

lean Claude Roy, Signal Hill from Fort Amherst, oil on canvas / huile sur toile, 48" x 72", 2006

FIELD TRIP GUIDEBOOK - B6

THE GRENVILLE PROVINCE OF SOUTHEAST LABRADOR AND ADJACENT QUEBEC

Leader: Charles F. Gower

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FIELD TRIP LEADER

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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.

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

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

Specific Hazards

Some of the stops on this field trip are in coastal localities. Access to the coastal sections may require short hikes, in some cases over rough, stony or wet terrain. Participants should be in good physical condition and accustomed to exercise. The coastal sections contain saltwater pools, seaweed, mud and other wet areas; in some cases it may be necessary to cross brooks or rivers. There is a strong possibility that participants will get their feet wet, and we recommend waterproof footwear. We also recommend footwear that provides sturdy ankle support, as localities may also involve traversing across beach boulders or uneven rock surfaces. On some of the coastal sections that have boulders or weed-covered sections, participants may find a hiking stick a useful aid in walking safely.

Coastal localities present some specific hazards, and participants MUST behave appropriately for the safety of all. High sea cliffs are extremely dangerous, and falls at such localities would almost certainly be fatal. Participants must stay clear of the cliff edges at all times, stay with the field trip group, and follow instructions from leaders. Coastal sections elsewhere may lie below cliff faces, and participants must be aware of the constant danger from falling debris. Please stay away from any overhanging cliffs or steep faces, and do not hammer any locations immediately beneath the cliffs. In all coastal localities, participants must keep a safe distance from the ocean, and be aware of the magnitude and reach of ocean waves. Participants should be aware that unusually large "freak" waves present a very real hazard in some areas. If you are swept off the rocks into the ocean, your chances of survival are negligible. If possible, stay on dry sections of outcrops that lack any seaweed or algal deposits, and stay well back from the open water. Remember that wave-washed surfaces may be slippery and treacherous, and avoid any area where there is even a slight possibility of falling into the water. If it is necessary to ascend from the shoreline, avoid unconsolidated material, and be aware that other participants may be below you. Take care descending to the shoreline from above.

Other field trip stops are located on or adjacent to roads. At these stops, participants should make sure that they stay off the roads, and pay careful attention to traffic, which may be distracted by the field trip group. Participants should be extremely cautious in crossing roads, and ensure that they are visible to any drivers. Roadcut outcrops present hazards from loose material, and they should be treated with the same caution as coastal cliffs; be extremely careful and avoid hammering beneath any overhanging surfaces.

The hammering of rock outcrops, which is in most cases completely unnecessary, represents a significant "flying debris" hazard to the perpetrator and other participants. For this reason, we ask that outcrops not be assaulted in this way; if you have a genuine reason to collect a sample, inform the leaders, and then make sure that you do so safely and with concern for others. Many locations on trips contain outcrops that have unusual features, and these should be preserved for future visitors. Frankly, our preference is that you leave hammers at home or in the field trip vans.

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

INTRODUCTION

This excursion is timely for three reasons. The first is that, following the completion of the Trans-Labrador Highway (Figure 1) it is now possible to conduct a cost-effective geological excursion in the interior of eastern Labrador. The second is that geological maps (at 1:100 000 scale and a 1:5000 000 compilation; Gower, 2010a, b) are newly available for the whole of eastern Labrador. The third is that this region is currently undergoing rapid change, including the establishment of new national and provincial parks, hydroelectric developments, and hosting an active mineral exploration sector (Gower, 2010c).

The excursion has three main themes:

- i. Late Paleoproterozoic and Middle Proterozoic accretionary history of the easternmost Grenville Province;
- ii. Grenvillian orogenesis in the region; and
- iii. Post-Grenvillian events, particularly those immediately preceding the creation of Iapetus Ocean.

As the latter two are superimposed on the earlier accretionary history throughout the region, it is necessary to intertwine all three throughout the excursion.

REGIONAL GEOLOGY

Eastern Labrador encompasses the eastern Makkovik Province and the easternmost part of the Grenville Province (Figures 2, 3 and 4, and Map 2010-50 – in pocket). The Makkovik Province will not be visited during the excursion.

MAKKOVIK PROVINCE

The Makkovik Province is a segment of a Paleoproterozoic accretionary orogen that developed on the southern flank of pre-Makkovikian Laurentia, mostly between 1900 and 1790 Ma. It is divided into three tectonic elements (Kerr *et al.*, 1996):

- i. The Kaipokok domain in the west;
- ii. The Aillik domain in the centre; and
- iii. The Cape Harrison domain in the east.

The Kaipokok domain comprises reworked Archean gneiss of the North Atlantic craton, overlain by Paleoproterozoic supracrustal rocks of the Moran Lake and Post Hill groups and intruded by Paleoproterozoic granitoid rocks, most of which have been traditionally







Figure 2. Regional geological map for the Eastern Grenville Province (modified from Gower et al., 2001). This map is in need of updating, but should be adequate for excursion purposes.



Figure 3. Regional geology map for eastern Labrador (Gower, 2010b). The legend for the map is attached to the 1:500 000-scale map provided with the guide. In general, mafic to felsic rocks correlate with blue to red in the spectrum and yellow indicates pelitic metased-imentary gneiss.



Figure 4. Terranes and major geological structures in eastern Labrador (Gower, 2008b).

assigned to the Island Harbour Bay Intrusive Suite. The Aillik domain is underlain mostly by Paleoproterozoic felsic volcanic rocks of the Aillik Group, associated granitoid intrusive units and tectonic slices of Archean gneiss. The Cape Harrison domain comprises mostly Paleoproterozoic granitoid and gneissic rocks, but includes some remnants of felsic volcanic rocks. The terms 'Post Hill' and 'Aillik' groups follow the redefined usage proposed by Ketchum *et al.* (2002).

GRENVILLE PROVINCE

The Grenville Province in eastern Labrador comprises Late Paleoproterozoic and Mesoproterozoic rocks that formed during multiple orogenic events between *ca.* 1810 and 950 Ma (Figure 5). Four orogenic events have been identified (Gower and Krogh, 2002, 2003), namely:

- i. 'Eagle River' (late Makkovikian correlative) orogenesis (1810–1770 Ma);
- ii. Labradorian orogenesis (1710–1600 Ma);
- iii. Pinwarian orogenesis (1520-1460 Ma); and
- iv. Grenvillian orogenesis (1085–985 Ma).

The first three of these orogenies were active-margin accretionary events, whereas the Grenvillian orogeny represents a continent-continent collision (which terminated active Proterozoic accretionary tectonism in this region).

'Eagle River' (Late Makkovikian Correlative) Orogenesis (1810–1770 Ma)

Rocks formed during this period can be divided into two groups, namely granitoid units and metasedimentary gneiss.

Granitoid Units

The granitoid rocks are mainly well-banded biotite granodiorite to hornblende quartz diorite gneiss. K-feldspar augen orthogneiss, hornblende granite and monzonite occur locally. In the Mealy Mountains terrane, three nominally coincident ages of 1800 ± 40 Ma¹, 1789 ± 29 Ma and $1786 \pm 11/-5$ Ma (Figure 6, top left part), were obtained from rocks that were all originally interpreted to have igneous protoliths (Gower *et al.*, 2008a). These results clearly establish the existence of a magmatic event in the EGP well before Labradorian orogenesis, and only slightly younger than events in the easternmost Makkovik Province (Ketchum *et al.*, 2002; Krogh *et al.*, 2002). Two additional samples from the southern MMT

¹ (1798 ± 240 Ma given by Gower et al. (2008a; Figure 6), but data have now been re-evaluated; Kamo, S., pers. comm., 2010)



Figure 5. *Geological time and eastern Labrador. Right-hand column modified from Gower and Krogh (2002).*

suggest that rocks of this age were once more extensive, but now only preserved as remnants. These are a quartzofeldspathic gneiss enclave having a 1771 ± 4 Ma probable protolith age, and inheritance preserved in younger granite indicating an age of 1779 ± 18 Ma. Gower and Krogh (2002, 2003) assigned an age span for this unnamed event as between 1782 and 1712 Ma, based on preliminary data. Re-assessment of that information, coupled with additional age determinations reported by Gower *et al.* (2008a), required adjustment of the time boundaries to 1810 and 1770 Ma.

Metasedimentary Gneiss

Deposition of the sediments in eastern Labrador was coeval with, or shortly after, the emplacement of granitoid magmatic rocks (Gower *et al.*, 2008a). Metasedimentary gneiss



Figure 6. U–Pb geochronological data for part of the interior Grenville Province in eastern Labrador (Gower et al., 2008a).

in eastern Labrador is overwhelmingly pelitic. There are two large coherent swathes of metasedimentary gneiss, namely,

- i. The Paradise metasedimentary gneiss belt; and
- ii. An unnamed belt east of the Mealy Mountains Intrusive Suite.

In addition, there are many smaller areas, largely reduced to shreds and patches as a result of thrusting and/or strike-slip faulting, during both pre-Grenvillian and Grenvillian orogeneses. The mineral assemblage in the pelitic gneiss varies according to metamorphic grade. The majority of the gneiss is biotite–garnet–sillimanite-bearing, but kyanite is common in parts of the Hawke River and Groswater Bay terranes (terranes shown on Figure 4). Cordierite occurs extensively in the eastern part of the Paradise metasedimentary gneiss belt and in metasedimentary gneiss east of the Mealy Mountains Intrusive Suite. Relict andalusite is known from one locality in the Mealy Mountains terrane and staurolite from two localities in the Hawke River terrane. Other noteworthy minerals are osumilite and sapphirine in the Sand Hill Big Pond area; sapphire west of St. Lewis; and sporadic (non-sapphire) corundum.

Associated rocks include psammitic gneiss, quartzite/metachert, amphibolite of supracrustal origin, and rocks derived from calcareous protoliths. Quartzite is generally finely laminated and is interpreted to have been derived from chemically precipitated chert and lean banded iron formation. The amphibolite of supracrustal origin is considered to have a mafic volcanic protolith. Unequivocal pillowform mafic volcanic rocks have been recognized in the Dead Islands Area (Gower and Swinden, 1991). The rocks derived from calcareous protoliths are mostly calc-silicate types, but rare marble has been found.

The depositional age of the metasedimentary gneiss still remains uncertain, but has been argued to have been between 1810 Ma and 1770 Ma (Wasteneys *et al.*, 1997; Gower and Krogh, 2003; Gower *et al.*, 2008a). In the Mealy Mountains terrane, inherited material in a granitoid rock emplaced at 1800 ± 40 Ma (*see* earlier), yielded ²⁰⁷Pb/²⁰⁶Pb ages of 2606 ± 3 Ma, 1902 ± 2 Ma and 1894 ± 3 Ma and is interpreted to have come from a metasedimentary source. An enclave of supracrustal origin sample within monzonite of the Mealy Mountains Intrusive suite contains grains having ages between *ca*. 1914 and 1770 Ma. Farther south, within an area predominantly underlain by Pinwarian rocks, a feldspathic quartzite contains zircon grains, interpreted to be detrital, having ages of *ca*. 2460 Ma and 2399 \pm 7 Ma, and the quartzofeldspathic gneiss enclave having a probable protolith age of 1771 ± 4 Ma, contains older grains suggesting source ages of 2745 ± 2 Ma, 2377 ± 2 and 2045 ± 2 Ma (Figure 6).

The ages of the inherited grains are compatible with derivation from the Archean Nain Craton or the flanking Paleoproterozoic Torngat and Makkovik orogens. An attractive correlative for the metasedimentary gneisses in Labrador is the southern part of the Ketilidian Mobile Belt in southernmost Greenland (Figure 7), where large areas of metasedimentary rocks compare very closely with those in eastern Labrador, in both lithological association and age. The supracrustal rocks in the Ketilidian Mobile Belt have been traditionally sub-divided into two zones, the psammite zone in the north and the pelite zone in the south. The psammite zone includes, in additional to psammite, minor basic metavolcanic rocks (including pillow lavas), variably migmatized pelitic and semipelitic rocks, calcareous metasediments, conglomerate and graphitic chert. The pelitic zone consists mainly of turbidite sediments, deposited in a deeper, more distal setting. Both zones are intruded by various mafic and granitic rocks. The supracrustal rocks were deposited between 1820 and 1790 Ma and are thought to represent sediments eroded from the emerging 1850–1800 Ma calc-alkaline Julianehåb batholith and its felsic volcanic carapace, and deposited in intra-and fore-arc basins (Chadwick and Garde, 1996; Garde *et al.*, 2002).

Labradorian Orogenesis (1710–1600 Ma)

Labradorian orogenesis in the EGP was reviewed by Gower and Krogh (2002, 2003), who suggested an evolving series of events reflecting accretion of an outboard arc (Figure 8). The key dictate of the model was (and still is) lack of evidence for early Labradorian magmatism and metamorphism (prior to arc accretion) within pre-Labradorian Laurentia. It was argued that had the Labradorian rocks formed in a continental margin setting then it would be expected to be commonplace. Note that there is inconsistency between the models of Figure 7 and 8, in that Figure 7 implies the pre-Labradorian metasedimentary gneiss accumulated at the edge of pre-Labradorian Laurentia, whereas Figure 8 implies they did not (the models are not irreconcilable, however).

Early Labradorian

Early Labradorian activity (Figure 8a) is taken here to include events between *ca*. 1710 and 1680 Ma. The only rock within this time period from eastern Labrador dated by U–Pb methods is a nebulitic granodiorite from the Groswater Bay terrane having a zircon age of 1709 + 7/-6 Ma (Schärer *et al.*, 1986). This rock is 30 million years older than the next U–Pb-dated rock and its exact significance within the Labradorian context remains uncertain.







Figure 8. Labradorian tectonic evolution (Gower and Krogh, 2002).

Early to Mid Labradorian Calc-alkaline Magmatism

Calc-alkaline magmatism related to Labradorian orogenesis occurred between 1680 and 1655 Ma (Figure 8b), and has been subdivided into three tentative age events at 1677 Ma, 1671 Ma and 1658–1649 Ma by Gower *et al.* (1992) that correlate spatially with the Lake Melville, Hawke Bay and Groswater Bay terranes, respectively, suggesting a northward decrease in age of plutonism (Gower *et al.*, 1992). Rocks involved are dominated by biotite-and hornblende-bearing quartz diorite to biotite granodiorite, but also include some tonalite, large quantities of K-feldspar megacrystic hornblende–biotite granodiorite to quartz mon-zonite, and lesser granite.

Pre- Trans-Labradorian Metamorphism and Deformation

Deformation and metamorphism were concentrated between 1665 and 1655 Ma, when a radical change in tectonic conditions took place. Labradorian deformation and migmatization have been rigorously constrained using bracketing ages at two sites in the Hawke River terrane. These are at Red Island bracketed between 1671 Ma and 1660 +8/-7 Ma (Gower *et al.*, 1992), and, at Shoal Bay, bracketed between 1671 Ma and 1662 \pm 3 Ma. Based on a leucogranitic vein interpreted by Scott *et al.* (1993) to be syntectonic, deformation was inferred to have occurred at 1664 +14/-9 Ma in the southeast Lake Melville terrane.

No recent investigations have been conducted in eastern Labrador regarding conditions of metamorphism. In early studies, from the southern Groswater Bay terrane, Gower and Erdmer (1988) reported P-T estimates of up to *ca*. 11-12 kb and 750-800°C. These values are comparable to those of 10-12 kb and 615-805°C obtained by van Nostrand (1988) and 11-13 kb, and 830-860°C reported by Corrigan *et al.* (2000). The latter results were obtained from samples collected from the Rigolet thrust zone, which defines the southern margin of the Groswater Bay terrane at Rigolet. South of the Groswater Bay terrane, Gower and Erdmer reported conditions of *ca*. 9 kb and 800°C from an overlying thrust sheet that may represent a structural outlier of either the Lake Melville terrane or the basal Mealy Mountains terrane. van Nostrand (1988) reported P-T estimates of 6-10 kb and 650-900°C from the Lake Melville and western Hawke River terranes. Arima and Gower (1991) concluded that P-T conditions in osumilite-bearing rocks marginal to the Sand Hill Big Pond gabbronorite (Hawke River terrane) reached 7-8 kb and 825-950°C. Corrigan *et al.* (2000) estimated conditions exceeding 8 kb and 725°C, for the northern Lake Melville terrane. Particularly in

the Lake Melville terrane, Grenvillian overprinting is geochronologically evident so distinctions (or the lack of them) drawn between Labradorian and later metamorphism must be regarded warily.

Trans-Labradorian Magmatism

Three groups of rocks are addressed under this heading. These are (i) the Trans-Labrador batholith, (ii) coeval supracrustal units, and (iii) coeval granitoid rocks in the interior part of the EGP.

The Trans-Labrador batholith (term introduced by Wardle and staff, 1982) forms a linear belt at least 600 km long and less than 100 km wide at the northern margin of the former Labrador orogen (Figures 2 and 8c). It was emplaced between 1654 and 1646 Ma. Rock types are dominated by equigranular to megacrystic quartz monzonite, monzogranite, monzosyenite, syenite and granite. The chemical character is transitional calc-alkaline to alkalicalcic. The Trans-Labrador batholith has a trend that is slightly oblique to the Grenville front, extending 50 km north of the Grenville front in eastern Labrador, but having its northern limit about 50 km south of the Grenville front in western Labrador. The southern boundary of the batholith has been described as intrusive, tectonic and/or transitional into granitoid gneiss. Based on re-evaluation of previous descriptions, samples and potential field data, Gower (2010a) concluded the Trans-Labrador batholith tapers out in an easterly direction as a distinct entity between the Makkovik Province and granitoid gneisses in the eastern Groswater Bay terrane. Note that granitoid rocks coeval with the Trans-Labrador batholith are also known in the Pinware terrane, where a gneissic quartz monzonite and a quartz monzonite have ages of 1650 + 18/-9 Ma and 1649 ± 7 Ma, respectively (Wasteneys *et al.*, 1997).

Integral with Trans-Labrador batholith magmatism are supracrustal sequences, dominated by felsic volcanic rocks, situated along its northern fringe. These have been interpreted as the extrusive carapace of the Trans-Labrador batholith, but preserved only on the northern side because of progressively deeper exhumation from north to south linked to Grenvillian thrusting (Gower, 1990; Nunn, 1993). These supracrustal packages are all situated west of eastern Labrador, with the exception of felsic volcanic rocks south of the Benedict Mountains, and minor supracrustal remnants scattered throughout the Groswater Bay terrane.

The felsic volcanic rocks on the south side of the Benedict Mountains Intrusive Suite were mapped by Gower (1981), who described them as rhyolitic to dacitic volcanic and volcanoclastites, together with some volcanic breccias and hypabyssal intrusions. They are undated, so it is not known for certain whether they are correlative with mid-Paleoproterozoic Aillik Group or, as tacitly implied here, the Trans-Labrador batholith. The main reason for considering that they might be Labradorian is their east-west trend, which contrasts with the north-northeast Makkovikian structural trend.

The supracrustal rocks in the Groswater Bay terrane are minor remnants having no consistent trend. They probably have felsic volcanic/volcanoclastic protoliths (Gower and Owen, 1984). Their age affiliations are unknown, and could equally be correlative with the Aillik Group, or be of Labradorian age.

Labradorian supracrustal rocks (Pitts Harbour Group), also occur in the Pinware terrane. They consist mostly of fine-grained, recrystallized, banded, quartzofeldspathic rocks, locally showing inhomogeneous texture, and interpreted to have been derived from a felsic volcanic/volcanoclastic protolith. The rocks have a common association with minor quartzite, calc-silicate units, pelitic schist and gneiss, and some banded mafic rocks thought to have been derived from mafic volcanic rocks (Gower *et al.*, 1994). Rocks assigned to the unit have been dated in two places, yielding ages of 1637 ± 8 Ma (Wasteneys *et al.*, 1997) and 1640 ± 7 Ma (Tucker and Gower, 1994). These ages are nominally slightly younger than the felsic volcanic rocks on the north side of the Trans-Labrador batholith.

Fine-grained, quartzofeldspathic rocks hosting REE mineralization in the St. Lewis area have been recently interpreted, on the basis of their chemical composition, as having a felsic volcanic protolith (Search Minerals Inc., 2010). The rocks are highly strained and do not retain primary textural features, which therefore leaves some latitude for other protolith choices. Acceptance of a supracrustal protolith for these rocks is relevant to the more general observation that there seems to be general dearth of felsic metavolcanic rocks in high-grade gneissic regions; this may well be more apparent than real (*cf.* article on protolith recognition of metamorphosed felsic volcanic rocks in high-grade terranes; Gower, 2007).

Post Trans-Labradorian Trimodal Mafic–Anorthositic–Monzogranitic Magmatism

Labradorian rocks included under this heading were emplaced between 1650 and 1625 Ma (Figure 8d). This time range overlaps with both the preceding Trans-Labradorian magmatism and events considered in the next section. It cannot be overstressed that the histories of the Trans-Labrador batholith and the trimodal mafic-anorthositic-monzogranitic magmatism are inextricably linked. Indirectly, this observation has already been made by Kerr (1989) who pointed out that some aspects of the Trans-Labradorian geochemical character (high F and high FeOt/FeOt+MgO) are comparable with AMCG suites (anorthosite–monzonite–charnockite–granite), a moniker that covers most of the rocks discussed in this section. The acronym 'AMCG' has shortcomings when applied here, because, (i) it does not adequately recognize associated, volumetrically important, mafic rocks, (ii) overemphasizes the role of charnockite and granite, and (iii) carries with it anorogenic tectonic-setting conceptual overtones that do not seem to be appropriate in the Labradorian context.

The mafic component of the trimodal magmatism is mostly represented by hydrous, commonly layered, mafic intrusions. These display rhythmic layering, cumulate textures, and, in part, evidence of crystallization from a water-rich magma. Rock types represented include lherzolite, troctolite, olivine gabbronorite, pyroxenite, norite, and gabbro, and are associated with leuconorite, leucogabbro, monzonorite, pyroxene-hornblende monzonite, locally grading into syenite or granite (and their metamorphic derivatives). In eastern Labrador, the best-known bodies include the Adlavik Intrusive Suite in the Makkovik Province (1649 \pm 1 Ma based on dating of a monzonite; Krogh and Schärer, 1987; Kerr *et* al., 1992), the Grady Island layered intrusion in the Groswater Bay terrane (1644 ± 2 Ma; Kamo et al., 1996) and the White Bear Arm complex (1640–1630 Ma; Kamo et al., 1996). Intrusive ages for mafic rocks in the Mealy Mountains Intrusive Suite have yet to be obtained, but amphibolites derived from mafic dykes have yielded metamorphic dates of 1640 \pm 2 Ma and 1628 \pm 8 Ma (Gower *et al.*, 2008a). In the Dome Mountain Intrusive Suite, in the Goose Bay area, an amphibolite hosting a Dome Mountain monzonite dyke yields a concordant zircon age of 1631 ± 2 Ma, interpreted to be metamorphic, although a slightly older, concordant 1636 ± 3 Ma grain may indicate time of emplacement of its protolith (Bussy et al., 1995).

In eastern Labrador, trimodal anorthositic magmatism is well represented in the Mealy Mountains Intrusive Suite; by the Alexis River anorthosite; and in parts of the White Bear Arm complex. Anorthositic rocks in the Mealy Mountains Intrusive suite include leucotroctolite, leuconorite and anorthosite (Emslie, 1976). Leucotroctolite is mostly in the southwest part of the complex (Kenemich massif), whereas anorthosite and leuconorite are dominant in the northeast (Etagualet massif). Farther south in the MMIS, the Crooks Lake anorthosite has yielded an age of 1632 ± 3 Ma. The Alexis River anorthosite (which also includes leucogabbronorite and lesser amounts of other rock types), is a narrow, linear body about 150 km long but averaging only about 5 km wide. It occurs in a zone of strong, high-grade, deformation (Gilbert River shear belt), hence is generally thoroughly recrystallized, but evi-

dence of primary layering can be seen locally. Neither it, nor anorthositic rocks in the White Bear Arm complex, has been dated.

Trimodal monzogranitic magmatism covers the compositional range from monzodiorite to granite, although monzonite is volumetrically dominant. Some rocks have been termed syenite. Association between monzogranitic and mafic rocks ranges from intimate-complex to mutually independent. The monzogranitic rocks are normally also separate from anorthositic units, although it is not uncommon to find enclaves of anorthosite in monzonite (but rarely the reverse). Monzogranitic rocks in the eastern Mealy Mountains Intrusive Suite have ages of 1646 ± 2 Ma from monzonite and $1635 \pm 22/-8$ Ma from granite (Emslie and Hunt, 1990). There are also some granitic bodies in eastern Labrador emplaced at about the same time that do not have apparent spatial links to mafic or anorthositic rocks. Three dated examples are (i) the Cartwright alkali-feldspar granite ($1645 \pm 7/-5$ Ma; Kamo *et al.*, 1996) at the Hawke River–Groswater Bay terrane boundary, (ii) the Double Mer Granite ($1632 \pm 10/-9$ Ma; Schärer *et al.*, 1986) in the western Groswater Bay terrane, and (iii) an unnamed granite in the Mealy Mountains terrane (1631 ± 1 Ma monazite age; Schärer and Gower, 1988).

Post-Trans-Labradorian Deformation and Metamorphism

Post-Trans-Labradorian deformation and metamorphism (between 1646 and 1625 Ma) is distinguished from pre-Trans-Labradorian deformation in that it extended over a longer period, was more sporadic, and was less intense. In the Hawke Bay terrane, concordant titanite ages of 1649 ± 4 Ma from granite, 1646 ± 2 Ma from tonalite–granodiorite gneiss, and 1642 ± 4 Ma from quartz diorite (Schärer and Gower, 1988) were interpreted as representing the final stages of Labradorian orogenesis in that area (and, concomitantly, implying the lack of subsequent severe Grenvillian imprint – *see* later). Two melt-product samples from the Paradise metasedimentary gneiss belt (a 10-cm-wide microgranite vein and a pegmatitic melt pod), when combined in a single regression, give an age of 1638 + 11/-3 Ma, which was interpreted to be the minimum age of emplacement of the veins (Kamo *et al.*, 1996). From the Paradise Arm pluton, a concordant monazite age of 1631 ± 2 Ma was suggested to be due to thermal overprinting (Kamo *et al.*, 1996).

Late Labradorian Events

Late Labradorian events, between 1625 and 1600 Ma (Figure 8c), involved the emplacement of minor granitic intrusions and sporadic, diverse, and mostly minor, metamorphism/deformation activity. Two examples of minor granitoid intrusions in eastern Labrador are a pegmatite from the Rigolet area (Groswater Bay–Lake Melville terrane boundary) having an age of 1619 + 16/-14 Ma (Corrigan *et al.*, 2000), and a pegmatite from the Hawke River terrane that yielded an age of 1622 ± 3 Ma (Gower *et al.*, 1992). Monazite ages of 1612 ± 5 Ma and 1610 ± 2 from a pelitic gneiss in the Rigolet area (Corrigan *et al.*, 2000), a concordant titanite age of 1617 ± 14 Ma from an amphibolitized mafic dyke discordantly intruding the early Labradorian gneiss at Shoal Bay, and near-concordant monazite ages of 1621 ± 1 Ma and 1613 ± 2 Ma are reported from the Paradise Arm pluton (Kamo *et al.*, 1996) are all examples of evidence for this activity in eastern Labrador.

Pinwarian Orogenesis (1520–1460 Ma)

The Pinware terrane was first identified as a separate tectonic entity by Gower *et al.* (1988) and rocks dated to be Pinwarian in the EGP were first reported by Tucker and Gower (1990). The term Pinwarian Orogeny was introduced by Tucker and Gower (1994) for rocks having ages between 1500 and 1470 Ma, but subsequent dating has extended these limits to between *ca.* 1520 and 1460 Ma (Gower and Krogh, 2002). The Pinwarian event was interpreted (Gower, 1996) as reflecting a continental-margin arc over a north-dipping subduction zone (Figure 9a).

Granitic Magmatism

The key feature that characterises dated Pinwarian magmatism is an overwhelmingly granitic (*sensu stricto*) character, as regards both sizable bodies and minor intrusions. Many intrusions have been dated in southern Labrador, adjacent eastern Quebec and in the Long Range Inlier in western Newfoundland (summarized by Gower and Krogh, 2002, with more recent examples reported by Heaman *et al.*, 2004 and Gower *et al.*, 2008a). In eastern Labrador, in the Upper Paradise River pluton, alkali-feldspar granites have ages of 1501 ± 9 Ma and 1495 ± 7 Ma (Wasteneys *et al.*, 1997). On the coast, the Cape Charles quartz monzonite, St. Peter Bay granite and Wolf Cove quartz monzonite, have ages of 1490 ± 5 Ma, 1479 ± 2 Ma and 1472 ± 3 Ma, respectively (Tucker and Gower, 1994). Minor granitic intrusions have ages of 1509 + 11/-12 Ma (Long Harbour granitic vein, Scott *et al.*, 1993), 1499 + 8/-7 Ma (Double Island pegmatite, Schärer *et al.*, 1986), 1474 + 10/-7 Ma (Wolfrey granite, Corrigan *et al.*, 2000). A worrisome feature of the seemingly valid data from the Wolfrey granite is that the lower intercept projects to 353 + 130/-126 Ma, apparently lacking any Grenvillian Pb-loss in an area where other geochronological evidence indicates such effects to be significant.



Figure 9. Pinwarian to end-of-Elsonian tectonic evolution (Gower and Krogh, 2002).

In addition to the dated intrusions being granite (sensu stricto), it has been observed that large bodies are confined to the southern part of the EGP, with only minor felsic magmatism farther north (Gower, 1996). A departure from these generalizations is the Rigolet quartz diorite in the northern part of the EGP, dated to be 1489 +2/-8 Ma (Corrigan *et al.*, 2000). Gower and Krogh (2002) suggested that the scattered data points reflect pre-Labradorian inheritance, Labradorian emplacement, and/or Labradorian, Pinwarian and Grenvillian Pb-loss events.

The qualifier "dated" Pinwarian magmatism was included above since a broad spectrum of magmatic products, other than granite, are present. For example, granite in the Upper Paradise River intrusion is spatially associated with pyroxene-bearing monzonite, anorthosite and gabbronoritic mafic rocks, collectively representing a typical AMCG association.

Pinwarian Deformation and Metamorphism

In addition to widespread granitic magmatism, Pinwarian activity also involved metamorphism and deformation. In eastern Labrador, early metamorphism is indicated in the Pinware terrane by *ca*. 1500 Ma ages from the Pleasure Cove quartzite and "The Lodge" quartz monzonite gneiss, which are coeval with a 1498 +9/-8 Ma high-grade event that produced the Disappointment Hill felsic gneiss in western Newfoundland. In the Hawke River terrane, a 1490 Ma titanite overprint is recorded from Labradorian granite. At Long Harbour (southeast Lake Melville terrane–Pinware terrane boundary a granitic vein has an age of 1509 +11/-12 Ma and was interpreted by Scott *et al.* (1993) to have been emplaced into an actively deforming shear zone.

Later Pinwarian dates from eastern Labrador include *ca*. 1469 Ma pegmatitic interboudin material in the Mealy Mountains terrane (Gower *et al.*, 2008a), a 1471 \pm 41 Ma titanite age from mafic volcanic rocks and a *ca*. 1470 Ma monazite age from pegmatitic leucogabbro, the latter two both in the Hawke River terrane (Kamo *et al.*, 1996).

Elsonian

Gower and Krogh (2002) reactivated the term 'Elsonian' to refer to the time period between 1460 Ma and 1230 Ma. The term Elsonian orogeny was originally introduced by Stockwell (1964) to describe an event characterized by AMCG magmatism and reworking of older gneisses. As pointed out by Emslie (1978), the Elsonian never attained status as an orogenic event and was better regarded in a magmatic context – as has been subsequent usage.

Gower and Krogh (2002) subdivided the Elsonian in three parts: Early (1460–1350 Ma), Middle (1350–1290 Ma), and Late (1290–1230 Ma) (Figure 5).

Early Elsonian

Most Early Elsonian magmatism occurred north of the Grenville front and involved emplacement of huge AMCG suites, namely the Michikamau, Harp Lake and Mistastin complexes (Figure 9b). Emplacement of these intrusions began at about 1460 Ma, coincident with the termination of Pinwarian magmatism.

In the Grenville Province in eastern Labrador, the main manifestation of Early Elsonian activity was the emplacement of a swarm of roughly east-northeast-trending, sheet-like bodies (mostly dykes) termed the Michael gabbro (1426 ± 6 Ma; Schärer *et al.*, 1986). The apparently somewhat older Shabogamo gabbro in western Labrador (1445 ± 4 Ma, Krogh, 1993) is chemically comparable and considered correlative. Collectively, the two suites form a belt about 700 km long and roughly 50 km wide, that lies close to, and south of the Grenville front, except in western Labrador where some intrusions occur north of the front. The Shabogamo and Michael gabbros are tholeiitic, subalkaline transitional to mildly alkaline basaltic rocks. Around the same time in eastern Labrador, the 1417 ± 5 Ma Mokami Hill quartz monzonite was emplaced in the Lake Melville terrane (Gower and Kamo, 1997).

Middle Elsonian

As with the Early Elsonian, most Middle Elsonian activity took place north of the Grenville front, especially the AMCG Nain Plutonic Suite (Figure 9c), the emplacement of which spanned the whole of Middle Elsonian time – from 1350 to 1290 Ma. In the Grenville Province in eastern Labrador, the only unit known to have a Middle Elsonian age is the 1296 +13/-12 Ma (Schärer *et al.*, 1986) Upper North River granite in the Lake Melville terrane. The age is anomalous for the district, but there seems no reason to challenge the data, especially as the rock is lithologically distinct from its surroundings.

Late Elsonian

Late Elsonian magmatism in eastern Laurentia was spatially generalized by Gower and Krogh (2002) as comprising felsic magmatism north and south of a central region of mafic magmatism, all occurring more-or-less concurrently (Figure 9d).

Well north of the Grenville front, the main representatives of the felsic magmatism are, (i) the 1290–1270 Ma Flowers River Igneous Suite, which comprises peralkaline granites, surrounding a circular area of subaerial felsic volcanic rocks (Hill and Miller, 1990; Hill, 1991), and (ii) the 1240 Ma Strange Lake peralkaline complex, an association of fine- and mediumgrained, porphyritic, pegmatitic, and exotic granitoid rocks containing an abundant and varied collection of rare-metal-bearing minerals.

The felsic magmatism in the south, well within the Grenville Province is mostly known from the Wakeham area, where various rhyolitic (intrusive) and granitic rocks have ages between 1271 and 1239 Ma (Loveridge, 1986; Clark and Machado, 1995; Martignole *et al.*, 1994). Geochronological data hints at concomitant metamorphism elsewhere during this period, namely from the Lac Joseph terrane (Connelly and Heaman, 1993) and from western Newfoundland (Currie and van Berkel, 1992).

The central region of mafic magmatism is represented by various mafic dyke suites, mostly east-northeast-trending, north of the Grenville front (Nutak, Nain, Harp dykes); by the Seal Lake Group, which is a sequence of sedimentary rocks, mafic volcanic rocks and associated sills straddling the northern margin of the Grenville Province; and the Mealy dykes, within the Grenville Province. A zircon age of 1273 ± 1 Ma from a Harp dyke was reported by Cadman *et al.* (1993). The minimum age of the Seal Lake Group is constrained by zircon-baddeleyite emplacement dates of 1250 + 14/-7 Ma and 1224 + 6/-5 Ma (Romer *et al.*, 1995) from two different gabbro sills intruding the supracrustal rocks. The Mealy dykes are northeast-trending dykes mostly found within the Mealy Mountains Intrusive Suite in eastern Labrador and were emplaced at 1250 ± 2 Ma (baddeleyite; Hamilton and Emslie, 1997).

A more recent date at variance with the north-to-south pattern of felsic-mafic-felsic activity identified by Gower and Krogh (2002) is a 1248 ± 5 Ma age from a gabbronorite at Lourdes-de-Blanc-Sablon, in the southern part of the Pinware terrane (Heaman *et al.*, 2004).

Post Elsonian–Pre-Grenvillian

Gower and Krogh (2002) employed the term 'Elzeverian' for that period of orogenic activity between 1250 and 1180 Ma in the Grenville Province. As a concept that identifies late-geon-12 to early-geon-11 orogenesis, the Elzevirian orogeny had its birth in the southwest Grenville Province (Moore and Thompson, 1980). The exact time limits differing according to authorship, but it is generally considered to have started there some time between 1250 and 1230 Ma and ended before 1180 Ma (*cf.* Lumbers *et al.*, 1990; Easton, 1992; Carr *et al.*, 2000). Throughout all of the EGP, evidence for an 'Elzevirian' orogenic event remains meagre and it has not been recognized in eastern Labrador.

The term 'Adirondian' for the period between 1180 and 1080 Ma in the Grenville Province was informally adopted by Gower *et al.* (1997a) as rocks of this age are well represented in the Adirondacks. This usage was continued by Gower and Krogh (2002), and has appeared sporadically in the literature subsequently. It was during this time span that the huge AMCG suites (*e.g.*, Marcy, Morin, Lac St. Jean, and Havre St. Pierre) were emplaced, mostly during the first 60 million years. In eastern Labrador, the 1132 +7/-6 Ma Gilbert River pluton (Gower *et al.*, 1991) is the most significant representative of Adirondian activity, with which an 1113 +6/-5 Ma minor granitic vein may be linked (Scott *et al.*, 1993).

Early and Mid Grenvillian

Grenvillian orogenesis in the EGP extended from 1085 to 985 Ma (*e.g.*, Gower, 1996; Gower and Krogh, 2002). Peak deformation and metamorphism occurred at different times in different areas. In eastern Labrador, the following major tectonothermal events are identified, and assigned time ranges, with the end of cooling (to *ca.* 300°C) given in brackets: (i) 1085–1040 Ma (1020 Ma) in the Lake Melville terrane, (ii) 1030–985 Ma (940 Ma) in the Pinware terrane, (iii) 1020–1000 Ma (990 Ma) in the Mealy Mountains terrane, (iv) 990–970 Ma in the Groswater Bay terrane.

Lake Melville Terrane (1085–1040 Ma)

A date of 1088 ± 3 Ma from monazite in a metapelite at the west end of Henrietta Island (Corrigan *et al.*, 2000) is the oldest age that can be considered Grenvillian in eastern Labrador. Grenvillian activity in the Lake Melville terrane was well underway by 1080 Ma, as indicated by zircon ages of 1080 ± 2 Ma for pegmatitic material in a boudinaged neck of a coronitic metagabbro dating deformation (Corrigan *et al.*, 2000) and 1079 ± 6 Ma from the Southwest Brook granite dating emplacement (Schärer and Gower, 1988), and monazite determinations from the Rexon's Cove granitic vein and the Alexis Bay polydeformed granodioritic gneiss at $1078 \pm$ and 1077 ± 3 Ma, respectively, both dating metamorphism (Scott *et al.*, 1993).

Continued Grenvillian activity in the Lake Melville terrane is recorded by a 1062 + 5/-6 Ma (zircon) resulting dating emplacement of the Mecklenburg Harbour granitic vein (Scott *et al.*, 1993), 1057 ± 4 Ma and 1046 ± 2 Ma for the West Henrietta Island metapelite and 1047 ± 4 Ma for the south side of Groswater Bay metapelite (all monazite ages dating metamorphism; Corrigan *et al.*, 2000), 1056 ± 2 Ma for the East Henrietta Island late-tectonic pegmatite (zircon dating emplacement; Corrigan *et al.*, 2000), and 1047 ± 3 Ma and 1038 ± 3 Ma from the Paradise River quartz diorite dyke (zircon/emplacement and monazite/metamorphism, respectively; Wasteneys *et al.*, 1997).

The end/aftermath of the event is inferred from titanite dates (in two cases regressed with zircon or monazite) of *ca.* 1038 Ma from the Upper North River amphibolite and syenite, 1030 ± 2 Ma from the Second Choice Lake migmatitic gneiss, and *ca.* 1026 Ma from the Neveisik Island megacrystic granitoid (all from Schärer *et al.*, 1986).

Geochronological data demonstrate two important points:

- i. There was no voluminous magmatism in the Lake Melville terrane during early Grenvillian orogenesis; the results date either minor granitoid intrusions, metamorphic events, or are linked to deformation. One exception might seem to be the Southwest Brook granite, which Schärer and Gower (1988) described as a 14-km-wide pluton, but Gower *et al.* (1991) clarified that it was likely a stockwork of granitic veins indeed, the dated rock came from one such vein. The sporadic magmatism that occurred throughout the period was probably local, linked to the prevailing metamorphic conditions.
- All titanite ages post-date 1040 Ma; earlier ages being based on zircon and monazite. That the titanite results fall within a specific period was first recognized by Schärer *et al.* (1986), who provided the first quantitative data substantiating distinction between the Lake Melville and Groswater Bay terranes. Schärer *et al.* (1986) regarded the period between 1040 and 1030 Ma as being a short-lived metamorphic-anatectic
event, but it is now clear that it reflects closure after a 40-million-year period of tectonism. It should be noted that the older zircon and monazite dates both span the entire pre-1040 Ma period, suggesting that high-grade conditions in the northern Lake Melville terrane were maintained throughout the period, rather than any progressive decline in temperature. The late-tectonic pegmatite of Corrigan *et al.* (2000) and the shallowly discordant granodiorite dyke of Wasteneys *et al.* (1997) indicate that most deformation was over at those localities by 1056 Ma and 1046 Ma, respectively. It may have been earlier or later elsewhere in the Lake Melville terrane, however (*see* below).

Pinware Terrane (1030–985 Ma)

Geochronological data (Tucker and Gower, 1994; Wasteneys *et al.*, 1997) indicate that the onset of Grenvillian metamorphism in the Pinware terrane was about 1030 Ma, based on lower intercept zircon ages of: (i) 1036 ± 17 Ma from the L'Anse-au-Loup pegmatite that dates the time of its emplacement as well as the metamorphism of its Labradorian volcanoclastic host, (ii) $1030 \pm 26/-18$ Ma from the Labradorian Country Cat monzonite, (iii) 1019 ± 14 Ma from the Lodge Bay quartz monzodiorite gneiss, and (iv) an imprecise monazite lower intercept of *ca.* 1020 Ma from the (>1500 Ma) Pleasure Cove quartzite.

Evidence for continued high-grade metamorphism is provided by zircon dates of 1009 \pm 10a from the Labradorian 'tributary of St. Pauls River' quartz monzonite, 1000 \pm 2 Ma from the St. Peter Bay mafic dyke and monazite dates of 982 \pm 5 Ma and 979 \pm 20 Ma from the Labradorian Country Cat Pond quartz monzonite and L'Anse-au-Loup volcanoclastic units, respectively. In contrast to the Lake Melville region, high-grade metamorphism was accompanied by significant magmatism in the form of the 'east of Upper St. Paul River' aegerine syenite emplaced at 991 \pm 5 Ma, the Picton Pond quartz monzonite at 988 \pm 6 Ma and the Upper Beaver Brook granite at 983 \pm 3 Ma. The last major deformation is bracketed between the very strongly deformed 991 Ma aegerine syenite and the weakly deformed 985 \pm 6 Ma L'Anse-au-Loup alkalic mafic dyke.

As with the Lake Melville terrane, the time of the last major deformation is linked to the onset of declining metamorphism. This is demonstrated by titanite ages (as a result of cooling following uplift) of 972 ± 5 Ma from the Country Cat Pond gneissic quartz monzonite, 964 ± 12 Ma from the Cape Charles quartz monzonite, 960 ± 6 Ma from the Lodge 947 ± 10 Bay quartz monzodiorite gneiss, 960 ± 5 Ma from the Upper Beaver Brook granite, 947 ± 10 Ma from the 'Tributary of St. Pauls River' quartz monzonite, and 939 ± 5 Ma from the 'west of Trout River' quartz monzonite. The span of titanite ages is longer than that in the Lake Melville area; which is attributed to the emplacement of late- to post-Grenvillian granitoid plutons that resulted in higher temperatures to be sustained over a longer period.

Mealy Mountains Terrane (1020–1000 Ma)

On the northeast flank of the Mealy Mountains terrane, long interpreted to be a strikeslip fault, a monazite date of 1013 ± 4 Ma from a pegmatite in the English River shear zone (Corrigan *et al.*, 2000) and a zircon–titanite regression of 1003 ± 6 Ma from the late-tectonic Second Choice Lake pegmatite farther southeast (Gower *et al.*, 1991), provide strong evidence for displacement coeval with that determined for the Cape Caribou River allochthon. It should be clarified that both of these sites have been previously assigned to the Lake Melville terrane, but, given the Lake Melville terrane's older Grenvillian metamorphic history and the close proximity of these sites to the Mealy Mountains terrane boundary, it is appropriate to include them here.

The presence of titanite in the 1003 Ma Second Choice Lake pegmatite is consistent with titanite ages of 990 ± 7 Ma and 987 ± 2 Ma from Lower Brook domain leucosome in granitic gneiss and quartz monzonite, respectively (Goose Bay area; Philippe *et al.*, 1993). These dates effectively mark the start of declining temperatures around 1000 Ma. Thrusting was around 1010 Ma, which also initiated cooling.

Groswater Bay Terrane (990 Ma?-970 Ma)

Grenvillian dates from the Groswater Bay terrane show a very different pattern to that evident in all the other regions described above. In contrast to the model of high-grade metamorphism, then thrusting followed by cooling, current data only indicate the final phase. This may be due to inadequate studies, but might genuinely reflect the tectonic signature of this region, noting that Pb-loss in zircon is relatively minor in most of the (Labradorian) rocks that make up the terrane.

The only geochronological straw to cling to regarding significant Grenvillian metamorphism is a lower-intercept result of 1010 + 10/-7 Ma based on baddeleyite and zircon from a sample that was assigned to Michael gabbro by Corrigan *et al.* (2000), but this date has

been challenged by Gower and Krogh (2002), as the upper intercept of 1472 Ma also is anomalously old. If data from the Michael gabbro obtained by Schärer *et al.* (1996) is included in the regression, the line would be rotated to younger upper and lower intercepts, which would be more consistent with other results in the district.

With two exceptions, all the remaining Grenvillian ages are based on titanite, although zircon is included on the regression line in two cases. The ages are 994 ± 2 Ma from migmatitic gneiss at the west end of the Groswater Bay terrane (Philippe et al., 1993), 980 \pm 4 Ma from the Bluff Head hornblende granodiorite, 978 \pm 4 Ma from the Double Island granodiorite to tonalite gneiss, 977 ± 2 Ma from the Saddle Island metasedimentary gneiss (all from Schärer *et al.*, 1986), 975 ± 27 Ma from the Susan River quartz diorite (Philippe et al., 1993), 973 ± 11 Ma from the Grady Island intrusion (Kamo et al., 1996), 972 ± 4 Ma from the Cuff Island nebulitic granodiorite, *ca.* 970 Ma from the Double Island pegmatite and 968 +7/-8 Ma from the Cuff Island banded granodiorite gneiss (all from Schärer et al., 1986). The ca. 970 Ma date from the Double Island pegmatite is a slightly discordant Pb-Pb titanite age based on one analytical point, but time of closure cannot have been very different from the 978 Ma date obtained from its host. Of the two excepts, one is an imprecise date of 941 + 39/-36 Ma from the Double Mer granite based on a long extrapolation from zircon analyses plotting close to the upper intercept (Schärer et al., 1986). The other is rutile from a gabbro at Cuff Island, which yielded nearly concordant results of 931 Ma and 923 Ma, hence establishing the end of Grenvillian effects in the Groswater Bay terrane.

The thesis that Grenvillian metamorphism was comparatively mild in the Groswater Bay terrane seems in conflict with a north-to-south systematic increase in metamorphism to high-grade metamorphic assemblages in the Michael gabbro that are comparable with those in its Labradorian hosts. As the 1426 Ma Michael gabbro postdates Labradorian metamorphism and there is no evidence for post-emplacement, pre-Grenvillian high-grade metamorphism, it would seem that the severe overprint must be Grenvillian. An escape from this dilemma was proposed by Gower and Erdmer (1988), whereby the high-grade assemblages in the Michael gabbro are attributed to subsolidus (isobaric?) cooling after intrusion. They postulated that the nature of the various coronitic assemblages depended on the depth at which re-equilibration occurred; gabbro that reached mid- to high-crustal levels only shows relatively moderate-grade assemblages, whereas that emplaced closer to the base of the crust developed a high-grade mineralogy. Following isostatic adjustments, the (now exposed) crust remained cool enough to escape Grenvillian high-grade conditions, but was reconfigured by stepped thrusts that exhumed progressively deeper crustal levels from north to south and brought about titanite closure. Note that this thesis is consistent with the model of Gower *et al.* (1997b) that the Lake Melville–Mealy Mountains terrane boundary represents the northern limit of Grenvillian allochthonous terranes and that the region to the northeast escaped much of this overthrusting.

Hawke River Terrane

Two determinations from the borders of the Hawke River terrane are mentioned at this juncture. These are an emplacement age of 1029 ± 2 Ma from the Beaver Brook microgranite dyke (monazite; Schärer *et al.*, 1986) and a metamorphic titanite age of 1020 ± 5 Ma from the 1645 Ma Cartwright alkali-feldspar granite (Kamo *et al.*, 1996). Recall that Labradorian titanite ages from the Hawke River terrane indicates that this region almost entirely escaped Grenvillian high-grade metamorphism. Both of the dating sites mentioned here are near the margins of the Hawke River terrane, which probably experienced some Grenvillian adjustments.

Late Grenvillian Magmatic Events

Late Grenvillian events are divided here into two groups. The older event (985 to 975 Ma) was characterized by alkalic mafic dyking, and anorthositic/alkalic magmatism, whereas the younger event (975 to 955 Ma) was one of monzonitic, syenitic and granitic magmatism. The first clearly developed into the second without any hiatus, but we feel there are sufficient time-compositional contrasts to merit reviewing them separately below.

Early Post-tectonic Magmatism (985–975 Ma)

Alkalic mafic dykes have been recognized in the Lake Melville terrane (Gilbert Bay dykes), where they are spatially associated with a major brittle facture zone (Gilbert River fault), and they are also widespread in the Pinware terrane (L'Anse-au-Diable dykes).

The dykes discordantly intrude their host rocks, are overall east-southeast-trending (although commonly irregular and branching), in some cases are extremely xenolithic, and may show magma-mingling characteristics (Gower *et al.*, 1994). The L'Anse-au-Diable dykes show the most mineralogical modification and were emplaced at deeper levels than the pristine Gilbert Bay dykes, which were intruded close to the surface (as indicated by amygdales in the mafic intrusions and clastic dykes in the Gilbert River fault). Two emplacement zircon ages have been obtained of 974 ± 6 Ma from a Gilbert Bay dyke in the north (Lake Melville terrane) and 985 ± 6 Ma from a L'Anse-au-Diable dyke in the south (Pinware terrane) (Wasteneys *et al.*, 1997). A titanite cooling age of 955 ± 20 Ma was also reported from the Gilbert Bay dyke by Wasteneys *et al.* (1997). Although precision limits permit coeval emplacement, the nominally older age obtained from the southern dyke is consistent with its mildly metamorphosed state, having been injected during waning Grenvillian metamorphism in the area. Thus it may be considered Grenvillian structurally, but post-Grenvillian magmatically. Note that the L'Anse-au-Diable alkalic mafic dyke discordantly intruded a pegmatite dated to be 1036 Ma (mentioned earlier), and is, itself, crosscut by an undated, sheared aplite.

Major intrusive bodies emplaced at the same time include the Red Bay gabbro (Gower *et al.*, 1994; Greenough and Owen, 1995), dated to be 980 ± 3 Ma, the 975 ± 2 Ma Vieux-Fort granophyric leuconorite and the 974 ± 6 Ma fayalite-bearing Lower Pinware River al-kali-feldspar syenite (all from Heaman *et al.*, 2004). The latter date supersedes an earlier result of 962 + 76/-120 Ma obtained by Wasteneys *et al.* (1997) who argued, on the basis of other geochronological data and field evidence, that emplacement was between 985 and 972 Ma.

Late Post-tectonic Magmatism (975–955 Ma)

Late post-tectonic magmatism can be classified as either minor granitic intrusions, up to a few metres across, or plutons several kilometres in diameter. Only one date has been reported for minor granitoid intrusions from eastern Labrador, but such rocks are undoubtedly widespread. The age, 974 ± 6 Ma from the St. Peter Bay aplite (Tucker and Gower, 1994), is based on titanite and cannot be considered rigorous; Tucker and Gower (1994) cautioned that their result could date reflect an event after emplacement (*e.g.*, metamorphism).

The granitoid plutons are discrete, circular to elliptical (in plan) bodies; range in composition between monzonite, syenite and granite; are typically homogeneous and massive; and locally show mantled feldspar textures. They are commonly associated with distinct positive aeromagnetic anomalies. Recognition of these intrusions as a representing a major addition of granitic magma to the EGP was first made by Gower *et al.* (1991), who, from limited knowledge of their distribution at the time, used aeromagnetic patterns and meagre reconnaissance geological mapping to predict that they would be found to be extensive and concentrated in the southern half of the EGP. The names 'Exterior Thrust Belt' and an 'Interior Magmatic Belt' were proposed to distinguish conceptually the northern and southern regions. Subsequent mapping has confirmed that many (but not all) of the magnetic anomalies correlate with late post-tectonic granitoid plutons. Few of the more recently mapped bodies have been studied geochronologically, so the number of known intrusions far exceeds those dated. This is primarily because such intrusions can be confidently identified in the field, which has allowed geochronological resources to be directed elsewhere. Ages determined are 966 ± 3 Ma for the Upper St. Lewis River (east) monzonite, 964 ± 3 Ma for the Joir River granite, 964 ± 2 Ma for the Chateau Pond granite, 964 ± 5 Ma for the Riviere Bujeault headwaters quartz syenite, 959 ± 2 Ma for the Southwest Pond granite, 960 ± 2 Ma for the Upper Pinware River granite, 959 ± 2 Ma for the Upper Trout River granite and 956 ± 1 Ma for the Upper St. Lewis River (west) granite. All ages are based on concordant or near-concordant arrays of zircon analyses that were reported by Gower and Loveridge (1987), Gower *et al.* (1991), Tucker and Gower (1994), or James *et al.* (2001).

Post-Grenvillian Waning (955–920 Ma)

On the basis of results from rutile from various parts of the EGP (*see* earlier), tectonothermal activity waned between 955 Ma and 920 Ma. After this, the region subsided into a wellearned repose after 900 million years of mountain building, moving and destroying.

Grenvillian Indentor Model

Grenvillian tectonism in eastern Labrador is interpreted in terms of an indentor model (Gower *et al.*, 2008b). The fundamental element of this thesis is a remarkable change from the northeast geochronological, structural and geophysical trends that prevail throughout much of the Grenville Province to southeast trends in eastern Labrador. A critical consequence of this model is that, contrary to traditional depictions showing the Grenville front as continuing its northeast trend out into the Atlantic Ocean and linking up with the Sveconorwegian front in Scandinavia, the Grenville orogen ends in eastern Labrador, the Sveconorwegian rocks of Scandinavia belong to a separate, albeit coeval, orogen, or sub-orogen. This does not deny, of course, prior Late Paleoproterozoic and earlier Mesoproterozoic orogenic links between Laurentia and Baltica.

Geochronological Criteria

U–Pb geochronological data compiled by Gower and Krogh (2002), together with Ar– Ar and K–Ar data reviewed by Gower (2003b), plus additional data and interpretation by Gower *et al.* (2008b), show that the boundary between Grenvillian and pre-Grenvillian ages (*i.e.*, 1085 Ma) is very nearly coincident regardless of whether U–Pb, Ar–Ar or K–Ar data are used. This line was termed by Gower (2003b) as the 'Grenvillian thermal threshold' (Figures 10 and 11). The U–Pb data rely on Grenvillian ages for zircon and monazite south of the line and pre-Grenvillian ages for titanite north of it. The Ar–Ar and K–Ar 1000 Ma thermochron occupies a position very close to the Grenvillian thermal threshold where both trend northeast, but the two lines diverge in the easternmost Grenville Province, such that the 1000 Ma thermochron is coincident with the southwest boundary of the Lake Melville terrane. Two features of the Grenvillian thermal threshold are considered here to be of key significance. The first is that, in the easternmost Grenville Province, instead of continuing northeast to the coast at Smokey, it turns southeast to follow the northeast boundary of the Lake Melville terrane. The second is that the Grenvillian thermal threshold makes a distinct bulge in the western part of the EGP.

U–Pb geochronological data, apart from confirming the position of the Grenvillian thermal threshold, can also be used to draw a boundary marking the northern limit of widespread U–Pb zircon and monazite 1045–1020 Ma ages (Figure 10b). Data are only adequate to position this boundary in easternmost Labrador, but, nevertheless, show the same dog-leg change in direction as indicated from the above-mentioned thermochrons. Hints exist, even farther south, that this pattern is likely to be mimicked by the northern limit of 1043–1039 Ma K-feldspar megacrystic granitoid plutons. Finally, the northern limit of the late- to post-Grenvillian plutons (975–950 Ma) also shows the same pattern (Gower, 2008b). In the same area, the sharp change in trend from northeast to southeast is shown by the inferred surface boundary between Labradorian (1710–1600 Ma) and Pinwarian (1520–1460 Ma) crust. Detailed information constraining these boundaries is given by Gower *et al.* (2008b).

Structural Criteria

In contrast to the system of northwest-vergent, lobate frontal thrusts that characterize much of the northern EGP, the key geological feature of eastern Labrador is a major northwest-trending zone of thrusts and strike-slip faults (Figure 4). This zone intersects the southeast coast of Labrador in the vicinity of St. Lewis and follows a sinuous trend northwest to the Rigolet area. The dog-leg change in trend from east-northeast in the west to south-southeast in the east is shown by both geological mapping and magnetic data. The zone coincides with the Lake Melville terrane, the southern part of which has also been termed the Gilbert River shear belt.



Boundary between pre-Grenvillian and Grenvillian U-Pb, Ar-Ar and K-Ar ages (i.e., 1085 Ma). Taken as northern limit of significant Grenvillian thermal imprint (Grenvillian thermal threshold).



Boundary between pre-Grenvillian and Grenvillian ages (i.e., 1085 Ma). (Grenvillian thermal threshold). Ar-Ar and K-Ar 1000 Ma thermochron for biotite and homblende Northern limit of 1045 -1020 Ma zircon and monazite U-Pb ages Northern limit of 1043-1039 Ma K-feldspar megacrystic granites Late- to post-tectonic Grenvillian granites and line defining their northern limit Labradorian (1710-1600 Ma) - Pinwarian (1520-1460 Ma) boundary The southern half of the shear belt, between St. Lewis and Paradise River, is interpreted as a composite Labradorian/Grenvillian feature involving southwest-directed Labradorian thrusting onto which dextral Grenvillian strike-slip movement has been imposed (Hanmer and Scott, 1990; Gower *et al.*, 1997; Gower, 2005). Farther north, between Paradise River and Rigolet, it seems more likely that the northeast- and north-directed thrusting is Grenvillian, although reactivating early Labradorian thrusting with the opposite sense of vergence (but kinematic data and age controls are scarce). West of Rigolet, the northwest-verging thrusts are Grenvillian.

From a Grenvillian perspective, the overall structural interpretation offered (Gower *et al.*, 1997; Gower, 2005) is that the northwest-trending part from St. Lewis to Rigolet is a lateral ramp, whereas, west of Rigolet, the system is frontal. The existence of much of the frontal ramp in eastern Labrador is obscured by the Lake Melville Rift system (Figure 4). The rift system and contained sediments are considered to be Neoproterozoic on the basis of paleomagnetic investigations and a structural model that integrates graben faulting, folding of the sedimentary fill, and emplacement of the 615 Ma Long Range dykes (Gower *et al.*, 1986).

Geophysical Criteria

In addition to magnetic data alluded to in the previous section, evidence that the Grenville Province terminates in easternmost Labrador is provided by gravity and seismic information. Gravity data are particularly telling (Figure 12). Whereas the well-known Grenville front 'gravity low' is clear in the western and central parts of the EGP, it is extremely attenuated in the easternmost Grenville Province. There is no indication that it continues offshore. Gower (2003) suggested that the anomaly is lacking in the east because the crustal thickening that accompanied the northwest-directed frontal thrusting farther west (and to which the negative anomaly is related) did not occur in the east.

Seismic reflection data acquired during the Lithoprobe ECSOOT project also deny extension of the Grenville Province offshore. There is no sign of the whole-crustal south-dipping shear zone reflectivity associated with the Grenville front to the west (Hall *et al.* (2002).

Figure 10 (opposite). Grenvillian thermochrons and related features illustrating thermochron bulge to the northwest-ward in western Labrador and change to southeasterly thermochron trend in eastern Labrador (Gower et al., 2008b). a) Distribution of age data localities and location of Grenvillian thermal threshold. b) Grenvillian thermal threshold and Grenvillian features farther south showing complementary pattern.



Figure 11. *High-pressure metamorphic belts, and areas in the interior Grenville Province lacking high-grade metamorphism in western Labrador and their correlative regions in eastern Labrador. a) Present configuration. b) Configuration after aligning belts in western Labrador with those in eastern Labrador (Gower et al., 2008b).*





Northwest Thermochron Bulge in the Western Part of the EGP

It is here postulated that the Lac Joseph terrane, plus allochthons farther west, and, to a lesser extent, the unnamed allochthonous terrane immediately to the east, were originally aligned with their central and eastern Labrador counterparts, but were transported *ca.* 150 km farther northwest during Grenvillian orogenesis. This postulate draws on the observation that, in an 'uncorrected' position, the Grenvillian thermal threshold, high-pressure terranes and areas in the interior part of the Grenville Province where high-grade Grenvillian metamorphism is lacking are markedly farther northwest in western Labrador than in the east (Figure 11a). The misalignment has been removed in Figure 11b by restoring the Lac Joseph terrane and other allochthonous terranes farther west, to about 150 km to the southeast.

It should be kept in mind that the terranes in the eastern part of the EGP have also moved northwest and that no claims are made regarding absolute displacements. Note that the restoration has been achieved by the most uncomplicated means possible and thus embodies the unintended implication that displacements between blocks were accomplished along simple transcurrent faults. This is hardly probable in the ductile regime envisaged here and no weight should be attached to the simplistic method used.

Restoring the western EGP terranes southeastward aligns positive Bouguer gravity anomalies underlying the Mealy Mountains terrane with positive gravity anomalies in the Lac Joseph terrane (Figure 12). Similarly, on their southern flank, a trough of lower Bouguer gravity anomalies also becomes aligned. It seems likely that the large geological bodies in the southwestern EGP, such as the Lac Fournier and Havre St. Pierre AMCG (anorthosite– monzonite–charnockite–granite) suites, south of the Lac Joseph terrane, and the adjacent Wakeham Group to the east, would also have been much farther south, which opens up new possibilities regarding their pre-Grenvillian tectonic significance. The Lac Fournier and Havre St. Pierre AMCG suites, for example, are brought into much closer proximity to the undated Petit Mecatina AMCG intrusion; are they correlative? The Wakeham Group (deposited between 1630 and 1500 Ma) would appear less 'intracratonic' than its present location suggests. The vast Paleoproterozoic metasedimentary terranes in western Labrador would trend north-northeast and be in better alignment with their (probable) Ketilidian counterparts in southern Greenland.

The presence of areas mildly affected by Grenvillian metamorphism well within the EGP (namely the Lac Joseph and Mealy Mountains terranes) has generated considerable

interpretational confusion in the past. Although comparison between the Lac Joseph and Mealy Mountains terranes, on the basis of mild Grenvillian metamorphism (Gower and Krogh, 2002; Krauss and Rivers, 2004), has previously been correctly made, comparisons between the Lac Joseph terrane and the Wilson Lake terrane (Gower and Krogh, 2002) and between the Lac Joseph terrane and the Hawke River terrane (Rivers *et al.*, 2002) have not (at least according to the concepts presented here). The Lac Joseph terrane is interior of the Grenvillian thermal threshold whereas the Wilson Lake terrane and Hawke River terrane are exterior of it. In other words, distinction must be made between parautochthonous terranes mildly or unaffected by Grenvillian metamorphism because they are at the fringe of the orogen, and allochthonous terranes regions in the interior EGP that lack significant Grenvillian metamorphism because high crustal levels were preserved throughout Grenvillian orogenesis.

Gower and Krogh (2002, p. 820), drawing partly on earlier work (Krogh, 1994; Connelly *et al.*, 1995), concluded that emplacement of allochthonous terranes over their footwall crust in the western part of the EGP was very rapid (between 1010 and 990 Ma). It is postulated that this was when the Lac Joseph and related areas were displaced northwest relative to regions farther east, and that it was facilitated by sliding over the passive continental margin sedimentary rocks of the Kaniapiskau Supergroup fringing the Superior Province.

Having rejected linkage between the Lac Joseph and Wilson Lake terranes in the previous section, it is, nevertheless, argued that their relationship must not be severed entirely. Neither the suggestion of northwest-directed Grenvillian thrusting of the Wilson Lake terrane, nor the concept that the terranes in the western part of the EGP behaved coherently (Gower and Krogh, 2002) should be discarded – merely that such cohesion developed during very late (1010–990 Ma) Grenvillian orogenesis, when only relatively 'cold' crust was involved, at which time Grenvillian effects in the northern EGP were confined to discrete shear zones.

The Himalayan–Tibetan Analogue and Differences From It

The first specific comparative comparison of the Grenville Province with the Himalayan–Tibet tectonic system respect to the EGP was made by Indares and Dunning (2004), with special application to the high pressure (HP) belt in the Manicouagan area (Indares *et al.*, 1998). As part of their comparison, they also recognized the attractiveness of channel-flow models for the Himalayan–Tibetan system developed by Beaumont *et al.* (2001, 2004). Following on, Krauss and Rivers (2004) have inferred that the Cape Caribou River Allochthon in central Labrador is part of the HP belt, and Gower (2005) has proposed that the Lake Melville terrane is the most likely equivalent of the HP belt farther east and represents a channel-flow analogue. Note that one must reverse a south-to-north cross-section for the Himalayas to match a north-to-south section across the Grenville Province. The 'restored' EGP of Figure 11b is used as the basis for making comparisons. Figure 13a illustrates how the Himalayan tectonic model might apply to the EGP. The cross-sections are taken from Beaumont (2001, 2004), the details of which are better seen in Figure 13b. Details are given by Gower *et al.* (2008b). Because the Grenville orogen terminates in eastern Labrador in a lateral ramp it is necessary to go beyond the two-dimensional, cross-sectional approach in making Himalayan-Grenvillian comparisons.

Firstly, the high-pressure belt associated with the Grenvillian crustal-scale frontal thrust system merges in eastern Labrador into the southeast-trending zone of dextral shearing and thrusting coincident with the Lake Melville terrane (the lateral ramp). This means, of course, that the high-pressure belt does not extrapolate directly northeastward to the coast. Also implied is that, progressing southeast along the Lake Melville terrane, Grenvillian pressures should decrease and the belt diminish as a high pressure entity. Testing this hypothesis, which has yet to be done, needs to be carried out very carefully in order to discriminate reliably Grenvillian from earlier Labradorian and Pinwarian metamorphic effects.

Secondly, although one might be tempted initially to compare the lateral ramp in eastern Labrador with the lateral ramps extending south from either the Nanga Parbat or Namcha Barwa syntaxes in the Himalayan system, such a comparison fails. The contrast in tectonic regime is that the Indian sub-continent is indenting into pre-India Asia and is subducting underneath it, whereas all the evidence for the EGP implies that, although indenting, Grenvillian-affected rocks were transported over pre-Grenvillian Laurentia (Figure 13b).

Thirdly, one likely factor in determining thrust vergence would seem to be earlier fossil subduction direction. In the EGP, evidence is in favour of southward Labradorian subduction (summarized by Gower and Krogh, 2003). This later became the locus for Grenvillian thrusting, which, therefore provides an explanation why the Grenville front and northern boundary of the Labradorian orogen are nearly coincident.

Fourthly, along the lateral ramp distant from the indentor corner (in a southeast direction in eastern Labrador), one would not expect to see major differences regardless whether the



Figure 13. *a)* Block diagram illustrating application to the eastern Grenville Province of a generic channel-flow model for Himalayan-Tibetan tectonic system. b) Block diagrams illustrating the difference between an overthrusting indenting continent (Grenvillian) and an underthrusting indenting continent (Himalayan) (Gower et al., 2008b).

indenting continent is thrust over or under, as both regions are simply strike-slip shear zones. It is at the indentor corner where huge implications for differences exist. In the Himalayan situation, the interior right angle at the indentor corner is a region of constriction, where tight, lithospheric–scale, syntaxial, antiformal folds have developed (at the Nanga Parbat and Namcha Barwa indentor corners), and where escape is partly vertical, leading to very rapid erosion (*e.g.*, Ding *et al.*, 2001). In the easternmost Grenville Province, overthrusting of the indenting crust would not have been so constraining in a horizontal sense, thus allowing 'tectonic spillover' at the syntaxial corner and northern part of the lateral ramp (Figure 4). The extent to which this might have occurred remains uncertain as much of the evidence, presumably at high crustal levels, would have been removed by erosion.

Opening of Iapetus Ocean

The post-Grenvillian repose lasted 300 million years, until the dawn of the opening of Iapetus Ocean, which was marked in the Grenville Province by the emplacement of the Long Range dykes dated to be 615 ± 2 Ma (Kamo *et al.*, 1989) and $615 \pm 6/-4$ Ma (Kamo and Gower, 1994). Other activity included the formation of huge quartz dykes; deposition of the Double Mer Formation in the Lake Melville Rift System (Gower *et al.*, 1986) and in the Sandwich Bay graben; deposition of the Bateau formation (Labrador Group); and extrusion of the Lighthouse Cove mafic volcanic rocks in southeastmost Labrador (Figure 14). Ferruginous clastic and mixed clastic-carbonate rocks of the Bradore and Forteau formations preserve the record of later flooding of the ancient Laurentian margin (Gower *et al.*, 1997a).



Figure 14. Post-Grenvillian Long Range dykes, major faults, rift basins and related supracrustal fill related to the opening of Iapetus Ocean.

EXCURSION ROUTE

The excursion will start in Happy Valley-Goose Bay and end at Vieux-Fort, making use of the recently completed (in 2010) eastern part of the Trans-Labrador Highway, from Happy Valley-Goose Bay to Red Bay for much of its route. In its entirety, the Trans-Labrador Highway stretches approximately 1150 km from southwest Labrador to southeasternmost Labrador, passing through Labrador City–Wabush, Churchill Falls and Happy Valley-Goose Bay.

In southeast Labrador, travelling eastward, the highway (Highway 510) links Happy Valley-Goose Bay to Port Hope Simpson (*via* Cartwright Junction), then passes by Mary's Harbour and Lodge Bay en route to Red Bay. Farther south, the road links up various communities between Red Bay and Blanc Sablon. Branch roads link up the coastal communities of Cartwright (Highway 516), Charlottetown and Pinsent Arm (Highways 514 and 515), and St. Lewis (Highway 513). Distances are as follows: Happy Valley-Goose Bay to Cartwright Junction – 287 km; Cartwright Junction to Blanc Sablon – 306 km; branch road from Cartwright Junction to Cartwright – 91 km; branch road to Charlottetown and Pinsent Arm – 29 + 24 km; branch road to St. Lewis – 30 km.

The various legs of the excursion, dictated by accommodation options, are as follows:

- Day 1 Happy Valley-Goose Bay to Cartwright;
- Day 2 Cartwright to Port Hope Simpson;
- Day 3 Port Hope Simpson to Mary's Harbour;
- Day 4 Mary's Harbour to L'Anse-au-Clair;
- Day 5 L'Anse au Clair to Vieux-Fort.

Not all the stops described in the guide will necessarily be made, depending on time, weather and other circumstances. Furthermore, Appendix 1 includes descriptions for a day visit to Battle Island, which, because of logistical difficulties, will not be included on this excursion. The destination, however, is worthwhile both geologically and culturally, and recommended to any post-excursion users of this guide book. Images of stained (for potassium) slabs of representative rock samples from most localities are included in Appendix 2.

EXCURSION STOPS

DAY 1. Goose Bay to Cartwright Junction (Figure 15)





STOP 1.1: Dome Mountain Intrusive Suite; South Side of Causeway across Churchill River. CG11-003 (667178 5903768)²

Wardle and Crisby (1986, 1987) and Wardle and Ash (1986) mapped the area as part of the Dome Mountain Intrusive Suite, which includes monzodiorite, quartz monzodiorite, monzonite, quartz monzonite, and granite, commonly with amphibolite-metagabbro inclusions. The quarry site (Plate 1a) exposes pink to buff, medium-grained and massive to weakly foliated alkali feldspar granite, granite and quartz syenite. Metagabbro–amphibolite inclusions are abundant. The granite is intruded by mafic dykes. The earliest phase is greybrown, deformed and dips steep to moderately north. It is discordantly intruded by a black, fine-grained, 1.5 m-wide dyke, also dipping north, but more steeply. It shows chilled margins and contains sulphide-filled amygdales. Wardle and Crisby (1987) note that some mafic dykes in this region are fresh and believed them to post-date Grenvillian orogenesis, perhaps related to the development of the Lake Melville graben, but as all mafic dykes at the quarry are intruded by near-horizontal, minor granitoid veins (assumed to be, at the latest, Grenvillian) the mafic dykes must be pre-Grenvillian. Extrapolating from elsewhere, the older dykes could be Labradorian, and the younger dykes part of the 1250 Ma Mealy swarm.

En route to next stop. After leaving the quarry, the route south follows the southwest end of the Lake Melville graben. The road then climbs onto the surrounding plateau, which is underlain by Labradorian igneous and metamorphic rocks of the Dome Mountain and Mealy Mountains intrusive suites. Eventually it descends into a broad valley underlain by Double Mer Formation, which is contained within a branch of the Lake Melville rift system.

STOP 1.2: Double Mer Formation; Kenamu River. CG09-058 (692576 5858497)

Cross-bedded, purplish-orange and maroon sandstone and pebbly conglomerate exposed in the quarry (Plate 1b) are correlated with the Double Mer Formation, which is the sedimentary fill of the Lake Melville rift system. The age of deposition of the sediments has never been determined, other than, because unmetamorphosed, the sediments must postdate Grenvillian orogenesis. The rocks have long been interpreted as late Neoproterozoic (Kindle, 1924). Structural inferences and paleomagnetic data endorse this position (Gower *et al.*, 1986; Murthy *et al.*, 1992, respectively). The formation of the Lake Melville rift system was a consequence of Rodinia break-up in the region, which heralded the opening of Iapetus Ocean.

 $^{^{2}}$ The alphanumeric code (e.g., CG11-003) is the author's data station number. The bracketed numbers are UTM co-ordinates; NAD 27, Zone 20 west of longitude 60°W and Zone 21 farther east.



Stop 1.1. Dome Mountain alkali-feldspar granite intruded by mafic dykes



Plate 1. Outcrop photographs for localities 1.1, 1.2, 1.5 and 1.6.

Stop 1.5. Mafic/ultramafic rocks of the No-Name Lake intrusion.



Stop 1.2. Double Mer Formation



Stop 1.6 Late- to post-tectonic Grenvillian pluton. Note horizontal jointing and lack of fabric (inset)

En route to next stop: There is very little roadside outcrop as the road climbs up the southeast side of the Lake Melville graben. The area is underlain by monzonitic rocks of the Mealy Mountains Intrusive Suite.

STOP 1.3: Mealy Mountain Intrusive Suite Monzonite to Monzodiorite; 10 km East of Kenamu River. CG09-056 (700151 5853110)

The predominant rock type is a pale-grey weathering, homogeneous, massive, clinopyroxene-bearing quartz monzodiorite to quartz monzonite. It is intruded by black, fine- to medium-grained, northeast- to east-northeast-trending Mealy dykes showing chilled margins against the host monzonitic rock. Quartz-K-feldspar pegmatitic pods are present.

En route to next stop: Road cuts expose monzonitic to monzogabbronoritic rocks of the Mealy Mountains Intrusive Suite.

STOP 1.4: Labradorian Monzonite; 26 km East of Kenamu River. CG10-011 (311994 5846906)

This outcrop is a substitute for one that is 800 m off the road to the south. The rock is a grey to purplish, medium- to coarse-grained, moderately foliated, recrystallized monzonite to monzogabbronorite. No detailed investigations have been carried out at this site. Before the road existed, a sample of a similar monzonitic rock from the outcrop 800 m to the south was dated and gave a U–Pb zircon emplacement age of 1658 ± 3 Ma (Figure 6). A monazite age of 1626 ± 10 Ma is interpreted as dating the time of recrystallization (Gower *et al.*, 2008a). This monzonite was emplaced toward the end of the main phase of Labradorian deformation, which was around 1660-1655 Ma. The Mealy Mountains Intrusive Suite was emplaced between 1646 and 1635 Ma.

En route to next stop: Northern boundary of No-Name Lake mafic intrusion crossed, but very little outcrop to demonstrate this.

STOP 1.5: No-Name Lake Mafic Intrusion; CG10-013 (319715 5835587)

The No-Name Lake mafic intrusion at this locality is a black-weathering, medium to coarse-grained, recrystallized hornblende-bearing melagabbro to ultramafic rock associated with minor clinopyroxene-bearing leucogabbronorite (Plate 1c). Farther east in the quarry,

the rock grades into a monzogabbronorite. The mafic rocks are intruded by a 2-m-wide, skeletal-hornblende-bearing pegmatite, carrying both pyrite and chalcopyrite. Traces of malachite staining are present. The age of the metagabbro is not known for certain. The only quantitative information is based on a zircon age of 1473 ± 19 Ma (obtained from a gabbroic pegmatite sampled 13 km to the east; Gower *et al.*, 2008a) (Figure 6).

The No-Name Lake intrusion is part of a belt of anorthositic–gabbronoritic– monzogranitic bodies that were emplaced into pre-Labradorian and Labradorian crust near the southern boundary of the Mealy Mountains terrane, and may be spatially controlled by the Mealy Mountains–Pinware terrane boundary. Two other named bodies are the Upper Paradise River suite and the Kyfanan layered mafic intrusion. Two dates of 1501 ± 9 Ma and 1494 ± 7 from granitoid rocks of the Upper Paradise River pluton (Wasteneys *et al.*, 1997) provide support for the Pinwarian age of these bodies.

En route to next stop: Continue through the remainder of the No-Name Lake mafic intrusion; the Pinware terrane is entered, which is mostly underlain by granitoid rocks. This part of the Pinware terrane is also intruded by late-to post-tectonic Grenvillian granite, monzonite and syenite plutons, one of which will be examined briefly at the next stop, if time permits (Day 4 provides an alternative opportunity to see a similar intrusion).

STOP 1.6: Late- to Post-Grenvillian Monzodiorite; 110 km East of Kenamu River; CG08-054 (374103 5827343)

Seen here is a grey-weathering, medium- to coarse-grained, homogeneous, unrecrystallized hornblende- and biotite-bearing monzodiorite. Rare mafic granulite enclaves and a few irregular patches containing large biotite flakes are present. Note the horizontal jointing (Plate 1d), which is very characteristic of the late- to post-Grenvillian plutons. Some bodies are transacted by hematite- and epidote-filled brittle shear zones, which may be Iapetusrift-related features. In general, the late- to post-Grenvillian plutons, especially the quartzrich variants, have resisted erosion more than their host Pinwarian granitoid rocks, so underlie the hills, which the road avoid. The late- to-post-Grenvillian plutons are characterized by positive magnetic anomalies (Figure 16), but note that the magnetic anomalies do not coincide exactly, in either position or size, with the mapped extent of the plutons (as determined by data station control and topography).

En route to next stop. Continuing within Pinware terrane.



to post-Grenvillian plutons. Data stations are shown as red dots and unit boundaries are shown dashed. Note that, although the correlation between pluton position and positive anomaly exists, there are discrepancies. These cannot be dismissed as resulting from inadequate Figure 16. Regional aeromagnetic data illustrating, in particular, the correlation between positive anomalies (shown in red) and lategeological control.

STOP 1.7: Granite; 145 km East of Kenamu River. CG07-027 (403892 5844263)

The rock at this locality is a grey to pink weathering, fine- to medium-grained recrystallized granite showing a flat-lying foliation that tends to be wavy and gradational into gneissic character in places (Plate 2a). Although there is some compositional heterogeneity resulting from concentrations of lensy K-feldspar-rich material, the rock is overall fairly homogeneous. One xenolith containing fine-grained green clinopyroxene and a broad mantle of hornblende has been noted. Amphibolite xenoliths are also present.

On the basis of many U–Pb ages, Gower *et al.* (2008a) defined a boundary between crustal regions defined by Labradorian ages to the north and Pinwarian ages to the south (Figure 17). This stop is on the Pinwarian side of the boundary (Figure 18). After examination of road cuts created during construction of Highway 510, it was concluded that, on the ground, this line separates more homogeneous (albeit strongly deformed and partially migmatized) granitoid rocks in the south from well-banded gneisses farther north (next excursion stop).

En route to next stop: Generally extensive wetland and poor outcrop.

STOP 1.8: Granodiorite Gneiss with Recumbent Z Folds; 155 km East of Kenamu River. CG07-023 (408614 5852516)

The dominant rock at this locality is pink, creamy and grey weathering granodiorite gneiss. It is well-banded, has abundant white and pink leucosome, and is also characterized by biotitic veneers and amphibolitic layers. Of particular note here are recumbent Z folds (gravity collapse structures?), giving a down-dip sense of movement (Plate 2b). Also present are local zones of K-feldspar megacrystic material, generally only a few metres wide. Rare, planar, discordant pegmatitic dykes are present, some carrying large biotite flakes. At the south end of the outcrop is a 40 m-wide layer of homogeneous granodiorite showing gradational margins into the adjacent gneiss. This outcrop can be taken as marking the boundary between the Pinware and Mealy Mountains terranes. Local evidence elsewhere indicates that it is a zone of ductile deformation, and this might be the case along its entire length.

En route to next stop: The route passes through the closure of a reclined regional Grenvillian fold (Figures 18), which formed between 1040 and 1020 Ma (Gower et al., 2008a). The closure is easily seen on aeromagnetic maps for the area, which clearly identify a series of



Stop 1.7. Pinwarian granite



Stop 1.9. Mangeritic rocks interpreted to be correlative with Mealy Mountains Intrusive Suite. Intruded by later pegmatite.



Stop 1.8. Granodiorite gneiss showing (gravity collapse?) Z-fold structures.



Stop 1.10. Potassic phase of a Long Range dyke



Figure 17. a) U–Pb geochronological data showing the distribution of pre-Labradorian, Labradorian and Pinwarian dated rocks and interpreted boundaries between them. b) U–Pb geochronological data showing division between a northern region only weakly affected by Grenvillian metamorphism and a strongly affected southern region (Gower et al., 2008a).





mafic, sill-like, bodies (Figure 16). These are interpreted as part of the No-Name - Kyfanan belt. They are exposed in rare road cuts. Unfortunately for the bedrock geologist, most of the outcrop is concealed by magnificent eskers.

STOP 1.9: Monzonite (Interpreted as Time Equivalent to the MMIS; 190 km East of Kenamu River. CG07-011 (434826 5872301)

At this stop (Plate 2c) is a creamy-pink, homogeneous, medium-grained, monzonite to quartz monzonite containing orthopyroxene, clinopyroxene, hornblende, K-feldspar, plagioclase, quartz and minor biotite. It is intruded by pegmatite. The unit is interpreted to be mid- to late-Labradorian and related regionally to the Mealy Mountains Intrusive Suite, but has not been dated at this locality.

Less than 4 km to the north, a similar rock was investigated geochronologically by Schärer and Gower (1988). It yielded a 1631 Ma monazite age and discordant zircons having Pb–Pb ages of 1735 and 1718 Ma. The 1631 Ma age was interpreted to be the time of crystallization and the older zircons to reflect inherited components, the source of which was unknown.

Since then, additional dating has demonstrated the existence of intact pre-Labradorian crust having an age range of 1810–1770 Ma (Figures 6 and 18), which may well be the source for the inherited zircon in this monzonite (Gower *et al.*, 2008a). Over the past two decades, U–Pb evidence has steadily accumulated that demonstrates the widespread existence of pre-Labradorian crust in the Mealy Mountains and Pinware terranes (Philippe *et al.*, 1993; Gower, 1996; Gower *et al.*, 1997b; Scott *et al.*, 1997; Wasteneys *et al.*, 1997; Gower and Krogh, 2002, 2003; Gower *et al.*, 2008a), for which Nd isotopic data provides support (Dickin, 2002).

En route to next stop: The remainder of the MMIS correlative intrusion crossed, then the Lake Melville terrane entered, which, in this region is underlain by orthogneiss, pelitic gneiss and K-feldspar megacrystic granitoid rocks. The object of the next stop is not to address Lake Melville terrane geology, but to see an unusual Long Range dyke.

STOP 1.10: Long Range Dyke Intruding K-feldspar Megacrystic Granitoid Rock; 200 km East of Kenamu River. CG07-031 (444431 5875589)

The east side of the outcrop exposes a pale-weathering, medium-grained, strongly recrystallized, K-feldspar megacrystic, biotite-bearing granitoid rock. The megacrysts are ovoid, 1-2 cm across, and have granulated, reduced margins. The west side of the outcrop is part of a Long Range dyke. This is regionally part of the westernmost Long Range dyke in southeast Labrador, which, 70 km to the north-northeast has been dated to be 615 ± 2 Ma. The K-feldspar megacrystic granitoid rock is also intruded by a 2-m wide diabase dyke, which is a satellite to the major Long Range dyke. The contact between the K-feldspar megacrystic granitoid rock and the Long Range dyke is a rubbly ocherous sulphide zone. Such zones are typical of the borders of the Long Range dykes, and may have economic significance. When the outcrop is followed in a westward direction, the rock grades into a coarse-grained, massive, pinkish weathering monzogabbroic to syenitic rock (Plate 2d). This has a width of at least 400 m (to the end of the exposed rock). Although it may not be immediately obvious that this rock is part of the Long Range dyke swarm, there are good reasons to accept it as such, namely: (i) it is unmetamorphosed, (ii) the outcrop is aligned with a major Long Range dyke, (iii) a similar rock type (Slabs 2) was found 30 km to the south along the same north-northeast trend (where it is also associated with unmetamorphosed satellite mafic dykes; Figure 19), (iv) alkalic rocks associated with the same dyke are known close to where this Long Range dyke crosses the Quebec North Shore coastline (Baie des Moutons complex; K-Ar age 570 Ma; Figure 14).

En route to next stop: By this time we are probably well behind schedule. Sorry that it has been a long day and we still have over 100 km to drive. We will be crossing the remainder of the Lake Melville terrane and the width of the Hawke River terrane, which will both be addressed tomorrow.



Figure 19. Location of Long Range syenite at Stop 1.10 (CG07-031). Compare stained slabs for CG07-031 and CG91-014 (cf. images of stained slabs – Appendix 2; Slabs 2). Slab CG91-014 was collected 30 km farther south along trend of the same dyke, where it is also associated with small mafic Long Range dykes.

DAY 2. Cartwright to Port Hope Simpson (Figure 20)



Figure 20. Day 2 excursion route and locations of described stops.

En route to first stop of the day: Much of the boundary between the Groswater Bay terrane, to the north, and the Hawke River terrane, to the south, is occupied by the Cartwright alkali-feldspar granite. Unfortunately, there is no easily accessible site at which to see either the Cartwright alkali-feldspar granite, or any feature that might be taken as the terrane boundary. All the outcrops before the first stop are mapped as part of the Earl Island quartz diorite – granodiorite suite. Note, in particular, the consistent south-dipping structural fabrics. These are interpreted as Labradorian and related to bivergent tectonism (Figure 21). This area was only mildly affected by Grenvillian deformation (Gower et al., 2008b).

STOP 2.1: Earl Island Quartz Diorite; 10 km South of Cartwright. CG04-157 (498034 5944231)

The rock here is a medium- to coarse-grained, fairly homogeneous diorite to quartz diorite. It is somewhat migmatitic, showing incipient partial melting to give white concordant and discordant veins. Also present are later pinkish pegmatitic patches containing large hornblende grains. Note that the south-dipping foliation, steep lineations, high-strain zones and kinematic indicators (*e.g.*, c-s fabrics, rotated porphyroclasts, asymmetric folds; Plate 3a) demonstrating top-to-the north-northeast (*cf.* Figure 22 for regional kinematic indicator information). The Earl Island quartz diorite has been dated to be 1668 +6/-4 Ma from Partridge Bay (Schärer and Gower, 1988) and 1660 +8/-7 Ma from Red Island (Schärer *et al.*, 1986). The rocks are cut by numerous late-stage hematized and silicified fractures, probably related to the Sandwich Bay graben.

En route to next stop: Time will not allow the next stop described to be visited, but information is included in case others use this guide another time at a more leisurely pace. The gabbronoritic rocks described are characteristic of both the Lake Melville and Hawke River terranes.

STOP 2.2: Dykes River Layered Mafic Intrusion; 6 km East of Highway on Branch Road. CG04-245 (503961 5941547)

The rocks include, (i) amphibolite to leucoamphibolite with ultramafic stringers, (ii) leucoamphibolite containing abundant enclaves of amphibolite, exhibiting a wide range of fine-, medium- and coarse-grained, non-porphyritic and porphyritic textures, (iii) metamorphosed ultramafites, probably derived from dunite and pyroxenite, and (iv) olivine gabbro coronite (Plate 3b; Slabs 3). The rocks are rusty-weathering in places and also contain lenses



Figure 21. Interpretation of Labradorian tectonics in terms of geodynamic modelling based on an offshore seismic reflection profile and onshore gravity, magnetic and geological data (Gower et al., 1997b). Line of section shown in Figure 21a.


Stop 2.1. Strongly deformed Earl Island diorite/granodiorite, showing rotated K-feldspar megacryst (top to right/north)



Surrogate for Stop 2.3. Paradise pelitic metasedimentary gneiss yielding 1654 +29/-28 Ma metamorphic age at site CG84-475



Stop 2.2. Dykes River mafic intrusion showing coronitic textures



Stop 2.5. Paradise Arm megacrystic granitoid rock

Plate 3. Outcrop photographs for localities 2.1, 2.2, 2.3 (surrogate) and 2.5.





of metallic oxide, up to 30 cm wide and several metres long. On the basis of anomalous chemistry, four sites have been designated as Cr occurrences. A site about 10 km southeast of this locality in similar mafic rocks has high V (Gower, 2010c). The rocks have not been dated here but are correlated with Labradorian mafic intrusions elsewhere, which have a 1650–1640 Ma age range.

En route to next stop: The remainder of the Earl Island intrusive suite is crossed and then the attenuated northwest end of the Paradise metasedimentary gneiss belt is entered.

STOP 2.3: Paradise River Metasedimentary Gneiss; 3 km from Highway on Branch Road to Community of Paradise River. CG04-285 (482104 5920404)

Where it is crossed by the highway, the Paradise metasedimentary gneiss belt is only about 2.5 km wide, in contrast to its southeast end where it is over 40 km in width. Kyanite is found sporadically at the northwest end of the belt and cordierite is typical at the southeast end. At this locality, the rock is typical pelitic gneiss. It is mottled pink, creamy and black; medium to coarse-grained, well-banded, contains some mafic enclaves and is intruded by deformed pegmatitic dykes. The prevailing mineral assemblage is garnet–sillimanite– biotite–feldspar-quartz–opaque minerals. The time of deposition of the protolith rocks in the Paradise metasedimentary belt remains uncertain, but regional data suggest 1810–1770 Ma. Pelitic gneiss from Saddle Island (Plate 3c) yielded an age of 1654 +29/-28 (Schärer and Gower, 1988), which was interpreted to be metamorphic. An age range of 1647–1627 Ma obtained from another locality (Gower *et al.*, 1992) was initially argued as potentially detrital, but this possibility was rejected by Kamo *et al.* (1996), on the basis of a 1638 +11/-3 Ma age from discordant microgranite and pegmatite at the same locality.

En route to next stop: Boundary between Paradise metasedimentary gneiss belt and Paradise Arm pluton crossed.

STOP 2.4: Long Range Dyke Intruding K-feldspar Megacrystic Granitoid Rock; 4 km from Highway on Branch Road to Community of Paradise River. CG04-288 (481171 5921015)

K-feldspar megacrystic granitoid rock is intruded by a *ca*. 70-m-wide Long Range dyke. The K-feldspar megacrystic granitoid rock is part of the Paradise Arm pluton, near its northern boundary. The megacrysts are bright pink in a white-weathering, recrystallized finegrained matrix. The Long Range dyke is coarse grained, ophitic textured and shows wide chilled margins.

En route to next stop: After returning to Highway 516, then travelling south 2 km, boundary between Paradise metasedimentary gneiss belt and Paradise Arm pluton is crossed again.

STOP 2.5: Paradise Arm Pluton; 4.5 km South of Turnoff to Paradise River. CG04-193 (481142 5916806)

The K-feldspar megacrystic biotite granodiorite (Plate 3d) seen at this locality is part of the Paradise Arm pluton. The rock is homogeneous and non-migmatitic, but shows considerable strain variation, some parts being mylonitic. No garnet, mafic enclaves or pegmatites are present, although rare quartz veins occur. Amphibolite occurs as fine-grained, lenticular boudins that probably represent former mafic dykes. The Paradise Arm pluton has been dated to be 1639 ± 2 Ma, interpreted to be the time of emplacement, and has also yielded monazite ages of 1631 ± 2 Ma, 1621 ± 1 Ma and 1613 ± 2 Ma (Kamo *et al.*, 1996).

En route to next stop: Continue through the rest of the Paradise Arm pluton then enter the White Bear Arm complex.

STOP 2.6: Syn-kinematic Pegmatites, Emplaced During Northeast-side-down Brittle– Ductile Grenvillian Faulting; 16 km South of Turn Off to Paradise River. CG04-209 (470403 5912175)

The host rock at this locality is a dark grey- to black-weathering, fine-grained, recrystallized mafic rock that is a metamorphic derivative of gabbronoritic rocks belonging to the White Bear Arm complex. This is the only locality on the excursion where the WBAC will be seen. This is the western fringe of the WBAC, where it is structurally mylonitized and imbricated. It is not typical of the near pristine gabbronorite that forms much of the body. In this region, the mylonites show a top-to-the-west sense of movement, which is interpreted to be Labradorian.

A key feature of interest here are the numerous pegmatites and microgranites. Note that they were emplaced along faults that consistently show a north-east-side-down sense of movement (Plate 4a). The pegmatites are interpreted to have been emplaced during faulting, probably at the moment when the host rock failed, unable to deform further in a ductile



Stop 2.6. Grenvillian pegmatite intruded during faulting. In this region, the sense of movement is consistently northeast-side-down



Stop 2.8. K-feldspar megacrystic granitoid rock showing transposition into high-strain zone



Stop 2.7. Alexis River anorthosite, showing reaction coronas between olivine (rusty-brown cores) and plagioclase (white)



Stop 2.9. Kinematic indicators in mylonitic granitic gneiss showing northeast-side-up sense of movement

Plate 4. Outcrop photographs for localities 2.6, 2.7, 2.8 and 2.9.

manner. The same pattern is repeated at other outcrops in the vicinity (Figure 23). The east-side-down pegmatites resolve the conundrum why deeper-level rocks are not present on the east side, given the top-to-the-west ductile kinematic indicators.

Keeping in mind an age of 1029 ± 2 Ma (Schärer *et al.*, 1986) for a dated microgranite 8 km south of this locality (Figure 23), these minor granitoid intrusions are interpreted to be Grenvillian and to document regional down throw to the northeast, thus explaining why the Hawke River terrane only carries a mild Grenvillian overprint (Figure 24).



Figure 23. Location of pegmatites at Lake Melville–Hawke River terrane boundary showing east-side-down sense of movement in the host rocks (Gower, 2005).



Figure 24. Very idealized sketch illustrating channel flow at an overthrusting syntaxis and embodying an explanation for why pegmatite-filled detachment faults occur where they do - in terms of a tectonic 'spillover' region (cf. Figure 4) in an over-thrusting indenting con-figuration (Gower, 2005).

En route to next stop: Many of the road cuts for the next 7-8 km show the same relationships as those just seen, namely imbricated White Bear Arm complex and east-side-down, pegmatite-filled faults. The ill-defined boundary between the Hawke River and Lake Melville terranes is crossed. As is characteristic for much of the Lake Melville terrane, the region is underlain by interleaved granitoid and pelitic gneisses.

STOP 2.7: Alexis River Anorthosite; 1 km North of Cartwright Junction. CG04-237 (465585 5881178)

The name 'Alexis River anorthosite' was introduced by Gower *et al.* (1987) for a body of anorthosite–leucogabbronorite and associated metamorphic derivatives that extend for at least 160 km along strike within the Lake Melville terrane. It rarely exceeds 10 km in width and is commonly less than 5 km wide. The extremely elongate shape of the body is interpreted to be partly a consequence of deformation related to a Grenvillian, dextral-strike-slip, lateral ramp tectonic setting (Gower *et al.*, 2008b), although earlier Labradorian and Pinwarian deformation may have played a role in the origin of the structure. Here, much of the rock is truly anorthositic, but elsewhere it is commonly leucogabbronorite or leucotroctolitic (Plate 4b). The body also includes gabbronorite, amphibolite, and diorite/quartz diorite gneiss (the latter interpreted to be *ca.* 1650–1640 Ma, similar to that of other Labradorian trimodal (AMCG) suites. The distinctive rocks and their continuity proved an invaluable marker rock type during regional mapping.

At this locality, the rock is much closer to its igneous appearance than its correlative at Port Hope Simpson (which will also be seen, time permitting). Nevertheless, it is still extensively recrystallized. Deformation at this locality is relatively weak and the shapes of primary mafic crystals, and to a lesser extent, plagioclase can be clearly seen. The primary mafic minerals were orthopyroxene and clinopyroxene. Both are fringed by amphibole. The cores of most mafic grains are altered to phyllosilicates.

The anorthosite here is intruded by an amphibolitized mafic dyke, which can be traced across the floor of the quarry by the distribution of rubble. The amphibolitized dyke is migmatized and shows more strain than its host rock. Later pegmatites are also present. The cause of a distinct mauve colour adjacent to some fractures is not known (traces of hematite?). *En route to next stop: Travelling along strike within Lake Melville terrane.*

STOP 2.8: K-feldspar Megacrystic Granitoid Rock, Pelitic Gneiss and Long Range Dykes; 25 km Southeast of Cartwright Junction. CG03-354 (484471 5865203)

This locality is a microcosm of the Lake Melville terrane. Most of the quarry is made up of two rock types, (i) garnet–sillimanite–biotite pelitic gneiss, in which garnet, up to 3 cm across, is very abundant, and (ii) a garnet-bearing, K-feldspar megacrystic biotite granitoid rock containing ovoid megacrysts. Rare remnants of amphibolitized mafic dykes are present, as are, also rare, discordant pegmatitic dykes.

A sample from a body of K-feldspar megacrystic granitoid rock in the northern Lake Melville terrane has yielded an age of 1678 ± 6 Ma (Schärer *et al.*, 1986). Another one from the southeast Lake Melville terrane has an age of 1644 + 8/-6 Ma (Scott *et al.*, 1993). Typically, the K-feldspar megacrysts measure roughly 2 by 2 cm, but can be much larger (4 by 6 cm is not uncommon). The dominant mafic mineral is biotite, but some relict hornblende is present.

At this locality the rocks have been very strongly deformed (Plate 4c). Most of the rocks have been too severely deformed to have preserved kinematic structures, and the texture is best termed porphyroclastic. This site is an excellent locality at which to appreciate how variation in strain can change the appearance of a rock.

These rocks are discordantly intruded by unmetamorphosed mafic dykes belonging to the Long Range swarm. Four have been noted by the author, but there may be others. One, 0.5 m-wide, is on the northwest side of the quarry and three closely spaced dykes (1.0, 0.5 and 0.3 m) are exposed on the north wall. The northwest-face dyke shows classic bayonet and bridge structure. The mafic dykes contain plagioclase phenocrysts up to about 2 cm long. Quenched plagioclase in the groundmass can be seen with a hand lens. The dykes are also amygdaloidal and have marked chilled margins. These dykes are on line with some much larger dykes to the north having a similar trend. They contain minor sulphide. Shallow drill holes in one of the dykes and the adjacent country rock indicate sampling for paleomagnetic studies.

Some sulphide-rich pegmatites are present and also some magnetite-sulphide-bearing pegmatites characterized by greenish plagioclase.

En route to next stop: Travelling along strike within Lake Melville terrane.

STOP 2.9: Kinematic Indicators in Mylonitic Granitic Gneiss; 56 km Southeast of Cartwright Junction. CG03-371 (508214 5846432)

At this locality, fine-grained, finely laminated mylonitic granitic gneiss is interlayered with amphibolite. The amphibolite occurs as concordant layers and larger boudinaged masses. Some irregular pink to brick-red pegmatite containing hornblende, magnetite and sulphides is also present. Staining indicates three feldspar types (K-rich, Na-rich and Na-Ca plagioclase; Slabs 4). Asymmetric structures indicate a top-to-the-south sense of movement (Plate 4d). This is interpreted to be Labradorian. The sub horizontal lineation is interpreted to be Grenvillian.

En route to next stop: Travelling along strike within Lake Melville terrane, until turn-off onto Highway 514 to Charlottetown (Labrador).

STOP 2.10: Complex Intrusive Relationships in Labradorian Granitoid Rocks; 1 km on Road Northeast Toward Charlottetown. CG04-054 (535813 5834342)

This outcrop is deemed representative of early Labradorian activity. The granitoid host rocks include a grey-weathering, strongly foliated, medium-grained, biotite, K-feldspar megacrystic granodiorite containing abundant garnet in the groundmass. The megacrysts (augen) are lenticular, recrystallized and average about 2 by 1 cm. Within the granodiorite are abundant boudinaged amphibolite lenses and layers, representing former mafic dykes. Associated with the megacrystic granodiorite are fine-grained granodiorite/psammitic gneiss and pelitic gneiss (at the north end of the outcrop). In both the megacrystic granodiorite and fine-grained granodiorite/psammite two phases of mafic dyke injection can be seen. The early dykes are strongly deformed, slightly migmatized and clearly discordant. The later dykes are, in turn, intruded by irregular pegmatites (Plate 5a).

Elsewhere in eastern Labrador, outcrops such as this, showing excellent field relationships (including two phases of mafic dyke injection), have been targeted for detailed geochronological investigation. The host rocks have been found to have a pre-1665 Ma age of emplacement and the migmatization to pre-date 1655 Ma. Pegmatites crosscutting metamorphosed but unmigmatized dykes have also yielded Labradorian ages, but it is not known if such is the case at this site.



Stop 2.10. Complex intrusive relationships in Labradorian intrusive rocks



Plate 5. Outcrop photographs for localities 2.10, 2.11, 2.12 and 2.13. Stop 2.12. Slightly metamorphosed mafic dyke, presently assigned to Gilbert Bay dykes

Stop 2.13. Gilbert pebbly arkose



Stop 2.11. Unmetamorphosed mafic dyke, previously assigned to Gilbert Bay dykes



En route to next stop: Travelling across strike within Lake Melville terrane.

STOP 2.11: Unmetamorphosed Dykes; 2 km Northeast of Gilbert River. CG04-029 (546939 5841084)

The key point of interest at this stop is an unmetamorphosed mafic dyke (Plate 5b). It intrudes somewhat irregularly banded, mylonitic, sillimanite-bearing pelitic gneiss, with which black, homogeneous amphibolite invaded by granitoid veins is associated. The mafic dyke was assigned to the Gilbert Bay dyke suite on the 1:100 000-scale map of Gower (2010a), as were two other dykes seen at nearby road side localities to the northeast, but this interpretation is probably incorrect.

The Gilbert Bay dykes belong to an early post-tectonic Grenvillian magmatic event along with (farther south) the L'Anse-au-Diable dykes, and (possibly) the York Point dykes (Figure 25). At least two of the Gilbert Bay dykes were first mapped by Wardle (1976, 1977), but most were located during mapping by Gower et al. (1987). Five more were discovered in 2004 following construction of Highway 510. The term 'Gilbert Bay dykes' entered the literature via Wasteneys et al. (1997), who obtained a U–Pb zircon age of 974 ± 6 Ma for one dyke. A U–Pb titanite age of 955 ± 20 Ma was obtained from the same sample. The Gilbert Bay dykes are confined to a 6-km-wide corridor extending for at least 80 km inland from the coast in a 285° direction. This trend is similar, but not identical, to that of the Gilbert River fault (295°), and the older structural fabric in the region. Despite being restricted to a well-defined corridor, individual dykes have variable trends, but are mostly southeasterly with southwest dips. Their widths are equally variable, ranging from a few centimetres up to 20-25 m. Some are parallel-sided intrusions, whereas others show irregular, anastamosing form, enclosing blocks of country rock. The dykes are brown or grey weathering, and exhibit obvious chilled margins against their host rocks. Grain size ranges from extremely fine to medium. Generally, the dykes are aphyric, but, rarely, contain plagioclase phenocrysts up to 2 cm long, although mostly between 3 and 4 mm. It is clear that the dykes were emplaced at a shallow level in a brittle environment, for which brecciation and slickensided surfaces in the adjacent, intruded country rock provides further evidence. The mineral assemblage in the Gilbert Bay dykes comprises plagioclase, amphibole (cf. actinolite), biotite, opaque minerals, apatite, zircon, and late-stage/secondary titanite, epidote and chlorite. None of the samples contains olivine or pyroxene (in contrast to the Long Range and Sandwich Bay dykes). Opaque minerals occur as subhedral to euhedral, single or clustered grains and also as acicular, quenched form showing herringbone dendritic habit.



Figure 25. Locations of Gilbert, York Point and L'Anse-au-Diable mafic dykes and relevant *U*–Pb geochronological data.

Sulphide and oxide are both present. Apatite is an abundant accessory mineral, commonly exhibiting skeletal, hollow capillary form. Several of the dykes are amygdaloidal, having ovoid amygdales up to about 2 mm in diameter and containing quartz, carbonate and a sulphide opaque mineral (*cf.* pyrite).

En route to next stop: Very close to previous stop.

STOP 2.12: Gilbert River Dyke?; 200 m North of Gilbert River Bridge. CG11-004 (545620 5840250)

Gilbert Bay dyke? intruded by pegmatite veinlets. The dyke is 30 cm wide, fine grained and dips steeply north (Plate 5c). The pegmatite veinlets are 2-3 cm wide and planar. Kinematic indicators in country rock imply north-side-up sense of movement. As this dyke is intruded by pegmatite it is inferred to pre-date final Grenvillian magmatism.

En route to next stop: Time will not allow the next stop described to be visited, as the site requires a 1 km hike from the road.

STOP 2.13: Gilbert River Pebbly Arkose (Clastic Dyke); 1 km Upstream of Gilbert River Bridge. CG86-490 (544607 5840455)

The Gilbert conglomerate was first identified by Piloski (1955) and has been described subsequently by Eade (1962), Bradley (1966) and Gower *et al.* (1987). Only one outcrop is known (Plate 5d). It is maroon-weathering, homogeneous arkosic sandstone to pebbly grit situated on the north shore of Gilbert River about 1 km west of Gilbert Lake. The pebbles and grains are rounded to subangular, generally less than 0.3 cm in diameter and comprise mostly quartz and minor feldspar. Bradley (1966) also noted the presence of granitic gneiss fragments. The arkose and conglomerate are confined to a 5-m-wide, parallel-sided, vertical zone that is parallel to the Gilbert River fault. The country rock is a mylonitized K-feldsparmegacrystic granitoid unit, but has been described previously as paragneiss (Piloski, 1955) and flow-banded rhyolite (Bradley, 1966). The most detailed examination of the outcrop remains that of Bradley (1966). He interpreted the 'conglomerate' as a clastic dike bounded on its south side by a minor fault.

The age of the Gilbert pebbly arkose is unknown, beyond that it must postdate Grenvillian orogenesis. It has traditionally been considered to be correlative with the Double Mer Formation in the Lake Melville Rift System and/or the Bateau Formation in southeasternmost Labrador. Both of these are considered Late Precambrian, related to rifting prior to the opening of Iapetus Ocean. An alternative possibility is that the Gilbert conglomerate formed at the same time as the Gilbert Bay alkalic mafic dykes. It is spatially associated with these dykes, and also with the Gilbert River fault, which was clearly active during the waning stages of Grenvillian orogenesis. Given that the Gilbert Bay dykes were emplaced at a very shallow level, it is not inconceivable that sand could have been transported from the surface down the same system of fissures as those occupied by the Gilbert Bay dykes. It would be exciting to find a site where the two met.

A thin section of the Gilbert arkose comprises rounded to subangular quartz grains, rounded grains of microcline, sparse subrounded plagioclase, opaque material (mostly as hematite cement, but also some larger clastic magnetite grains), and a few small, ragged flakes of biotite within composite quartz-feldspar clasts. The texture is that of a clast-supported arenaceous sediment. The only sign of any superimposed deformation takes the form of narrow crush zones transecting the sample.

En route to next stop: Return to Highway 510 and continue southeast along the highway, which obliquely crosses strike in the Lake Melville terrane.

STOP 2.14: Sillimanite–Garnet Pelitic Gneiss; 11.5 km West of Port Hope Simpson. CG03-238 (539944 5829246)

One of the more distinctive rock types in eastern Labrador is pelitic gneiss containing garnet, sillimanite and biotite. Some layers at this locality are particularly garnetiferous (greater than 80% garnet). Garnet in pelitic gneiss has a characteristic lilac, mauve or rose colour (Plate 6a). The pelitic gneiss is probably one of the oldest rock types in eastern Labrador. The best estimate for its age is 1810–1770 Ma.

STOP 2.15: K-feldspar Megacrystic Granitoid Rock with Rotated K-feldspar Megacrysts; 1 km from Highway Turnoff 11 km West of Port Hope Simpson. CG04-142 (538232 5829204)

The object of this stop is to observe superb rotational features in K-feldspar megacrystic granitoid rocks. The sense of movement is dextral strike-slip (Plate 6b). At least two types



Stop 2.14. Extremely garnetiferous part of garnet-sillimanite-biotite pelitic gneiss



Plate 6. Outcrop photographs for localities 2.14, 2.15 and 2.16.

Stop 2.16. Alexis River metamorphosed leucogabbronorite



Stop 2.15. Rotated K-feldspar megacrysts



of kinematic indicator can be seen here, (i) step-up structures, and (ii) rotated megacrysts. The deformation is interpreted to be Grenvillian.

En route to next stop: Return to Highway 510 and continue southeast parallel to strike in the Lake Melville terrane.

STOP 2.16: Alexis River anorthosite; quarry 1 km north of Alexis River. CG03-224 (547414 5823482)

At this locality, the rock is very heterogeneous, recrystallized and deformed (Plate 6c). Almost all pyroxene has been altered to clusters of hornblende. The rock is intruded by K-feldspar-rich pegmatites hosting abundant allanite and, commonly, also epidote rich (Plate 6d). Late stage faulting and brecciation is also evident. Cavities in the breccia host some zeolite-family minerals (stilbite, scolecite, chabazite) plus illite, albite and prehnite (Gower, 2010c).

En route to next stop: Cross Alexis River causeway and head to accommodation.

DAY 3. Port Hope Simpson to Mary's Harbour (Figure 26)





En route to first stop of day: Road obliquely crosses strike in the southern Lake Melville terrane, exposing various mafic and dioritic gneisses in road cuts. These are interpreted as metamorphic derivatives of gabbronoritic and leucogabbronoritic phases of the Alexis River intrusion.

STOP 3.1: Garnetiferous Granitoid and Amphibolitic Gneiss; 10 km Southeast of Port Hope Simpson. CG03-208 (553818 5816841)

The south end of the outcrop is characterized by granite gneiss. Progressing north there is an increase in amphibolite with associated white concordant veins. This is followed by syenite/monzonite gneiss containing abundant garnet (retrograded in part; Slabs 6). Much of the amphibolite also contains abundant garnet (Plate 7a) and also shows irregular melt patches, some containing pale green K-feldspar. The amphibolite is associated with pink and grey granodioritic gneiss. The abundance of garnet distinguishes this outcrop from those situated farther south. It is interpreted here to mean that a deeper crustal level is exposed, consistent with the north-side-up sense of movement (Labradorian) seen in kinematic indicators between here and the St. Lewis River.

A major fault is interpreted to pass about 800 m south of this locality to explain the abrupt change in dominant lineation orientation – mainly horizontal here versus characteristically steep south of the fault. The steep lineations are interpreted to be Labradorian and the near horizontal lineations here (Plate 7b) to be Grenvillian.

En route to next stop: Continuing obliquely across strike in the Lake Melville terrane, but moving tectonically from a zone of predominant Grenvillian deformation to predominantly Labradorian deformation.

STOP 3.2: Amphibolitic gneiss with pegmatite; 13 km southeast of Port Hope Simpson. CG03-204 (554578 5814696)

Amphibolitic, leucoamphibolitic and quartz dioritic gneiss with common concordant pegmatite stringers are present. Amphibolite is partially melted resulting in development of irregular white pegmatitic patches containing hornblende. Although strongly deformed, the rock is not as intensely mylonitized as will be seen at the outcrops on the north side of the St. Lewis Inlet causeway (next stop). A noteworthy pegmatite contains biotite and K-feldspar crystals both up to 1 metre across. Interesting minerals at this site are graphite, ti-tanite, specular hematite and small uncommon grains of chatoyant feldspar.



Stop 3.1. Very garnetiferous amphibolite



Stop 3.3. Mylonitic (straight) gneiss



Stop 3.1. Near-horizontal lineations, interpreted to be Grenvillian



Stop 3.3. Steeply lineated mylonite intruded by pegmatite at the boundary between the Pinware/Mealy Mountains and Lake Melville terranes

Plate 7. Outcrop photographs for localities 3.1 and 3.3.

En route to next stop: Continuing obliquely across strike in the Lake Melville terrane, where it is underlain mostly by granitoid rocks, all very strongly deformed.

STOP 3.3: Mylonite Marking Boundary Between Lake Melville and Pinware Terranes; North Side of St. Lewis Inlet Causeway. CG03-181 (561224 5806540)

Superbly displayed at this locality and at least 2 km shallowly obliquely across strike to the west along the road are ultramylonitic rocks (straight gneisses; Plate 7c). Fabric is defined by leucosome layers, biotitic veneers, narrow amphibolitic partings, and compositional heterogeneities. Locally, the mylonitic fabric is folded. For the most part these rocks are too severely deformed to retain obvious kinematic indicators, but those present indicate a north-side-up sense of movement. The lineations are interpreted to be Labradorian. Compositionally, the rocks include granite, granodiorite, amphibolite and diorite. Pegmatites occur as porphyroclastic remnants and as later, discordant intrusions, up to several metres wide (Plate 7d).

En route to next stop; Back track to turnoff to St. Lewis; follow road along strike in the Lake Melville terrane to next stop. Dominant rock types are K-feldspar megacrystic granitoid rocks and some mafic lithologies. All strongly deformed.

STOP 3.4: 'Road Belt'; 8.5 km West of St Lewis. CG03-288 (582004 5805888)

Rock types in Fox Harbour area include metamorphosed felsic and mafic supracrustal sequences (of which the Road Belt is one; name used by Search Minerals Inc.), variably mylonitized megacrystic granitic augen gneiss, and a plagioclase–amphibole \pm garnet unit (derived from a gabbroic protolith). The felsic volcanic and metasedimentary rocks (Plate 8a) are mineralized, whereas the mafic volcanic rocks largely lack mineralization. The felsic volcanic rocks are devoid of primary structures, and are highly folded and mylonitized, thus making protolith identification difficult. Apart from REE mineralization, narrow pyritic zones are also present and purple fluorite is present on joint surfaces. Epidote and chalcopyrite can be seen on the south side of the road.

The drill program at the nearby Foxtrot Prospect intersected LREE–Zr–Y–Nb mineralization at depths of 50 and 100 m along a 2 km strike length. Mineralization consists of fergusonite, allanite and zircon in rocks interpreted to be metamorphosed fine grained felsic volcanic rocks. Weighted averages from the best interval (DDH FH-10-08: 90.3 m) give



Stop 3.4. Road Belt gneiss of supracrustal origin with green amazonite leucosome



Stop 3.6. Detail of mineralization on HighREE Island. Pale yellow-green Stop 3.7. Dioritic roch material is fergusonite.

Plate 8. Outcrop photographs for localities 3.4, 3.5, 3.6 and 3.7.



Stop 3.5. Isoclinally folded mylonitized rocks at Lake Melville - Pinware terrane boundary



Stop 3.7. Dioritic rocks at northern fringe of Pinware terrane

values of 245 ppm Dy, 1,311 ppm Y, 11,233 ppm Zr, 684 ppm Nb and 0.90% TREE (not including Y) or 1.04% TREE +Y over 5.3 m (true width). Other, wider, mineralized intersections range from 8.03–11.57 m length (true width).

En route to next stop; Continue along highway to St. Lewis Inlet; Follow road around the harbour to its end about 1 km south of the community centre.

STOP 3.5: Mylonite Marking Lake Melville–Pinware Terrane Boundary; 1 km South of St Lewis. VN87-459 (589400 5801289)

A major mylonite zone well-exposed on the shoreline south of St. Lewis marks the boundary between the Lake Melville terrane and the Pinware terrane and is interpreted as correlative with that seen on the north side of the St. Lewis River causeway. The zone consists of steeply north-dipping, fine-grained, finely laminated, isoclinally folded mylonite and ultramylonite (Plate 8b) grading into rocks recognizably derived from monzonite, K-feldspar-megacrystic granodiorite, granite, quartz diorite and amphibolite. Lineations consistently plunge north to northwest at $40-65^{\circ}$ (Figure 27), and indicate north-side-up sense of movement. Small asymmetrical extensions shear giving a dextral sense of displacement are also present (Hanmer and Scott, 1990).

En route to next stop; Back track to main highway, cross first part of St. Lewis Inlet causeway.

STOP 3.6: Dioritic, Granodioritic and Granitic Gneiss with REE Mineralization on HighRee Island. CG03-180 (561450 5806632)

The host rocks on HighREE Island mainly consist of strongly recrystallized foliated granitic rocks. These contain remnants of amphibolite-grade mafic dykes. There is also a wide range of pegmatite and aplite intrusions, of differing compositions and of varying ages, which pre- and post-date mineralization.

This prospect contains significant REE mineralization which is heavy-REE enriched. The mineralization is predominantly found in quartz-magnetite bearing pegmatitic veins (Plate 8c). Fergusonite ((Y,Er,Ce)(Na,Ta)O₄) and allanite are the dominant REE-bearing minerals, and abundant zircon and apatite are also present. Amazonite (Pb-bearing potassium feldspar), fluorite, molybdenite as well as other disseminated sulphides such as pyrite and chalcopyrite can also be found on the island.





The first phase drill program at the HighREE Island Prospect consisted of 13 holes, drilled in late 2010 (*see* Search Minerals Inc. news release, Oct. 5, 2010), that were positioned to trace outcropping HREE–Zr–Y–Nb veins to depths down to 170 m. Weighted averages from the best interval (DDH HI-10-04: 16.37–16.67 m) give values of 334 ppm Dy, 2,510 ppm Y, 22,380 ppm Zr, 3850 ppm Nb and 0.74% TREE (total rare earth elements; not including Y) or 1.00% TREE + Y over 0.3 m (true width) (Search Minerals Inc. press release, June 13, 2011; http://www.searchminerals.ca/newsreleases/NR06-13-11.pdf)³.

En route to next stop; Cross second part of St. Lewis Inlet causeway, at the same time passing from the Lake Melville terrane to the Pinware terrane. The Mealy Mountains terrane, if present, is an attenuated sliver inbetween.

STOP 3.7: Dioritic, Quartz Dioritic and K-feldspar Megacrystic Rocks at Northern Fringe of Pinware Terrane. CG03-176 (560536 5804525)

The dominant rock type in this outcrop is pale grey to white, homogeneous, weakly foliated, coarse-grained leucodiorite to diorite, containing biotite and hornblende as mafic minerals and trace accessory sulphide (Plate 8d). The rock is intruded by minor pegmatite. Farther north, there is a gradation into a K-feldspar-augen-bearing variant. Some amphibolite and pegmatite are present. The rocks are strongly foliated and a few high-strain zones can be seen, but the pervasive, very severe, mylonitization seen north of St. Lewis Inlet is lacking. The K-feldspar augen rock is only about 50 m wide, then it grades back into diorite and quartz diorite, which continue to the end of the outcrop.

En route to next stop; Continue across and along strike in the northern part of the Pinware terrane mostly underlain by granitic gneiss.

STOP 3.8: Pinwarian Terrane Granitoid and Gneissic rocks. CG03-155 (567428 5797079)

Fine-grained, grey weathering, psammitic and calc-silicate supracrustal gneisses can be seen at the east end of the outcrop. These are intruded by grey, seriate-textures granite to granodiorite that is fairly homogeneous, although locally having streaky gneissic textures. The granite granodiorite grades into a mylonitic gneiss showing kinematic indicators (shear bands and rotated porphyroclasts) implying N-side-up sense of transportation. Following a zone of relatively high-level brittle faulting is pink homogeneous, coarse-grained biotite

³cf. Search Minerals press release April 27, 2012 for most recent update.

granite lacking amphibolitic material, which, in turn, is succeeded by a grey granite-granodiorite, then a creamy pink, medium to coarse grained, homogeneous biotite granite. These rocks are typical of those found throughout the Pinware terrane, and are either Labradorian or Pinwarian in age.

En route to next stop; continuing across and along strike in the northern part of the Pinware terrane, and more granitic gneiss to Mary's Harbour. Those using this guide independently could set aside an extra day for a trip to Battle Harbour taking the ferry (summer only) from Mary's Harbour. A guide to the geology of Battle Harbour is given in Appendix 1. DAY 4. Mary's Harbour to L'Anse-au-Clair (Figure 28)



Figure 28. Day 4 excursion route and locations of described stops.

En route to first stop of day: Travelling across strike in northern part of Pinware terrane. Road cuts exposes dioritic to granitic gneisses, associated with minor remnants of supracrustal rocks.

STOP 4.1: Supracrustal and Other Gneissic Rocks; 17 km South of Mary's Harbour. CG03-113 (570310 5784110)

Light- and dark-grey, well-banded gneisses with some greenish calc-silicate layers at this locality are interpreted to have been derived from a metasedimentary protolith (psammite and calcareous psammite), although there are few diagnostic features to demonstrate this convincingly. Amphibolite is intercalated in places. The mineral assemblage comprises plagioclase, quartz, K-feldspar, hornblende and biotite. Garnet occurs sporadically in the leucosome. Magnetite crystals, surrounded by leucocratic haloes, occur in places. The gneisses are intruded by a grey granodioritic rock which postdates some of the pegmatite (Plate 9a). The pink-and-white pegmatites contain abundant magnetite, and some contain clinopyroxene. Fault breccia is also present.

The rocks at this locality and a few other sites in the vicinity are interpreted as a northward extension of the Pitts Harbour Group to be seen farther south.

En route to next stop: Travelling across strike in northern part of Pinware terrane. Road traverses granitic gneisses and minor remnants of supracrustal rocks, then enters the late-to post-Grenvillian Chateau Pond granite.

STOP 4.2: Chateau Pond Granite; 43 km South of Mary's Harbour. CG03-073 (554046 5766696)

The Chateau Pond granite is an example of numerous late- to post-tectonic granitoid plutons emplaced between 970 and 950 Ma and found throughout the southern half of the EGP. The Chateau Pond granite is circular to elliptical in outline and its emplacement has imparted, and reoriented, foliations in the surrounding rocks into parallelism with the margin of the pluton. The northwest half of the pluton has been sinistrally displaced 1.5 km along a northeast-trending fault. The intrusion is mostly granite, but is gradational into quartz monzonite in places. A sample from the pluton was determined to have an age of 964 ± 5 Ma (Gower *et al.*, 1991). The pluton contains large rafts of foliated biotite granite and remnants of quartzofeldspathic supracrustal rocks, which are inferred to be xenoliths of the sur-



Stop 4.1. Psammitic and calcareous psammitic gneiss intruded by grey granodiorite



Stop 4.2. Chateau Pond granite with hematite alteration close to fracture



Stop 4.4. Coarse-grained, light pinkish brown nepheline in nepheline syenite Plate 9. Outcrop photographs for localities 4.1, 4.2, 4.3, and 4.4. Stop 4.3. Pelitic gneiss of Pitts Harbour Group showing minor sulphide mineralization

rounding or underlying rocks. Rare mafic to dioritic enclaves are present in places. The pluton is not intruded by mafic dykes, and minor granite intrusions are sparse. The granite is pink to white weathering, coarse to very coarse grained, massive and homogeneous (Plate 9b). The essential minerals are plagioclase, quartz, and K-feldspar. Biotite is the dominant mafic mineral, but relict blue-green hornblende is present in most samples. Accessory minerals include titanite, allanite, apatite, ilmenite, pyrite and zircon. Chlorite, epidote, rutile and white mica are minor secondary minerals after biotite and/or hornblende. Minor fluorite was found in one pluton.

En route to next stop: Road crosses the remainder of Chateau Pond granite, then back into granitoid gneiss and supracrustal remnants in the Pinware terrane.

STOP 4.3: Pitts Harbour Group; 6 km South of Outside Big Pond. CG03-052 (545408 5755385)

The Pitts Harbour Group is the name given by Gower et al. (1988) for a package of supracrustal rocks found in the Pinware terrane, mostly between Red Bay and Henley Harbour. Considerable uncertainty remains as to which rocks should be included in the group. The supracrustal rocks mostly comprise quartzofeldspathic rocks thought to have a felsic volcanic/volcanoclastic and/or quartzofeldspathic clastic metasedimentary protolith. Other rock types include quartzite, quartz-rich meta-arkose, sillimanite- and muscovite-bearing pelitic rocks (Plate 9c), calc-silicate rocks and banded amphibolite (interpreted to have been derived from a mafic volcanic protolith). The high proportion of rocks potentially having a felsic volcanoclastic origin together with the concomitant dearth of pelitic gneiss, are two criteria that distinguish these rocks from the Paradise metasedimentary gneiss belt and correlative rocks farther north. In addition, two U–Pb zircon ages of 1640 ± 7 Ma and $1637 \pm$ 8 Ma, obtained from rocks interpreted to have been derived from a felsic volcanoclastic protolith (Tucker and Gower, 1994; Wasteneys et al., 1997), provide strong evidence that these rocks are much younger than the 1810–1770 Ma best-age estimate for the Paradise metasedimentary gneiss belt and similar pelitic gneisses. The Pitts Harbour Group in the Henley Harbour district has a lower metamorphic grade than other parts of the Pinware terrane, which Gower (2007) explained to result from preservation in a down-faulted basin formed during the early stages of Iapetus-Ocean-related rifting (Figure 29).

The Pitts Harbour Group has received special attention from explorationists because of its spatial association with Cu–U–Mo–Ag–Au–As anomalies in lake sediments (Gower *et al.*, 1995). Cu, pyrite, Mo, U, and fluorite mineral occurrences have been found.



Figure 29. Metamorphic assemblage data in pelitic rocks in southern Pinware terrane. The data demonstrate a lower metamorphic grade in the northeast area. This is attributed to preservation in an lapetus-related down-faulted basin. The location of the basin is controlled by differing orientations of two fault systems (see inset diagrams) (Gower, 2007) En route to next stop: Road continues across strike in Pinware terrane exposing a mixture of supracrustal and granitoid gneisses.

STOP 4.4: Nepheline Syenite; 21 km South of Outside Big Pond. CG03-029 (542216 5742869)

A distinctive nepheline-bearing alkali-feldspar syenite, 10 km north-northeast of Red Bay, was discovered during 1:100 000-scale mapping of the area (Gower *et al.*, 1994). The syenite was subsequently dated as having a syn- to late-Grenvillian age of 1015 ± 6 Ma (Heaman *et al.*, 2004). The intrusion is probably less than 200 m wide and of uncertain length. It was initially reported to be about 1 km long (Gower et al., 1994), but Gower et al. (1995) indicated that the body could be much larger, following examination of thin sections prepared for H. Bostock during his earlier investigation (Bostock, 1983). A mineral listed by Bostock as an 'unknown' is altered nepheline. The minimum strike length of the nepheline syenite was thus inferred to be at least 4.5 km, trending in a northeast direction. The syenite is white-weathering, medium to coarse grained, recrystallized and weakly to moderately foliated. Nepheline is easily recognizable as chalky-white, creamy-brown, or pink grains in hand sample (Plate 9d). From hand sample and thin section estimates, nepheline forms up to about 40% of the rock. Other minerals are well-twinned albite, microcline, zircon (2942 ppm Zr in one occurrence) and magnetite. Magnetite, aegerine and garnet were provisionally identified in hand sample, but were not included in the thin sections cut.

One other nepheline occurrence is known in eastern Labrador, and it is also in the Pinware terrane. The rock type is a leucosyenite consisting of albite and K-feldspar with minor nepheline, and accessory opaque minerals (oxide and sulphide), muscovite, biotite and zircon. The nepheline was only seen in thin section. Despite this being a trivial occurrence on its own, and in a very poorly exposed, remote area, it is worth pointing out that alkalifeldspar syenitic rocks are common in that region (typically containing sodic clinopyroxene and/or amphibole, rather than nepheline), so there is good reason to suspect that other similar rocks may be present. One of the aegerine-bearing syenites has a late-Grenvillian age of 991 ± 5 Ma (Wasteneys *et al.*, 1997). Whether alkalic activity was continuous between the times of the two dated alkali-feldspar syenitic intrusions in the Pinware terrane (*i.e.*, 1015 to 991 Ma) is unknown.

En route to next stop: Road continues across strike in Pinware terrane exposing mostly granitoid gneisses.

STOP 4.5: Layered Mafic Intrusion; Red Bay Downtown. VN93-033 (539536 5730926)

The Red Bay pluton (Plate 10a) has been mapped by Bostock (1983) and Gower *et al.* (1994) and investigated petrologically by Greenough and Owen (1995). Greenough and Owen (from whom most of the following information is summarized) term the body a jotunitic or Fe-Ti-P (FTP) gabbroic intrusion and categorize the rocks as leucocratic cumulates, melanocratic cumulates, relatively massive gabbros and granophyres. Layering is common in the stratigraphically lowest exposed part of the body (at the southern side of Saddle Island). It is mostly planar-tabular, but trough cross-beds are locally present and allow determination of the top of the intrusion. Modal layering is present in both continuous and lensoid layers. Cumulous phases include aluminous augite, orthopyroxene (XMg between 0.58 and 0.78), plagioclase and apatite. Other silicate phases include intercumulus TiO2-rich biotite and amphibole rimming augite. Titano-hematite and ilmenite are important rock-forming minerals in all samples. The age of the intrusion is 980 \pm 3 Ma based on three analytically overlapping zircon fractions (Heaman *et al.*, 2004), but one point is excluded.

En route to next stop: Road continues across strike in Pinware terrane exposing mostly granitoid gneisses. Lower Pinware River alkali-feldspar syenite entered.

STOP 4.6: Intrusive Contact Between Lower Pinware River Alkali-feldspar Syenite and Labradorian Quartz Monzonite; 2 km West of Country Cat Pond. CG93-027 (528574 5731649)

At this locality the intrusive contact between the Lower Pinware River (LPR) alkalifeldspar syenite and its host gneissic quartz monzonite was exposed in 1993 (Plate 10b).

The host gneissic monzonite is typical of the strongly foliated granitoid rocks that underlie much of the Pinware terrane. The mineral assemblage in the quartz monzonite is quartz, alkali feldspar, plagioclase, amphibole, accessory opaque minerals, biotite, apatite, zircon, allanite, monazite, titanite, and secondary carbonate and chlorite. It is intruded by alkalic mafic dykes that have not been found in the LPR alkali-feldspar syenite. Foliations in the gneissic granitoid rocks wrap around the intrusion and must have existed prior to emplacement of the LPR alkali-feldspar syenite pluton.

The syenite consists mostly of alkali feldspar (86%) and clinopyroxene (13%), together with accessory opaque minerals, fayalite, amphibole, apatite and zircon. It also contains



Stop 4.5. Red Bay gabbronorite





Stop 4.7. Pinwarian K-feldspar megacrystic granite; age 1467 ± 8 Ma.



Stop 4.6. Contact between Labradorian quartz monzonite and Lower Pinware River alkali-feldspar syenite (as exposed in 1993)



screens of sillimanite-bearing metasedimentary gneiss at this locality and hosts huge rafts of country-rock gneiss in other parts of the pluton. A strong, northwest-trending fabric in parts of the pluton indicates post-emplacement regional deformation.

Four U–Pb zircon analyses for the gneissic monzonite yielded discordant U–Pb ages, but collinearly aligned in the middle fifth of a mixing line between 1650 ± 10 Ma and 1030 ± 15 Ma (Wasteneys *et al.*, 1997). The lack of spread on the zircon data prompted analysis of monazite and titanite which, unusually, coexist in this gneissic rock. One of two monazite analyses has a concordant U–Pb age of 982 ± 5 Ma, whereas two concordant titanite analyses yield an age of 972 ± 5 Ma and are younger than the interpreted 1030 ± 15 Ma time of metamorphism (Wasteneys *et al.*, 1997).

Wasteneys *et al.* (1997) also attempted to determine the age of the Lower Pinware River (LPR) alkali-feldspar syenite. Six multigrain zircon fractions defined a narrow range of discordant U–Pb ages. An unconstrained regression line though eight mid-chord points has intercepts at 1359 +87/-56 Ma and 962 +76/-120 Ma. Geological evidence indicates that the LPR alkali-feldspar syenite intruded the gneissic quartz monzonite, for which a lower intercept age of 1030 Ma defines the age of migmatization, lacking in the LPR alkali-feldspar syenite is not intruded by mafic dykes that belong to the *ca.* 980 Ma alkaline mafic dyke suite described elsewhere in this guide. The LPR alkali-feldspar syenite was inferred to be older than the 972 \pm 5 Ma age of titanite in the adjacent gneissic quartz monzonite host rock as the high emplacement temperature of the LPR alkali-feldspar syenite would probably have affected the titanite.

Not satisfied with these somewhat equivocal conclusions another sample was collected (CG93-062), but farther from the border of the intrusion on the thinking that results from the previous sample reflected country-rock contamination. Two zircon fractions (Heaman *et al.*, 2004) demonstrated the same mid-chord problem as that previously detected by Wasterneys *et al.* (1997). On the encouragement of Dr. T. Krogh, a pegmatitic syenite present at the initially investigated locality was collected (CG93-027C). A regression line based on two points from the pegmatite (one concordant at the lower intercept) and two points from CG93-062) give upper and lower intercepts of 1411 ± 16 Ma and 974 ± 6 Ma, respectively (Heaman *et al.*, 2004). The age of the pegmatitic syenite is therefore accepted to be 974 ± 6 Ma, and this age is regarded as not very much younger than the whole body, with which it is compositionally similar.
En route to next stop: Lower Pinware River alkali feldspar syenite crossed, then back into typical Pinware terrane granitoid gneiss.

STOP 4.7: Pinware K-feldspar Megacrystic Granite; 500 m North of Pinware. CG93-187 (519941 5719704)

The Pinware K-feldspar megacrystic granodiorite to granite is an irregularly shaped body exposed on the coast at the mouth of the Pinware River and farther inland. The shape of the body is based on the mapping of Gower *et al.* (1994), but earlier description of these rocks was given by Bostock (1983), who used the term augen granodiorite for them. The rock at this locality is a fairly uniform, coarse-grained, hornblende biotite granitoid rock containing seriate to megacrystic K-feldspar and showing a strong foliation (Plate 10c). It contains large magnetite crystals with mafic-mineral-depleted haloes, normally considered to be caused by biotite oxidation (Biotite + O_2 = Magnetite + K-feldspar + H₂O). The foliation is discordantly truncated by buff-coloured microgranite dykes.

The sample collected for U–Pb geochronological study consists of plagioclase, K-feldspar, quartz, bronzy-orange, slightly chloritized biotite, ragged green hornblende, and accessory minerals. The plagioclase is anhedral to polygonal, well-twinned, and moderately to heavily sericitized. Anhedral, partially to completely recrystallized K-feldspar aggregates up to 2 cm long are interpreted as former megacrysts make up to 20% of the rock. They commonly exhibit white albitic rims. Most of the K-feldspar is poorly exsolved stringlet to bead perthite, but some microline is also present. Accessory minerals include an opaque oxide, traces of opaque sulphide, apatite, zircon and allanite (no titanite). Zircon is unusually abundant; one 1.8 mm field of view contains a cluster of 40 zircons, both euhedral and rounded and without obvious rims or cores.

A regression line constructed to pass through six zircon analyses yields an upper intercept date of 1466.4 ± 8.4 Ma, which is interpreted as the age of emplacement of the granite. Anchoring a reference line at 985 ± 5 Ma (the time of termination of significant Grenvillian metamorphism in the area), yields a similar age of 1459 ± 26 Ma (Heaman *et al.*, 2004).

En route to next stop: Short journey to next stop, crossing more Pinware terrane granitoid rocks.

STOP 4.8: Basal Cambrian Unconformity; Roadstone Quarry, 1 km North of West St. Modeste. CG93-193 (519359 5716611)

This quarry exposes the basal unconformity between Grenvillian basement and the Bradore Formation, upper Labrador Group (Plate 10d). The unconformity is broadly planar with local depressions and truncates northwest-trending, moderately northeast-dipping gneisses that host granitic and pegmatitic veins.

The crystalline rocks below the unconformity are altered. Brown-red, hematitic zones occur locally associated with irregular patches of green colouration that affects the rocks for a few metres below the surface. This alteration is probably the remnants of a once wide-spread regolith. XRD studies of the red zones show little alteration except the presence of illite and haematite. However, the green zones host a mineral assemblage that includes sani-dine and the fine grained phyllosilicates taeniolite, montdorite, illite and greenalite. Similar green clay zones and iron-rich alteration are described in Scotland beneath the basal unconformity of the Lower Cambrian Eriboll Formation (red sandstone) with Lewisian basement. The Scottish alteration zones are also interpreted as a regolith, the product of deep weathering in a tropical, humid climate (Russell and Allison, 1985). The fact that the regolith is only sporadically preserved indicates that the Cambrian fluvial system rapidly reworked the weathered basement profile to exhume unweathered basement rocks at a sharp unconformity surface similar to that seen at the coast southeast of Blanc-Sablon.

The basal Bradore Formation consists of crudely stratified to crossbedded, brown-red pebbly sandstone. The sandstone ranges from poorly sorted and very-coarse grained to better sorted and fine grained between undulose scours that are spaced through the section. The better-sorted sands may display lamination. Lenses of small pebble conglomerate occur at the unconformity and just above the scours. Heavy mineral laminae occur in the cross sets. The poorly sorted lithofacies above the unconformity are characteristic of braided streams deposited on a braid plain (Rust, 1972; Miall, 1977). The crudely stratified gravels formed as longitudinal bars during flood phase with local crossbeds deposited as in-channel dunes and ripples during waning flow of the river.

En route to next stop: Road follows the eastern flank of an outlier of the Bradore Group, which consists of sandstones of the Bradore Formation, overlain by limestones of the Forteau Formation.

STOP 4.9: Labradorian Volcanoclastic Rocks Intruded by Grenvillian Pegmatite and Alkalic Mafic Dyke; 1 km West of Capstan Island. CG93-268 (517524 5712120)

At the locality, the host rock is a banded volcanoclastic(?) unit that is discordantly intruded by pegmatite, which is itself intruded by an alkaline mafic dyke and crosscut by a sheared felsic veinlet (Plates 11a, b).

The dominant rock at this outcrop is well-banded, multi-coloured, fine-grained, recrystallized and quartzofeldspathic. In contrast to similar rocks elsewhere in the Pinware terrane, the supracrustal parentage of the sample collected from L'Anse-au-Diable is fairly certain. The uniformity of banding (interpreted as bedding) is good reason to consider it to be supracrustal. It is a close association with felsic rocks displaying a lensoid, streaky appearance suggesting pyroclasts (for example on the shoreline 200 m to the north) and its regional affiliation with ferruginous quartzite, calc-silicate layers, and sillimanite-bearing schists that justifies protolith interpretation as volcanoclastic (Gower *et al.*, 1994). The 36% modal quartz, rather high for most igneous rocks, supports a sedimentary derivation. Other minerals are alkali feldspar, plagioclase, accessory biotite, zircon, and secondary chlorite.

A pink-weathering, planar pegmatite dyke, 1-m-wide, discordantly intrudes the host rocks, and shows both internal and marginal deformation. Its mineral assemblage is quartz, alkali feldspar, plagioclase, together with trace biotite, opaque minerals and zircon, and secondary chlorite and hematite.

The later alkalic mafic dyke is a planar 1.5-m-wide intrusion, trending at 130° and discordantly intruding the pegmatite and its banded quartzofeldspathic host. The dyke is fine grained, black-weathering and homogeneous. Minerals recognized in thin section are primary plagioclase, amphibole, biotite, opaque minerals and skeletal apatite. Chemically, the rock belongs to the same group as the Gilbert Bay dykes. The alkalic mafic dyke is discordantly intruded by a 1-cm-wide aplite dyke that has been dextrally sheared.

Zircon data for the banded, quartzofeldspathic rock define a discordant array between a Labradorian protolith and Grenvillian metamorphism. Incorporating data for the crosscutting pegmatite (see below) the line has an upper intercept of 1637 ± 8 Ma (Wasteneys *et al.*, 1997). If the zircons in the volcanoclastic rock are magmatically inherent to it, then the 1637 Ma date represents the time of magmatism. An alternative possibility is that the rock has an epiclastic rather than strictly volcaniclastic origin, in which case it would be younger.



Stop 4.9. Pitts Harbour Group banded volcaniclastic rocks intruded by pegmatite



Stop 4.9. Pegmatite intruded by alkalic mafic dyke



Plate 11. Outcrop photographs for localities 4.9, 5.1 and 5.2.

Stop 5.1 Layered metagabbro and metanorite 1248 \pm 5 Ma

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From the pegmatite, a concordant analysis based on 6 zircon fragments broken away from the externides of larger grains, has an age of 1049 ± 30 Ma. If this result, in conjunction with analyses for the pegmatite, is combined with data from the host banded, quartzofelds-pathic rock, then an age of 1036 ± 17 Ma is obtained for the pegmatite (Wasteneys *et al.*, 1997).

The alkalic mafic dyke contains abundant small zircons that consistently display skeletal forms such as elongate crystals with rod-shaped axial tubes. Three multigrain fractions yield a nearly concordant age of 985 \pm 6 Ma for age of emplacement of the dyke. This date overlaps, within error, a 974 \pm 6 Ma age obtained from a Gilbert Bay dyke farther north. The Gilbert dykes have similar whole-rock chemistry to discordant mafic dykes in the Pinware terrane suggesting that they are all related to the same intrusive event. Nevertheless, because the L'Anse-au-Diable dyke is more altered than the Gilbert Bay dyke, the nominal 11 million year difference between the two dated dykes may reflect a real age contrast. A single monazite crystal from the quartzofeldspathic rock yielded a near-concordant U–Pb age of 979 \pm 20 Ma (Wasteneys *et al.*, 1997). The aplite has not been dated, but its presence is in keeping with known late- to post-Grenvillian plutonism in the area.

En route to L'Anse-au-Clair: Road climbs over outliers of the Bradore Group, descending into intervening valleys underlain by granitoid rocks of the Pinware terrane. The flat tops of the hills are capped by limestones of the Forteau Formation. DAY 5. L'Anse Amour to Vieux-Fort (Figure 30)





STOP 5.1: Gabbronorite Boudin in Gneissic Granitoid Rocks; on Shoreline Near Hospital in Lourdes-de-Blanc-Sablon. 97SP-068 (485555 5695421)

En route to Blanc Sablon: Road climbs over outlier of the Bradore Group, back onto granitoid rocks of the Pinware terrane.

This locality shows a mega-boudin of brown-weathering, olivine gabbro to norite in well-banded gneissic granitoid rocks (Plate 11c). The gabbronorite is intruded by pegmatite.

The olivine gabbro to norite is coarse grained to pegmatitic and shows compositional and grain size layering. Igneous cross-bedding is present in places with truncation indicating top of the intrusion to the southeast. Pegmatitic gabbro forms metre-sized pockets and veins that intrude the rest of the complex. Granophyre veins and veinlets are locally present. Corona textures are evident, including olivine mantled by orthopyroxene, clinopyroxene mantled by hornblende + garnet, and opaque minerals mantled by biotite and hornblende. Although igneous textures are preserved, most coronas show extensive recrystallization; millimetre-scale recrystallized domains are common. Some metamorphic hornblende veinlets are present.

A sample collected for U–Pb geochronological studies (97SP-68B) contains baddeleyite, polycrystalline zircon (interpreted to be metamorphic) overgrowths on baddeleyite and colourless zircon fragments. A concordant baddeleyite yielded an age of 1248 ± 5 Ma, which was interpreted to be the age of emplacement. Using the most concordant of four zircon analyses, plus the baddeleyite upper intercept, resulted in a lower intercept date of *ca*. 974 \pm 35 Ma, interpreted to date a late stage of Grenvillian metamorphism (Heaman *et al.*, 2004).

The margin of the gabbronorite intrusion is sheared and contains shredded pegmatite and remnants of fine-grained metagabbro/amphibolite. The fine-grained metagabbro or amphibolite is composed mainly of granoblastic hornblende and plagioclase with locally finegrained granoblastic orthopyroxene and relict crystals of broken igneous plagioclase. A gradation between the coronitic gabbronorite and fine-grained amphibolite is observed, expressed by grain-size reduction and transformation of coronas into poikiloblastic hornblende–plagioclase–biotite intergrowths. The pegmatites truncate layering in the gabbronorite but are transposed into parallelism with the sheared contact. The contact between the gabbronorite and the country-rock gneissic granitoid rocks is sharp. The country rock to the mafic intrusion was derived originally from a coarse-grained, K-feldspar-rich granitoid rock having biotite as its dominant mafic mineral. Although strongly foliated, little of it can be regarded as gneiss. Near the mafic intrusion, pegmatitic and amphibolitic layers in the granitoid rock are strongly foliated, boudinaged and parallel to the contact, giving the bulk rock an overall gneissic appearance. Farther away, where deformation is less severe, mafic dykes truncate pegmatite within foliated granitoid rock.

If the mafic dykes within the granitoid rock are genetically related to the gabbronorite intrusion, the sequence of events is: (i) granitoid emplacement, (ii) pegmatite injection, (iii) gabbronorite and satellite mafic dyke intrusion, (iv) pegmatite emplacement, (v) shearing along contact.

En route to next stop. Drive west along highway for 7.6 km, turn left on Rue Blais. Drive to yellow house. Park.

STOP 5.2: Nodular Sillimanite-bearing Paragneiss; Bradore. 97SP-008

These outcrops are part of a paragneiss unit that is within the gneissic complex of the Pinware Terrane. The dominant lithology comprises biotite-bearing, fairly homogeneous, fine- to medium-grained, quartzofeldspathic paragneiss with layers of quartzite. Enclosed within the quartzofeldspathic paragneiss are hematite-rich, quartzofeldspathic nodules containing sillimanite, some muscovite but lacking garnet (Plate 11d). The nodules are mostly a few centimetres to decimetres long and all have the same orientation.

On a broader scale, a delicate layering is evident and expressed by red staining of some layers. It is commonly oblique to the prevailing foliation, and the alignment of pods seems to be independent of this layering. Although this layering is parallel to conformable bands of quartzite, and may be interpreted as primary depositional bedding, it is more probable that this layering represents liesegang bands formed by diagenetic processes during Cambrian times.

There seems little doubt that the paragneiss was derived from a metasedimentary protolith, including some quartzite. The origin of the nodules is speculative but may be (i) cobbles within a deformed oligomictic conglomerate, (ii) the result of boudinage of intercalated pelitic and psammitic layers, or (iii) the restite of partially melted pelitic layers. Note transposition fabrics, including extensional shears, giving an east-side-down sense of displacement. Some 200 m north of this outcrop, folding, associated with a late deformational event, can be seen.

En route to next stop. Return to highway; head west 4.8 km to Bradore River. Odometer reading 13.8 km.

STOP 5.3: Folded, Interlayered Pelitic Gneiss and Quartzite; Bradore River. 96SP-002

This outcrop consists of rusty-weathering, schistose, graphite- and sulphide-rich, sillimanite-bearing pelitic gneisses interlayered with garnet-rich quartzite layers (Plate 12a). Cordierite-bearing paragneiss is also present as thin layers in the sillimanite-bearing paragneiss. The graphitic rusty paragneiss bands are composed of centimetre-thick, pyritiferous quartz-rich bands and lenses in a graphite–sillimanite–biotite paragneiss. Sulphides are mainly pyrrhotite and pyrite. Disseminated chalcopyrite is observed locally. Deformed, decimetre-thick quartz veins and lenses are locally mineralized with pyrite and chalcopyrite.

The quartzite is thin- to thick-bedded and studded with mauve to pink garnet. It is tightly to isoclinally folded and sheared into pods in places. The folds plunge to the northwest and a strong lineation is present in the pelitic layers. Farther inland, the paragneisses show polyphase deformation with two sets of folds well exposed on the top of the hills. Dome and basin structures and interference patterns of types 1 and 2 are common. The Bradore River marks the location of the Iapetus-related Bradore Fault.

En route to next stop. Continue west for 0.4 km. Turn left onto gravel track and stop at small quarry (100 m off the highway).

STOP 5.4: Bradore River Megacrystic Granite; 400 m West of Bridge Across Bradore River. 96SP-004 (482579 5705449)

The stop exposes typical granitoid rocks in the area (Plate 12b). They consist mostly of pink and grey weathering, coarse-grained biotite granite. The granite is somewhat inhomogeneous, although the range in textures is limited overall. Some pinkish, diffuse hornblende quartz syenite grading into granite and granitic pegmatite veins, which pinch and swell, are



Stop 5.3 Folded quartzite with biotite-rich paragneiss and graphitic rush sillimanite-bearing paragneiss



Stop 5.5 Late- to post-kinematic dykes and sills in granitic augen orthogneiss



Stop 5.4 Quarry in porphyritic granite to augen granitic gneiss



Stop 5.6 Agmatite formed of amphibolite (metagabbro) with pegmatite and pink microgranite

Plate 12. Outcrop photographs for localities 5.3, 5.4, 5.5 and 5.6.

also present. The granite is magnetite rich, seriate to megacrystic and contains amphibolerich schlieren, boudinaged amphibolite lenses and enclaves of metasedimentary gneiss. It has a strongly foliated to gneissic appearance, rather than being well-banded gneiss.

The megacrystic gneissic granite was sampled for geochronology. Regression of the three zircon analyses define a discordia line with an upper intercept age of 1632 ± 8 Ma and a lower intercept age of 921 ± 10 Ma. The upper intercept was interpreted as the crystallization age for this granite and indicates the presence of Labradorian granitoid magmatism in the area. The lower intercept was interpreted as the minimum time of Grenvillian metamorphism.

En route to next stop. Continue west along the highway for 0.7 km. Stop at road cut at top of hill.

STOP 5.5: Foliated to Gneissic Granitoid Rocks and Amphibolite; Road Cut at Top of Hill West of Bradore River. 97SP-015

The rocks exposed at this locality are rather similar to the previous stop and presumably are part of the same granitoid body (Plate 12c). The rocks are grey to pink inhomogeneous granite. They have a strongly foliated to gneissic appearance and contain some diffuse amphibole-rich layers. Also present is black-weathering, weakly foliated amphibolite containing a few K-feldspar-hornblende-bearing veinlets, and some disrupted magnetite-bearing pegmatites.

En route to next stop. Continue west along highway for 8.3 km.

STOP 5.6: Agmatite Formed of Amphibolite, Pegmatite and Microgranite; on Highway West of Lac de Pointe de Fleche. 97SP-021

The outcrop comprises an agmatite formed of amphibolite, pegmatite and microgranite (Plate 12d). The amphibolite is black weathering, medium grained and contains discordant, monomineralic biotite veins. Pegmatite occurs as irregular, massive to foliated, coarse to very coarse grained patches that vary from syenite to granite and are locally rich in magnetite and allanite. It is white adjacent to amphibolite. Sugary textured, pink microgranite containing some amphibolite is present at the margins of the outcrop. At the east end of the outcrop, the amphibolite grades into a metagabbronorite in which igneous relict textures

are locally preserved. Orthopyroxene and clinopyroxene are commonly mantled by hornblende. The metagabbronorite is magnetic. This metagabbronorite, which can be traced over a distance of 2 km, is 150 to 200 m wide. The age of this gabbronorite body is uncertain but may be the same as the layered mafic intrusion at the Hospital of Lourdes-de-Blanc-Sablon.

En route to next stop. Continue along highway for 20.9 km.

STOP 5.7: Granodioritic to Granitic Gneisses; on Highway West of Baie au Salmon. 97-SP-038

This outcrop exposes pink- and grey-weathering, well-banded granodiorite to granite gneisses containing mafic schlieren, amphibolitic bands and concordant pegmatitic layers (Plate 13a). The gneissosity is refolded with flat-lying axial surfaces and has boudin interfill material. These rocks are discordantly intruded by pink, magnetite-rich pegmatite.

En route to next stop. Continue along highway for about 8 km to Rivière-Saint-Paul. Stop at the rest area on the top of the hill.

STOP 5.8: Rivière-Saint-Paul Plutonic Suite; on Highway, West Side of Baie des Esquimaux and East of the Village of Saint-Paul River 97SP-046 (451766 5702298)

The meta-plutonic suite of Rivière-Saint-Paul (RSPPS) outcrops mostly on the west side of the Saint-Paul River and the Baie des Esquimaux. The best outcrops are along road cuts on the highway (Plate 13b). On the top of the hill near the rest area, the Rivière-Saint-Paul plutonic suite is composed of gabbronorite and diorite, whereas, near the river, gneissic tonalite, granodiorite and megacrystic granite are the main lithologies. Two suites of granite veins and dykes, pegmatite veins and late gabbro dykes cut most of the facies of the RSPPS. The degree of deformation is highly variable as gabbro and diorite are usually less deformed than the granitic facies. Near the bridge, the gneissic structure of the tonalite and granite is deformed by large-scale folds with a subvertical axial surface and shallowly plunging fold axes. Locally, refolded gneissic structures and boudinage suggest that these rocks are poly-deformed.

On top of the hill, near the rest area, the gabbro facies grades into a magnetite-rich dioritic facies. The diorite is characterized by 2-5% magnetite. The magnetite forms at the



Stop 5.7 Granitic to granodioritic migmatite with disrupted folded layers of amphibolite



Stop 5.9 Vieux-Fort coarse-grained anorthosite with orthopyroxene and ilmenite



Stop 5.8 Rivière-Saint-Paul plutonic suite showing gray tonalitic to granodioritic otthogneiss and foliated medium-grained granite



Stop 5.10 Irregular basal Cambrian unconformity eroding attered granitoid gneiss and overlain by sandstones of the Bradore Formation

Plate 13. Outcrop photographs for localities 5.7, 5.8, 5.9 and 5.10.

center of plagioclase coronas that give a spotty texture to the rock. Biotite and hornblende are the main mafic minerals of the diorite. Progressing downhill along the road, the diorite grades into a gray gneissic tonalite as the quartz content and the deformation increase. Finally, at the core of the large-scale fold structure, the tonalite grades into a granodiorite and to a biotite and hornblende-bearing megacrystic granite. Locally, the megacrystic granite is weakly deformed, but it is best described as granitic augen gneiss. The first generation of granite veins that cut the RSPPS is a gray to pinkish hornblende-bearing granite. The granite is medium-grained and locally hornblende phenocrysts are present. The contact with the host rocks is usually diffuse and the veins are deformed. The second generation of dykes is composed of a medium to fine grained massive to weakly biotite-bearing granite. Contacts with the host rock are clear and sharps.

A sample of the gneissic tonalite (97SP-046A) was taken for geochronology (Heaman *et al.*, 2004). Three zircon and two titanite fractions were analyzed. A reference line constructed to pass through zircon fraction 3 (one of the least discordant analyses) and the ²⁰⁷Pb/²⁰⁶Pb age of *ca.* 950 Ma obtained for the most precise titanite analysis (fraction 5) yields an upper intercept age of 1504 ± 9 Ma. This is interpreted as the approximate age of emplacement and is clearly part of Pinwarian magmatism. The ²⁰⁷Pb/²⁰⁶Pb age of 953 ± 2 Ma for the more precise titanite analysis (fraction 4) is interpreted as the best estimate for the timing of titanite growth in this sample and correspond to the late stage of Grenvillian metamorphism.

A sample from the first generation of granite veins (97SP-046C) was also sampled for geochronology (Heaman *et al.*, 2004). A total of six zircon fractions were analysed from this sample. A discordia line constructed to pass through five of the six analyses yields an upper intercept age of 1526 ± 14 Ma and a lower intercept age of 999 ± 23 Ma. As with sample 97SP-046A above (from the same outcrop), the older age is interpreted as the best estimate for the age of granite emplacement. This sample also displays significant Pb-loss during Grenvillian metamorphism.

In conclusion, the Rivière-Saint-Paul plutonic suite crystallized and was emplaced during the Pinwarian. The imprecise value of the ages observed with the zircons can be attributed to a high-grade metamorphic event during the Pinwarian as reflected in a zircon age of 1504 Ma in the gneissic tonalite. The ages obtained with the titanite are attributed to the closure of the U–Pb system in the mineral and represent a point of T-t in the cooling history after the peak of the Grenvillian metamorphism. En route to next stop. Continue along Highway 138 to Vieux-Fort. Turn right at restaurant in Vieux-Fort and drive to the end of the road. Park at power relay station, walk along track, then over rough ground to reach power transmission pylon on top of hill.

STOP 5.9: Vieux-Fort Anorthosite; 1 km North of Vieux-Fort. 97SP-052 (442300 5700200)

The Vieux-Fort anorthosite is a small (~60 km²) complex composed mostly of massive to weakly deformed anorthosite and leuconorite with small amounts of leucogabbro, pegmatitic gabbro, and gabbro north of the northeast-trending Vieux-Fort fault. It is bordered by mangeritic rocks north of the fault. South of the fault, leuconorite at the contact of the pluton is foliated parallel to the regional foliation in the adjacent Pinware terrane granitic gneiss. The complex is truncated by the northeast-trending, normal late-Proterozoic or Paleozoic Vieux-Fort fault, which displays both ductile-brittle deformation. Along the fault zone, the anorthosite shows local mylonitization but mostly it is marked by cataclastic shear zones and by epidote-carbonate alterations.

Zircons were recovered from a massive pegmatitic pod of quartz-bearing granophyric leuconorite (Plate 13c). A best-fit regression of six analyses yields an upper intercept age of 974.5 \pm 1.8 Ma, which is interpreted as a crystallization age (Heaman *et al.*, 2004). The Vieux-Fort anorthosite is the youngest known anorthosite in the Grenville Province.

Return to Blanc Sablon. Drive southeast out of Blanc-Sablon for 0.75 km beginning at the brook in the town. Park off the highway and cross to the low cliff above a rocky and sandy shoreline. Walk southeast along foot of the cliff.

STOP 5.10: Basal Cambrian Unconformity; Shoreline East of Blanc Sablon. 97SP-027

This locality was described and illustrated by Cumming (1983). The Bradore Formation rests unconformably on granitic gneiss (Plate 13d). The unconformity ranges from planar upon, to downcutting into, the basement. The overlying red sandstone of the Bradore Formation displays crude planar stratification overlain by trough cross bedding. A thin conglomerate of small rounded pebbles marks the base of the stratified sandstone.

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APPENDIX 1

Walking Tour of Battle Harbour (Figure 31)

STOP 1: Phanerozoic Dyke Intruding Psammitic Rocks; South End of Battle Island. CG07-159 (596544 5792056)

A vertical, east-northeast-trending diabase (Plate 14a) discordantly intrudes pegmatite and earlier psammite, and also truncates north-northeast-trending, hematite-filled brittle fractures. The dyke is 2 m thick and has a smaller dyke branching off from it. The dyke varies from fine to medium grained at its centre to very fine grained at it chilled margins. It has a distinctive jointing pattern across the width of the dyke, considered to be related to cooling normal to the dyke walls. K-feldspar in pegmatite adjacent to the dyke takes on a greenish hue, in contrast to its vivid pink colour farther away. This is interpreted as reduction of ferric to ferrous Fe in the feldspar due to dyke emplacement. The dyke is unmetamorphosed and mineralogically fresh. It is the youngest bedrock unit on the island.

In thin section, the dyke is seen to consist of plagioclase, clinopyroxene, biotite, an opaque oxide and fine-grained, granular brown material. Plagioclase forms primary, well-twinned, and locally skeletal laths, and also occurs a local clusters of larger grains suggested here to represent slightly earlier crystallizing crystals that aggregated during magma ascent. The clinopyroxene occurs as brown primary grains, in ophitic texture with plagioclase. The biotite is orange brown and ragged. The granular, brown material is too fine-grained to be unequivocally identified, but it is suspected to be a Ti-bearing phase, possibly titanite.

STOP 2: Amazonite-bearing Pegmatite; East Side of Battle Island. CG07-138 (596695 5792749)

Pink- and white-weathering pegmatites are found in all parts of Battle Island, but are particularly abundant along the spine of the island. The pegmatites vary in width from dykes tens of metres to veins less than 1 cm, but most intrusions typically have decimetre- to metre-scale widths. Contacts against the host metasedimentary rocks are sharp and commonly irregular due to post-emplacement deformation. Concordant and discordant pegmatites are both present. Concordant screens of psammite and calc-silicate rock are common in the larger pegmatites, and have maintained their original pre-pegmatite-injection orientation, suggesting a passive, *lit-par-lit* type of intrusion. *En echelon* pegmatites exhibiting bayonet terminations and bridge features are common.



Figure 31. Geological map of Battle Island (Gower, 2009) showing locations of stops included in Appendix 1.



Stop 1. Phanerozoic mafic dyke



Stop 4. Amphibolite sills; metamorphic age 1030 ± 4 Ma Plate 14. Outcrop photographs for Battle Island. Stops 1, 2, 3 and 4. Stop 3. Heavy mineral laminations in cross-bedded psammite



Stop 2. Amazonite-bearing pegmatite, dated to be 1024 ± 3 Ma



Crosscutting relationships indicate several emplacement events, possibly over an extended period. The state of deformation varies greatly, suggesting syn- to post-tectonic emplacement times. The rocks are almost entirely coarse or very coarse grained; aplitic rocks are extremely rare.

Two pegmatites containing amazonite (green, Pb-bearing K-feldspar) were found on the east side of Battle Island, one of which is seen at this site (Plate 14b). Each was traced about 50 m. Both pegmatites are strongly boudinaged and appear to be among the earliest present on the island. One of the amazonite-bearing pegmatites was examined in thin section. It comprises slightly recrystallized quartz, moderately sericitized, well-twinned plagioclase having albitic borders, well-twinned microcline, interstitial muscovite, an opaque oxide, partially metamict monazite, zircon, traces of chlorite, and a dark brown poorly preserved mineral that is suspected to be allanite. The accessory minerals are unusually abundant in this pegmatite. The high Pb content of the rock indicated by the amazonite is confirmed by whole-rock analysis. High Nb and Ta suggest that this type of pegmatite might have potential for columbite-tantalite mineralization.

This pegmatite was sampled for dating. A large quantity of zircon was recovered from this sample, but the grains were pervasively cracked and extensively altered. After chemical abrasion, most grains were hazy to whitish, but a few cracked fragments remained relatively clear and these were selected for analysis. These give an upper intercept age of 1024 ± 3 Ma (MSWD = 0.36) and a lower intercept of 284 ± 83 Ma. The time of emplacement of the pegmatite is taken as 1024 ± 3 Ma (Kamo *et al.*, 2011).

STOP 3: Crossbedded Psammite; Northeast End of Island. CG07-130 (596481 5792935)

The easternmost unit on Battle Island is a crossbedded psammite. This rock was targeted for detrital zircon geochronological study. It has a light grey, sugary texture where its weathered, brownish crust has been removed by erosion, but is maroon where hematized. It is a relatively homogeneous, fine- to medium-grained rock, about 100 m thick at its widest part, but of unknown total width, as its eastern boundary is not exposed. Three features are characteristic of this unit. The first is the presence of bedding in the form of parallel and cross-bedding lamination (Plate 14c). The laminae are enriched in biotite and opaque minerals. The crossbedding laminations, which were first described by Kranck (1939), are confined to particular layers, commonly about 30 cm thick. Tops are to the west. This is the only lo-

cality in the Grenville Province in eastern Labrador where sedimentary structures in pre-Grenvillian rocks are unequivocally preserved. The second feature is a spotted appearance due to amphibole poikiloblasts up to about 1 cm across and surrounded by haloes depleted in mafic minerals. The poikiloblasts are dark green to blue-green and are thoroughly sieved with abundant quartz, plagioclase and microcline; it seems clear that as they grew they enveloped the felsic minerals. The area around the poikiloblasts is depleted in biotite, which was consumed at the expense of amphibole growth. The third feature is a few yellowishgreen layers, generally less than 1-2 cm wide. The yellow-green colour is due to markedly pleochroic epidote. These are interpreted as having a calc-arenite protolith.

West of the crossbedded psammite, a heterogeneous metasedimentary unit, about 25 m thick, comprising psammite, calc-silicate schist, semi-pelitic schist, quartzite and calc-silicate hornfels, is present. The protolith for this unit was probably a mixed sequence of muddy calcareous rocks, grading into limestone in places.

The geochronological sample comprises mostly recrystallized quartz, lesser plagioclase, and interstitial well-twinned microcline, associated with aligned flakes of buff-green biotite. It includes heavy mineral laminations consisting mostly of an opaque oxide (*cf.* ilmenomagnetite), but rounded zircon and apatite grains are common. Titanite is also common in these layers, partly mantling the opaque oxide. Minor epidote and chlorite are found throughout. The geochronologically investigated sample contains 86.5% SiO₂ (Gower 2009). Zircon crystals are pale brown to colourless, generally rounded, equant to 3:1 prismatic grains. Both ID-TIMS and MC-ICP-MS analyses were carried out on zircon grains from this sample.

Eight chemically-abraded grains gave a range of ages with the youngest at 1204 ± 2 Ma (2.0% discordant), and 6 ranging from 1396 ± 3 Ma to 1631 ± 2 Ma (Kamo *et al.*, 2011). The ²⁰⁷Pb/²⁰⁶Pb ages can be taken as minimum detrital source ages if the data plot on, or close to, the concordia curve. The youngest age of 1204 ± 2 Ma represents a maximum for deposition of the sedimentary protolith.

Despite the near concordancy of the data for the 1204 Ma grain, it appeared possible that it was on a mixing line with other data between Pinwarian and Grenvillian events. The five youngest data points together define a line with upper and lower intercepts of 1532 ± 20 Ma and 1138 ± 34 Ma (MSWD = 3.0), respectively. Within error, the upper intercept could be Pinwarian, and the lower intercept, although predating Grenvillian orogenesis in

eastern Labrador, could be coeval with the age of emplacement of the Gilbert Bay granite (1132 + 7/-6 Ma; Gower et al., 1991) or a granitic vein close to the Gilbert Bay pluton having an age of 1113 + 6/-5 Ma (Scott *et al.*, 1993).

To investigate further the possible existence of young detrital zircon grains of igneous origin in this sample, a broader selection of grains from the psammite was imaged and dated using the LA-MC-ICPMS analytical method (144 analyses from 101 grains). These grains were selected from the same concentrate used for TIMS dating. Several age modes are recognized in this detrital zircon population at ~2.72, 2.05, 1.95, 1.85, 1.80, 1.75, 1.65, 1.60, 1.45, 1.30 and 1.05 Ga (Kamo *et al.*, 2011). The data were interpreted to indicate that there are indeed <1.3 Ga detrital zircon grains in this sample and are consistent with the conclusion that the youngest concordant TIMS date of 1204 Ma provides a maximum constraint for the depositional age of this psammite.

STOP 4: Amphibolite; North End of Island. CG07-132 (596406 5792885)

The amphibolite is concordant with the supracrustal rocks and is interpreted as a sill (Plate 14d). It can be subdivided into two subunits, both mafic, separated by discontinuous lenses and tabular bodies of greenish-weathering calc-silicate rocks.

Amphibolite in the eastern half of the unit is more leucocratic than the west, but both subunits are medium to coarse grained, black to grey weathering, and everywhere very strongly lineated. The lineation is defined by hornblende, whereas the foliation is defined partly by biotite. The eastern, more leucocratic part shows streaky textures, due to varied concentrations of plagioclase and mafic minerals. Apart from this streakiness, the rock is uniform, except for the presence of small elliptical more melanocratic enclaves, which are common in some places. The amphibolite in the west is quite melanocratic near its contact against the lighter coloured amphibolite, where it is also rusty weathering and locally schistose.

Samples from both the eastern and western amphibolites were examined in thin section. The eastern amphibolite has a very strong foliation, defined by strings of segmented plagioclase grains, interspersed with elongate grains of pale-green amphibole (*cf.* actinolitic hornblende) and laths of orange-brown biotite, both of which define the same strong fabric. The sample from the western amphibolite, which was investigated geochronologically, lacks the fabric of its eastern counterpart, showing a granoblastic texture instead. It also shows some mineralogical differences. The amphibole is typical hornblende, rather than being actinolitic and the rock contains very abundant titanite. The titanite occurs in clusters of equant grains, commonly cored by an opaque oxide. Minor sulphide, chlorite and K-feldspar are present, the latter two minerals are found as secondary spindles in biotite.

The lack of internal variability in both units suggests that they are more likely intrusive than extrusive, although no chilled margins are evident. They are interpreted as two separate sills, and the variation in colour index within the western unit to indicate some differentiation. If the unit is differentiated, then top is to the west, consistent with crossbedding evidence in the easternmost unit.

Concordant data for two, colourless, low U, euhedral zircon tips overlap and have a ${}^{206}Pb/{}^{238}U$ mean of 1030 ± 4 Ma (MSWD=0.19). Two additional data plot just below these and are interpreted to have a lost a small amount of Pb. Crystallization of zircon grains in this sill at 1030 ± 4 Ma is considered to be a product of amphibolite facies metamorphism. The time of emplacement of the sill remains unknown, other than between 1200 Ma and 1030 Ma (Kamo *et al.*, 2011).

STOP 5: Calc-silicate Rocks; Northwest Part of Island. CG07-129 (596346 5792717)

The calc-silicate unit occupies a wide swath from the northwest tip of Battle Island to the central part of the southeastern shoreline, albeit heavily injected by pegmatite. The rocks are generally light to dark green weathering, medium grained, thinly and well bedded, mineralogically variable, both in mineral composition and their habits of (metamorphic) growth. Typically, the rocks have a very ribbed or pitted surface appearance due to alternating positively and recessively eroding layers and differential weathering of the various minerals present.

Apart from calc-silicate rocks, amphibolitic, semi-pelitic and psammitic layers are also present. Rusty-weathering, sulphide-bearing patches are common, locally forming pods up to about 1 m thick and 2 m long. Although rubiginous and having a sulphurous smell on fresh surface, sulphide content is minor.

Five samples were examined in thin section from this site. All contain plagioclase, K-feldspar, phlogopitic mica, (an) opaque mineral(s), and titanite. Plagioclase is typically anhedral with straight grain boundaries and 120° triple junctions and heavily sericitized. K-feldspar shows the same habit, and is characteristically well-twinned microcline. The phologopitic mica ranges from pale orange to reddish orange and commonly defines a strong fabric. Both oxide and sulphide opaque minerals are present. Titanite varies from anhedral and amoeboid to euhedral. It is abnormally large in one sample, where it occurs as grains up to 3 mm long. Other minerals include diopside and minor stable and secondary tremolite.

APPENDIX 2

Appendix 2 consists of images of representative stained slabs from most of the excursion stops. For those unfamiliar with this technique, the process involves etching with hydrofluoric acid then staining the etched surface with a saturated solution of sodium cobaltinitrate. The stain is specific for potassium. Much more information can be gleaned from the staining than simply determining the amount of potassium feldspar in the sample. Other minerals also take on diagnostic character, for example: plagioclase – white, quartz grey, albite – commonly coral pink, biotite – greenish yellow, hornblende – black, pyroxene – grey (although orthopyroxene may be creamy-grey). Textures are commonly well displayed, for example: diabasic texture, quenched plagioclase in diabase, corona textures, partially retrograded garnet, rapakivi textures, and mylonitic fabrics. Care must be exercised in interpreting the stained slabs, as the stains are not uniformly perfect. Dirty slabs, inadequate etching and/or inadequate rinsing of the slab after staining are common causes for poor stains.



Double Mer Formation arkose

Stop 1.3

Dome Mountain Intrusive Suite granite

Mealy Mountains Intrusive suite monzodiorite



Labradorian monzonite 1658 ± 3 Ma Slabs 1. Stained slabs for localities 1.1-1.5.



Labradorian monzonite



No-Name Lake monzogabbronorite



Late/post Grenvillian monzodiorite



Pinwarian/Labradorian granitoid rocks



Pinwarian granite



Mealy Mountains Intrusive Suite correlative monzonite



Labradorian granitoid & Long Range dyke



Long Range syenogabbro (two localities 30 km apart)

Slabs 2. Stained slabs for localities 1.6-1.10.


Earl Island monzodiorite



Paradise metasedimentary gneiss



Paradise Arm pluton



Dykes Lake mafic intrusion



Paradise Arm pluton and Long Range dyke



White Bear Arm complex amphibolite **Slabs 3.** *Stained slabs for localities 2.1-2.6.*





Alexis River anorthosite



Pegmatite (K-fs - yellow; albite - pink; plagioclase - white)



Unmetamorphosed mafic dyke

L. Melville terrane metasedimentary gneiss



Granodiorite gneiss (probably early Labradorian)



Gilbert Bay dyke (or earlier)

Slabs 4. *Stained slabs for localities 2.7-2.12.*



Gilbert pebbly arkose



L. Melville terrane metasedimentary gneiss



L. Melville terrane megacrystic granitoid



Alexis River anorthosite

Slabs 5. Stained slabs for localities 2.13-2.16.



L. Melville terrane gnt amphibolite (retrograded)





L. Melville terrane leucoamphibolitic gneiss



Granodioritic gneiss (probably Labradorian) fe

Quartzofeldspathic gneiss (psammitic or felsic volcanic protolith)

13 A 08





Stop 3.7







Pitts Harbour Group pelitic gneiss



Red Bay gabbronorite 980 ± 3 Ma



Chateau Pond granite 964 ± 2 Ma



Nepheline syenite 1015 ± 6 Ma



Lower Pinware River alkali-feldspar syenite 974 \pm 6 Ma

Slabs 7. *Stained slabs for localities 4.1-4.6.*



Pinware K-feldspar seriate granodiorite 1466 ± 8 Ma



Labradorian volcanoclastic rock 1637 ± 8 Ma (Pitts Harbour Group)



L'Anse-au-Diable mafic dyke 985 \pm 6 Ma



Bradore Formation arkose



Grenvillian pegmatite 1036 ± 17 Ma



dyke 985 ± 6 Ma Microgranite intruding L'Anse-au-Diable mafic dyke Slabs 8. Stained slabs for localities 4.7-4.9.



Lourde-de-Blanc-Sablon gabbronorite boudin 1248 ± 5 Ma



Rivière-Saint-Paul granite 1526 ± 14 Ma Slabs 9. Stained sl



Bradore River K-felspar megacrystic granite 1632 ± 8 Ma



Rivière-Saint-Paul tonalite 1504 ± 9 Ma



Vieux-Fort anorthosite 975 ± 2 Ma

Slabs 9. Stained slabs for localities 5.1-5.9.



Battle Island unmetamorphosed mafic dyke Grenvillian pegmatite 1024 ± 3 Ma





Cross-bedded psammite <1204 Ma Amphibolite 1030 ± 4 Ma (metamorphic age) **Slabs 10.** Stained slabs for Battle Island, Stops 1, 2, 3 and 4.



The following are field trips organized for the GAC – MAC Meeting, St. John's 2012.

PRE-MEETING TRIPS

FT-A1	Accreted Terranes of the Appalachian Orogen in Newfoundland: In the Footsteps of
	Hank Williams

Cees van Staal and Alexandre Zagorevski

- FT-A2The Dawn of the Paleozoic on the Burin Peninsula
Paul Myrow and Guy Narbonne
- **FT-A4** Mistaken Point: A Potential World Heritage Site for the Ediacaran Biota Richard Thomas
- FT-A5 Neoproterozoic Epithermal Gold Mineralization of the Northeastern Avalon Peninsula, Newfoundland

Sean J. O'Brien, Gregory W. Sparkes, Greg Dunning, Benoît Dubé and Barry Sparkes

FT-A9 Cores from the Ben Nevis and Jeanne d'Arc Reservois: A Study in Contrasts Duncan McIlroy, Iain Sinclair, Jordan Stead and Alison Turpin

POST-MEETING TRIPS

FT-B1	When Life Got Big: Ediacaran Glaciation, Oxidation, and the Mistaken Point Biota of
	Newfoundland
	Guy M. Narbonne, Marc Laflamme, Richard Thomas, Catherine Ward and Alex G. Liu
FT-B2	Peri-Gondwanan Arc-Back Arc Complex and Badger Retroarc Foreland Basin:
	Development of the Exploits Orocline of Central Newfoundland
	Brian O'Brien
FT-B3	Stratigraphy, Tectonics and Petroleum Potential of the Deformed Laurentian Margin
	and Foreland Basins in western Newfoundland
	John W.F. Waldron, Larry Hicks and Shawna E. White
FT-B4	Volcanic Massive Sulphide Deposits of the Appalachian Central Mobile Belt
	Steve Piercey and John Hinchey
FT-B5	Meguma Terrane Revisited: Stratigraphy, Metamorphism, Paleontology and
	Provenance
	Chris E. White and Sandra M. Barr
FT-B6	The Grenville Province of Southeastern Labrador and Adjacent Quebec
	Charles F. Gower
FT-B7	Geotourism and the Coastal Geologic Heritage of the Bonavista Peninsula: Current
	Challenges and Future Opportunities
	Amanda McCallum and Sean O'Brien