GAC Newfoundland and Labrador Section

2007 Fall Field Trip

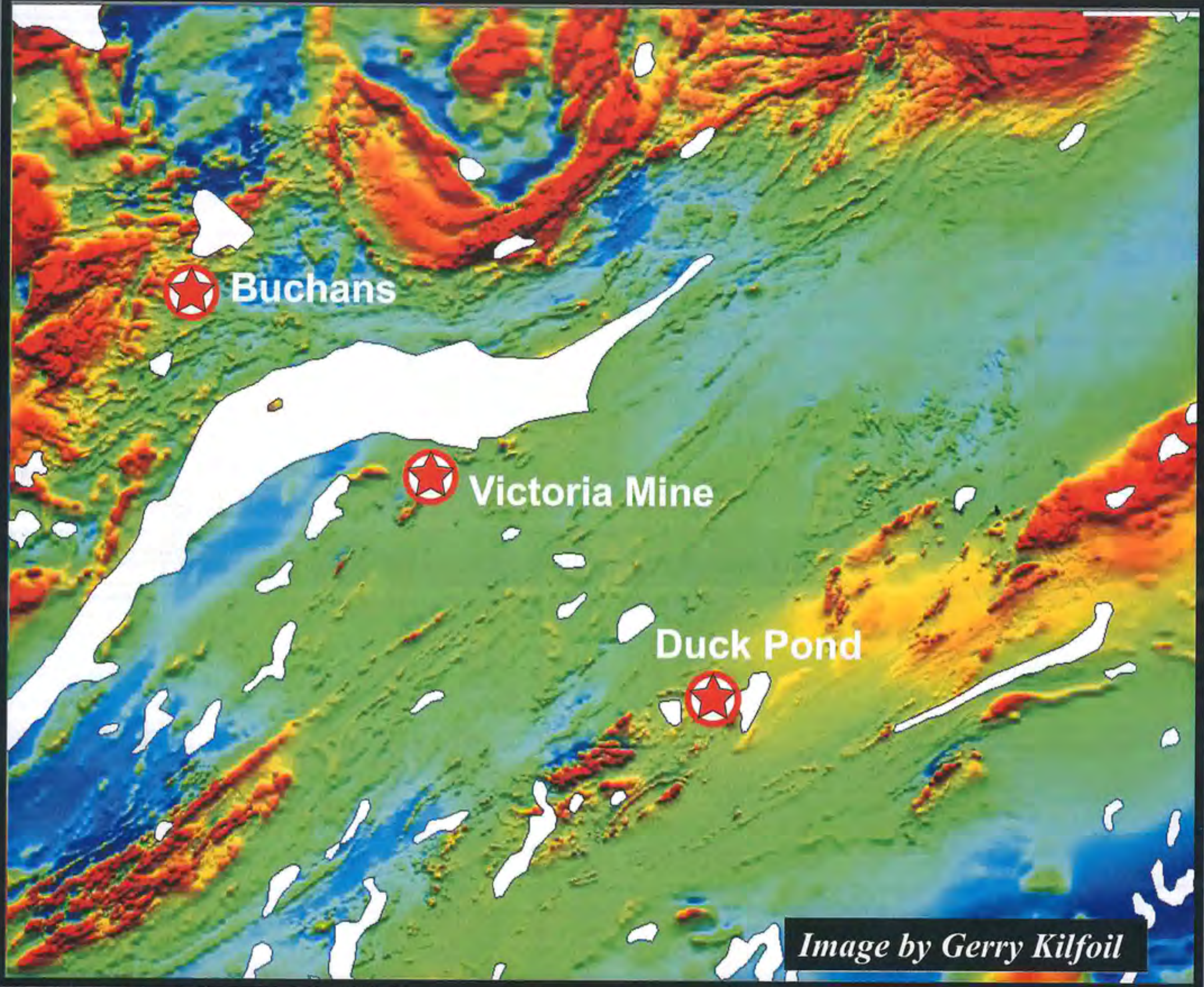

Image by Gerry Kilfoil

Tectonics and Time Down on the Red Indian Line

Led by Alex Zagorevski and Cees van Staal

October 13 - 15

Background Information and Stop Descriptions

GEOLOGICAL ASSOCIATION OF CANADA
NEWFOUNDLAND AND LABRADOR SECTION

2007 FALL FIELD TRIP

TECTONICS AND TIME DOWN ON THE RED INDIAN LINE

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Cover: Total Field Magnetic Image of the Red Indian Lake area (G. Kilfoil, GSNL)

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WELCOME

The Newfoundland and Labrador Section of the Geological Association of Canada welcomes all participants to the 2007 Fall Field Trip. This year's destination is the area surrounding Red Indian Lake, where we will see rocks that formed in island arcs on both sides of the Iapetus Ocean, and visit the newest mining operation in Newfoundland.

This guidebook is intended only as a simplified and abbreviated overview, and readers are referred to the references therein for full details of the geology, and complete supporting data for statements and ideas. Like all such guidebooks, it is a "snapshot in time" of ideas about an area or subject, and some of its contents will be subject to future revision in the light of new data. It may contain inconsistencies and errors as an inevitable consequence of its rapid preparation, and references are better made to the original publications cited within the text.

ACKNOWLEDGMENTS

The Fall Field Trips of the Newfoundland Section of GAC are a long-standing tradition that is made possible by the efforts of volunteers and direct and in-kind subsidies. The 2007 field trip is no exception. The provision of vehicles by the Geological Survey of Newfoundland and Labrador (part of the Department of Natural Resources) is also important in making this trip possible, and is gratefully acknowledged. A subsidy for students attending the trip was provided by the Department of Earth Sciences at Memorial University, and we are also grateful for their help. The Geological Survey of Canada, through the Targeted Geoscience Initiative (TGI) program covered the expenses of the field trip leaders and assisted with transportation. Joanne Rooney and Chris Pereira at the Geological Survey provided invaluable assistance in preparing and producing the field trip guide. We are grateful also for the efforts of Lil Saunders at the Badger Diner and Motel for making our stay in the area comfortable and affordable, and for her culinary skills. The staff of Kellie's Motel and Badger Brook Efficiency Units are also thanked for their assistance with accommodations. The management and staff of Aur Resources, operators of the Duck Pond Mine, went to great lengths to ensure a safe and rewarding visit to their operation, and we are deeply grateful to them for their efforts.

SAFETY INFORMATION

General Information

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

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

Specific Hazards

Most of the stops on this field trip are on, or close to, forest access roads. This field trip involves some short hikes, of which the longest is about 500 m. Participants should be in good physical condition and accustomed to exercise. 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 old logs or uneven rock surfaces. Weather is unpredictable in this area and participants should be prepared for a wide range of temperatures and conditions. Always take suitable clothing. A rain suit, sweater, sturdy footwear are essential at almost any time of the year. Insect repellent and/or sunscreen may be necessary, depending on conditions.

The field trip stops require specific safety precautions. The greatest danger is traffic, notably on the main forest or mine access roads, where heavy trucks may be travelling at high speeds. Never assume that the road will always be empty! Driving on these roads requires a defensive attitude, and close attention to speed. The surface can deteriorate rapidly, and bends, bridges and other hazards are generally not signposted. It is best to assume that all oncoming traffic is driving in the centre of the road, and be extremely careful on blind curves and hills.

Many areas have recently been logged, and much debris may remain, in some cases hidden in undergrowth. When walking on paths or old trails, be careful of roots, stumps and old logs, which can cause a nasty fall if undetected. The animal population is generally benign, but black bears are not uncommon. Moose are generally not a hazard (unless they jump out into the road and you are driving too fast) but humans hunting them in the fall may be armed and dangerous. Field trip groups should stay together for safety, and we recommend bright clothing and loud conversations in the woods.

Anyone hammering on outcrops or boulders to collect samples should wear eye protection. Such activity should not take place where other participants could be injured by flying rocks or hammer chips. The leaders may request that some outcrops or features not be hammered for safety reasons, or for reasons of preservation. Please respect these instructions.

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

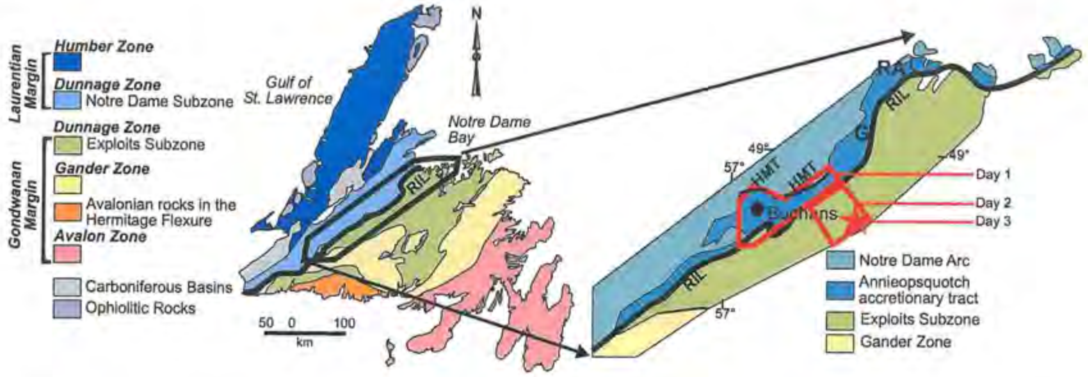


Figure 1. Tectonic-stratigraphic zones of the Newfoundland Appalachians (modified after Williams et al., 1988) and subdivision of the Notre Dame subzone into the Notre Dame Arc and Annieopsquotch accretionary tract. HMT Hungry Mountain Thrust, RIL Red Indian Line (modified from van Staal et al., 1998). Areas covered during the fieldtrip are indicated by the red polygons.

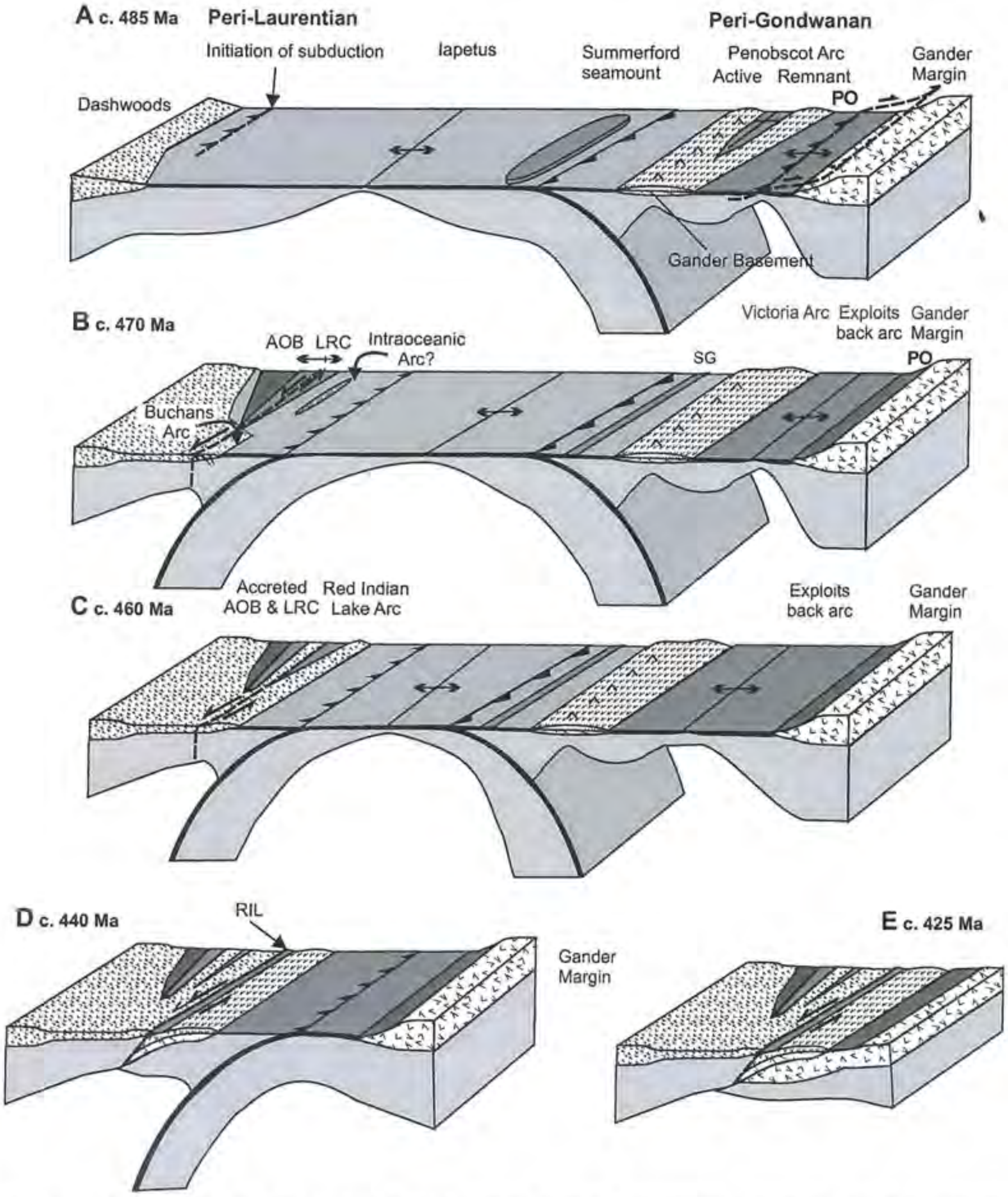


Figure 2. Early Ordovician to late Silurian tectonic evolution of the central Newfoundland Appalachians. AAT Annieopsquotch Accretionary Tract; AOB Annieopsquotch Ophiolite Belt; LRC Lloyds River Ophiolite Complex; PO Penobscot ophiolites; RIL Red Indian Line; SG Summerford Group (from Zagorevski, 2006).

INTRODUCTION

Overview of field trip

This three day field trip will focus on the stratigraphy, tectonics and metallogeny of the island-arc and back-arc basin complexes that lie adjacent to the Red Indian Line in the central Newfoundland Appalachians. The Red Indian Line is a fundamental boundary between rocks developed on the Laurentian (i.e., North American) and Gondwanan (i.e., European and African) sides of the early Paleozoic Iapetus Ocean, prior to its closure and formation of the Appalachian Orogen. Recent mapping, geochronology and geochemical studies were conducted in this area as part of the Targeted Geoscience Initiative (TGI) programs TGI-1 (2000-2003) and TGI-3 (2005-2010) by the Geological Survey of Canada, and related programs by the Geological Survey of Newfoundland and Labrador. The results allow unparalleled resolution of the tectonostratigraphic assemblages that make up this complex and economically important region (Evans and Kean, 2002; Lissenberg et al., 2005a; Lissenberg et al., 2005b; Pollock et al., 2002; Rogers et al., 2005a; Rogers et al., 2006; Rogers et al., 2005b; Squires and Moore, 2004; van Staal et al., 2005a; van Staal et al., 2005b; van Staal et al., 2005c; Zagorevski et al., 2007a; Zagorevski et al., 2006; Zagorevski et al., 2007c). For more detailed information the reader is referred to the aforementioned publications.

Geological Background

The Central Mobile Belt of Newfoundland consists of the Dunnage and Gander Zones (Figure 1; Williams et al., 1988). The Dunnage Zone comprises a complex tectonic collage of island arcs and backarc basins that formed within the Iapetan realm in between Laurentia and Gondwana. The Dunnage Zone has two contrasting halves, i.e., the Notre Dame Subzone (formed on the Laurentian side of Iapetus) and the Exploits Subzone (formed on the Gondwanan side; Williams et al., 1988) The juxtaposition of these various "Iapetan" terranes was piecemeal, involving several arc-continent and arc-arc collisions (Figure 2), and it seems likely that the Iapetus Ocean had a paleogeographic complexity similar to that of the modern island arcs in the southwest Pacific (e.g., van Staal et al., 1998). As in the southwest Pacific region (Hall, 2000), accretionary processes in the Iapetus Ocean operated on very short time scales, with the accretion of many arc-backarc terranes to bounding continental blocks occurring within 5 to 10 Ma of their initial formation (Lissenberg et al., 2005a; Zagorevski et al., 2006). The accretion of these terranes over time led to significant growth of the eastern margin (present coordinates) of North America and (ultimately) to the formation of the Appalachian-Caledonian Orogen. The accretionary events took place mostly during the Cambrian and Ordovician periods, with the eventual closure and collision of the continental blocks occurring in the Silurian period (Figure 2).

The Dunnage zone is bisected by an ancient arc-arc collision zone that marks the suture zone along which the largest tract of Iapetus was consumed (Figure 2); this is known as the Red Indian Line, and it separates the Notre Dame and Exploits subzones of Williams et al. (1988). Specifically, the Red Indian Line juxtaposes relatively young rocks formed in the Red Indian Lake arc (Laurentian side) and the Victoria arc (Gondwanan side). This coeval volcanism on both sides of the Red Indian Line (e.g., Dunning et al., 1987; MacLachlan and Dunning, 1998b; O'Brien et al., 1997; Zagorevski et al., 2007a; Zagorevski et al., 2006), combined with other contrasts, such as fauna, Pb-isotopes and paleomagnetic data (Williams et al., 1988) indicates that subduction occurred on both sides of the Iapetus Ocean simultaneously during its final closure, as indicated in Figure 2 (panels C and D).

The development of these island arcs and related terranes, and their accretion to the Laurentian continental margin, is of more than academic interest, for these rocks have made, and continue to make, a very significant contribution to the mineral economy of the Province of Newfoundland and Labrador. Volcanogenic massive sulphide (VMS) deposits occur on both sides of the Red Indian Line, although different terranes are viewed as having different levels of prospectivity. On the northwestern side, the Buchans deposits were some of the richest of their kind anywhere in the Appalachians – in addition to Zn, Pb and Cu, Buchans was the largest single gold producer on the island. On the southeastern side, the Victoria Lake supergroup hosts an early (ca. 1905) copper mine (the Victoria Mine) and also the newly-opened Duck Pond mine, which is an important source of Cu, Zn, Ag and Au. The region hosts many other prospects and showings, and is a focus for active exploration for both base metals and precious metals. The TGI 3 project of the Geological Survey of Canada is aimed at improving geological knowledge in such areas of high potential, with the ultimate objective of assisting industry to find new resources to support Canada's minerals industry.

The 2007 Field Trip is structured in three parts. The first part (Day 1) focuses on the northwestern side of the Red Indian Line, and upon new geological work within the rocks traditionally known as the Buchans Group, which are now suspected to instead be a collage of volcanic terranes formed at different times (e.g., Zagorevksi et al., 2007). The second part (Day 2) ventures across the Red Indian Line to examine rocks within the Victoria Lake supergroup, notably those of the Sutherlands Pond and Tulks groups. This area hosts the historic Victoria Mine deposit. Day 3 of the field trip consists of a surface and underground visit to the new Duck Pond Mine, which is located within an older Cambrian arc terrane within the Victoria Lake supergroup, known as the Tally Pond group.

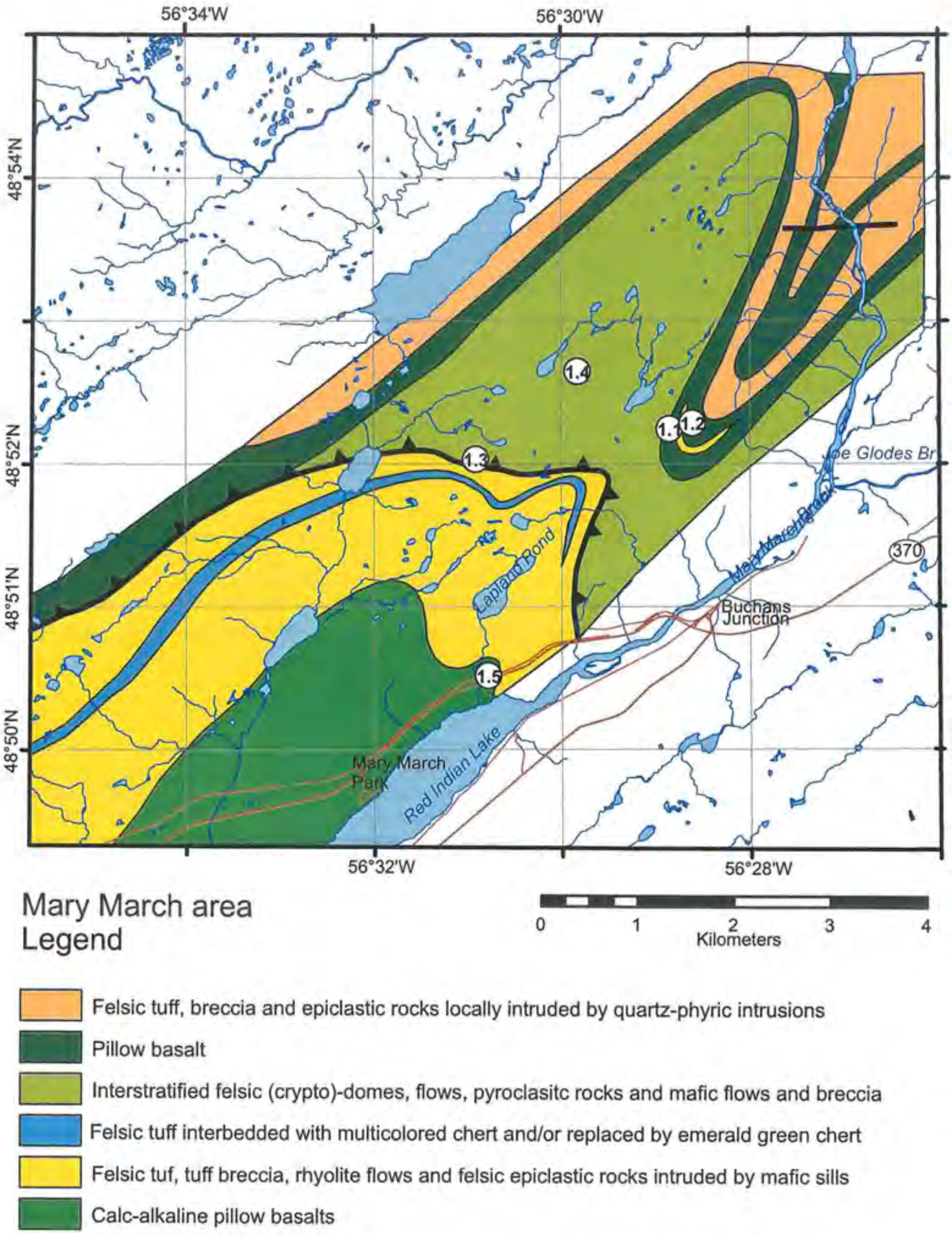


Figure 3. Preliminary simplified geological map of the Mary March Brook area.

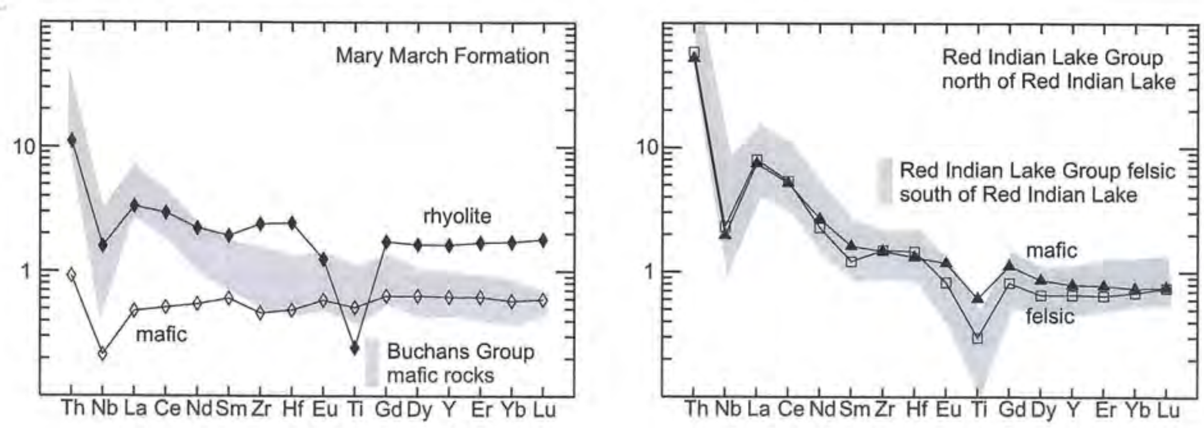


Figure 4. N-MORB normalized (Sun and McDonough, 1989) extended REE spidergrams of the Mary March Brook formation and structurally underlying Red Indian Lake group.

DAY 1: THE PERI-LAURENTIAN ANNIEOPSQUOTCH ACCRETIONARY TRACT NORTHWEST OF RED INDIAN LAKE

Leaders: Alexandre Zagorevski and Cees R. van Staal, Geological Survey of Canada, Ottawa, Ontario.

Geological Background

The Notre Dame Subzone (i.e., the peri-Laurentian portion of the Dunnage Zone) is dominated by Ordovician volcanic and plutonic rocks of the Notre Dame Arc and the volcanic and sedimentary rocks of the Annieopsquotch Accretionary Tract, which were deformed and metamorphosed during the Taconic Orogeny (Whalen et al., 1997; van Staal et al., 1998). The Notre Dame Subzone is unconformably overlain by Silurian red beds and lacks Caradocian (~455 Ma) black shales. The latter are characteristic of the Exploits Subzone, which represents the peri-Gondwanan portion of the Dunnage Zone, and in which there is a more continuous sedimentary record between the Ordovician and Silurian (Williams et al., 1988). This portion of the fieldtrip will focus on the tectonostratigraphic packages that occur immediately to the west of the Red Indian Line, and which constitute the most outboard units of the peri-Laurentian Annieopsquotch Accretionary Tract. These were thus some of the later Iapetan arc terranes to be accreted to the margin of Laurentia in the manner depicted in Figure 2.

Annieopsquotch Accretionary Tract

The Annieopsquotch Accretionary Tract (Figure 1) is bounded to the west by the Lloyds River Fault/Hungry Mountain thrust system (Lissenberg and van Staal, 2006; Lissenberg et al., 2005a; Thurlow, 1981) and to the east by the Red Indian Line (Zagorevski et al., 2007a; Zagorevski et al., 2006). Internally, the constituent units of the Annieopsquotch Accretionary Tract are juxtaposed along northwest-dipping oblique reverse shear zones, which appear to become progressively younger to the southeast, suggesting progressive accretion of these terranes to the Laurentian margin.

The structural relationships between the units of the Annieopsquotch Accretionary Tract are well preserved in the Buchans area (Figure 1), where an extensive south-southeast-directed, northwest-dipping thrust duplex system was recognized (Calon and Green, 1987; Thurlow et al., 1992; Thurlow and Swanson, 1987). The Hungry Mountain thrust (Thurlow, 1981) forms the roof thrust to this system, and the Red Indian Line (Williams et al., 1988) forms the floor thrust (Thurlow et al., 1992). Three-dimensional relationships are well-understood in the immediate Buchans area, where there has been extensive drilling over more than 50 years, and a seismic-reflection survey, but information (and outcrop) is sparse elsewhere.

Structural relationships are more complicated south and southeast of Buchans, where the intensity of deformation increases towards the Red Indian Line and several phases of deformation are preserved. The polyphase deformation in those areas has resulted in tight to isoclinal folding, steepening and reactivation of the thrusts as steep,

Table 1: Stratigraphy of the Buchans Group (from Thurlow and Swanson, 1987)

Formation	Rock types	Former Stratigraphic Names
Sandy Lake Formation	Basaltic pillow lava, pillow breccia intertonguing with coarse grained, redeposited clastic rocks of felsic volcanic derivation (arkosic conglomerate, arkose, wacke, siltstone). Local abundant tuff, breccia, polylithic pyroclastic breccia and tuffaceous sedimentary rocks.	Sandy Lake Basalt, Upper Arkose, Lake Seven Basalt, Footwall Arkose, Footwall Basalt, part of Prominent Quartz sequence,
Buchans River Formation	Felsic tuff, rhyolite, rhyolite breccia, pyritic silstone, wacke, polylithic breccia-conglomerate, granite boulder conglomerate, high-grade in situ and transported sulphide orebodies.	Lucky Strike Ore Horizon sequence, Oriental Ore Horizon sequence. parts of Intermediate Footwall.
Ski Hill Formation	Basaltic to andesitic pyroclastic rocks, breccia, pillow lava, massive flows. Minor felsic tuff.	Ski Hill sequence, parts of Intermediate Footwall, Oriental Intermediate.
Lundberg Hill Formation	Felsic pyroclastic rocks, coarse pyroclastic breccia, rhyolite, tuffaceous wacke, siltstone, lesser basalt, minor chert and magnetic iron-formation.	Part of Prominent Quartz sequence, Wiley's Prominent Quartz sequence, Little Sandy sequence (?).

Table 2: Major element whole-rock geochemical analyses of basalts from the Mary March Brook formation.

	Mary March basalt	
SiO_2	38.11	39.84
TiO_2	0.65	0.67
Al_2O_3	13.07	13.07
Fe_2O_3	7.57	7.27
MnO	0.19	0.15
MgO	4.59	4.13
CaO	15.29	14.54
Na_2O	4.39	4.62
K_2O	0.08	0.06
P_2O_5	0.08	0.07
LOI	16.09	15.62
Total	100.19	100.11

southeast directed sinistral oblique reverse faults, as well as local overturning and reactivation of thrusts as northwest directed faults (Zagorevski et al., in press).

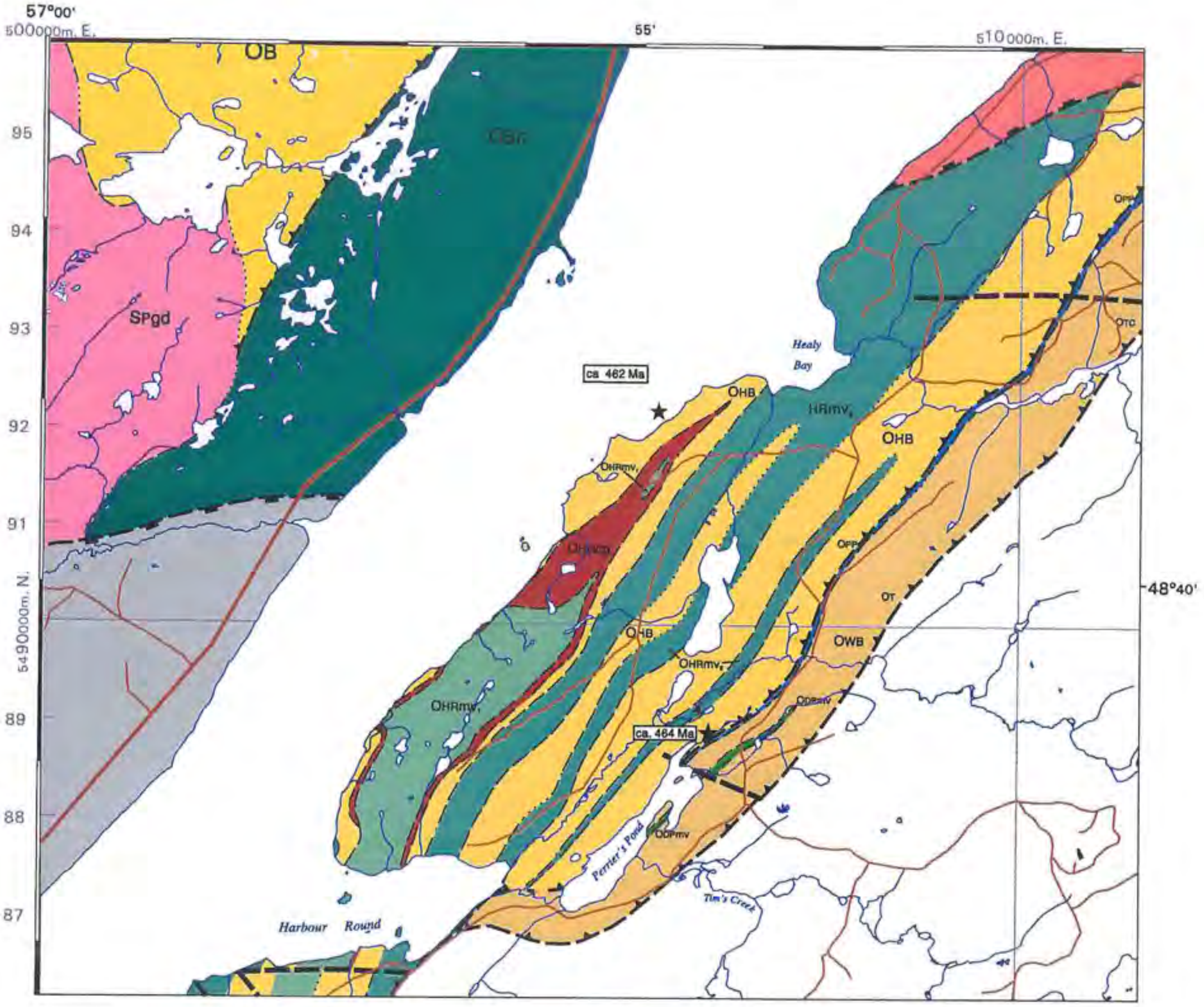
From northwest to southeast, the Annieopsquotch Accretionary Tract contains several discrete structural panels comprising the Annieopsquotch Ophiolite Belt (U/Pb zircon dates of 477.5 +2.6/-2, 481 +4/-1.9 Ma: Dunning and Krogh, 1985), Lloyds River Ophiolite Complex (U/Pb zircon dates of 473 ± 3.7 Ma: Zagorevski et al., 2006), Otter Pond Complex (U/Pb zircon dates of 468 ± 2 Ma: Lissenberg et al., 2005a), Buchans Group (U/Pb zircon dates of 473 +3/-2: Dunning et al., 1987; 467 to 462 Ma: Zagorevski et al., unpublished data) and the Red Indian Lake group (U/Pb zircon dates of 464.8 ± 3.5, 462 +2/-9, 465 ± 2, 463 ± 3 Ma: Zagorevski et al., 2006) respectively, which have a combined structural thickness of 8 to 15 km.

The formation and assembly of the AAT occurred piecemeal, as indicated by Figure 2 (Lissenberg et al., 2005a; Zagorevski et al., 2006). Initial formation of the inboard ophiolite and continental arc complexes occurred between 480 and 473 Ma, followed by accretion to the Dashwoods (Laurentian) margin between 470 and 468 Ma (Lissenberg et al., 2005a). Subsequent arc formation and rifting (Harbour Round and Skidder formations in the Red Indian Lake group) was followed by termination of subduction due to collision with the peri-GondwananVictoria Arc and terminal closure of the main Iapetan basin by ca. 455 Ma (van Staal et al., 1998). This portion of the fieldtrip will concentrate on the continental arc and backarc complexes that form part of the Buchans Group (Thurlow, 1981; Thurlow et al., 1992; Thurlow and Swanson, 1987; Zagorevski et al., 2007b) and the Red Indian Lake group (Zagorevski et al., 2006).

Buchans Group

The Buchans mining camp produced 16.2 million tonnes of ore at an average grade of 14.5% zinc, 7.6% lead, 1.3% copper, 126g/t Ag and 1.37 g/t Au at from 1928 until the mining operations ceased in 1984. The ore was mostly mined from five main orebodies thought to represent a single stratigraphic horizon within the Buchans Group (i.e., Thurlow and Swanson, 1987). The stratigraphy of the Buchans Group underwent significant revision prior to and following the mine closure. Recognition of numerous significant thrust faults allowed simplification of the stratigraphic relationships (Thurlow et al., 1992; Thurlow and Swanson, 1987). The most recent stratigraphy of the Buchans Group is primarily based on relationships established in the mineralized fault-bounded blocks that host the Oriental and McLean orebodies, and it was from the Oriental block that the Lundberg Hill, Ski Hill, Buchans River and Sandy Lake formations were defined (Table 1: Thurlow and Swanson, 1987). The revised stratigraphy (Thurlow and Swanson, 1987) successfully predicted repetitions of ore horizons and related rocks by thrust faults hundreds of metres below the MacLean orebody and allowed accurate constraints on the displacements of faults (J.G. Thurlow, personal communication, 2006).

Despite this, it has proved difficult to apply the existing mine-scale stratigraphy outside of the main mineralized blocks. Geochemical data (Jenner, 2002b) and recent geochronological sampling provide new data that raise questions about the existing



LEGEND

(Ordovician and older rocks are generally foliated and metamorphosed, as are parts of the Silurian and Devonian sequences).

CARBONIFEROUS

C *SHANADITHIT FORMATION: mainly poorly indurated red and grey sandstone and conglomerate, minor limestone and siltstone.*

SILURIAN AND/OR DEVONIAN

SDs *Red sandstone and conglomerate, minor siltstone.*

NOTRE DAME/DASHWOODS SUBZONES

SILURIAN

PUDDLE POND COMPLEX (circa 431 Ma)
Complex includes Main Gut and related intrusions.

SPgd *Unfoliated to foliated, medium- to coarse-grained, orange to white biotite-hornblende tonalite to biotite granite. Biotite is often replaced by chlorite. Contains locally megacrysts of K-feldspar.*

LOWER–MIDDLE ORDOVICIAN

RED INDIAN LAKE GROUP (Arenig–Llanvirn)

OHB *HEALY BAY FORMATION (Llanvirn): mainly light grey to white, ash to quartz crystal tuff, minor rhyolite, volcanogenic sandstone and shale. All lithologies are locally interlayered with red shale and/or chert.*

OHRgb
OHRcg
HRmv$_1$
HRmv$_2$

HARBOUR ROUND FORMATION (Llanvirn): mainly green to red haematized, pillow to massive basalt, pillow breccia, diabase, gabbro (OHRgb), and andesite. All lithologies are interlayered with red chert and shale, whereas the pillow basalt locally contains interstitial limestone. Basalt are divided into two members separated by a largely volcanogenic polymictic conglomerate (OHRcg). The basalt stratigraphically below the conglomerate exhibit predominantly island-arc to transitional island-arc/back-arc compositions (OHRmv$_1$). The upper basalt (OHRmv$_2$) is predominantly calc-alkaline.

OSK *SKIDDER FORMATION (Arenig–Llanvirn): mainly amygdaloidal and/or variolitic, green pillow, pillow breccia, and massive basalt. Minor trondhjemetic pods and dykes (circa 464 Ma) and red jasperitic chert. Basalt are island-arc to transitional island-arc/back-arc in composition; slight difference in trace element and REE characteristics distinguish this sequence from OHRmv$_1$.*

BUCHANS GROUP (Arenig)

OB *Undivided; mainly felsic and mafic arc-related volcanic rocks and associated sedimentary rocks and massive and/or disseminated sulphide.*

EXPLOITS SUBZONE

VICTORIA LAKE SUPERGROUP

WIGWAM BROOK GROUP (Arenig–Caradoc)

OWB *Undivided, mainly grey to light brown, felsic volcanic rocks of the Dragon Pond Formation and volcaniclastic sandstone, siltstones, and minor shale of the Halfway Pond Formation. Minor locally pillowed, island-arc tholeiitic basalt, red to black, cherty, aphyric dacite and/or rhyolite, and interlayed red shale. Locally includes black shales typical of the Perriers Pond Formation.*

🟦 *PERRIERS POND FORMATION (Caradoc): black shale, locally calcareous, and minor interlayered volcanogenic siltstone and sandstone. In part transformed into broken formation or mélange.*

Figure 5. Geological map of the type locality of the Red Indian Lake group showing the relationships between the constituent formations (from Rogers et al., 2005b).

correlations. Buchans was previously dated at c. 473 Ma (Dunning et al., 1987); however, recently obtained U/Pb zircon dates suggest that volcanism in the Buchans Group was also occurring at ca. 462 to 467 Ma (V. J. McNicoll, unpublished data). Several structural panels outside the mine area have been assigned to several different formations over the past several decades and are now in the process of being re-examined, including the provisional Mary March Brook formation (Zagorevski et al., 2007b, see below) which has more similarity with rocks of the Gullbridge area than with the Buchans Group (cf., O'Brien, 2007). Reconciling these problems will hopefully allow better delineation of prospective horizons within the Buchans area beyond the historic mining camp, and aid in the establishment of a consistent stratigraphic and structural framework for the wider Buchans-Robert's Arm belt.

Mary March Brook formation

The Mary March Brook formation is a provisionally proposed unit of volcanic rocks that are best exposed in the highlands to the west of Mary March Brook (Figure 3). It comprises a bimodal volcanic sequence previously included in the Sandy Lake Formation (Davenport et al., 1996), Lundberg Hill Formation (Davenport et al., 1996; Thurlow and Swanson, 1987) or correlated with the Skidder basalt (Thurlow and Swanson, 1981). Rare observations of younging directions in the Mary March Brook formation volcanic rocks suggest that they are internally folded, and such patterns are supported by the newly acquired geophysical surveys (Dumont et al., 2007). The Mary March Brook formation volcanic rocks consist of aphyric to finely quartz-phyric, quartz-feldspar-phyric, and feldspar glomeroporphyritc rhyolite flows and (crypto)-domes. The margins of the flows/domes are commonly strongly vesicular and are associated with rhyolite breccia, lapilli tuff and bedded, laminated, fine grained felsic tuffs, and epiclastic rocks. The rhyolite is intimately intercalated with mafic to andesitic pillow lava, pillow breccia and minor mafic tuff-breccia, indicating coeval andesitic-felsic magmatism. Geochemical analyses indicate tholeiitic to transitional calc-alkaline arc chemistry, which is distinct from the published analyses of the Buchans Group (Figure 4; Jenner, 2002a).

Mary March Brook formation volcanic rocks show evidence of pervasive hydrothermal alteration. Rhyolite and rhyolite dykes are locally sulphidized and contain disseminated pyrite. Pillowed andesites are strongly altered and locally converted into epidosite. This unit appears to be highly prospective and is host to the Connel Option and Little Sandy Lake prospects, as well as the Beaver Pond Zinc and Silver showing, and Buchans Junction North showings. Preliminary work suggests that Mary March Brook formation continues into the Gullbridge area (Figure 1), where it is called the "bimodal unit" (O'Brien, 2007) or the Baker Brook tract (Swinden and Sacks, 1996).

Red Indian Lake group

The Red Indian Lake group (Zagorevski et al., 2006), mostly exposed along the shores of Red Indian Lake, comprises rocks that were previously allocated to several informal units, such as the Healy Bay siltstone, Harbour Round basalt (Thurlow et al., 1992), Harbour Round formation (Kean and Jayasinghe, 1980) and Skidder basalt (Pickett, 1987). These have been expanded upon to reflect the lithological characteristics

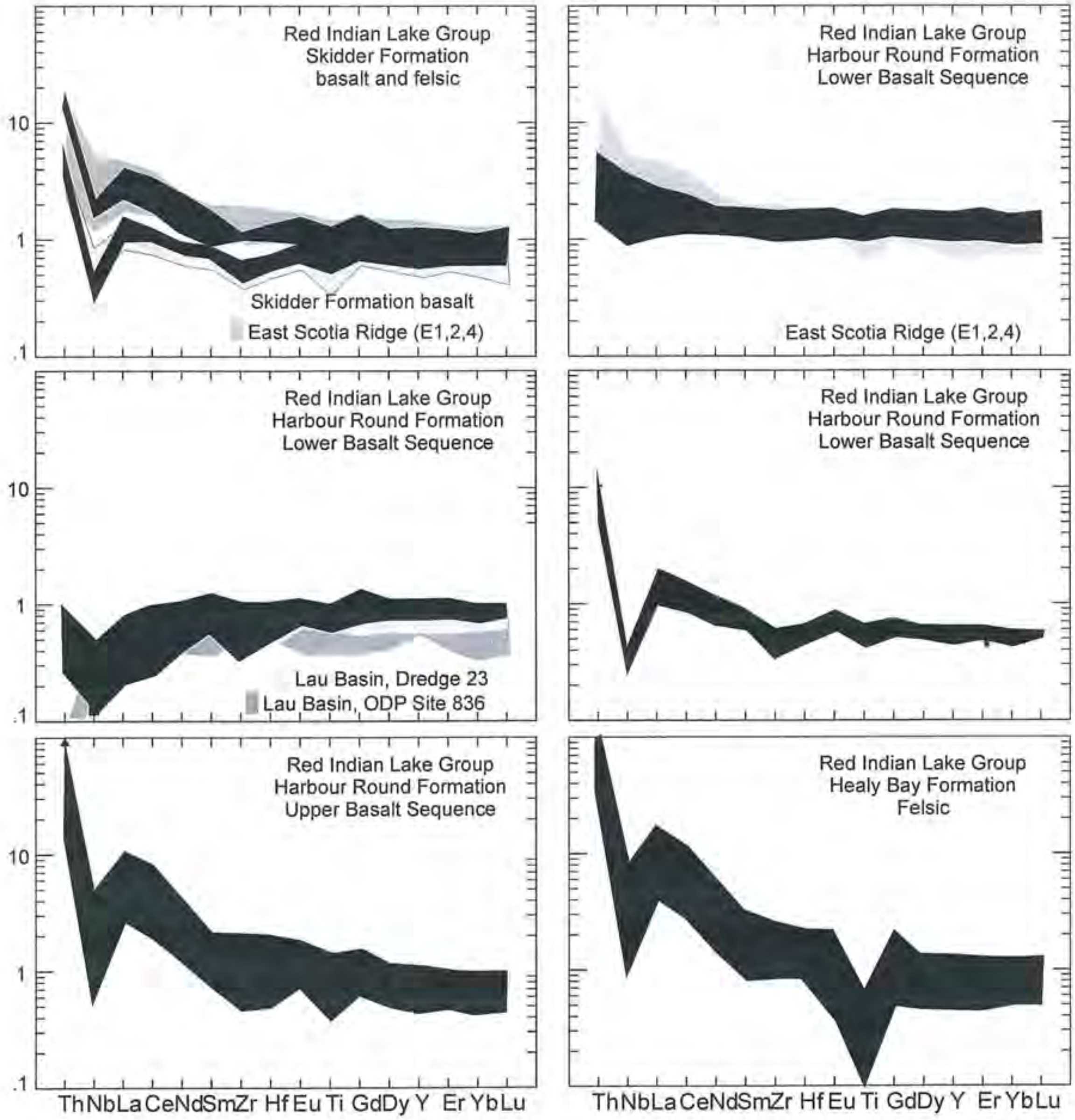


Figure 6. N-MORB normalized (Sun and McDonough, 1989) extended REE spidergrams of the chemical groups defined in Zagorevski et al. (2006). Shaded fields are Skidder formation and Buchans Group basalt (Davenport et al., 1996b); selected samples from back-arc East Scotia Sea Ridge (Fretzdorff et al., 2002; Leat et al., 2000); selected samples from Lau Basin Dredge 23 (Pearce et al., 1995); selected samples from Site 836, ODP Leg 135 (Hawkins and Allan, 1994).

in the type localities, and three revised units were proposed for the Red Indian Lake group, i.e., the Harbour Round, Healy Bay and Skidder formations. The general geology of the Red Indian Lake group is shown in Figure 5.

The Red Indian Lake Group is separated from the structurally underlying peri-Gondwanan Victoria Lake supergroup (Evans and Kean, 2002; see Day 2) by the Red Indian Line. The contact of the Red Indian Lake group with the Buchans Group is inferred to be a fault. The Healy Bay formation is stratigraphically intercalated with the more extensive Harbour Round formation. The Red Indian Lake group is exposed in a 1-6 km wide, imbricated belt for at least 150 km from Wood Lake to Red Indian Lake and correlatives may exist in the Roberts Arm – Chanceport area, well to the northeast.

Harbour Round Formation: The Harbour Round Formation is informally subdivided into the lower and upper basalt members, with the lower basalt member dominating the southern portion of the formation's exposures and the upper basalt the northern part. All rock types are intercalated with felsic tuff typical of the Healy Bay Formation. The lower basalt member comprises predominantly light green pillow basalt of tholeiitic character (Figure 6) associated with hematitic red shale, interstitial limestone, diabase, gabbro, iron formation and felsic tuff. The appearance of a polymictic volcanogenic conglomerate to breccia marks the base of the upper calc-alkaline basalt member (Figure 6). The conglomerate ranges from clast- to matrix-supported, and from thinly bedded to massive. The clasts comprise felsic volcanic rocks, mafic volcanic rocks and jasper. In the stratigraphically higher levels the conglomerate is associated with hematized pillow basalts, which are chemically distinct from the lower basalt member.

Healy Bay Formation: The Healy Bay Formation comprises mainly light grey to white, ash to crystal tuff locally associated with rhyolite (465±2, 463±3, 462+2/-9 Ma: Zagorevski et al., 2006), volcanoclastic sandstone and shale. All rock types are locally interlayered with red shale and/or hematitic chert. Bedded red shale, typical of the Llanvirn stage in the Appalachians, can locally be abundant with a thickness exceeding several metres.

Skidder Formation: The Skidder Formation, which is named after the previously defined Skidder basalt (Pickett, 1987), is a tholeiitic sequence (Figure 6) of predominantly pillowed and massive amygdaloidal and variolitic basalt, and pillow breccia that locally hosts significant VMS-style mineralization (Skidder Prospect; Pickett, 1987). These basaltic rocks are associated with interstitial jasper, interflow hematitic siltstone and jasper, and are intruded by gabbroic dykes and pods of chemically related trondhjemite (Davenport et al., 1996; Pickett, 1987). The Skidder Formation is well exposed in Skidder Brook, east of the Skidder Prospect, where pillow lava and breccia are cut by fine grained trondhjemitic dykes dated at 464.8 ± 3.5 Ma (Zagorevski et al., 2006). The absence of calc-alkaline basalt and felsic tuff distinguishes the Skidder formation from the upper basalt of the Harbour Round Formation.

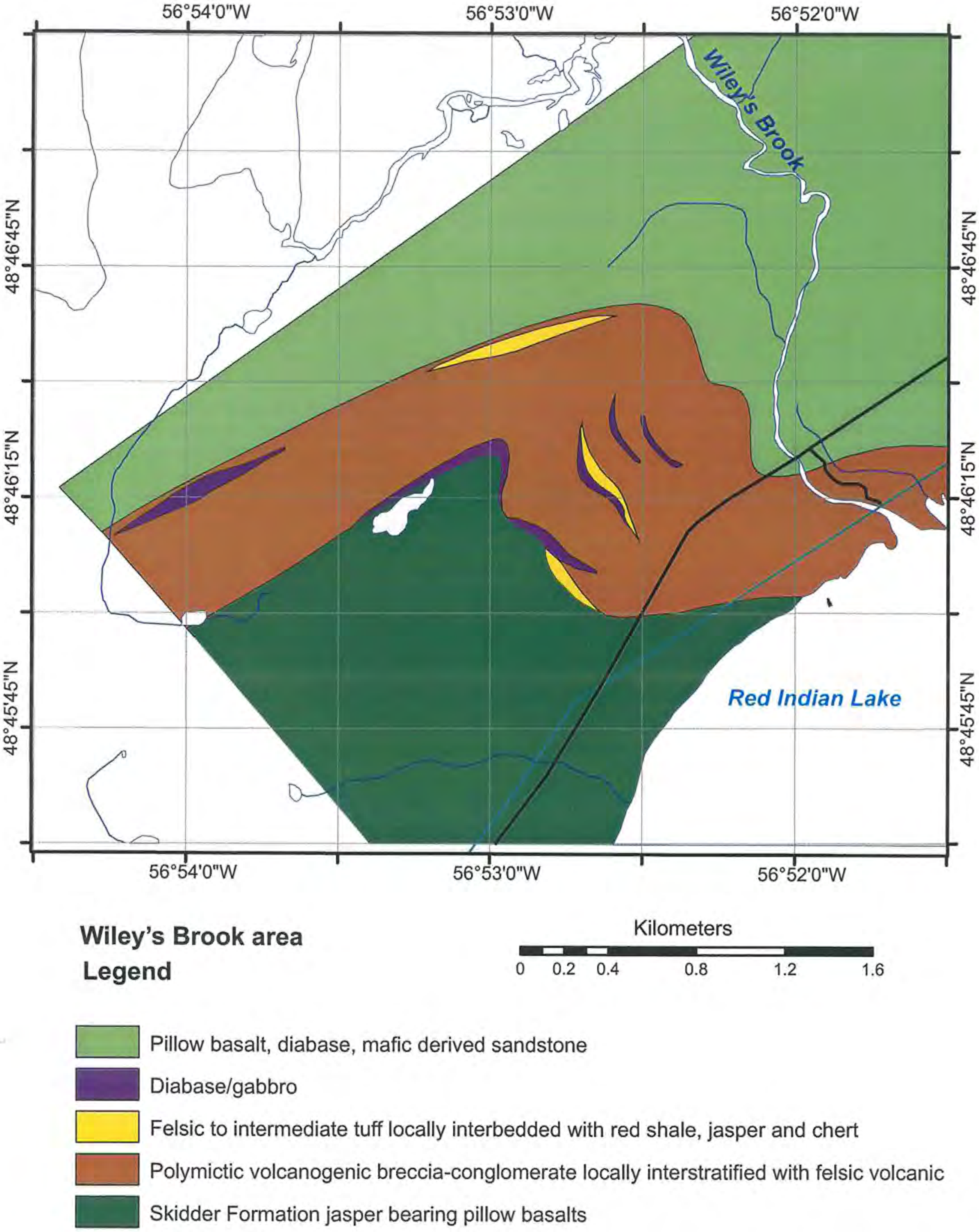


Figure 7. Preliminary simplified geological map of the Wiley's Brook area.

Zagorevski et al. (2006) proposed the Skidder formation to be correlative with the Harbour Round formation on the south side of Red Indian Lake. Recent logging in the Skidder Brook area has exposed a section through the cover sequence to the Skidder formation (Figure 7). The relationships in this cover sequence are remarkably similar to those seen in the Harbour Round formation (Figure 8). The Skidder formation appears to be stratigraphically overlain by a poorly-exposed unit of interbedded red shale, epiclastic sandstone, felsic tuff, jasper, and grey to cream chert, which are partially channelled and overlain by a poorly stratified breccia /volcanogenic conglomerate unit. The conglomerate appears to cut significantly down section, and locally directly overlies the Skidder formation jasperitic pillow lavas. The conglomerate is intruded by pillowed mafic intrusions and interstratified with mafic sandstones and tuffs. It is overlain by a thick basaltic sequence with calc-alkaline chemistry and felsic pyroclastic rocks containing Whiterockian carbonate clasts (Nowlan and Thurlow, 1984).

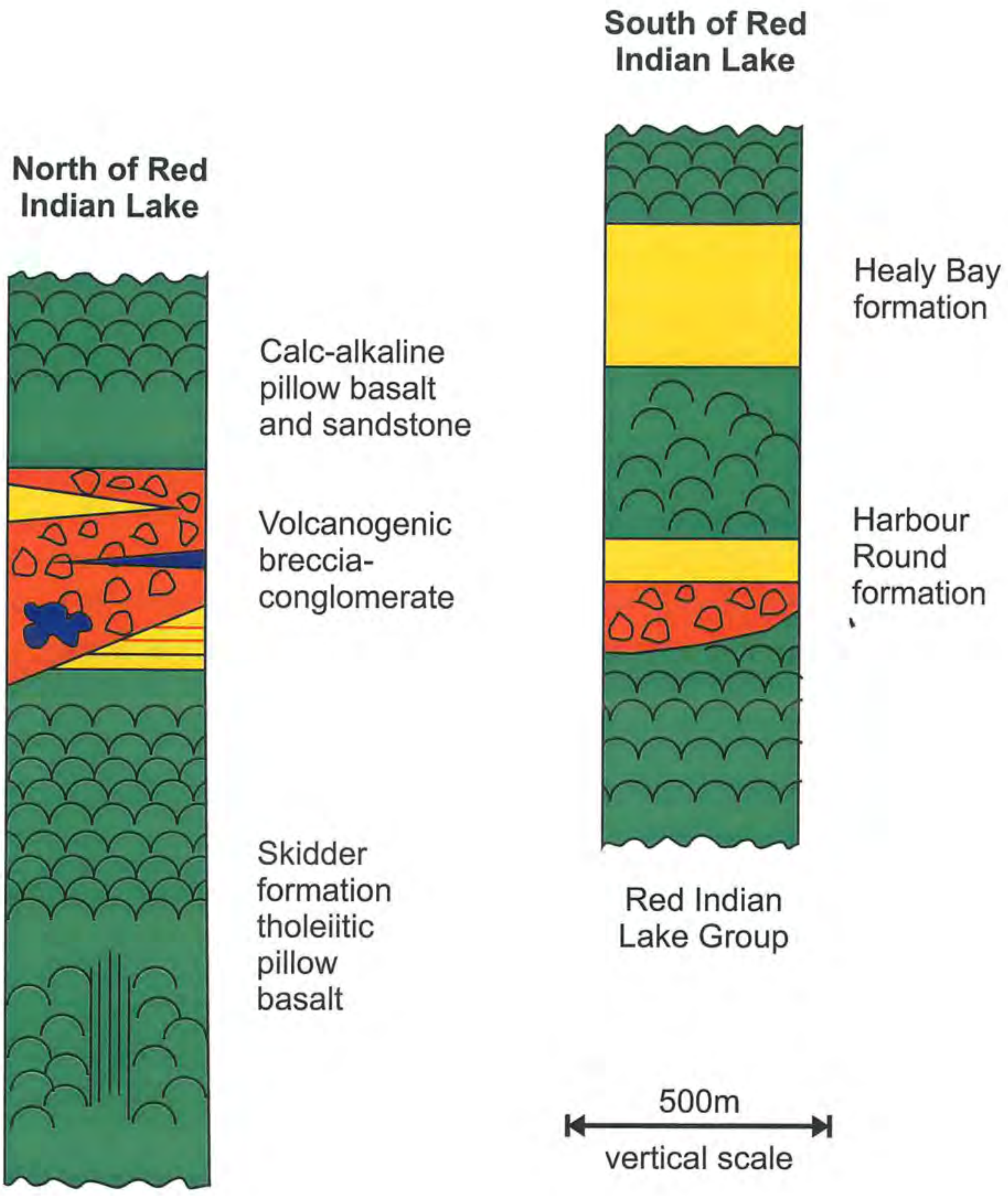


Figure 8. Comparison of the stratigraphy of the Red Indian Lake group south of Red Indian Lake and the Skidder formation north of the Red Indian Lake.

DAY 1 FIELD TRIP STOPS

General Information

The Day 1 field trip stops are in two areas. The first group is located northwest of Buchans Junction, and is accessed by forest roads. The second group is located southwest of Buchans in the area around Skidder Brook and Wiley's Brook. These are accessed by a forest road along the shore of Red Indian Lake. The information below includes UTM coordinates for both NAD27 and NAD83 systems (most topographic maps use the NAD27 data) and vehicle odometer information. Note that vehicle odometers vary in accuracy by about +/- 10%, so your vehicle may give slightly different results. To minimize problems, we have in all cases logged mileage from the nearest stop or landmark. Note also that none of these roads are part of the public system, and they are not regularly maintained – indeed, some are not maintained at all! Road information is current as of early Fall 2007, but the conditions may have changed since.

Stop 1.1: Mary March Brook formation (mafic and felsic rocks)

(UTM Zone 21; NAD27 - 537944 5412980, NAD83 - 538038 5413191)

Drive on the highway from Badger to Buchans Junction, and reset the odometer at the Mary March Lounge (opposite the log-cabin church). Continue for 2.0 km towards Buchans, and turn right onto a forest access road. Continue for 1.8 km, and go straight on at a junction. Continue for a further 1.3 km, and turn left at the junction (be careful for washouts). Continue along this rather rough road for 1.0 km to a large outcrop. Outcrop 1 (see below) is a short distance along the road, on the left.

Mary March Brook formation is predominantly exposed along Mary March Brook and on the logging roads to the west. Recent logging has opened this previously largely inaccessible area to more detailed study. The series of large outcrops seen in this stop are characteristic of the mafic portions of the bimodal Mary March Brook formation, and show the transition into felsic rocks. Outcrop 1 (west) is stratigraphically lowest in this section.

Outcrop 1: Amygdaloidal brown weathering pillow basalts on the south side of the road. These pillow basalts have well defined shapes and cusps indicating younging to the east. The vertical face in this outcrop and next indicates that the basalts are slightly overturned, consistent with moderately to steeply dipping foliation developed in these rocks. The younging direction observed in this outcrop is extremely important as folding was not previously recognized in this area, except by Pickett and Woolham (1995). The pillow basalts in this and next stop are extremely altered with 38% SiO_2 and >12% LOI (Table 2).

Outcrop 2: This is the large outcrop used as a landmark above. The pillow basalts exposed in a steep face are more deformed and flattened; near the ditch they grade into well-preserved pillow breccia which shows haematitic alteration to the east, near its contact with the felsic volcanic rocks.

Outcrop 3: These outcrops are located a short distance eastward from outcrop 2. The outcrops of both sides of the road outcrops display the typical textures of the felsic pyroclastic rocks of the Mary March Brook formation, including quartz-phyric crystal tuff and tuff breccia containing pink, flow-banded rhyolite, pumiceous rhyolite flow, and autoclastic rhyolite breccia containing large blocks of weakly flow-banded, grey rhyolite.

Stop 1.2: Mary March Brook formation (mafic rocks with stretched amygdules)

(UTM Zone 21; NAD27 – 538241 5413259; NAD83 – 538335 5413270

From Stop 1.2, turn around and go about 0.3 km to a large "parking lot" area. Park in this area. Outcrops are located on the north side of the road. They consist of very well-formed pillow basalts with interpillow white chert. The pillows are highly elongated down the steep dip direction. This lineation can also be clearly observed in the amydgules which have high aspect ratios. The northern portion of the outcrop has several very well formed pillows that indicate younging to the northeast. The change from the previous outcrop, combined with the northeasterly trend of fold hinges, indicates that we are in the hinge of an F2 syncline.

Stop 1.3: Mary March Brook formation rhyolite domes

(UTM Zone 21: NAD27 – 536777 5413707; NAD83 - 536838 5413931)

From Stop 1.2, return to the junction, turn right, and drive 1.3 km to the next junction, and turn right. From this junction, drive 1.8 km to another junction, and turn right again. Continue along this road for another 1.7 km, or as far as your vehicle can go. Parts of it are rough, and you may have to walk the last section. The stop is a large white-weathering outcrop on the left hand side of the road.

Outcrop 1: Park beside the large outcrop at the top of the hill. The outcrop is an autobrecciated, weakly quartz- and feldspar-porphyritic rhyolite flow or rhyolite breccia. Portions of the outcrop display pumiceous textures, and the western part of the outcrop contains several dark grey rhyolite tongues in this material. The Mary March Brook formation contains multiple rhyolite domes and cryptodomes characterized by massive interiors and auto-brecciated to pumiceous margins. The typical rhyolite dome is ~200 m thick and up to 1 km in strike length. The rhyolites are interfingered with chloritized bimodal to mafic breccias on the regional scale. Rare younging indicators observed to the northeast indicate that this outcrop is located on the northwest dipping limb of a northeast plunging anticline.

Outcrop 2: From outcrop 1, walk or drive about 0.6 km back along the road, to another large outcrop of felsic rocks. From here, walk through the cutover along the ridge defined by the felsic unit. The roadside outcrop represents the central portion of the dome and is relatively massive. Outcrops about 150 m along the ridge represent the outer and/or upper section of the dome and are heterogeneous, autobrecciated and more altered. The transition illustrates the facies variability of the felsic rocks. Depending on time and weather conditions, this outcrop may be omitted.

Stop 1.4: Mary March Brook formation epidosites

(UTM Zone 21; NAD27 – 535439 5412577; NAD83 - 535519 5412782)

From Stop 1.3, return to the junction, and this time turn right, and drive for about 0.5 km. The road is rough and it may be necessary to walk. Park on the side of the logging road and walk 100 m into the clear-cut towards a large outcrop.

The outcrop consists of banded schist. The schist is formed by flattening of highly altered pillow lavas. The white-weathering, presumably albite- and chlorite-rich, bands represent the pillow rims, whereas the epidosite bands are inferred to represent cores of the pillows. Better-preserved pillow shapes can be seen on the back side of the outcrop. The strong fabric seen in this outcrop is at high angle to the axial traces of F2 folds described in previous outcrops. It may represent part of a D1 shear zone that was folded by the regional F2 folds. If correct, then the underlying calc-alkaline sequence, which chemically differs from these rocks, is probably an unrelated, structurally-juxtaposed, tectonic slice.

Stop 1.5: Mineralized Pillow Basalts of the Red Indian Lake group

(UTM Zone 21; NAD27 – 535982 5409859; NAD83 - 536057 5410073)

From Stop 1.4, return to the Buchans Highway, by going straight on at the first junction and turning right at the second junction. Turn right onto the highway and drive 0.7 km to a large outcrop located beneath the power line. *BE WARY OF TRAFFIC AT THIS OUTCROP!*

This outcrop contains well-preserved mineralized pillow basalts of the calc-alkaline sequence that occurs structurally below the previously-visited outcrops of the Mary March Brook formation. The basalts dip moderately to steeply, and young to the northwest. Calcite amygdales are commonly elongated and locally contain chalcopyrite, pyrite, and bornite. Several veins cutting the outcrop contain similar mineral assemblages.

Lunch Stop – Red Indian Lake

From Stop 1.5, continue on the highway towards Buchans. Turn left on a gravel road just before the first major river bridge. This road leads to cabins located on the shore of Red Indian Lake. The beach is a pleasant place for a picnic lunch. If there is a time, a walk of about 20 minutes northeastward along the shore will bring you to small outcrops of Carboniferous sandstone, but these are really rather boring, and not really worth the hike unless you just want some exercise.

Stop 1.6a: Skidder Formation Pillow Basalts

(UTM Zone 21; NAD27 – 506502 5397894; NAD83 - 506573 5398110)

From Stop 1.5 or the lunch stop, continue towards Buchans. After crossing the Buchans River, look for the intersection of a major woods road on the left hand side, and turn onto this road. Turn right at the first junction, and drive to the bridge at Wiley's Brook, located about 7.7 km from the junction with the Buchans highway. Continue for another 5.4 km to a large outcrop on the right hand side of the road. *NOTE THAT THIS ROAD MAY BE USED BY LOGGING TRUCKS – BEWARE OF TRAFFIC!*

The large, bulbous outcrop on the north side of the road consists of large, well-formed pillow basalts of the Skidder formation. Similar basalts host the Cu-rich Skidder VMS prospect located approximately 0.8 km NNW of here (Pickett, 1987; Tallman, 2007). The interpillow jasper and chert are a common feature of the Skidder formation, as is replacement-style and locally bedded jasper. The pillows in this outcrop young to the northeast, at a high angle to the locally developed S_2 foliation, suggesting that the outcrop is located in a northeast plunging F_2 fold hinge.

Stop 1.6b: Trondhjemite Veins cutting Skidder Formation Basalts

(UTM Zone 21; NAD27 – 506008 5397242; NAD83 – 506078 5397456)

This is an optional stop that is not suitable for large groups, and may be omitted. From Stop 1.6a, continue for another 0.8 km to the bridge over Skidder Brook. The outcrops are exposed in the brook, upstream from the bridge.

The basalts at this outcrop are cut by numerous trondhjemitic veins, which were dated at 464.8 ± 3.5 Ma (Zagorevski et al., 2006). This age provides a minimum age for the Skidder formation basalts. However, some Silurian zircons were also recovered, which presents an interesting problem – do these perhaps come from some very thin veins in the outcrop?

Stop 1.7: Skidder Formation cover sequence

(UTM Zone 21; NAD27 – 508645 5401858; NAD83 - 508712 5402055)

From the previous stop, drive back towards Wiley's Brook. Just before reaching the bridge, turn left on a secondary woods road that leads up the hill. Reset the odometer. Keep right at the first junction, and then just keep heading uphill, for a distance of about 1.3 km, where there is a junction. It may be necessary to walk the last 400 m or so up the hill from here if you do not have a 4WD vehicle.

The large semi-continuous outcrop on the northeast side of the road preserves many of the features of the relatively thick volcanogenic breccia-conglomerate unit which overlies the variolitic, jasperoidal pillow basalts typical of the Skidder formation (Pickett, 1987). The internal complexity of the breccia unit is clearly demonstrated by this outcrop and may shed light on its origin. Portion of the outcrop are dominated by mafic volcanic clasts, while others are more polymictic, containing mafic rocks, felsic volcanic rocks and porphyries, jasper, and iron formation. The mixed provenance for the breccias is evident throughout this unit and may be helpful to determine its stratigraphic position. Another interesting feature in this outcrop is the presence of pillowed mafic intrusions, indicating coeval sedimentation and mafic magmatism, because they appear to have been intruded into partly consolidated material. The mafic intrusions have a vague dyke-like form, and are located in the lowermost portion of the outcrop.

Stop 1.8: The Lucky Strike Open Pit, Buchans

If time permits, we will visit the town of Buchans. Return to the highway and turn left. The road ends at the open pit developed at the surface intersection of the Lucky Strike orebody, which is just one of several Zn-Pb-Cu-Ag-Au deposits in the mining camp. Buchans was an extremely rich deposit that was in many respects a Voisey's Bay of its era, and the mines here operated for over 50 years. The area remains under active exploration, and there may well be undiscovered orebodies hidden in complex subsurface geology. The base-metal potential of the Buchans area provides the rationale for detailed geological studies in the surrounding area by GSC and GSNL.

There is an interesting museum in Buchans that may be available for a short visit by the field trip group.

DAY 2: THE RED INDIAN LINE AND THE NORTHERN PART OF THE PERI-GONDWANAN VICTORIA LAKE SUPERGROUP

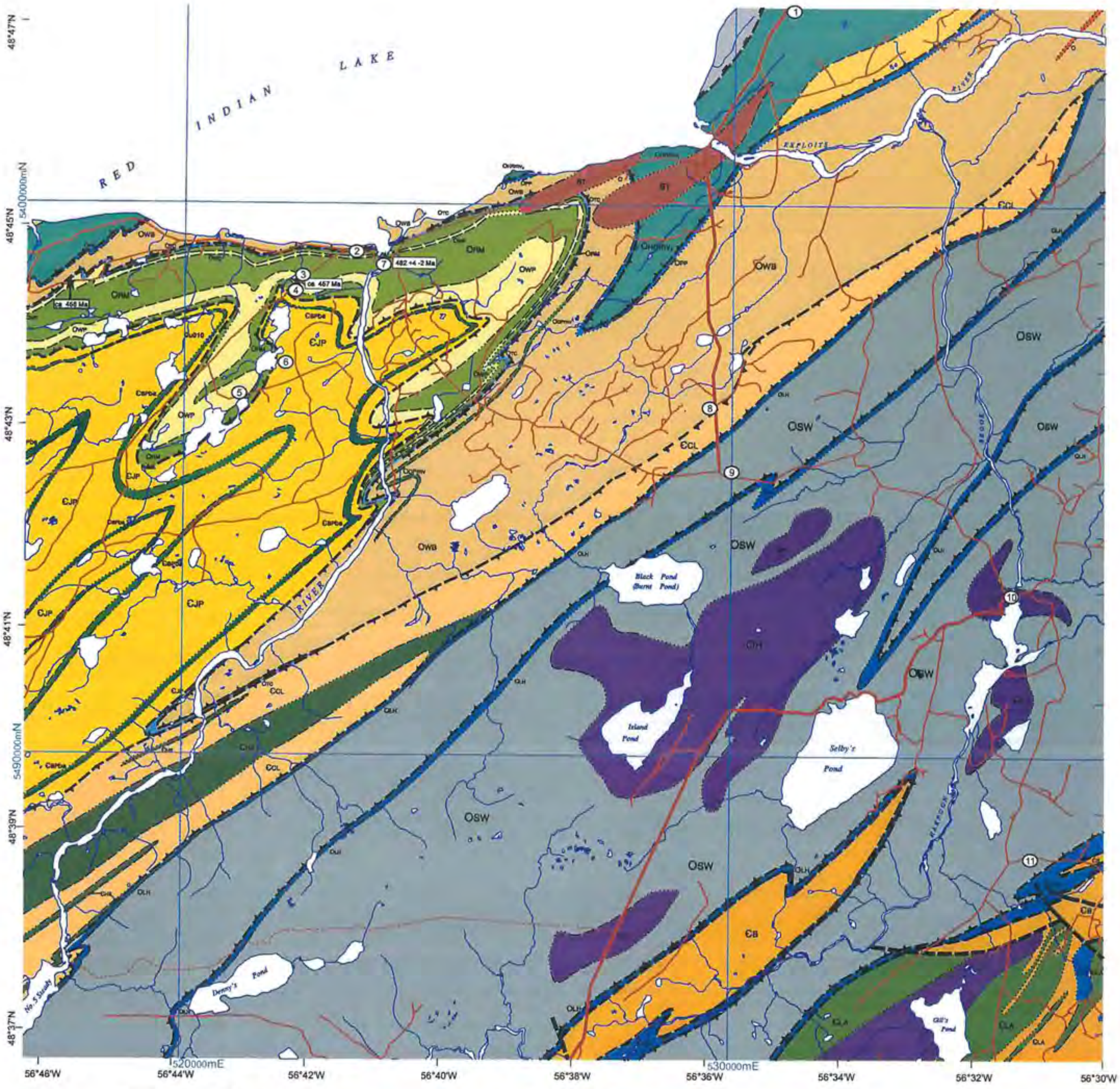
Leaders: Alexandre Zagorevski and Cees R. van Staal, Geological Survey of Canada;
John Hinchey and Andy Kerr, Geological Survey of Newfoundland-Labrador.

Geological Background

The Victoria Lake supergroup is bounded by the Red Indian Line to the west, and by a structure termed Noel Pauls Line to the east, and is overlain by or in fault contact with the Ordovician to Silurian sedimentary rocks of the Badger Group (Williams et al., 1995) to the northeast (Kean and Jayasinghe, 1980; Rogers et al., 2005b). Detailed investigations of the original Victoria Lake Group required its informal elevation to supergroup status in order to reflect its composite nature (Evans and Kean, 2002; Evans et al., 1990; Rogers and van Staal, 2002). There have been several subdivisions of the Victoria Lake supergroup, of which the most recent subdivides it into distinct fault-bounded tectonostratigraphic units that each has discrete stratigraphic features and/or ages (Lissenberg et al., 2005b; Rogers et al., 2005b; van Staal et al., 2005a; van Staal et al., 2005b; van Staal et al., 2005c). From oldest to youngest these include the Tally Pond group (c. 513 Ma: Dunning et al., 1991; Rogers et al., 2006), the Long Lake group (c. 506 Ma: McNicoll and Rogers, unpublished data *in* van Staal et al., 2005c), the Tulks group (498 to 495 Ma: Evans et al., 1990), the Pats Pond group (487±3 Ma: Zagorevski et al., 2007a), the Noel Pauls group (457 Ma: Zagorevski et al., 2007c), the Sutherlands Pond group (462 to 457 Ma: Dunning et al., 1987; Zagorevski et al., 2007c), and the Wigwam Brook group (453 Ma: Zagorevski et al., 2007a). This portion of the fieldtrip will focus on the tectonostratigraphic units that occur adjacent to the Red Indian Line and constitute the most outboard units of the peri-Gondwanan Victoria Lake supergroup (Figures 9 and 10). Most of the rocks examined today belong to the Tulks group, Sutherlands Pond group, and Wigwam Brook group. However, we will also examine parts of the Red Indian Lake group, which is separated from the Victoria Lake supergroup here by the Red Indian Line. The generalized geology of the Victoria Lake supergroup is shown in Figure 13 (see Day 3 information) although not all of the subdivisions noted above are shown at this scale, for reasons of clarity.

Tectonic setting of the Victoria Lake Supergroup

The Exploits Subzone in Newfoundland can be subdivided into two distinct arc-related sequences (Jenner and Swinden, 1993; MacLachlan and Dunning, 1998a; MacLachlan and Dunning, 1998b; O'Brien et al., 1997; Rogers et al., 2006; van Staal et al., 1998; Zagorevski et al., 2007a). The older sequence, the Penobscot arc and backarc, contains c. 513 to 485 Ma volcaniclastic and sedimentary rocks that formed above east-dipping subduction along the margin of Ganderia (Figure 2; Rogers et al., 2006; Zagorevski et al., 2007a), a postulated peri-Gondwanan microcontinent (van Staal et al., 1996). A gap in magmatism in the Exploits Subzone (485 to 478 Ma) is correlated with the collision of the Penobscot arc with Ganderia at c. 480 to 485 Ma and obduction of the Penobscot backarc ophiolites (Jenner and Swinden, 1993) onto the Newfoundland Gander Zone (e.g., Colman-Sadd et al., 1992; Tucker et al., 1994; van Staal et al., 1998). The



NOTRE DAME/DASHWOODS SUBZONES

SILURIAN

	TOPSAILS INTRUSIVE SUITE (circa 429 Ma)
ST	*Undivided, granitic to granodioritic rocks.*
	LOWER–MIDDLE ORDOVICIAN
	RED INDIAN LAKE GROUP (Arenig–Llanvirn)
OHB	*HEALY BAY FORMATION (Llanvirn): mainly light grey to white, ash to quartz crystal tuff, minor rhyolite, volcanogenic sandstone and shale. All lithologies are locally interlayered with red shale and/or chert.*
OHRgb OHRcg OHRmv₁ OHRmv₂	*HARBOUR ROUND FORMATION (Llanvirn): mainly green to red haematized, pillow to massive basalt, pillow breccia, diabase, gabbro (OHRgb), and andesite. All lithologies are interlayered with red chert and shale, whereas the pillow basalt locally contains interstitial limestone. Basalt are divided into two members separated by a largely volcanogenic polymictic conglomerate (OHRcg). The basalt stratigraphically below the conglomerate exhibit predominantly island-arc to transitional island-arc/back-arc compositions (OHRmv₁). The upper basalt (OHRmv₂) is predominantly calc-alkaline.*
	VICTORIA LAKE SUPERGROUP
	WIGWAM BROOK GROUP (Arenig–Caradoc)
OWB OOPmv OOPrs	*Undivided, mainly grey to light brown, felsic volcanic rocks of the Dragon Pond Formation and volcaniclastic sandstone, siltstones, and minor shale of the Halfway Pond Formation. Minor locally pillowed, island-arc tholeiitic basalt (OOPmv), red to black, cherty, aphyric dacite and/or rhyolite, and interlayered red shale (OOPrs). Locally includes black shales typical of the Perriers Pond Formation.*
OPP	*PERRIERS POND FORMATION (Caradoc): black shale, locally calcareous, and minor interlayered volcanogenic siltstone and sandstone. In part transformed into broken formation or mélange.*
	SUTHERLANDS POND GROUP (Llanvirn–Caradoc)
OTC	*TIMS CREEK FORMATION (Llanvirn–Caradoc): black shale, minor limestone and volcanogenic siltstone and sandstone. In part transformed into broken formation or mélange.*
ORM	*VICTORIA RIVER MOUTH FORMATION (Llanvirn–Caradoc): green, tholeiitic pillow basalt, compositionally E-MORB-like, locally interlayered with limestone. Contains minor rhyolite.*
OWP	*WEASEL POND FORMATION (Llanvirn–Caradoc): mainly light grey, rhyolitic breccias, minor aphyric to quartz and feldspar porphyritic flows and/or subvolcanic intrusions.*
	HARPOON GABBRO SUITE (Arenig–Llanvirn)
OH	*Green, locally plagioclase-phyric gabbro, diorite, and diabase.*
	NOEL PAUL'S BROOK GROUP (Arenig–Caradoc)
OLH	*LAWRENCE HARBOUR FORMATION (Caradoc): black shale, locally interlayered with thin felsic ash tuff beds. In part transformed into broken formation or mélange.*
OSW	*STANLEY WATERS FORMATION (Arenig–Llanvirn): mainly volcanogenic sandstone and siltstone, minor chert and red shale. Locally includes some mafic and felsic volcanic rocks.*
	TULKS GROUP (Upper Cambrian)
ЄJP	*JACKS POND FORMATION: mainly light grey to brown quartz- and/or feldspar-phyric tuff, lapilli tuff, volcanic breccia (Daniels Pond pyroclastics) and aphyric, locally flow-banded rhyolite (Mount Joshua rhyolite). Locally includes massive and/or disseminated sulphide mineralization.*
ЄBPba ЄBPbe	*BOBBYS POND FORMATION: mainly light green, island arc-like tholeiitic basalt to andesite, locally pillowed. Divided into the Baxters Pond (ЄBPba) and Beaton's Pond (ЄBPbe) basalts on basis of their chemical composition.*
	LONG LAKE GROUP (Middle–Upper Cambrian)
ЄCL	*COSTIGAN LAKE FORMATION: mainly white to light grey dacitic to rhyolitic, quartz and feldspar crystal tuffs; minor aphyric rhyolite. Locally includes graphitic shale, volcanogenic sandstone and siltstone and massive and/or disseminated sulphide mineralization.*
ЄHS	*HARMSWORTH STEADY FORMATION: mainly green, pillowed, tholeiitic to calc-alkaline basalt to andesite, diabase and minor breccia.*
	TALLY POND GROUP (Lower–Middle Cambrian)
ЄB ЄBg	*BINDONS POND FORMATION: mainly rhyolite, locally flow banded and/or quartz-phyric, rhyolite breccia, lapilli tuff, quartz porphyry, crystal tuff and subvolcanic granitic rocks (ЄBg).*
ЄLA	*LAKE AMBROSE FORMATION: mainly vesicular and amygdaloidal, generally pillowed basalt, mafic to andesitic tuff, and volcanic breccia.*

Geological boundary (approximate, assumed)

Fault, undefined (approximate or assumed)

Thrust fault, (approximate or assumed)

Unconformity (approximate or assumed)

U-Pb zircon age determination 513 ± 2 Ma ★

Field trip stop ⑩

Figure 9. Geological map of part of the Victoria Lake supergroup adjacent to the Red Indian Line (from Rogers et al., 2005b).

Penobscot arc is stratigraphically overlain by c. 473 to 453 Ma volcano-sedimentary rocks (e.g., Evans and Kean, 2002; MacLachlan and Dunning, 1998b; Zagorevski et al., 2007a), which are referred to as the Victoria Arc in central Newfoundland. The Victoria Arc is a correlative of the Popelogan arc of New Brunswick (van Staal et al., 1998).

The tectonic setting of the Victoria Arc and its correlative Popelogan arc in New Brunswick is well constrained in the northern Appalachians (e.g., van Staal et al., 1998). The earliest Victoria Arc volcanism in Newfoundland occurred at c. 473 Ma (Wild Bight Group; MacLachlan and Dunning, 1998b; Figure 2). Coeval eruption of arc and backarc-related volcanic rocks (Exploits Group: O'Brien et al., 1997; Wild Bight Group: MacLachlan and Dunning, 1998b) indicates an extensional phase of arc magmatism, which led to the rifting of the Victoria and Popelogan arcs from Ganderia and opening of the Exploits-Tetagouche backarc basin in Newfoundland and New Brunswick (MacLachlan and Dunning, 1998b; O'Brien et al., 1997; Valverde-Vaquero et al., 2006; van Staal et al., 1998; Bathurst Supergroup: van Staal et al., 2003). Abundant fossil and some geochronological evidence indicate that the Victoria Arc was active until at least Middle Llanvirn time (e.g., O'Brien et al., 1997). For example, Victoria Arc-related basalts of the Sops Head Complex in the Notre Dame Bay form peperitic contacts with Llanvirn limestone (McConnell et al., 2002).

In central Newfoundland the Victoria Arc is represented by the Sutherlands Pond group (c. 457–462 Ma: Dunning et al., 1987; Rogers et al., 2005b; Zagorevski et al., 2007c), the Noel Paul's Brook group (c. 457–465 Ma: van Staal et al., 2005c), and the Wigwam Brook group (453±4 Ma: Zagorevski et al., 2007a), all of which suggest that the cessation of arc magmatism was followed by deposition of back shales (Zagorevski et al., 2007a).

Exploits Subzone cover

One of the key characteristics of the Exploits Subzone is the presence of the regionally transgressive Caradocian black shale cover accompanied by the general cessation of volcanism (van der Pluijm et al., 1987; Williams, 1995). In the Notre Dame Bay area, this is marked by the deposition of the black shale of the Lawrence Harbour and Shoal Arm formations and the Strong Island chert (e.g., O'Brien et al., 1997; Williams et al., 1995). In central Newfoundland, the Wigwam Brook group and Stanley Waters formation (van Staal et al., 2005c) mirror the relationships in the Notre Dame Bay area and indicate cessation of volcanism followed by deposition of Caradocian black shale.

The Ashgill to Wenlock (449-424 Ma: McKerrow and van Staal, 2000) Badger Group (Williams et al., 1993) stratigraphically overlies the Caradocian black shale and comprises an upward-coarsening sedimentary sequence of deep-marine turbidite to shallow-marine conglomerate. Structural and sedimentological investigations of the Badger Group indicate deposition in a syn-tectonic setting (e.g., Kusky et al., 1987; Williams et al., 1995). The detrital provenance of the sedimentary rocks suggests derivation from the Notre Dame Subzone (see Williams et al., 1995), confirmed by the U/Pb detrital zircon data (McNicoll et al., 2001). The syntectonic setting and provenance

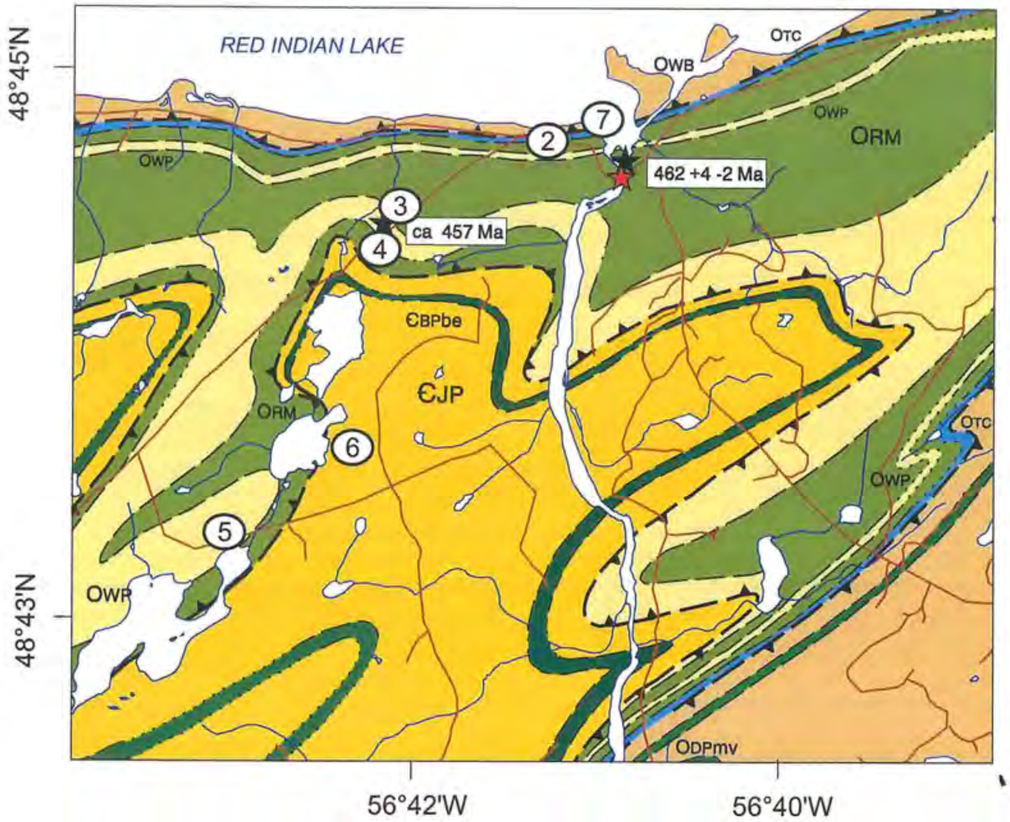


Figure 10. Detailed geological map of the Victoria Lake supergroup adjacent to the Red Indian Line in the area of the field trip stops (from Rogers et al., 2005b).
For complete details of rock types and units, see Figure 9.

OWB - Wigwam Brook group

ORM - Sutherlands Pond group (Victoria River Mouth Formation)

OWP - Sutherlands Pond group (Weasel Pond Formation)

OTC - Tim's Creek Formation

CJP - Tulks Group (Jacks Pond Formation) has led to the interpretation of the Badger Group as a successor basin(s) over the Red Indian Line in the forearc region (arc-trench gap) of the Late Ordovician to Early Silurian subduction complex formed during the closure of the Tetagouche-Exploits back-arc basin (Figure 2; Kusky et al., 1987; Pickering, 1987; Valverde-Vaquero et al., 2006; van Staal et al., 1998).

Tectonic Implications of the Exploits cover

The deposition of black shale above the Victoria Arc and its basement, followed by deposition of deep-marine turbidites of the Badger Group (Williams et al., 1993) indicate rapid submergence of the Victoria Arc (e.g., Williams, 1995). The zircon provenance of the turbidites in the lower Badger Group suggests derivation from the Laurentian margin or Notre Dame Subzone (McNicoll et al., 2001), indicating that the collision of the Victoria Arc and the Annieopsquotch Accretionary Tract had already started by Early Ashgill time.

In modern arc-arc collisions (e.g., Molucca and Solomon Sea), the down-going plate (i.e. Snellius Plateau and Morobe Shelf) experiences rapid subsidence as indicated by drowned carbonate platforms (e.g., Abers and McCaffrey, 1994; Galewsky and Silver, 1997; Pubellier et al., 1999). At the same time, the overriding plate is rapidly uplifted and forms an emergent orogen. The detritus derived from the emergent orogen in the overriding plate is transported parallel to the trench and deposited as thick turbidite sequences such as the Markam Canyon turbidites in the Solomon Sea (Galewsky and Silver, 1997; Whitmore et al., 1999).

The concurrence of the subsidence of the Victoria Arc and influx of the peri-Laurentian detritus suggests that both were caused by its collision with the Red Indian Lake Arc (Figure 11). Structural and seismic reflection studies indicate that the Victoria Arc occupies a lower plate setting with respect to the Red Indian Lake Arc (Figure 12; e.g., van der Velden et al., 2004), which is consistent with this model. Hence, partial subduction of the Victoria Arc under the Red Indian Lake Arc resulted in loading of the Victoria Arc crust, and rapid subsidence of the lower plate, creating the basin within which the black shales and younger turbidite sequences accumulated. At the same time, the Red Indian Lake Arc (and other components of the Notre Dame Subzone) were uplifted and eroded, until deposition of terrestrial sediments resumed in the Silurian (Figure 11).

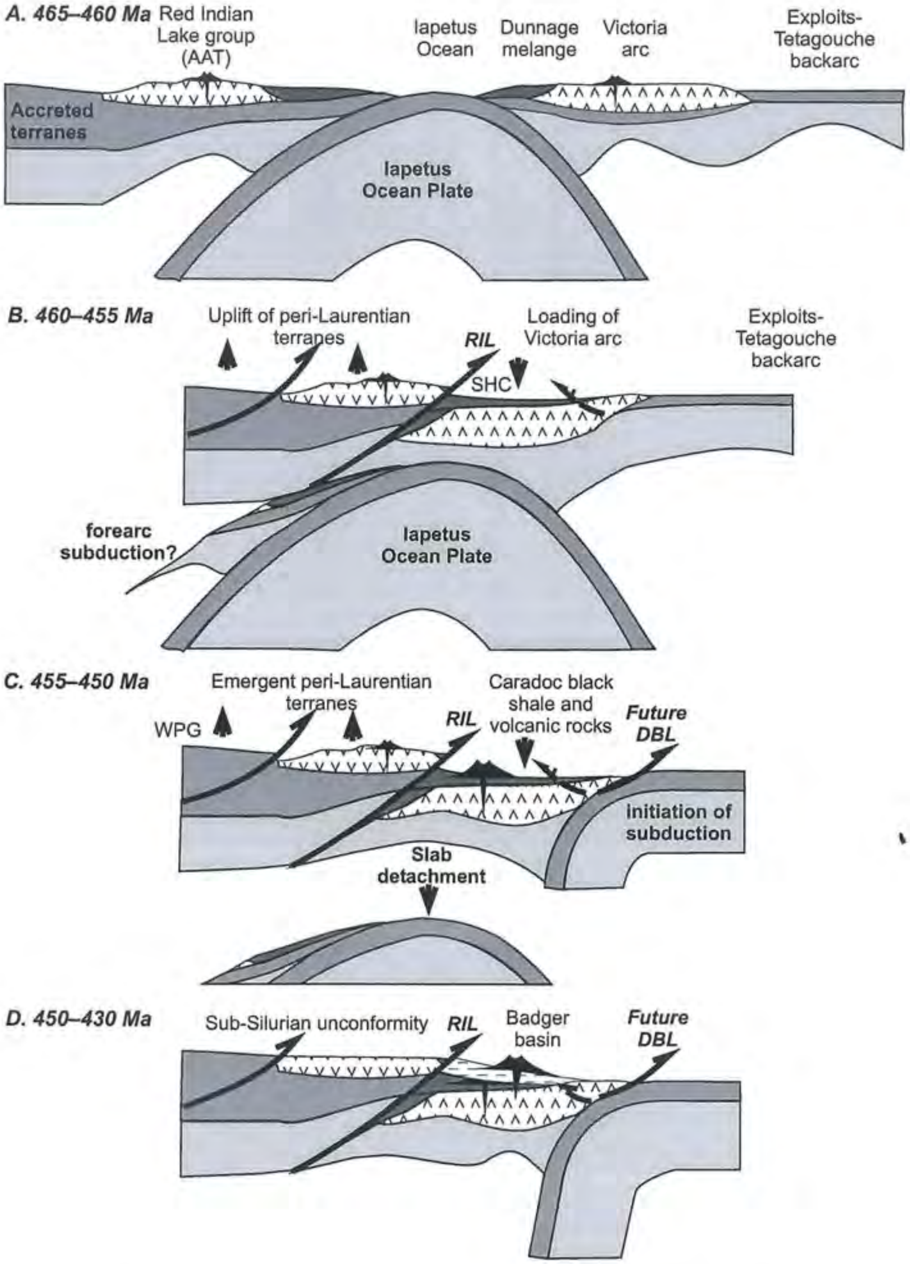


Figure 11. Tectonic model for the Caradoc arc-arc collision in central Newfoundland (from Zagorevski et al., 2007c). DGB-Dog Bay Line, RIL-Red Indian Line, SHC-Sops Head Complex, WPG-Windsor Point Group.

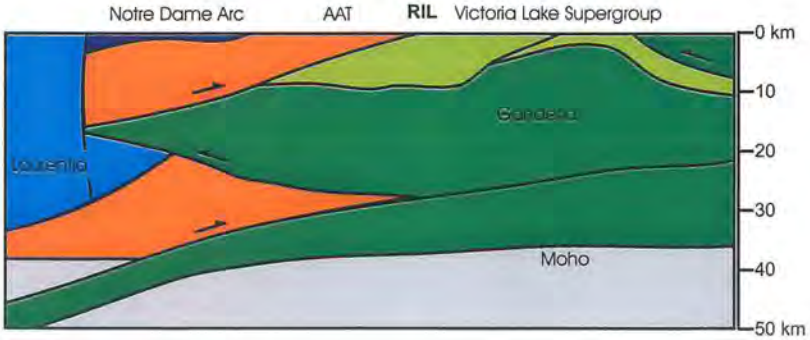


Figure 12. Interpretation of migrated seismic reflection data from the northern Lithoprobe profile (from van der Velden et al. 2004). Compare with panels C and D of Figure 11.

DAY 2 FIELD TRIP STOPS

General Information

The field trip stops on Day 2 are all located on the southeast side of Red Indian Lake, and most (but not all) lie within the peri-Gondwanan Victoria Lake supergroup. The first and last stops of the day lie across the Red Indian Line, in mafic rocks of the Red Indian Lake group. As for Day 1, coordinates are provided with reference to both the NAD27 and NAD83 systems, and directions are provided using odometer readings from the nearest stops or landmarks.

It should be noted that the main forest access road leading south from Millertown across the Exploits River is a very busy road used by numerous logging trucks and also by concentrate trucks from the Duck Pond Mine. Extreme care should be exercised when driving on this road, particularly around blind curves, hills and narrow bridges. *WATCH FOR TRUCK TRAFFIC AND YIELD TO TRUCKS AT ALL TIMES!*

Stop 2.1: Red Indian Lake Group

(UTM Zone 21; NAD27 – 530881 5403312; NAD83 - 530969 5403513)

From Badger, drive south along the highway to Buchans Junction. Reset the odometer at the Mary March Lounge, at the junction for Millertown. Continue from here to Millertown, where the paved road ends at kilometre 7.1. From this point, continue for another 3.8 km, where there is a large rock quarry on the south side of the road. *PLEASE BE CAREFUL AROUND THE WALLS OF THE QUARRY !*

Outcrop 1: The quarry outcrop on the side of the road reveals epidotized light green basalt, locally hematitised and plagioclase-phyric. The outcrop is extensively "veined" with chert/jasper and red shale typical of the Llanvirn Harbour Round formation, with which it has been correlated. Although the majority of the outcrop is massive basalt, pillow margins are locally developed.

Outcrop 2: This is a smaller outcrop located on a side road, about 200 m back from outcrop 1. This is not a very good outcrop, but it is dominated by red chert and shale representing the sedimentary component in outcrop 1. It will only be visited if time permits.

Stop 2.2 : Victoria Delta Fault

(UTM Zone 21; NAD27 – 523185 5398915; NAD83 - 523175 5399115)

From Stop 2.1, continue on the main road and cross the Exploits River on the steel bridge. Continue beyond the bridge for about 1.6 km, and turn right at the junction. Stay on this road for 5 km until the Victoria River bridge. This road has no concentrate trucks, but it has many bends and there may be logging trucks using it. BE CAREFUL! The outcrop is located about 0.7 km beyond the bridge. It may be necessary to park some vehicles on the bend just north of the outcrop.

The Victoria Delta Fault is exposed in the quarry outcrop on the side of the road. The fault is typically marked by black shale mélange (classification follows Raymond, 1984), and as such it is generally poorly exposed, except where it is used for road construction. Although this outcrop is small, blocks found here clearly display boudinaged tuffaceous sandstone in black shale matrix. This is a typical texture for the tectonites marking the Victoria Delta Fault and the Red Indian Line along the length of Red Indian Lake (Rogers and van Staal, 2002). Limited exposures of various stages of deformation intensity of these tectonites throughout the Victoria Lake supergroup suggest formation of the mélange by progressive tectonic disaggregation of interbedded shale-tuff-sandstone rather than sedimentary olistostromal origin (cf. Raymond, 1984). However, a partly olistostromal origin cannot be ruled out.

The fault, and some interesting rocks, are also exposed on the shoreline near here and will be visited during a lunchtime stop (see Stop 2.7 below).

Stop 2.3: Sutherlands Pond Group Rhyolite and epiclastic rocks

(UTM Zone 21; NAD27 – 522082 5398410; NAD83 - 522156 5398618)

From Stop 2.3, continue for about 0.4 km to a road junction, and then turn left. The road deteriorates and becomes narrow, but remains passable. Continue along this road for 1.0 km to the location for Stop 2.3. There is not really any parking space here, so it is best to continue for another 0.3 km to the Victoria Mine locality (Stop 2.4), and then walk back along the road.

This large outcrop of cherty and aphyric rhyolite is located behind a thick alder hedge on the north side of the road. This is the dated locality of the Sutherlands Pond Rhyolite (457 Ma). Originally this rhyolite was correlated with the rhyolite hosting the nearby Victoria Mine (Stop 2.4); however, chemical and petrographic differences separate this sequence from that hosting the Victoria Mine VMS deposit, which on basis of chemistry and petrography is now correlated with the volcanic rocks that host the Tulks deposit, i.e., the Tulks group (c. 498 Ma: Evans et al., 1990). This aphyric rhyolite, together with the Victoria Delta rhyolite dated by Dunning et al., (1987) are typical of the bimodal Sutherlands Pond group (462 to 457 Ma: Zagorevski et al., 2007c) which is considered to be in fault contact with the older Tulks group. The Sutherlands Pond group appears to be generally barren of VMS mineralization, although it is possible that the Jig Zone (see below) is hosted by these rocks rather than by the Tulks group.

A small outcrop located on the south side of the road here features juvenile epiclastic plagioclase-phyric lithic tuff of the Sutherlands Pond group. These tuffs appear to be derived from the poorly exposed mafic volcanic rocks that have E-MORB-like chemical characteristics, distinct from the rare island-arc tholeiite mafic rocks in the Tulks group (Rogers, 2004). This outcrop is of interest in the context of the nearby Jig Zone VMS mineralization, where similar mafic tuffaceous rocks are present (see below).

Stop 2.4a: Victoria Mine Locality

(UTM Zone 21; NAD27 – 521879 5398188; NAD83 - 521969 5398391)

From Stop 2.4, walk back to the parking area. The Victoria Mine was located at this spot. The shafts have been refilled for safety reasons, but abundant mineralized float remains.

In the immediate vicinity of this stop, three shallow exploration development shafts were sunk on high-grade chalcopyrite-pyrite outcrops ca. 1905, and small stockpiles of massive chalcopyrite-pyrite ore with ubiquitous black chlorite and dolomite alteration are abundant on site. Grab samples from these dumps gave values up to 7.5% Cu, 2.4% Zn, 1.5% Pb, 140 ppb Au and 12 ppm Ag. (Kean et al., 1988). Although the grades are impressive, the extent of mineralization is limited. Work by Asarco in the late 1980's to early 1990's resulted in an estimate grade and tonnage of 10,000 tonnes grading 6% Cu in the Main zone of the deposit, 20,000 tonnes grading 3.5% Cu in the Brook zone, and a low-grade zone containing ~ 25,000 tonnes grading 0.5% Cu, 1.2 % Pb and 5.9% Zn.

The stratigraphy in the area of the mine consists of an east-west striking, north-dipping sequence of volcanic and sedimentary rocks. In general, the stratigraphy can be broken into: 1) hanging wall aphyric felsic to intermediate lapilli tuffs, 2) intensely altered and mineralized felsic tuffaceous rocks comprising the ore horizon, and 3) footwall mafic volcanic rocks and associated volcaniclastic sedimentary rocks. The mineralization occurs within altered felsic pyroclastic rocks or breccias in a sequence of rocks that are currently grouped with the Tulks Hill volcanics (Tulks group of GSC terminology), although a U-Pb zircon age from a nearby rhyolite gave a younger age (~ 462 Ma) compared to the Tulks group (Dunning et al., 1987). However, recent work by Celtic Minerals suggests that the felsic volcanic host rocks to the mineralization have a similar geochemical signature to felsic volcanic rocks assigned elsewhere to the Tulks group. The current interpretation suggests that the mineralization is spatially associated with a zone of deformation that separates the Tulks group from younger rocks assigned to the Sutherlands Pond group. One possible explanation that is consistent with lithological and textural features is that the mineralization actually represents structurally remobilized sulphides (e.g. Desnoyers, 1990), rather than a deformed stockwork-type feeder zone.

The rocks around the ore zone consist of strongly schistose, altered dacitic to rhyolitic tuff and tuff breccias. The deformation zone described above appears to be the locus of intense black chlorite, sericite, carbonate and quartz alteration, with associated disseminated and stringer pyrite-chalcopyrite. Examples of what is termed "chaotic quartz-carbonate alteration" closely resemble well-documented examples found at the Duck Pond Deposit (Squires et al., 2001). The intense chlorite-carbonate alteration differs from the typically sericite-silica rich alteration associated with most of the VMS occurrences in the Tulks group. Most of the material remaining on surface today consists of intensely chloritized and carbonatized felsic volcaniclastic material, containing variable amounts of pyrite and chalcopyrite. Based on examination of diamond drill core, this material likely represents the upper portions of the ore horizon.

Stop 2.4b: Jig Zone VMS Mineralization and its Host Rocks
(UTM Zone 21; NAD27 – 522216 5398171; NAD83 – 522296 5398374)

From the Victoria Mine site, walk along an old drill road for about 350 m to the east. Parts of this old road may be wet and muddy. The road leads to the Jig Zone VMS showing, where interesting geological relationships are exposed in a large stripped and trenched area.

The Jig Zone outcrop area contains essentially three rock types. The southern part is dominated by altered felsic rocks interpreted as rhyolites and related breccias. These contain disseminated and stringer-style mineralization that is typical of "footwall-style" VMS environments. The felsic rocks are cut by strongly sheared zones, or have responded differently to superimposed deformation, depending on their degree of alteration. The northern part of the outcrop consists of green intermediate or mafic tuffaceous rocks that exhibit primary sedimentary features such as graded bedding, suggesting that they are upright. These are unaltered, and resemble the mafic tuffs seen at Stop 2.3, there assigned to the Sutherlands Pond group. The central part of the outcrop consists of massive sulphide mineralization, in the form of pyrite, chalcopyrite and sphalerite. The massive sulphides form a (boudinaged?) lens-like body that appears to be in conformable contact with the mafic tuffs, which seem to represent the stratigraphic hanging wall. The relationship to the felsic tuff in the footwall is not fully exposed, but the coincidence of stringer-style mineralization in these latter rocks, immediately below a massive sulphide lens, implies a stratigraphic transition rather than a structural contact.

There is no doubt that the outcrop has considerable structural complexity, and it is interpreted to be folded, with the vergence of folds towards the southeast (T. Calon, report to Celtic Minerals, unpublished). The possible relationship between the massive sulphides and the mafic tuffs is of interest in the context of the mineral potential of the Sutherlands Pond group, if this is indeed what the mafic tuffs represent. Alternatively, are the mafic tuffs here actually part of the Tulks group? The felsic rocks below the massive sulphide lens represent possible targets for U-Pb geochronology aimed at resolving this question.

The mineralization here is of limited extent, likely reflecting structural attenuation. The best results were 11 m of 2.9% Cu and 5.7% Zn. The most recent exploration here (by Celtic Minerals) suggested that the Jig Zone represented the same horizon as the nearby Victoria Mine, but the styles of mineralization and alteration appear to be different.

Stop 2.5: Tulks Group - Sutherlands Pond Group Boundary

(UTM Zone 21; NAD27 – 520950 5396290; NAD83 - 521024 5396506)

From the Victoria Mine (Stop 2.4) continue for 2.1 km along the road, and then turn left at a junction. Continue for another 1.0 km and park by a cairn, at a spot where cabins are visible. The outcrops are in and around the road.

This outcrop is located very close to the Tulks group -Sutherlands Pond group boundary and features pebbly mudstones to black shales which may represent olistostromes formed during closure of the main Iapetan tract that separated the peri-Gondwanan Victoria Arc and peri-Laurentian Red Indian Lake Arc. The Sutherlands Pond group volcanic rocks (462 to 457 Ma) grade into this unit and Caradoc black shales. Thus, the overall stratigraphy of this sequence suggests that the younger Sutherlands Pond group faces towards the older Tulks group, requiring a major tectonic break between the two.

Stop 2.6: Tulks Group Felsic Volcanic Rocks

(UTM Zone 21; NAD27 – 521820 5396879; NAD 83 - 521895 5397092)

From Stop 2.5, continue for another 1.2 km to a junction and park. Walk about 200 m along the branch road to the left, and the outcrops will appear in the cutover ahead.

This outcrop displays felsic volcanic rocks typical of the Tulks group. Although the outcrop is not mineralized, extensive black chloritic veining in this rhyolite breccia is common for many felsic volcanic rocks in the Tulks Group. This outcrop contains evidence for two phases of deformation, with an early S1 cleavage folded by F2 folds. This indicates refolding of earlier structures and provides structural evidence for the large F2 fold thought to core the Tulks group volcanic rocks in this area.

Stop 2.7: Victoria Delta – Lunch stop on a fault zone and rocks formerly known as the Buchans Group

(UTM Zone 21; NAD27 – 523352 5399038; NAD83 – 523429 5399241)

From Stop 2.6, return to the Victoria River bridge and park on the bend about 500 m west of the bridge. Walk towards the bridge, and there is a trail on the left hand side of the road. This well-defined trail leads to the outcrops and beach by the mouth of the Victoria River. It is less than 500 m to walk, and there is only one boggy stretch to contend with. *THE RIVER MOUTH HERE IS VERY DEEP, AND IT IS NOT GOOD PLACE TO FALL IN THE WATER IF YOU CANNOT SWIM!*

(On the other hand, if you can swim and the weather is hot, this is a really good place for a refreshing dip, and the river mouth is noticeably warmer than Red Indian Lake, which is cold year-round.)

The outcrops in the Victoria River underneath the bridge and immediately downstream contain rhyolite, basalt, shale and limestone assigned to the Sutherlands Pond group. The basis of the separation from the Tulks group is the distinct age of the rhyolite (462 Ma: Dunning et al., 1987), association of the rhyolite with E-MORB-like mafic lavas and presence of Llanvirn limestone. Interesting as they are, these outcrops will not be examined today due to time constraints. The shales are best exposed on the southern side of the Victoria River delta, downstream of the bridge, where they are moderately deformed and locally into tectonic mélange (Raymond, 1984). On the north side of the delta, the mélange is intruded by a syn-tectonic dyke (Thurlow et al., 1992) dated at c. 432 Ma (Zagorevski et al., in press).

The short walk along the shore here crosses fissile, schistose sedimentary rocks that represent the Victoria Delta fault, also seen at Stop 2.2. The intensity of deformation is better displayed here than in the roadside outcrop. The outcrops on the beautiful beach beyond are pinkish sedimentary rocks including arkoses and some conglomerates. These rocks were for many years grouped as part of the Buchans Group, implying that the fault at this locality actually represented the Red Indian Line. More recent GSC mapping instead places these outcrops as part of the Wigwam Brook Group, meaning that we are still on the peri-Gondwanan side of Iapetus. The Red Indian Line presumably lies out there somewhere beneath the lake that it is named for! The details of the geology here might be debatable and controversial to some, but all will agree on the beauty of the location. It provides a perfect spot for lunch.

Stop 2.8: Wigwam Brook Group Tuffs

(UTM Zone 21; NAD27 – 529599 5396143; NAD83 - 529680 5396320)

From Stop 2.7, return to the vehicles, and drive back to the junction just south of the Exploits River. Turn right, towards the Duck Pond mine. Continue southward for about 4.1 km. There are so few outcrops on this road that you are unlikely to get confused about which one to stop at. *BE CAREFUL OF CONCENTRATE AND LOGGING TRUCKS WHEN DRIVING, AND WHEN CROSSING THE ROAD!*

There are outcrops on both sides of the road, but the one on the east side is the better location. This epiclastic lithic tuff of felsic composition is a typical facies of the Dragon Pond formation of the Wigwam Brook group. It features abundant black shale or grey shale rafts, sandstone pebbles and felsic volcanic clasts enclosed in a smoky quartz and lithic-fragment-rich matrix. Dating of a petrographically similar epiclastic tuff in the Pats Pond area (a long way southwest of here) produced a c. 453 Ma age, consistent with its close spatial association or interlayering with dated Caradoc black shale. This unit is capped by Caradoc black shale. The strain is very high in this outcrop. All fragments are highly lineated with long aspect ratios.

Stop 2.9: Stanley Waters Formation

(UTM Zone 21; NAD27 – 529899 5394869; NAD83 - 529974 5395086)

This small outcrop is located about 1.4 km from Stop 2.8. It may not be suitable for large groups and may be omitted to save time.

The Stanley Waters formation of the Noel Paul's Brook group is similar to some portions of the Wigwam Brook group and Sutherlands Pond group. However, the Noel Paul's Brook group encompasses a significantly longer sedimentation period than either of these two groups. This is indicated by intrusion of the Harpoon Gabbro suite (c. 465 Ma) into the Stanley Waters formation. This formation has yielded several fossil localities, including, this stop, where crinoid (?) fragments in black shale have been recovered. Rare felsic tuffs that occur close to this stratigraphic level gave a ca. 457 Ma U-Pb zircon age (Zagorevski et al., 2007c).

Stop 2.10: Harpoon Gabbro

(UTM Zone 21; NAD27 – 535033 5392703; NAD83 - 535097 5392927)

From Stop 2.9, continue for another 6.8 km to the bridge on Harpoon Brook. Park on the far side of the bridge, where there is a roadside outcrop. This is good for sample collection, but the better outcrop is a natural one below the bridge, north of the road.

The large outcrop of the Harpoon Gabbro below the bridge was previously interpreted as a Devonian intrusion, but has been recently dated at c. 465 Ma (McNicoll and Pollock, unpublished data). This gabbro intrudes into the middle to lower portions of the Stanley Waters formation placing a minimum age constraint on the timing of deposition of the stratigraphically lowest sedimentary rocks. In many cases the gabbro forms sills whose folded geometry is commonly displayed by magnetic anomalies. The gabbro is mildly metamorphosed and contains epidote and chlorite. The outcrop contains some coarser-grained "pegmatitic" zones.

Stop 2.11: Stanley Waters Formation

(UTM Zone 21; NAD27 – 535416 5387965; NAD83 - 535500 5388171)

This large outcrop is located 6.3 km beyond Stop 2.10, approaching the Duck Pond mine. It is the largest outcrop anywhere in the neighbourhood. If time is a problem, we may defer this outcrop to Day 3.

The long broken outcrop on the side of the mine road exposes massive to thickly-bedded sandstones, that are part of the Stanley Waters formation. These sandstones are intruded by the Harpoon Gabbro. Several blocks in this outcrop contain numerous poorly preserved graptolites.

Stop 2.12: Mineralized Pillow Breccias of the Harbour Round Formation
(UTM Zone 21: NAD27 - 532879 5406092; NAD83 – 532969 5406292)

From Stop 2.11 (or wherever you are) return along the main road to Millertown. Just after the pavement starts, take a left turn into the community, and park by the lumber mill at the bottom of the first hill. Walk westward around the mill, and onto an old road. A short trail diverges, and leads to some rather dilapidated wooden steps, which provide access to the shore of Red Indian Lake. When you reach the shore, turn left and walk a short distance to the rusty outcrops, which should be obvious.

These outcrops consist of mineralized and altered pillow breccias, which are associated with lesser amounts of better-preserved pillow lava. The mineralization is dominantly pyrite, although it is anomalous in base metals, notably Cu. The alteration and mineralization is clearly focused in the more permeable "matrix" to the breccias, and is considered to be broadly syngenetic, developed by hydrothermal circulation and venting soon after the formation of the host rocks. According to the MODS file for the showing, it has never been tested by drilling. Better-preserved pillow lavas, with epidote-hematite alteration akin to Stop 2.1, are exposed to the southwest along the shoreline.

DAY 3: THE DUCK POND MINE

General Information

Day 3 of the field trip consists of a surface and underground visit to the Duck Pond Mine, which will be led by personnel from Aur Resources. No surface outcrops will be examined, for the simple reason that there are no outcrops in the mine area. The Duck Pond deposits are hosted by volcanic rocks of the Tally Pond group, which is one of the older (Cambrian) components of the Victoria Lake supergroup. This section of the guide summarizes some background information about the host rocks and the mineralization. It is drawn from a paper on the results of detailed U-Pb geochronological studies of the Tally Pond group and the immediate host rocks to the Duck Pond deposit (McNicoll et al., in prep.). Further information on mine-scale geology and detailed relationships will be presented separately by Aur Resources.

Regional geological and metallogenic framework

The Appalachian Orogen in Newfoundland (Figure 1; after Williams, 1979; Williams et al., 1988) comprises bounding cratonic blocks of Laurentian and Gondwanan affinity (the Humber and Avalon zones, respectively) astride a composite central mobile belt (the Dunnage and Gander zones). The Dunnage Zone is the largest remnant of the early Paleozoic Iapetus oceanic realm, and is subdivided into contrasting peri-Laurentian and peri-Gondwanan subzones, separated by the Red Indian Line. The southeastern (peri-Gondwanan) segment of the Dunnage Zone is termed the Exploits Subzone, and the Victoria Lake supergroup is the largest tract of Cambrian and Ordovician volcanic and sedimentary rocks within it. The northwestern (Laurentian) portion of the Dunnage Zone (Notre Dame and Dashwoods subzones) is not discussed further in this guide.

The Victoria Lake supergroup (see Figure 13) was originally defined at group level by Kean (1977) and Kean et al. (1981), and eventually raised in status by Evans and Kean (2002). It is presently defined as including all pre-Caradocian (i.e., > 450 Ma) rocks located between the Red Indian Line and a distinctive Silurian unit known as the *Rogerson Lake conglomerate*, which rests unconformably upon the older rocks (Rogers and van Staal, 2002). Traditionally, the Victoria Lake Supergroup consists of two large volcanic tracts (the *Tally Pond volcanic belt* and *Tulks volcanic belt*; Kean and Jayasinghe, 1980), that are separated by tracts of clastic sedimentary rocks, in part of immature volcanogenic origin. Intrusive rocks also occupy large areas, and these range in composition from gabbro to quartz monzonite and granite. At least two intrusions are late Precambrian (565-563 Ma) in age (Evans et al., 1990), and are probably fault-bounded inliers of older basement, perhaps representing part of the crustal block termed "Ganderia" (e.g., van Staal et al., 1998). Previous geochronological data (Dunning et al., 1987; Evans et al., 1990; Dunning et al., 1991) showed that the Victoria Lake supergroup was composite, but poor exposure and broadly similar geochemical patterns impeded detailed subdivision of the volcanic belts. Rogers and van Staal (2002) suggested a revised provisional framework on the basis of existing data and new results (e.g., Zagorevski et al., 2003), some of which remain unpublished. In the south, the Tulks Volcanic Belt was subdivided into the Long Lake group (ca. 505 Ma), Tulks group (ca. 498 Ma), Pats Pond group (ca. 488 Ma) and Sutherlands Pond group (ca. 460 Ma). In the north, the Tally Pond Belt was redefined as the Tally Pond group, and assigned a Cambrian age (after Dunning et al., 1991) but was not subdivided. The sedimentary rocks that dominate much of the intervening area were assigned to the newly-defined Noel Paul's Brook and Wigwam Brook groups, and considered to be of Arenig to Caradocian age (~490 to 450 Ma).

Subsequent work has demonstrated additional complexity within the rocks of the Tally Pond group. Rogers et al. (2006) obtained a late Precambrian age directly from felsic volcanic rocks included within the group. Using geochemical and Nd isotopic data to extrapolate, they defined the Sandy Brook group to include possible Precambrian volcanic rocks (essentially equivalent to the Sandy Lake sequence of previous workers). However, there is considerable compositional overlap between these rocks and the dated Cambrian volcanic rocks of the Tally Pond group, and the precise extent of each package and their mutual contact relationships remain problematic.

Volcanogenic massive sulphide (VMS) mineralization is present in virtually all of the volcanic subdivisions defined by Rogers and van Staal (2002) within the Victoria Lake supergroup. The regional metallogeny is discussed elsewhere (Kean and Evans, 1988; Evans and Kean, 2002; Hinchey, 2007), and the metallogeny of the Tally Pond group was reviewed by Kean (1985) and Squires and Moore (2004). At Duck Pond, polymetallic massive sulphides are associated regionally with felsic volcanic rocks of late Cambrian age (Evans et al., 1990; Dunning et al., 1991). In the western part of the Tally Pond Group, analogous VMS mineralization is associated with similar host rocks, but these are undated. To the southeast, polymetallic mineralization at the Burnt Pond prospect is hosted by felsic volcanic rocks along strike from known late Precambrian rhyolites (Rogers et al., 2006). U-Pb dating of the host rocks to the Burnt Pond mineralization confirms that they, too, are Precambrian (McNicoll et al., in prep.), and several other small VMS prospects are now suspected to be of this age. The Precambrian rocks now assigned to the Sandy Brook group are not discussed further in this guide.

Geology of the Tally Pond Group

The volcanic and sedimentary rocks of the Tally Pond area are in general very poorly exposed, and the precise distribution of units and their mutual contact relationships are poorly known; consequently, more than one interpretation is possible.

It has long been recognized that the volcanic rocks of the Tally Pond group fall into two contrasting compositional groups. The "Lake Ambrose basalts" of Kean (1977) were redefined as the Lake Ambrose formation by Rogers et al. (2006). This consists of massive to locally pillowed tholeiitic basalts, associated with tuffs, pillow breccias, andesitic flows and minor sedimentary rocks. These rocks are generally unmineralized and little-altered. The previously unnamed felsic rocks were assigned to the Bindons

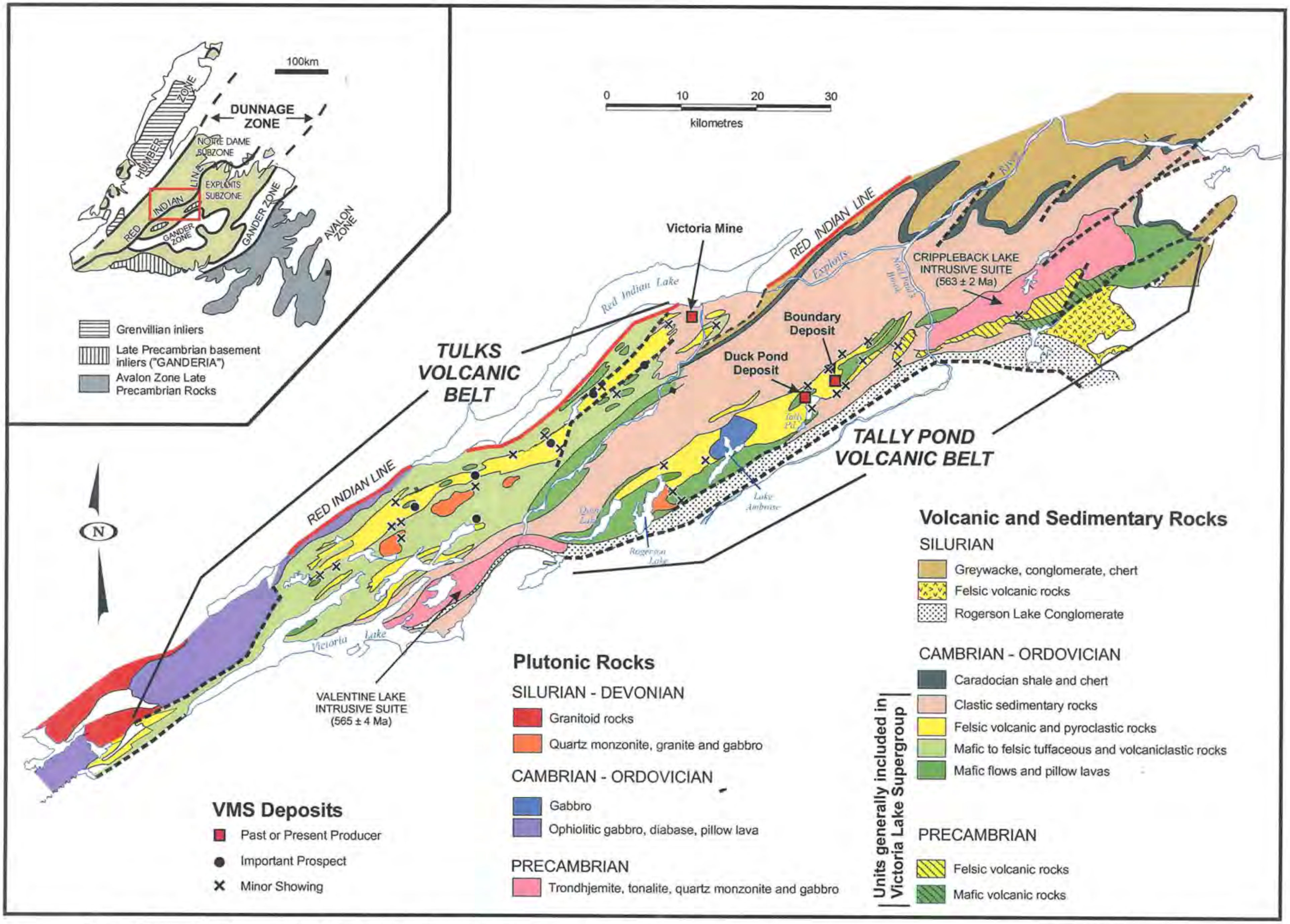


Figure 13. Simplified map of the Victoria Lake Supergroup and surrounding units, showing the location of the Tally Pond volcanic belt and VMS deposits. Modified after Evans et al. (1990) and Squires and Moore (2004). Note that subdivisions of the Tulks Volcanic Belt and area suggested by Rogers and van Staal (2002) are not shown for reasons of clarity at this scale.

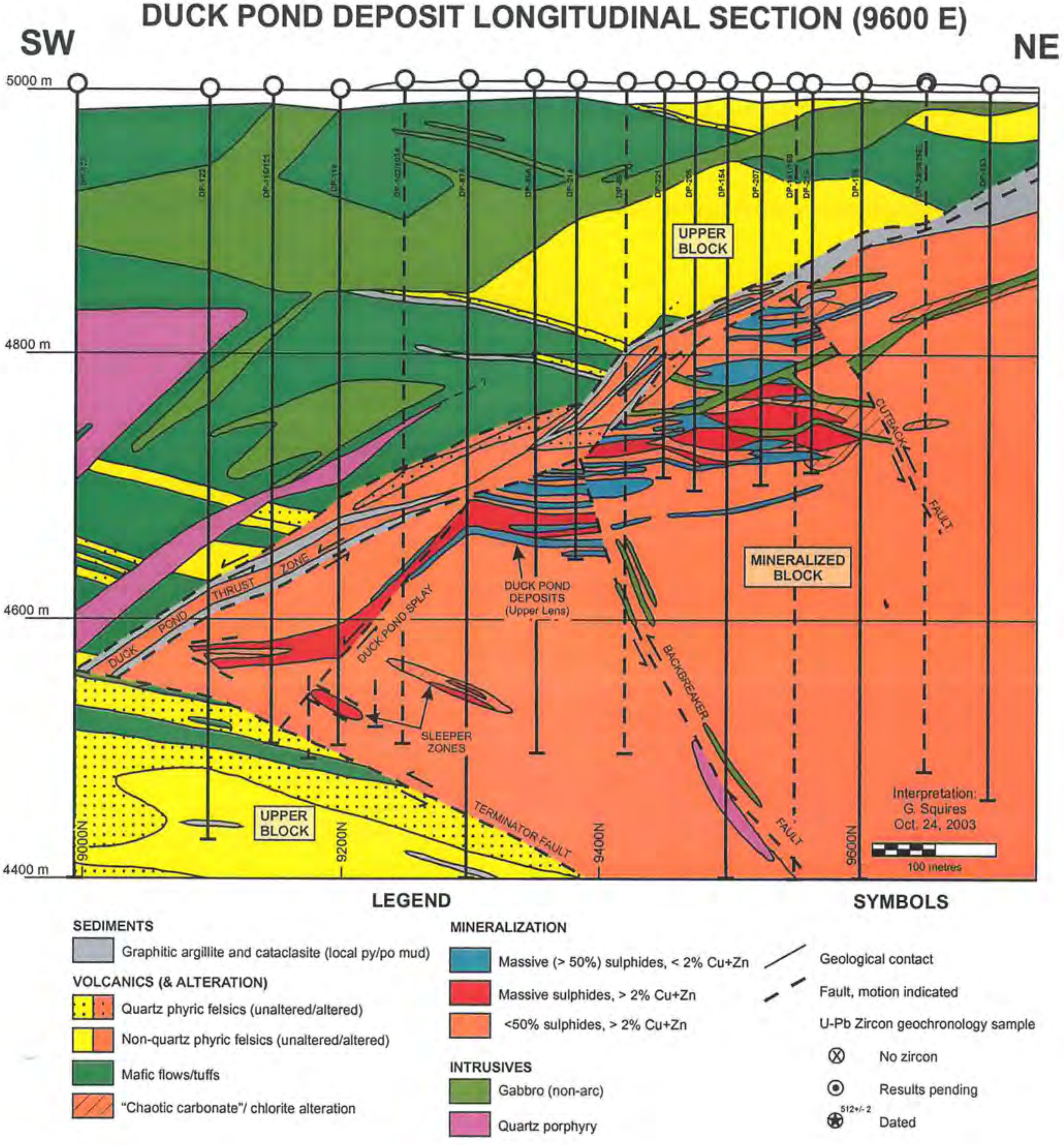


Figure 14. A Southwest-Northeast cross-section through the Duck Pond Cu-Zn-Pb-Ag-Au deposit, illustrating the essential geological relationships. From Squires and Moore (2004).

Pond formation by Rogers et al. (2006). These consist of aphyric to massive or flow-banded dacites and rhyolite, felsic tuffs, breccias, sedimentary rocks and subvolcanic (?) quartz-feldspar porphyry. In contrast to the Lake Ambrose formation, these rocks commonly display hydrothermal alteration and are locally mineralized. Rogers et al. (2006) suggest that the Lake Ambrose and Bindons Pond formations represent the lower and upper portions of the Tally Pond Group, respectively, although the distribution of mafic and felsic rock types in the field is more complex than this simple model predicts. This suggests the presence of structural repetition, and/or the presence of more than two compositionally distinct sequences. In the Duck Pond area (see below), detailed drilling shows that unmineralized rocks are structurally emplaced above the mineralized sequence (Squires et al., 1991; 2001; Figure 13), and similar structural repetitions could account for the complex map patterns throughout the area. Mafic volcanic rocks of the Tally Pond group are broadly arc-related in compositional terms, and are mostly classified as island arc tholeiites; both the mafic and felsic rocks overlap in composition with their counterparts in the Precambrian Sandy Brook group (Rogers et al., 2006). However, there are some subtle differences in trace element patterns, and the Tally Pond group also appears to have a more primitive Nd isotopic signature than the Sandy Brook group (Rogers et al., 2006).

Duck Pond and Boundary Cu-Zn-Ag-Au Deposits

The Duck Pond and Boundary deposits are the most important mineral resources in the Tally Pond area, with a total resource base of some 4.5 million tonnes at ~ 3.3% Cu, 5.8% Zn, 0.9% Pb, 59 g/t Ag and 0.9 g/t Au. The deposits were discovered in the late 1980s (Squires et al., 1991) but at that time were considered subeconomic. Further exploration over the last 10 years delineated additional resources, and Duck Pond finally entered production in early 2007, with a projected mine life of some 7 years.

The Duck Pond massive sulphide deposit is described in detail elsewhere (Squires et al., 1991, 2001; Squires and Moore, 2004), and the following is only an abbreviated summary. A SW-NE cross-section through the deposit (Figure 14, after Squires and Moore, 2004) shows most of the essential relationships. An originally continuous massive sulphide lens, and several disseminated to semimassive sulphide zones, are now disposed in at least three discrete zones as a result of later faulting (Figure 13). The orebodies are hosted by altered felsic volcanic, pyroclastic and volcaniclastic rocks that are termed the *Mineralized Block*. The upper boundary of these rocks is formed by a prominent fault zone that separates them from an upper panel of unmineralized rocks dominated by mafic volcanic rocks and lesser felsic rocks. This region, which extends to surface, is termed the *Upper Block*. The latest motions on this fault clearly have a normal sense of motion, but it is believed to have originated as a thrust fault, and is thus termed the *Duck Pond thrust* (Squires et al., 1991; 2001). The Duck Pond thrust appears in part to be localized within a thin sequence of graphitic sedimentary rocks that locally include exhalative-style mineralization and ore-bearing debris flows (the Serendipity showing). The sedimentary rocks locally appear to conformably overly the altered felsic rocks that host most of the sulphides. Although high-grade sulphide mineralization at Duck Pond locally displays striking banding reminiscent of primary bedding, it is probably not exhalative in origin. The textures instead suggest that the sulphides replaced unconsolidated felsic tuffs to variable extents in a subseafloor environment (Squires et al., 1991; 2001). However, the mineralizing fluids likely did vent locally onto the seafloor, as suggested by the debris-flow mineralization in rocks stratigraphically above the main ore lenses, which likely represents material transported from vent chimneys and sulphide mounds. These argillaceous sedimentary rocks may have acted as a quasi-impermeable "cap rock" that promoted ponding of fluids and replacement of more permeable units below the seafloor (Squires et al., 2001). However, the mineralization is still viewed as syngenetic, because the time gap between deposition of host rocks and their pervasive replacement by sulphides is not significant in geological terms. A "feeder" alteration pipe has not been firmly identified in the footwall sequence at Duck Pond, and it is possible that the deposits have been separated from deeper parts of their own hydrothermal system by thrusting.

The Boundary deposit is located some 4 km northeast of the main Duck Pond deposit, and comprises three subcropping lenses of massive sulphide mineralization. The mineralization closely resembles that seen at the Duck Pond deposit, and the altered felsic volcanic host rocks are also identical. The Boundary deposits are truncated at depth by a gently-dipping fault zone that likely represents the Duck Pond thrust, suggesting that they may be structurally detached pieces of the main Duck Pond orebody, which may originally have been much larger (Squires et al., 1991; 2001). The footwall to the Boundary Deposit is formed by graphitic sedimentary rocks, which resemble those seen within and below the Duck Pond thrust in the main mine area.

Geochronological data (Rogers et al., 2006, McNicoll et al., in prep.) indicate that the host rocks to the Boundary and Duck Pond deposits have the same age (~ 509 Ma), supporting their correlation. The unmineralized rocks that sit structurally above the ore horizon yield slightly older ages, ranging up to ~ 515 Ma, indicating that they represent an older portion of the Tally Pond group, and that the Duck Pond thrust fully deserves its name, even though it was later reactivated as a normal fault (McNicoll et al., in prep.).

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