Centre



## GEOLOGIC SETTING

Two geologic subzones make up Eastern Notre Dame Bay of North central Newfoundland, bound by the Lukes Arm Fault (Fig. 22)—a steep structure that separates Cambrian and Early Ordovician volcanic and intrusive rocks to the north (Notre Dame Subzone) from Early Ordovician volcanic rocks, Ordovician-Silurian shales and turbidites, and Silurian redbeds to the south (Exploits Subzone). The southern extent of the of Notre Dame Subzone represents the Chanceport Group, a sequence of mafic pillow lavas, lesser pillow breccias and minor turbidites correlated to the Robert Arm Group to the west (Dean, 1978). These rocks are bipartite and include both calc-alkalic basalt-andesite and island-arc tholeiitic basalts. The Chanceport Group is progressively attenuated to the east of the Moreton's Harbour peninsula due to convergence of the Lukes Arm and Chanceport fault, and is pinched out where the two faults merge on the northeastern part of the New World Island (Figs. 22 and 23).

The Chanceport Fault structurally juxtaposes the Moretons Harbour Group, Sleepy Cove Formation and Twillingate Granite from the Chanceport Group. The Twillingate granite consists of medium- to coarse-grained trondhjemite, dated as  $507 \pm 3$  Ma, that intrudes the Sleepy Cove Formation.

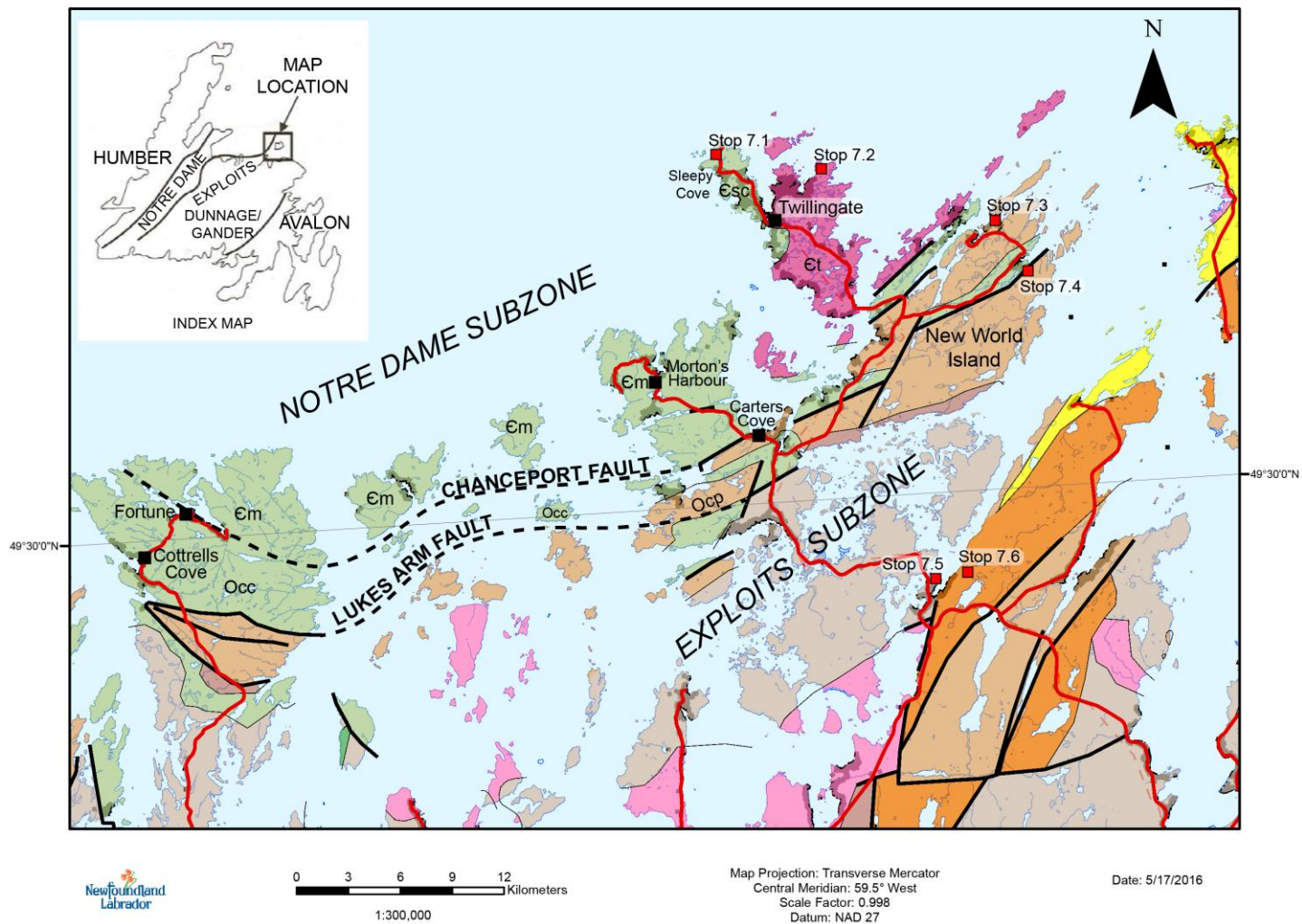
The Sleepy Cove Formation consists of mafic volcanic rocks and minor mafic dykes, with rare felsic volcanic rocks and sedimentary rocks (Fig. 23). Mafic volcanic rocks comprise mainly pillow lavas and local pillow breccias and massive flows. Pillows range between 30 to 50 cm, and the rocks have been metamorphosed to greenschist facies and now consist of the assemblage chlorite, albite and sphene with local minor secondary amphibole, magnetite and epidote. Pervasive chloritic alteration yields a distinctive dark green to black rock colour. The volcanic rocks are variably sheared and deformed and contain local chlorite- and/or calcite- filled amygdules. Abundant northwest-trending faults crosscut the sequence, with strong topographic expressions and local strong carbonatization of adjacent rocks. due to the lithological monotony of the rocks, it is difficult to constrain repetition or excision of stratigraphy; hence, no meaningful estimate of original thickness is possible.

Ordovician and Silurian rocks crop out in three belts on eastern New World Island between the Dunnage Mélange and the Lukes Arm Fault (Fig. 22; Williams, 1963). In the Southeast Belt, Middle Ordovician black shales pass conformably upwards through sandstone turbidites into Silurian conglomerates; Silurian mélange caps this section. In the Central Belt, Middle Ordovician and older volcanic rocks, limestones, and black shales also pass conformably upwards through sandstone turbidites into Silurian conglomerates. In the Northwest Belt, however, Ordovician volcanic rocks are overlain unconformably by Silurian conglomerates (Stop 7.2).

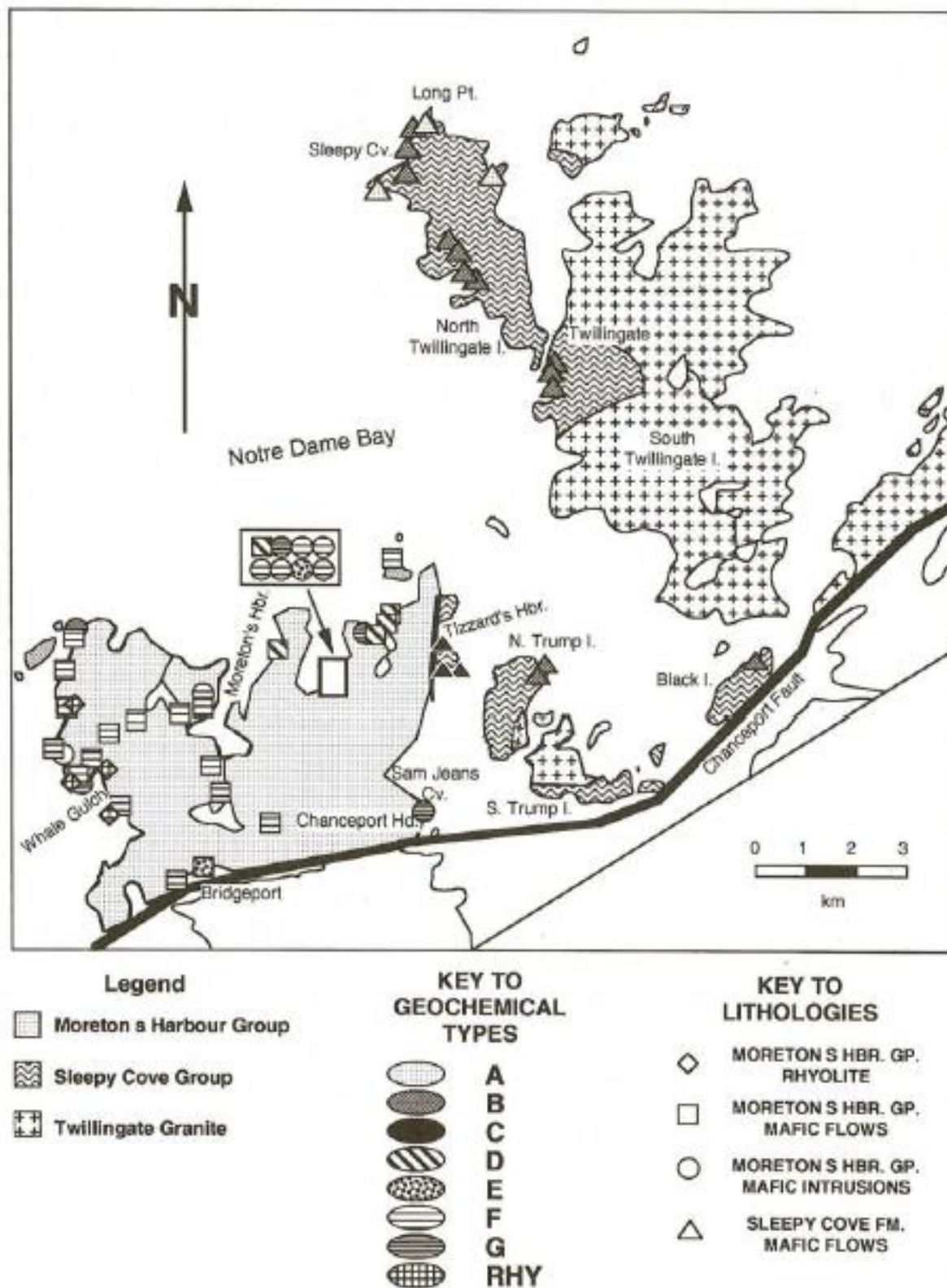
Silurian mélange (Stop 7.3) occurs within a steep fault zone that separates the Southeast and Central belts. It is composed of a shaly matrix (Silurian) and coarse clasts of black shales, limestones, sandstones, and basalts. These clasts are typical of rocks of the Central Belt.

The Dunnage Mélange (Stop 7.4) occupies an extensive area adjacent to the Southeast Belt (Kay, 1976). Its matrix is dark shale of Early Ordovician age. Blocks are dominantly elastic sedimentary and volcanic rocks of Cambrian and Early Ordovician age and range up to 3,000 ft (1,000 m) in size.





**Figure 22.** General geology of the eastern part of Notre Dame Bay. Et = Twillingate batholith; Esc = Sleepy Cove Group; Em = Moretons Harbour Group; Occ = Cottrells Cove Group; Ocp = Chanceport Group. Modified from geoscience atlas of Newfoundland and Labrador (<http://geoatlas.gov.nl.ca/>)



**Figure 23.** General geology of the Moreton's Harbour—Twillingate are. Symbols show sample locations, rock types and geochemical affinities. From Swinden (1996).

## DAY 7 — FIELD STOPS

### Stop 7.1: The Old Sleepy Cove Mine

Mineralization at Sleepy Cove was probably recognized well before the turn of the century, but it was not until the early 1900's that there were any serious attempts at development. At this time, a mining operation was initiated by the Great Northern Copper Company, which reportedly spent considerable sums on a mining plant and related infrastructure. A shaft was sunk to a depth of ~36.5 m, and an open cut 49 m long was evacuated. Mining operations continued sporadically until the First World War, but little ore was ever shipped.

#### Location.

From the parking lot in the Sleepy Cove park, follow the walking trail down to the shoreline below the parking lot. The cove is immediately ahead is Sleepy Cove, and the site of the old mine is on the rocky point about 100 m to the north.

#### Description.

Walking along the shoreline, the cliffs to the right are pillow lavas of the Cambrian Sleepy Cove Group, cut by the fg felsic dykes related to the Twillingate Trondhjemite. Walking out along the rocks north shore of the Sleepy Cove, alteration and mineralization related to the Sleepy Cove deposit is encountered. A pervasive, regional chloritization is overprinted by heterogeneous epidote and/or black chlorite alteration with associated sulphide minerals (po, py and minor ccp).

Alteration is most intense close to the main shaft and includes local alteration breccias in which fragments of relatively unaltered rock are hosted by a matrix of black chlorite and sulphides. The exposed alteration and mineralization is a good examples of relatively lean volcanogenic stockwork system. The alteration assemblages exposed here are typical of those in the periphery of more intense systems associated with exhalative sulphides elsewhere in central Newfoundland. Judging from the results of limited diamond drilling here in 1970, the tenor of the mineralization does not improve appreciably either below the main shaft or along strike to the northeast.

A small ore dump on the hillside, to the left of a small adit, contains a sampling of fist-sized fragments of mineralized rock. The alteration and mineralization in these samples are similar to the exposures near the shaft, and are likely from underground ore spilled during loading.

A walking trail near this dump leads up the hill to the northeast, toward the flat ground under the lighthouse. Between 1 and 1.5 km along this trail, a number of old trenches and an old exploration shaft are encountered. Sparsely mineralized material in dumps around the edges of these excavations contains the same style and amount of mineralization as at the main zone in Sleepy Cove.

The Sleepy Cove deposit and the prospects along strike to the northeast appear to be remnants of a single large volcanogenic stockwork system. The strong linear expression of the mineralization suggests that it was originally controlled by faulting and has been modified by later faulting.

## **Stop 7.2: The Oldest and Youngest Intrusive Rocks in Notre Dame Bay**

### **Location.**

Park in the lot at the end of the road in Jenkins Cove and walk around the shore to the left.

### **Description.**

The principal rock type which outcrops on the shoreline is the Twillingate Trondhjemite, the oldest intrusive rock in Notre Dame Bay. At this locality, the Twillingate Trondhjemite is a medium grained, equigranular to slightly porphyritic rock.

The trondhjemite is cut by a 10 to 20cm wide, north-striking, black lamprophyre dyke. This dyke is a biotite-phyric and undeformed, and it is interpreted to record the tensional environment related to the breakup of the North American Margin.

## **Stop 7.3: Clarkes Cove—Silurian unconformity**

### **Location.**

From Cobbs Arm, continue north on Newfoundland 346. Turn right onto the road to Pikes Arm and then left onto the road to Green Cove. Near the top of the hill before descending toward Green Cove, turn right down a short, steep, side road that ends at Clarkes Cove. Walk east along the rocky beach about 300 ft (100 m) to the unconformity between conglomerates and basalts.

### **Description.**

An unconformity separating a Silurian conglomerate unit from Middle Ordovician basalts is well exposed in beach outcrops. In detail, it is a sharp, depositional surface. The overlying conglomerate unit faces northwest. Sandstones near its base contain Silurian corals. Pebbles in the conglomerates are limited in variety and of local derivation. The underlying basalts, which are massive and without bedding, appear to be no more deformed than the conglomerates (although both the basalts and the conglomerates are exceptionally competent and generally do not display pronounced effects of deformation other than tilting). It is therefore difficult to establish the relationship between basement and cover as angular or disconformable.

An unconformable relationship between Ordovician and Silurian rocks is typical of westerly parts of the Newfoundland Appalachians. This stop should prepare the visitor for appreciating the unique nature of the continuous sections exposed in the adjacent thrust sheets to the southeast.

## **Stop 7.4: Rogers Cove—Silurian mélange**

### **Location.**

Proceed to the end of the Rogers Cove road. Park there and walk through the yard of the last house (a white house with green trim belonging to a very amiable Mr. Sydney Mills). Be sure to close the gate in the front yard and take care climbing over the fence in the back yard and descending along the path to Rogers Cove.

### **Description.**

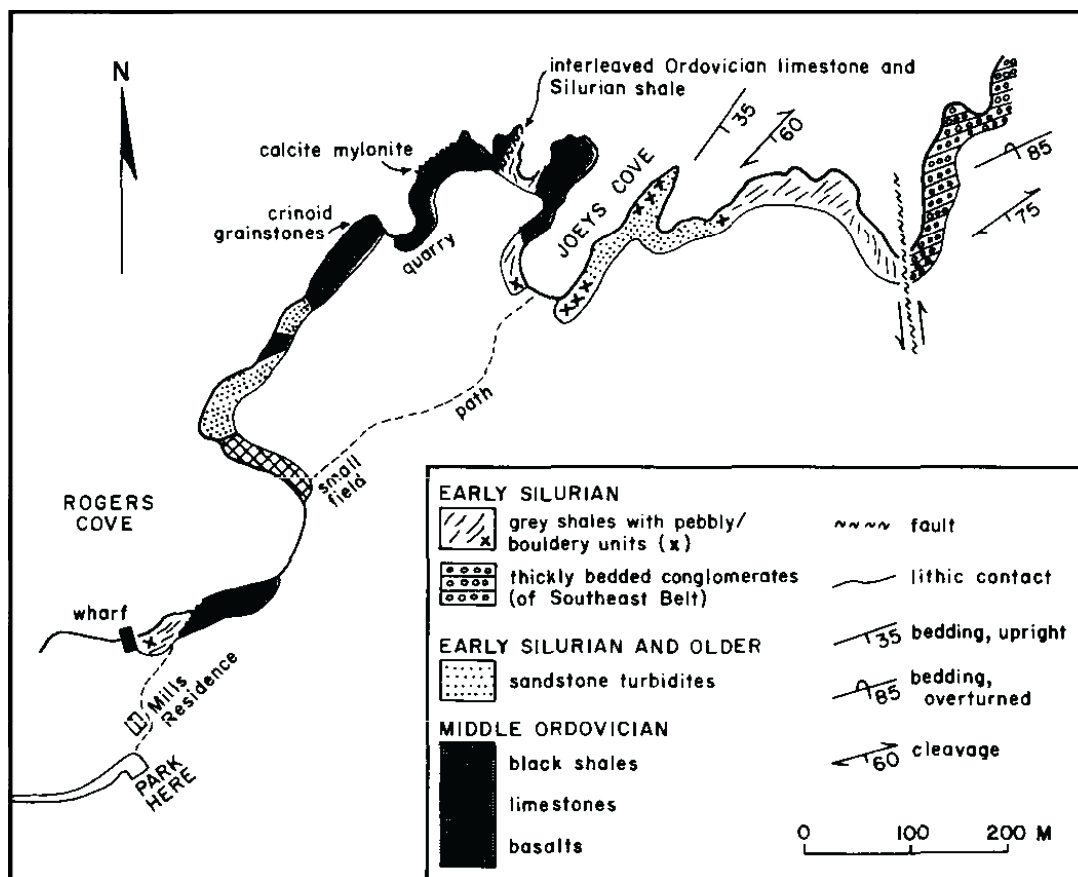
Amygdaloidal basalts, limestones, and black shales, representing typical Middle Ordovician rocks, and gray shales, which form the matrix of the *mélange*, maybe seen in Rogers Cove directly at the foot of the path that descends from the Mills residence (Fig. 24). Within the gray shales, note the scattered remains of the Silurian brachiopods *Stricklandia lens progressa* and also pebbly horizons, located several feet (meters) to the west near the wharf, that contain angular clasts of Middle Ordovician black shales.

The most spectacular exposure of *mélange* in the area is located along the northeastern shoreline of the cove. A large mass of Middle Ordovician limestone is surrounded by Silurian gray shales containing fragments, up to boulder-size, of limestone, black shale, and lesser basalt. Note the penetrations of Silurian gray shale into the Ordovician limestone: the shale appears to have been highly mobile, whereas the limestone was fragmented, locally forming inclusions in the shale matrix (a relationship analogous to xenoliths within an intrusion). Note also faulted contacts and the internally veined and brecciated limestone, which suggest high-level, extremely brittle deformation.

Additional examples of bouldery shales may be seen in Joeys Cove to the northeast of Rogers Cove, accessible by a slightly overgrown path through the woods adjacent to a fence around a small field (Fig. 24). Sandstone turbidites and shales, located along the shoreline to the east of Joeys Cove, contain Silurian brachiopods and corals and are locally complexly deformed. The more coherent beds dip and face southeast and dip less steeply than cleavage. They are structurally anomalous in comparison with thickly bedded Silurian conglomerates of the Southeast Belt that face northwest and that dip more steeply than cleavage; these are located still farther east on the far side of a sinistral cross fault. The Silurian conglomerates contain an assemblage of pebbles fairly representative of the Ordovician volcanic-tonalite-ophiolite terrane to the west that was eroded during the Taconic orogeny (Dunning, 1987; Helwig and Sarpi, 1969).

Some scrambling through the woods may be required to arrive at outcrops northwest of Joeys Cove. Along an exposed contact between Ordovician limestones and Silurian shales, the limestone and shale are delicately interleaved, indicating that the contact is tectonic. The limestones in particular display markedly inhomogeneous deformation: in the vicinity of an old quarry that faces Cobbs Arm, crinoid columns with no distortion contrast





**Figure 24.** Generalized geological map of the Rogers Cove area (Stop 7.4: Silurian mélange). From Reusch (1987).

### Stop 7.5: Reach Run—Dunnage Mélange

#### Location.

Park in the quarry on the southeast (mainland) side of Reach Run.

#### Description.

Where Newfoundland 340 crosses high ground north of Dildo Run Provincial Park, it provides a sweeping vista of Dildo Run between New World Island and Port Albert Peninsula. Many of the myriad islands and abrupt hills are discrete clasts of resistant sedimentary and volcanic rocks within the Dunnage Mélange.

The quarry on the south side of Reach Run exposes the shaly matrix of the mélange and clasts of various sizes and types set within it. The chaotic texture and lack of bedding are impressive and are fairly representative of the mélange as a whole.

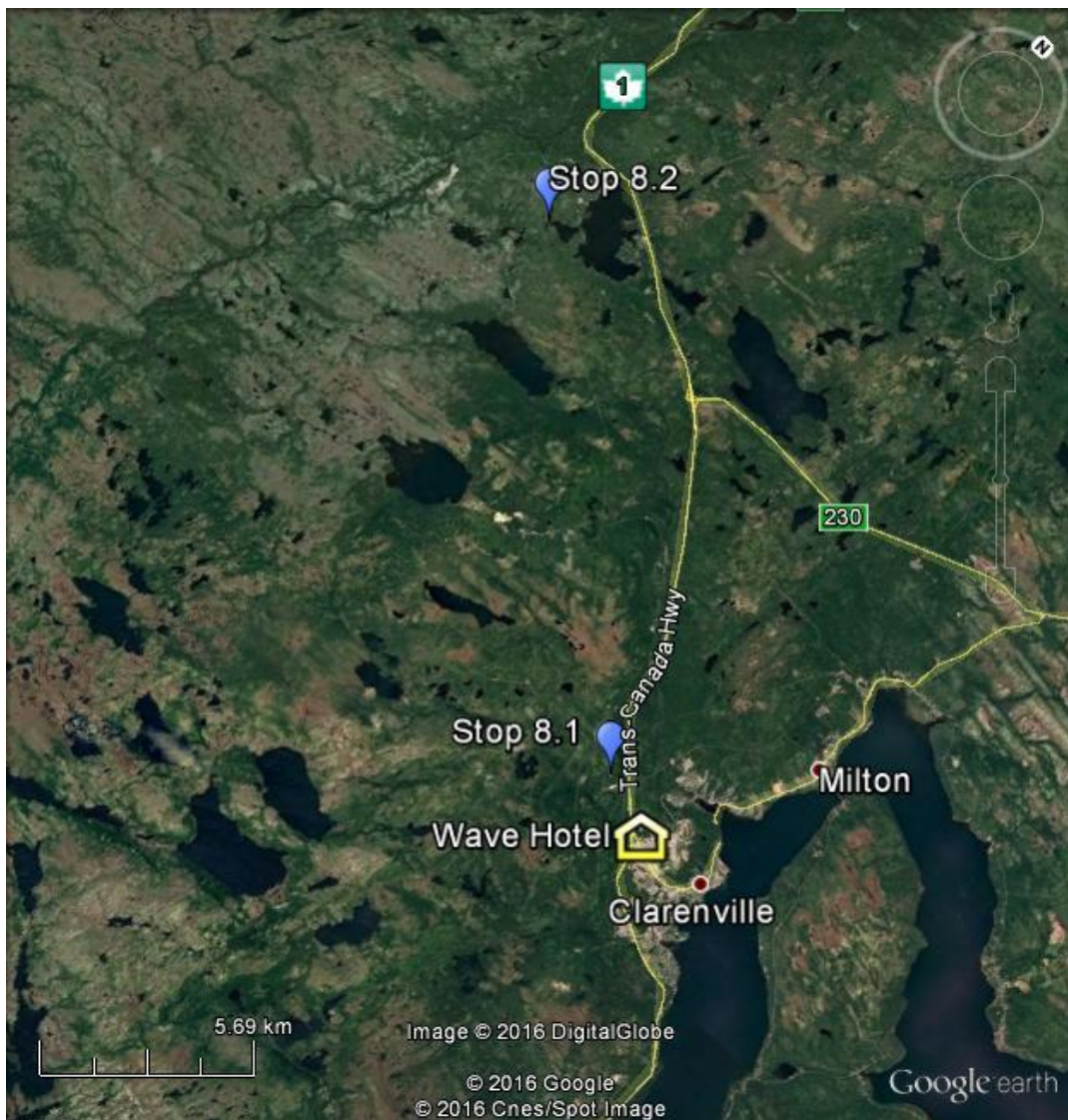
Along the shoreline of Reach Run about 300 ft (100 m) north of the quarry, the mélange matrix includes bands 2 to 10 cm thick of green and black shales. A dike of dacite porphyry exposed nearby is typical of the Coaker Porphyry, the most extensive of several types of intrusive rocks within the Dunnage Mélange (Lorenz, 1982).

### Stop 7.6: Beothuk Interpretation Centre, Provincial Historic Site

## DAY 8: EPITHERMAL SYSTEMS OF THE AVALON ZONE

### DAY 8 — STOP LIST

- Stop 8.1 Musgravetown Group
- Stop 8.2 Big Easy Prospect
  - Stop 8.2A Unaltered Musgravetown Group
  - Stop 8.2B Trench 7
  - Stop 8.2C Trench 4
  - Stop 8.2D Trench 6



## INTRODUCTION

This section contains a simplified summary and an explanation of some of the terminology that applies to epithermal deposits. Most of the information in this summary is from Taylor (2007), Sparkes (2012; 2013) and references therein. Epithermal deposits are a type of lode deposit (i.e., a mineral deposit consisting of a zone of veins, veinlets, disseminations, or planar breccias) consisting of economic concentrations of Au ( $\pm$ Ag and base metals). They form near the surface ( $<1.5$  km) by replacement or by open-space filling which typically reflects that of the structural control of the hydrothermal fluids. Epithermal deposits are distinguished on the basis of the sulphidation state of the sulphide mineralogy as belonging to one of two subtypes: 1) high sulphidation and 2) low-sulphidation (Figs. 25, 26).

High sulphidation subtype deposits usually occur close to magmatic sources of heat and volatiles, and form from acidic hydrothermal fluids containing magmatic S, C, and Cl (Fig. 26). They are typically larger and have more widespread alteration than low sulphidation subtype deposits. The ore mineral assemblage associated with high sulphidation deposits includes: native Au, electrum, tellurides, bismuthinite, and base metal sulphides. Precious metals are typically associated with pyrite-enargite $\pm$ covellite $\pm$ bornite $\pm$ chalcocite. Total sulphide contents are generally higher in high sulphidation than its counterpart. The alteration mineral assemblage typically associated with this subtype includes: alunite, kaolinite, pyrophyllite, sericite, adularia (illite), chlorite, and barite. Calcite is not characteristic of high sulphidation deposits due to the low pH of the hydrothermal fluids. A texture diagnostic to high sulphidation deposits include coarse-grained alunite.

Low-sulphidation subtype fluids are thought to be near-neutral, dominated by meteoric waters, but containing some magmatic C and S (Fig. 26). They cover larger areas than typical of high sulphidation deposits, even though alteration mineral assemblages are restricted to generally narrow zones enclosing veins and breccias. The ore mineral assemblage associated with low sulphidation deposits includes: electrum, Hg-Sb-As sulphides, and base metal sulphides. The alteration mineral assemblage typically associated with this subtype includes: sericite, adularia, kaolinite, calcite, rhodochrosite, Fe-chlorite, fluorite and quartz. In sediment-hosted low sulphidation deposits, the characteristic assemblage of gangue minerals commonly includes cinnabar, orpiment-realgar, and stibnite, in addition to jasperoid, quartz, dolomite, and calcite. Chalcedonic quartz veins and jasperoid are typically associated with ore, whereas calcite veins are more common further from ore, or are paragenetically late. Textures diagnostic to boiling and low sulphidation deposits include lamellar or platy ('angel wing') calcite, in some cases pseudomorphically replaced by silica. Rhombic adularia can also be indicative of boiling.

Geological evidence for shallow emplacement includes: sinter deposits, fluid inclusion or textural evidence (e.g., lamellar calcite or their quartz pseudomorphs) for boiling, hydrothermal breccias and eruption deposits, open- space crustiform veins, and marked.  $^{18}\text{O}$  depletion of wall rocks. Other characteristics of epithermal deposits include vertical zoning of alteration minerals, lower Au/Ag ratios in electrum with depth, and spatial and temporal separation of Au and abundant base metals. Gold is the principal commodity of epithermal deposits and compared to the low-grade, bulk-tonnage porphyry deposits, epithermal deposits are typically small in size (1-100 Mt of ore). They can however reach high grades (up to 200 g/t Au in some cases; e.g., El

Indio, Chile).

Geology of the Western Avalon Zone (from Sparkes, 2013 and references therein) The Avalon Zone of Newfoundland is dominated by late Neoproterozoic volcanic and sedimentary rocks, which include several discrete volcanic and sedimentary sequences, ranging in age from ~ 760 Ma to ~ 550 Ma. The rocks of most interest in the context of this excursion are the younger parts of the succession, commencing at ~ 570 Ma. Late Neoproterozoic rocks are in turn overlain by a Cambrian platformal sedimentary cover sequence that marks the cessation of volcanic activity and related epithermal systems within the Avalon Zone. The Neoproterozoic rocks, along with the associated Paleozoic cover sequence, are unconformably overlain by Late Silurian to Early Devonian terrestrial volcanic and associated siliciclastic rocks, preserved within isolated outliers throughout the Burin Peninsula. Within the Avalon Zone of Newfoundland, the intensity of Paleozoic deformation broadly increases from east to west toward the Dover and Hermitage Bay faults, which mark the western extent of Avalonian rocks and defines their tectonic contact with the adjacent Gander Zone (Fig. 27). Consequently, examples of epithermal-style alteration and mineralization in the west are generally more strongly deformed than those located farther east on the Avalon Peninsula. The majority of the deformation is attributed to the Devonian Acadian orogeny; however evidence for older, Precambrian deformational events is also locally preserved.

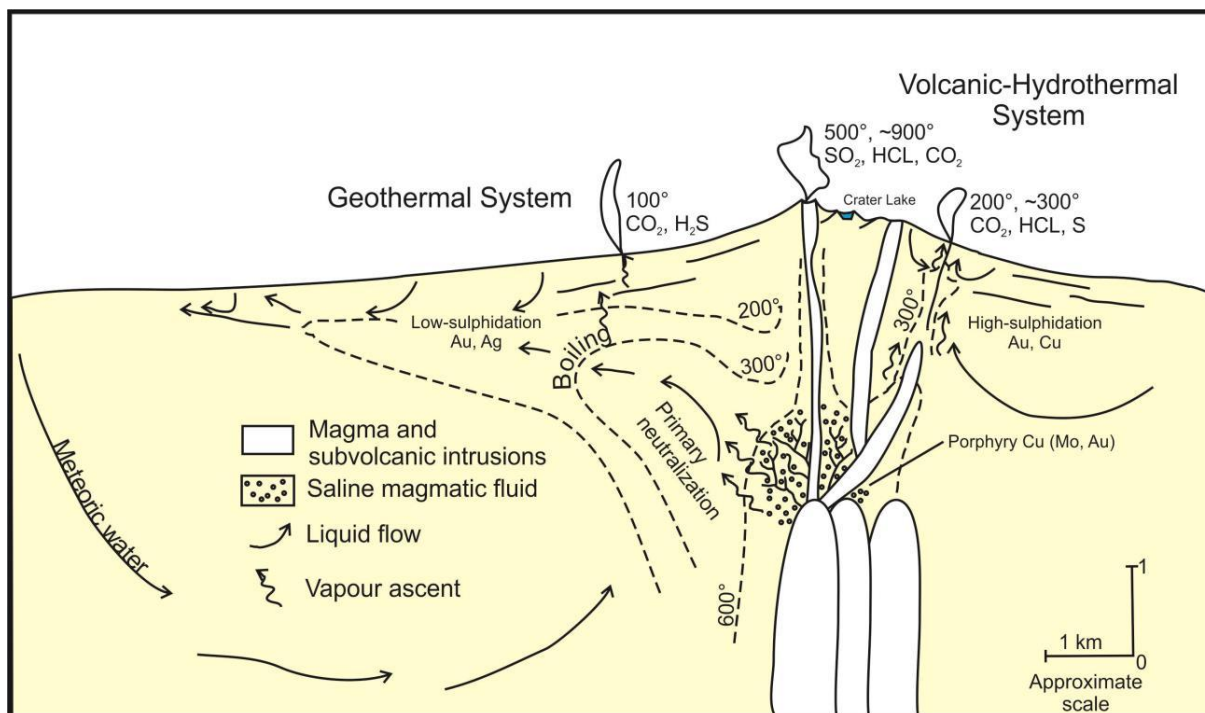
Within the western Avalon Zone, epithermal alteration and mineralization is most abundant in volcanic rocks of the ca. 590–570 Ma Marystown Group (Fig. 27). This sequence generally comprises greenschist-facies subaerial flows and related pyroclastic and volcanoclastic rocks ranging in composition from basalt, through andesite and rhyodacite, to rhyolite. The volcanic rocks are of both calc-alkaline and tholeiitic affinity. The Marystown Group represents the main core of the Burin Peninsula, forming a broad-scale anticlinorium, which is flanked to the east by a shoaling-upward sequence of marine to terrestrial sedimentary rocks of the Neoproterozoic Musgravetown Group; volcanic rocks at the base of the Musgravetown Group (Bull Arm Formation) have been locally dated at 570  $\pm$  5/-3 Ma.

To the west and north, the Marystown Group is overlain by the ca. 570 to 550 Ma Long Harbour Group (Fig. 27). The Long Harbour Group is dominated by shallow marine sedimentary rocks and subaerial felsic volcanic rocks of alkaline to peralkaline affinity, along with related clastic rocks, which pass conformably upward into fossiliferous Cambrian sedimentary rocks related to the development of a platformal cover sequence. The Long Harbour Group is divisible into a lower volcanic sequence (Belle Bay Formation) and an upper volcanic sequence (Mooring Cove Formation), which are separated by a clastic sedimentary unit known as the Anderson's Cove Formation. Rhyolites from both the Belle Bay and Mooring Cove formations have been dated at 568  $\pm$  5 and 552  $\pm$  3, respectively.

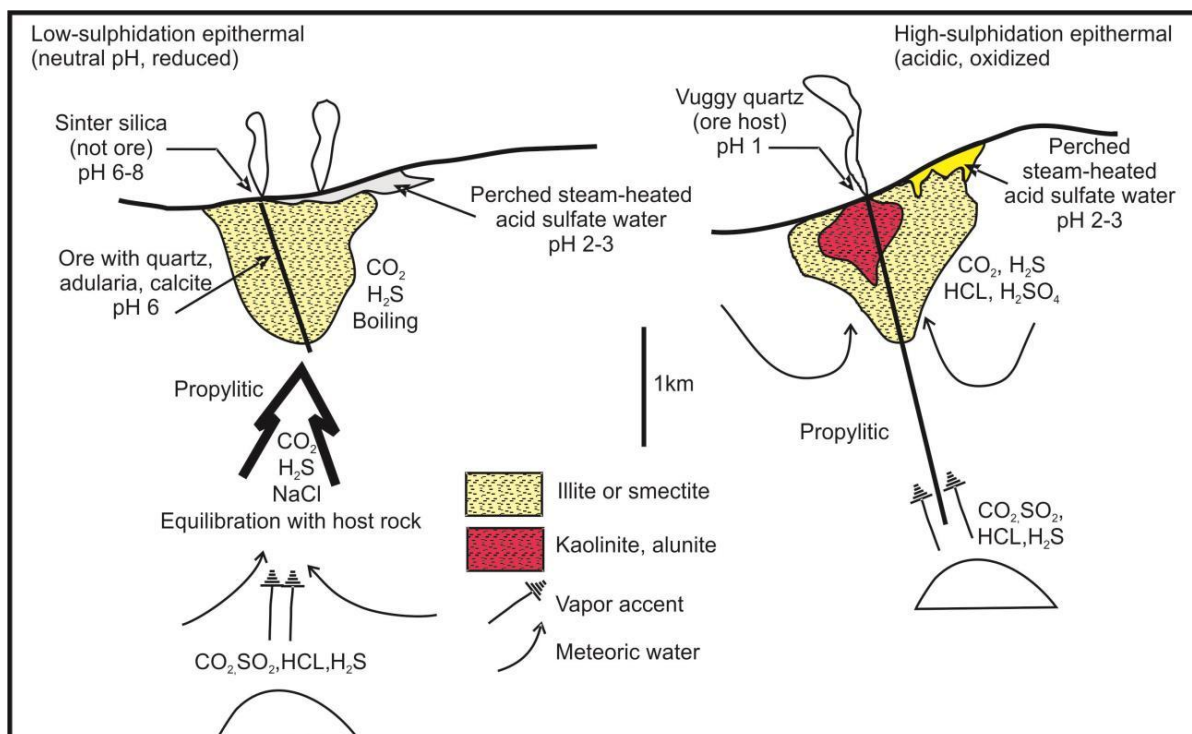
North of the Burin Peninsula, the volcano-sedimentary sequence can be traced northeast to the area of Bonavista Bay (Fig. 27), where it is truncated by the Dover Fault. In the area of Bonavista Bay, the ca. 620 Ma Love Cove Group and the conformably overlying siliciclastic sedimentary rocks of the Connecting Point Group form a 5 km thick succession, referred to as the Eastport basin. A tuff bed from the middle of the Connecting Point Group stratigraphy was dated at ca. 610 Ma.

The volcano-sedimentary rocks underlying the area between the Burin Peninsula and Bonavista Bay are divisible into two broad northeast–southwest trending belts, separated by sedimentary rocks of the Musgravetown Group. These two belts represent two different packages of volcanic rocks; the Love Cove Group, confined to the eastern belt, and the younger volcanic rocks inferred to be related to the ca. 570 Ma Musgravetown Group dominate the western belt. Both the eastern and western belts contain local evidence for epithermal mineralization (i.e. Big Easy, Calvin's Landing; Fig. 27). Within the volcanic rocks of the Bonavista Bay area, numerous zones of silicification, pyritization and sericitization have also been identified, and are locally accompanied by anomalous gold mineralization (up to 575 ppb Au). In the area of Bonavista Bay, an angular unconformity locally separates rocks of the Connecting Point Group from the overlying Musgravetown Group.

Several high-level plutons dominated by granitoid rocks intrude along the western margin of the Avalon Zone in Newfoundland (Fig. 27). Most occur within the Burin Peninsula area and form a broad, semi-continuous, north-northeast trending plutonic belt consisting of hornblende-biotite granite, diorite and gabbro. Limited geochronological data are available for these plutonic units. The Swift Current Granite is locally dated at  $577 \pm 3$  Ma. Other plutonic units, including the Cape Roger Mountain Granite and the "Burin Knee Granite" are inferred to be coeval with the Swift Current Granite. At the northeastern end of the belt, in the vicinity of Bonavista Bay, the Louil Hills Intrusive Suite is dated at  $572 +3/-2$  Ma and is interpreted to be coeval with alkaline volcanism associated with the Musgravetown Group within the western belt of volcanic rocks. In the area northwest of the Burin Peninsula, the Long Harbour Group is locally intruded by the Cross Hills Intrusive Suite, which has a preliminary age of  $547 +3/-6$  Ma and hosts Zr–Nb–REE mineralization. This intrusion represents one of the youngest magmatic events prior to the cessation of hydrothermal activity within the region.

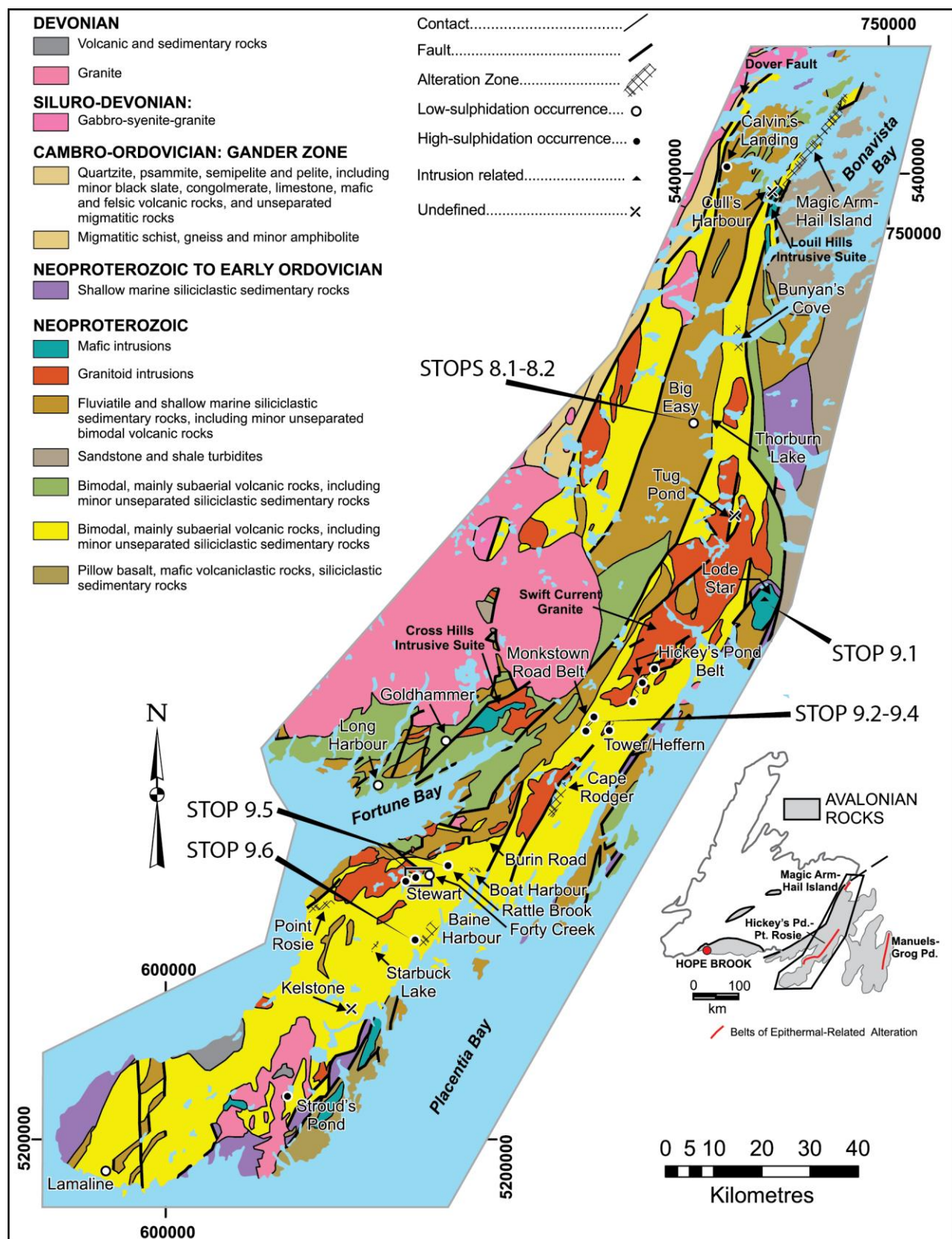


**Figure 25.** Schematic cross section through an intrusive centered hydrothermal system outlining the environments of porphyry, high sulphidation and low sulphidation systems (Hedenquist and Lowestern, 1994).



**Figure 26.** Schematic diagram of the fluid types and alteration zoning around high and low sulphidation epithermal systems (White and Hedenquist, 1995).





**Figure 27.** Regional geology map of the western Avalon Zone outlining the distribution of known epithermal prospects (from Sparkes, 2012; modified after O'Brien et al., 1998).

## DAY 8 — FIELD STOPS

### **Stop 8.1: Musgravetown Group (UTM 21 721878E, 5339899N)**

#### **Location.**

From Clarenville, continue to Thorburn Lake and turn left on a gravel road just past the lake, located 7 km north (beyond) the junction for the Discovery Trail and Bonavista/Trinity. Stop at the quarry approximately 200 m along the road.

#### **Description.**

These outcrops are dominated by grey-green coarse-grained sandstone of the Musgravetown Group, locally displaying well-developed cross-bedding. These rocks dip moderately to the west and are inferred to have a faulted contact with the Love Cove Group volcanic rocks to the east (see introduction section for more details on the geological relationship). This stop illustrates the style of sedimentation and the relatively undeformed nature of the Musgravetown Group outside of the alteration zone that is observed on and around the Big Easy Prospect.

### **Stop 8.2: Big Easy Prospect (UTM 21 710397E 5349322N—parking)**

#### **Location.**

From Stop 8.1, continue on the gravel road. There is an area suitable for parking at UTM 710397E/5349322N, which is relatively close to the power line. From here an ATV trail leads to the main occurrence and side trails lead to the other locations discussed below. Waterproof footwear is highly recommended for this section of the field trip. We will tour several of the exploration trenches to observe the styles of alteration and veining developed at the prospect.

#### **Description.**

This stop will take a good part of the day. It will be led by a number of geologists, who have worked on the property, including: Peter Dimmell, Dr. Graham Layne, and Greg Sparkes.

Early exploration in the area discovered a silica-pyrite alteration that measured 500 m in width and 1.8 km in length (Harris, 1996). Silver Spruce Resources discovered well-developed low-sulphidation-style chalcedonic silica veins and related brecciation. Exploration also uncovered large blocks of layered chalcedonic silica material interpreted as sinter deposits related to hot springs.

The host volcanoclastic sedimentary rocks at the Big Easy prospect are correlated with the late Neoproterozoic Musgravetown Group (Meyer et al., 1984). The area immediately north of the Big Easy prospect, in the vicinity of Clode Sound, was mapped by O'Brien (1993). In this area, the Musgravetown Group is described as consisting of coarse-grained, mainly red, fluvial clastic sedimentary rocks with locally developed basal conglomerate, overlain by a bimodal volcanic sequence. A rhyolite unit from the base of the Musgravetown Group has been dated at ca. 570 Ma and the sequence is locally unconformably overlain by Cambrian

sedimentary rocks (Hayes, 1948; O'Brien, 1987; O'Brien et al, 1989). Within the immediate area of the Big Easy prospect, the sedimentary rocks distal to the development of the silica–pyrite alteration consist of red, coarse-grained sandstone and lesser interbedded pebble to cobble conglomerate. The extensive silica–pyrite alteration at the prospect hinders recognition of the host rocks but relict rounded sedimentary clasts are locally observed, suggesting that the host rock is similar to the surrounding sedimentary rocks outside the main alteration zone. A mafic dyke collected from drill hole BE-11-03, which crosscuts the silica alteration, was dated at  $566 \pm 2$  Ma (Clarke, 2012), demonstrating the Neoproterozoic age of the low-sulphidation system. The preservation of surficial sinter deposits in a low- sulphidation system of this age makes this occurrence very unique.

Veins up to 50 cm wide, display typical low-sulphidation-style textures such as crustiform–colloform banded chalcedonic silica and relict lattice blading (Fig. 28). Some of the veins crosscut sedimentary layering at a relatively high angle. In addition, large blocks (interpreted to represent subcrop) containing cm-scale layers of chalcedonic silica interlayered with coarse-grained sandstone are also present. Elsewhere, fragments of similar chalcedonic material form clasts within coarse conglomeratic units. These relationships suggest the formation and simultaneous erosion of epithermal sinter deposits during the deposition of the late Neoproterozoic Musgravetown Group.



**Figure 28.** Lattice bladed texture, indicative of fluid boiling, hosted within chalcedonic silica veins at Big Easy prospect (from Sparkes, 2013).

### **Stop 8.2A: Unaltered Musgravetown Group**

We will first visit the area of drill hole BE-11-06. In the vicinity of the drill hole collar, large blocks (interpreted as subcrop) illustrate the red coloration of the unaltered sandstone and interbedded pebble conglomerate. A small stream separates the unaltered and altered rock in this area; however the contact in drill core is preserved as a sharp faulted contact.

### **Stop 8.2B: Trench 7**

We are now into the main alteration zone, which consists of silicification and white mica alteration of the host sedimentary rocks. At this location several 10-20 cm wide chalcedonic silica veins cut across the outcrop. Note the difficulty in seeing the veins on the lichen-covered portion of the outcrop versus the stripped portion of the outcrop.

### **Stop 8.2C: Trench 4**

Here we continue to move along strike within the alteration zone. Locally, relict bedding within the host sedimentary sequence appears to be westward dipping. This sequence is interpreted to be the same host rock as that observed at the last stop.

### **Stop 8.2D: Trench 6**

This trench represents the southernmost exposure of the alteration zone. Here, layers of chalcedonic silica can be seen interbedded with the volcanoclastic sandstone (Fig. 29). Locally, chalcedonic silica veins crosscut the sinter at relatively high angles to bedding. These large blocks of sinter material are interpreted as subcrop, as the bedding orientations do not seem to match with those taken elsewhere in the immediate vicinity. Drill hole BE-11-01, which is located just to the west of this location, and oriented towards the east, failed to intersect any significant sinter material in drill core.



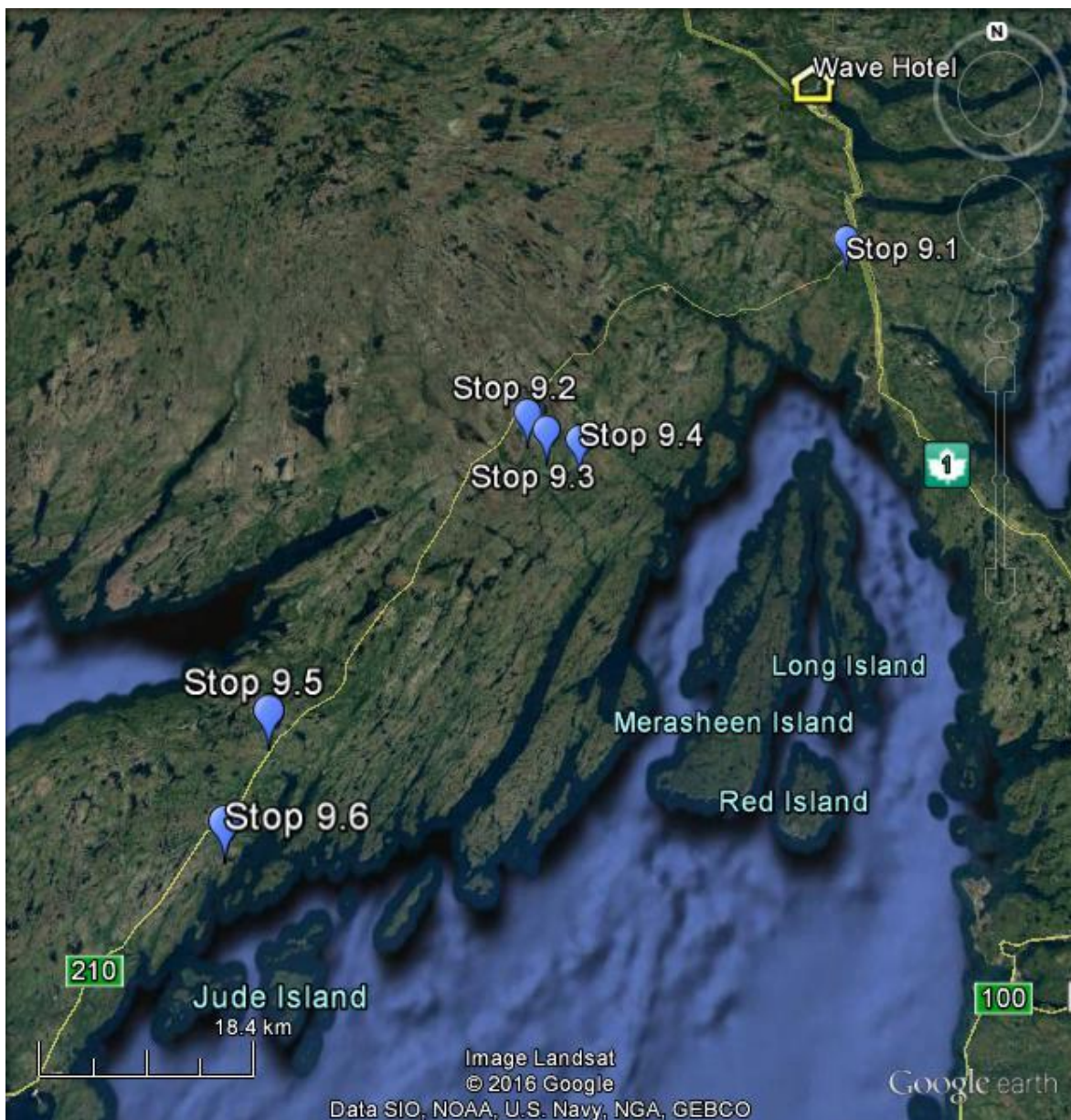


**Figure 29.** Sinter deposit consisting of alternating layers of chalcedonic silica and volcaniclastic sandstone; note local erosional truncation of beds indicating right way up at Big Easy prospect (from Sparkes, 2013).

## DAY 9: EPITHERMAL SYSTEMS OF THE AVALON ZONE (Cont'd)

### DAY 9 — STOP LIST

- Stop 9.1 Lodestar prospect
- Stop 9.2 Monkstown Road Shear Zone
- Stop 9.3 Monkstown Lazulite Showing
- Stop 9.4 Tower Zone
- Stop 9.5 Rattle Brook Prospect
- Stop 9.6 Baine Harbour Shear Zone





## **DAY 9 — FIELD STOPS**

### **Stop 9.1      Lodestar prospect (UTM 21 724914E, 5312761N)**

#### **Location.**

Directions: The Lodestar prospect is located along an old gravel road that joins the Burin Peninsula highway about 4.4 km from its junction with the TCH. The road is no longer passable for vehicles and a walk of about 15 minutes is required. Waterproof footwear is recommended for this stop.

#### **Description.**

Discovered in 1998, the Lodestar prospect represents a breccia-hosted, intrusion-related style of hydrothermal mineralization. The development of the hydrothermal brecciation is associated with the ca. 600 Ma Powder Horn Intrusive Suite (O'Brien et al., 2000), developed close to its contact with adjacent sedimentary rocks of the Connecting Point Group. The mineralized hydrothermal breccias are polyolithic and include both fragments of sedimentary and magmatic units (Fig. 30) and are interpreted to have a phreatomagmatic or magmatic-hydrothermal origin (Hinchey et al., 2000).

The Powder Horn Intrusive Suite consists of several phases as outlined by Hinchey et al. (2000). These include a pre-mineralization medium- to coarse-grained, equigranular, black and white gabbro/diorite and rare felsic dykes; post-mineralization phases of the intrusion include fine-grained, dark green, diorite to gabbro and lesser aplite, feldspar porphyry and quartz-feldspar porphyry.

The mineralized breccia is exposed over an area of approximately 20 m in length and is host to gold in association with Cu, As, and Zn mineralization along with hydrothermal magnetite, all of which occur within the matrix of the breccia (Hinchey et al., 2000). The mineralized portions of the breccia include arsenopyrite, pyrite, chalcopyrite, magnetite, bornite, and sphalerite. Moving away from the mineralized portions, chlorite and actinolite dominate the breccia matrix (Hinchey et al., 2000).



**Figure 30.** Representative drill core slabs of the hydrothermal breccia containing both sedimentary and intrusive fragments (from Sparkes, 2013).

## **Stop 9.2      Monkstown Road Shear Zone (UTM 21 686934E, 5289699N)**

### **Location.**

From the parking area at Stop 9.1, continue southward on the Burin Peninsula Highway to the Monkstown Junction. This stop is located approximately 2.9 km eastward along the Monkstown Road, near the power line.

### **Description.**

This stop and the following two provide a cross-section of the Hickey's Pond belt, part of Fig. 27). This belt contains high-sulphidation style alteration locally in association with up to 31 g/t Au. This alteration extends for more than 90 km across the Burin peninsula.

This stop reveals rocks that are relatively unaltered and strongly deformed, which are transformed by high- sulphidation alteration at subsequent stops. The rocks here are affected by a regional chlorite-epidote alteration and show a penetrative fabric. Deformation in the area is

discrete, confined to relatively narrow (up to several 100m) high-strain zones subparallel to the regional north-northeast trend of the geological units. Kinematic analysis of these structures suggests thrusting towards the east.

### **Stop 9.3      Monkstown Lazulite Showing (UTM 21 688984E, 5287590N)**

#### **Location.**

This stop is located approximately 5.8 km off the main Burin Peninsula highway along the Monkstown Road. It is a short walk north from the road and waterproof footwear is essential unless you wish to have wet feet for the remainder of the day. It is best to continue east along the Monkstown Road, then walk north, and backtrack to the UTM location, because the swamp north of the road is very wet and deep. Although hammering and sampling will be tempting, we ask that you refrain from despoiling the outcrop.

#### **Description.**

This stop is located in the main high-sulphidation style alteration zone, dominated by silica-alunite-specularite and lesser pyrophyllite alteration. You can find at this location lazulite, a bright blue mineral of composition  $\text{MgAl}_2(\text{PO}_4)_2(\text{OH})_2$ , within quartz-specularite veins. The outcrop also contains discrete zones of hydrothermal brecciation consisting of pale pink siliceous, angular, fragments within a dark grey, specularite-rich matrix. It is important to note that the development of these breccias is generally limited on a regional scale. This outcrop is barren of precious metal mineralization and could be attributed to the alteration having formed at relatively shallow depths within the hydrothermal system evidenced by the abundance of alunite.

### **Stop 9.4      Tower Zone (UTM 21 692485E, 5286362N)**

#### **Location.**

From Stop 9.3, continue for about 6.7 km east on the Monkstown Road, and turn on to a small side road by a shed. The outcrops and trenches require a short walk to the north, for which waterproof footwear is recommended.

#### **Description.**

From the previous stop, we will walk through a section of unaltered mafic and felsic subaerial volcanic rocks. This section is part of the second of the two subparallel belts of high-sulphidation-style alteration. Rocks hosting the alteration have locally been dated at ca. 575 Ma. Hydrothermal alteration in these rocks has been attributed to the intrusion of the coeval Swift Current Granite and related intrusions (O'Brien et al., 1999).

Walking to the trenches, we pass through relatively weakly altered, highly strained, lapilli-tuff containing cm-scale elongated polymictic fragments. These rocks show intense silica-alunite-specularite alteration, obliterating all primary features, and minor in Au content (<62 ppb Au over 3.0 m; Dyke and Pratt, 2008). SWIR analysis of this alteration indicate Na-alunite, minor pyrophyllite, and locally topaz. These latter minerals are indicative of a hot (250°-300°C) acidic

hydrothermal fluid. In contrast, the volcanoclastic rocks marginal to the main alteration zone are dominated by phengite (white mica) alteration which is indicative of a more neutral pH environment.

The prospect is characterized by a northeast trending alteration zone that can be traced along strike for up to 950 m and can locally reach up to 200 m in width.

### **Stop 9.5      Rattle Brook Prospect (UTM 21 661655E, 5257483N)**

#### **Location.**

From Stop 9.4, return to the Burin Peninsula Highway, turn left and drive south until the bridge at Rattle Brook. The outcrops are located approximately 250 m upstream of the bridge at Rattle Brook. Beware of oncoming traffic while crossing the road!

#### **Description.**

This stop reveals advance argillic alteration hosted within the volcanic rocks of the Marystown Group. Here the alteration is developed close to a fault structure that separates mafic volcanic rocks to the north, from felsic volcanic rocks to the south. Local intense silicification in association with pyrophyllite-alunite-dickite alteration is associated with anomalous gold mineralization. In some of the trenches the intense silicification has become tectonically brecciated during post-mineralization deformation. The hydrothermal alteration can be traced along strike for approximately 1.5 km, where it pinches out along a fault towards the west-northwest.

This area is unusual with respect to the regional northeast trending Hickey's Pond – Point Rosie Belt because here the overall trend of the alteration and the associated fabric within the host rock become deflected toward a more east-west orientation. Further along this trend towards the west-southwest are the Forty Creek and Stewart prospects (Sparkes, 2012 and references therein). The Forty Creek prospect represents a new discovery of an intermediate-sulphidation style of mineralization, locally hosting up to 59 g/t Au and 2290 g/t Ag in association with lead and silver telluride minerals. The nearby Stewart prospect represents a zone of advanced argillic alteration extending for upwards of 4 km in length and up to 700 m in width, locally hosting anomalous Au and Cu mineralization. This zone may represent a telescoped epithermal system with the advanced argillic alteration superimposed on the underlying porphyry-related mineralization.

### **Stop 9.6      Baine Harbour Shear Zone (UTM 21 658500E, 5247193N)**

#### **Location.**

From Stop 9.5, and continue southward to the Baine Harbour junction. Turn left towards Baine Harbour, and proceed approximately 4.5 km to a large quarry on the right hand side of the road. Be cautious of the cliff faces and stay well back from high areas.

#### **Description.**

This stop highlights the different styles of alteration present on the Burin Peninsula. This location is characterized by a shear zone hosting a pervasive white mica alteration, dominated

by phengite with lesser pyrite. Here the alteration is developed along a reverse sense shear zone, which is being thrust towards the east. The alteration contains no precious metal mineralization.

Why is this alteration not associated with precious metal mineralization? It is currently unclear whether it is linked to the regionally extensive epithermal-style alteration, or part of an entirely separate event. Dating of the shear zone (using Ar-Ar) has produced ages ranging from  $369 \pm 10$  to  $388 \pm 10$  Ma, indicating a much younger age (Devonian) for the formation of the alteration, although it remains possible that this has overprinted older Neoproterozoic alteration.

## OPTIONAL STOPS (DAY 10)

### Stop 10.1 Steep Nap Prospect (UTM 22 352688E, 5263406N)

#### Location.

From Memorial University, head east on Prince Phillip Dr and turn left onto Allendale Rd; keep left on Allendale and follow signs for Trans-Canada Hwy/NL-1 W. Turn right onto Trans-Canada and Follow Trans-Canada Hwy/NL-1 W and NL-2 W to Minerals Rd in Conception Bay South. Take the exit toward NL-60 from NL-2 W for 22 km. Turn left onto Minerals Rd, then turn left onto Anchorage Road for 1.9 km. Stop at long exposure on the south side of the road.

#### Directions

The outcrop on the south side of the road forms part of the Steep Nap Prospect. Discovered in 1995, the prospect consists of gold-bearing hydrothermal quartz-hematite-K-feldspar veins in pyroclastic and hydrothermal breccias within the Manuels Volcanic Suite of the "Harbour Main Group" (Mills et al., 1998; O'Brien et al., 2001). The veins in this exposure have many of the characteristics of low-sulfidation (adularia-sericite) epithermal gold mineralization: e.g., 1) adularia- and chalcedony-bearing; 2) crustiform and colloform textures; 3) high silver/gold ratio; 4) chalcedonic recrystallization texture; and 5) carbonate replacement texture.

We are located in the northern part of the Eastern Avalon High-alumina Belt, about 3 km to the north of the Oval Pit pyrophyllite mine. The largest veins in this outcrop have returned assays of 3.3 g/t Au and 20 g/t Ag (Mills et al., 1998). This 60 m long outcrop of felsic pyroclastic rocks contains at least 100 veins, ranging in size from 1 mm up to 1.7 m; most are less than 2 cm wide. Several types of breccia are also exposed. The main auriferous material forms a 1.7 m wide composite vein composed of crustiform bands of K-feldspar-quartz-chalcedony and minor hematite. Very little sulfide mineralization is present in any of the veins. The largest auriferous veins have been traced, with consistent thickness, along strike for more than 300 m. Float from this area has returned values up to 4.4 g/t Au.

The earliest veins are crustiform-banded and consist of grey recrystallized chalcedony and white quartz, with or without minor chlorite and hematite. A second group of veins consist of crustiform and locally colloform bands of K-feldspar, grey recrystallized chalcedony, white quartz and hematite. These display chalcedonic recrystallization texture (mosaic texture) and carbonate replacement texture (parallel bladed) in thin section, and are anomalous in gold.

The latest veins are characterized by weakly banded quartz along the margin, bounded by crystalline comb quartz nearer the centre, surrounding a hematite core. Veins such as these, which contain coarse-grained crystalline texture are in many cases barren or only weakly anomalous in gold. In many instances, especially in the larger veins, internal brecciation of the vein material by hematite has occurred. Hematite fracturing of the surrounding outcrop occurs locally.

The earliest hydrothermal breccias are gold-bearing and have a matrix of grey recrystallized chalcedony and minor K-feldspar that forms cockade textures cored by sericite-



chlorite-altered clasts. This breccia is crosscut by the main adularia-quartz-hematite vein, and by smaller veins cored by comb quartz and hematite. Other later breccias have either black, chlorite-rich and/or brown, hematite-rich matrix. These breccias contain fragments of banded vein material and are thus either late syn-, and/or post-veining. The two matrix types are typically mixed. The late breccias with vein material fragments return anomalous gold values.

Sericite, chlorite, and hematite are the main wall rock alteration phases; there is also evidence of some potassic and silica alteration. Most (although not necessarily all) of the more intense sericite alteration is post-veining and related to brittle deformation. Less intense but more pervasive sericite alteration is present in the northern half of the outcrop. Chlorite alteration is mainly confined to thin halos around pre-veining fractures and veinlets. A more extensive area of chloritic alteration (ca. 2 m wide) is developed adjacent to (west of) the widest vein. Hematite alteration occurs sporadically throughout the outcrop, both as early remobilization halos and as later patches and halos around late veinlets and fractures.

The presence of crustiform textures with chalcedonic silica and adularia indicate the mineralized veins formed during boiling of near-neutral pH fluids associated with episodic pressure release. Neutral fluids rose into a zone of increased permeability, in this case created by faults. Confining pressure was reduced as fluids neared the paleosurface; the fluid boiled, CO<sub>2</sub> was given off; the resultant drop in pH and temperature led to low-T, K-feldspar formation, and metal precipitation from silica gels. The system gradually sealed, pressure built up and boiling stopped; renewed fracturing broke the sealed cap in the system, and the process repeated.

The early cockade-textured hydrothermal breccia reflects hydrofracturing and tectonic brecciation synchronous with boiling; this is evidenced by crustiform-banded adularia and chalcedonic silica in matrix. Breccias also formed during later stage hydrothermal activity in the same system. These are Au-Ag-bearing only where they contain mineralized adularia-bearing vein fragments.

The features preserved here demonstrate that these rocks formed at or immediately above boiling level in a low-sulphidation epithermal system and at a depth suitable for precious-metal deposition.

The Steep Nap Prospect and related Ag-Au mineralization is the first late Neoproterozoic, Ag-Au-bearing, low-sulphidation-type epithermal system documented in Avalonian rocks, and is amongst the oldest confirmed examples of that style of mineralization known anywhere. Low-sulphidation-type alteration systems, which may host either bulk tonnage or bonanza-style mineralization, represent a new and challenging target for precious-metal exploration within the Avalonian Belt.

## **Stop 10.2    Oval Pit – Pyrophyllite mine (UTM 22 352760E 5260919N)**

### **Location.**

From stop 10.1, return to Minerals Road, turn left and continue to pyrophyllite mine. Stop at the Mine office.

## **Description.**

Why is pyrophyllite mined? In part, to produce a variety of high-end pyrophyllite products, including fillers and whiteners for paper, plastic and paint, plus a number of ceramic uses. Product is milled and packaged on-site.

The pyrophyllite deposits of this area were discovered in 1898. The view from the top of the pit shows a number of features including the outline of the pyrophyllite-diaspore ore zone, the unconformably overlying sediments, which are rich in detrital altered clasts, and some of the larger scale structures affecting the alteration system. The most notable of these is a steep reverse fault that juxtaposes the alteration zone (in the south pit extension) with the sedimentary succession. The structure has about 60 m of vertical throw. The same structure has a significant component of subhorizontal displacement. Vertical and horizontal displacement of the ore zone along this fault is mimicked in the overall shape of the open pit, particularly the southwest extension.

A well-exposed section through an extensive advanced argillic hydrothermal system is preserved in the Oval Pit Mine and in the immediately surrounding area. Alteration can be subdivided from east to west into subzones of argillic, advanced argillic and massive silicic alteration. The argillic zone is characterized by the presence of silica and sericite, with or without pyrophyllite, and the common occurrence of hydrothermal hematite. The advanced argillic zone contains subzones of massive pyrophyllite, sericite and diaspore with minor barite and rutile (e.g., Oval Pit), and of silica, pyrophyllite and sericite, locally with 5 to 10 percent pyrite. Smaller zones of massive silicic alteration are mainly in the form of metre-scale pods of high-grade silica, containing less than 5 percent sericite and/or pyrophyllite. Locally, pyrite forms the matrix of associated silica breccias. No large and continuous zone of silicic alteration has been identified at surface. The zones of silicic alteration are irregularly distributed in detail, but appear to be located mainly to the northeast of the advanced argillic zone. The original distribution of silica and pyrophyllite within the advanced argillic alteration zone indicate that they are essentially contemporaneous. Pyritic rocks intimately associated with the pyrophyllite are not typically anomalous in gold. The highest gold values noted to date are associated with hydrothermal breccias at the edge of the advanced argillic zone.

The advanced argillic alteration zone passes outward into red subaerial rhyolites, showing mild silicic alteration associated with the formation of quartz-hematite veins and breccia. The first stage of hematite alteration is regionally distributed, predates the advanced-argillic alteration, and formed by syn-volcanic thermal oxidation. A younger hematite-alteration event is the result of leaching from hematite-rich volcanic rocks during advanced argillic alteration, and has resulted in the formation of the afore-mentioned hematite veinlets and breccias. The commonly developed anastomosing pattern illustrated by the outcrop-scale distribution of silica and pyrophyllite in zones of low to medium strain is the result of inhomogeneous post-alteration deformation.

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