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PRELIMINARY GEOLOGY OF THE TWILLICK BROOK MAP AREA (NTS 2D/04), NEWFOUNDLAND

G.S. Santos
Regional Geology Section

ABSTRACT

In 2023, a new 1:50 000-scale bedrock-mapping project commenced in the Twillick Brook map area (NTS 2D/04). The mapping survey is located in the Exploits Subzone in south-central Newfoundland, and includes metasedimentary and subordinate metavolcanic rocks of the Riches Island, St. Joseph's Cove, Salmon River Dam and North Steady Pond formations of the Ordovician Bay d'Espoir Group. In addition, plutonic phases of the North Bay Granite Suite, Missing Island Granodiorite, Matthews Pond Granodiorite, Rocky Bottom Tonalite, Partridgeberry Hills Granite and Round Pond composite pluton occur in the map area.

The area has a complex deformation history. The earliest deformation event (D_1) resulted in the transposition of beds and the formation of a foliation parallel to the northeast-striking axial plane of isoclinal folds in the Bay d'Espoir Group. A second event (D_2) formed a new generation of isoclinal folds and an axial plane cleavage at small angle to D_1 transposed beds. A third deformation event (D_3) resulted in the formation of folds ranging from open to closed with an axial plane cleavage striking northwest. A possible fourth and less well-constrained event (D_4) is associated with the formation of the east–west foliation that dominates the north part of the map area. Metamorphism is restricted to greenschist facies.

INTRODUCTION

In 2017, the Geological Survey of Newfoundland and Labrador (GSNL) initiated a bedrock-mapping project in the Bay d'Espoir area, south-central Newfoundland, resulting in an updated 1:50 000-scale map (Westhues, 2022) and associated reports (Westhues, 2017a, b; Westhues and Hamilton, 2018). Expanding on earlier mapping (Colman-Sadd, 1978, 1979, 1980a), this present project will update the geological understanding of the Twillick Brook map area (NTS 2D/04). Field mapping benefitted from recent airborne magnetic surveys (Kilfoil, 2019, 2021), and will focus on expanding the limited whole-rock geochemistry, isotopic, and geochronology framework of the area. This report describes preliminary results from 2023 field survey, including field descriptions of the units, preliminary structural interpretations and avenues of further research.

PREVIOUS WORK

Slipp (1952) mapped the northwestern corner of the area near Round Pond, at a 1:24 000 scale. Anderson and Williams (1970) produced the first bedrock map covering the entire Twillick Brook area, at a scale of 1:250 000. The work of Slipp (1952), and Anderson and Williams (1970) preceded the construction of the Bay d'Espoir hydro system and the subsequent flooding of the reservoir that today covers most of the western half of the map area. The most recent bedrock geology mapping and accompanying reports for the area are the Bay d'Espoir 1:50 000-scale mapping campaign by Colman-Sadd (1978, 1979, 1980a).

Anderson and Williams (1970) interpreted the metasedimentary and metavolcanic units in the Twillick Brook area as forming a link between the Bay d'Espoir Group (Anderson, 1967) in the south and the Gander Lake Group (Jenness, 1963) in the north. Colman-Sadd (1980a) interpreted the same rocks as part of the Bay d'Espoir Group, reporting a conformable contact between the units in the St. Alban's and Twillick Brook areas and the Bay d'Espoir series described by Jewell (1939).

REGIONAL GEOLOGY

The Twillick Brook map area in south-central Newfoundland covers part of the Exploits Subzone of the Dunnage Zone, one of the major tectonostratigraphic divisions in Newfoundland (Williams, 1979; Figure 1). The Dunnage Zone is separated from the Humber Zone in the east and the Gander Zone in the west by orogen-scale faults, although stratigraphic and tectonic relations between these tectonostratigraphic divisions are complex in central Newfoundland (*e.g.*, Currie, 1991; Colman-Sadd *et al.*, 1992; Valverde-Vaquero *et al.*, 2006; Zagorevski *et al.*,

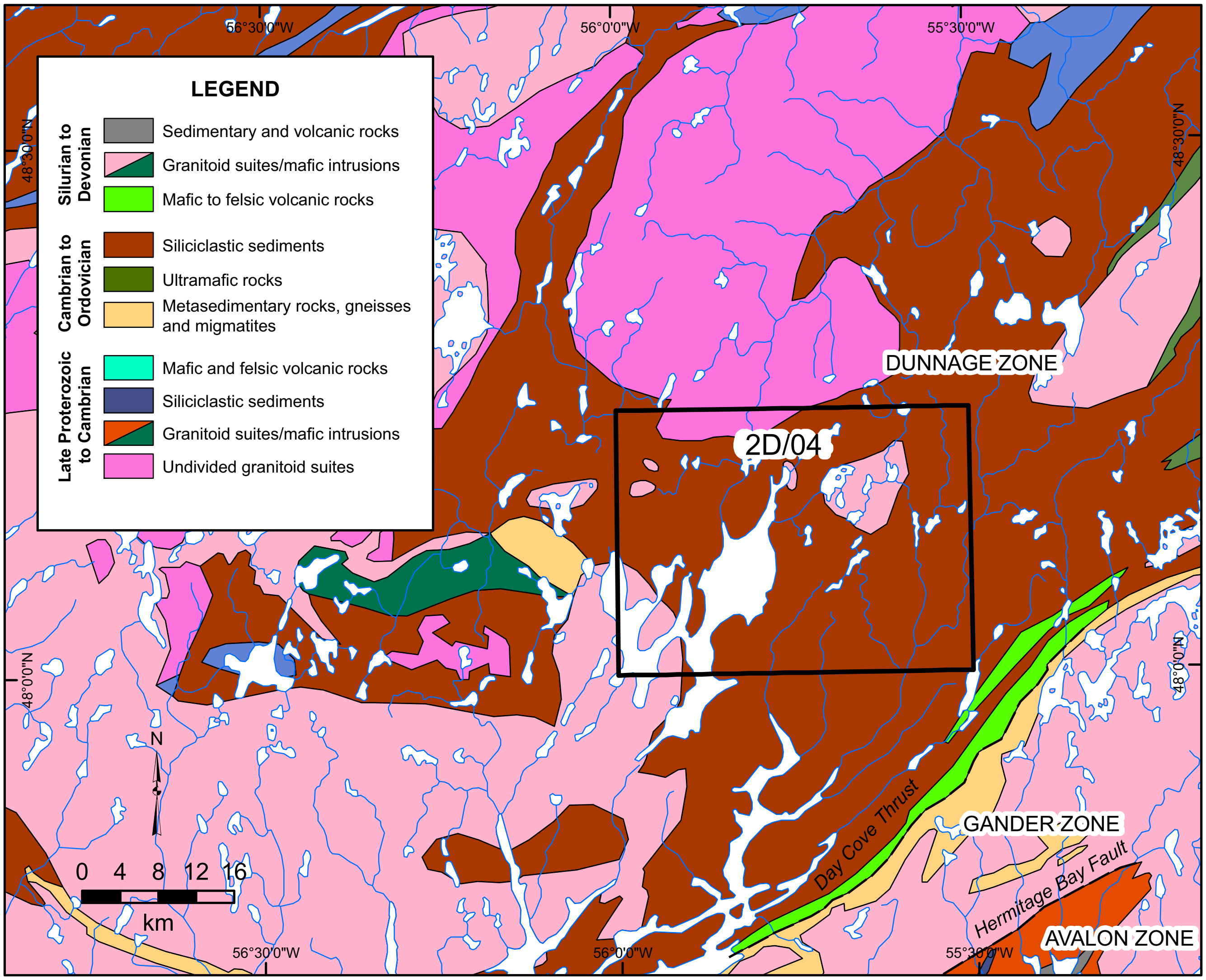


Figure 1. *Simplified regional geology of south-central Newfoundland (modified after Colman-Sadd* et al.*, 1990) and information from the GSNL geoscience atlas, showing the location of NTS map area 2D/04 and major tectonostratigraphic zones.*

2010). The Dunnage Zone mainly comprises Peri-Laurentian (Notre Dame Subzone) and Peri-Gondwanan (Exploits Subzone) continental and oceanic-arc terranes related to the evolution of the Iapetus Ocean (van Staal and Barr, 2012).

The Exploits Subzone in the Twillick Brook area consists of the metasedimentary and metavolcanic sequences of the Ordovician Bay d'Espoir Group. The Bay d'Espoir Group (Colman-Sadd, 1976, 1980a; Westhues and Hamilton, 2018) comprises metasedimentary and subordinate metavolcanic rocks, interpreted as back-arc and intra-oceanic-arc rocks, formed on the Gondwanan margin of the Iapetus Ocean (Colman-Sadd, 1980b; van Staal *et al.*, 1998; Westhues and Hamilton 2018). Colman-Sadd (1980b) correlated the Bay d'Espoir, Davidsville and Gander groups and proposed a model where they were deposited in an Ordovician back-arc basin that developed in the eastern margin of the Iapetus Ocean. More recently, van Staal *et al.* (2021) correlated the Bay d'Espoir Group to several other metasedimentary and metavolcanic units across the Northern Appalachians, interpreting them as unconformably overlying the metasediments of the Gander Group and Penobscot ophiolites. In their model, the Bay d'Espoir Group and their correlatives were deposited on the trailing passive margin of the Tetagouche–Exploits back-arc basin, following the 470 Ma rift of the Popelogan–Victoria arc from the Gander Margin (Valverde-Vaquero *et al.*, 2006; Zagorevski *et al.*, 2010; van Staal *et al.*, 2021; Figure 2).

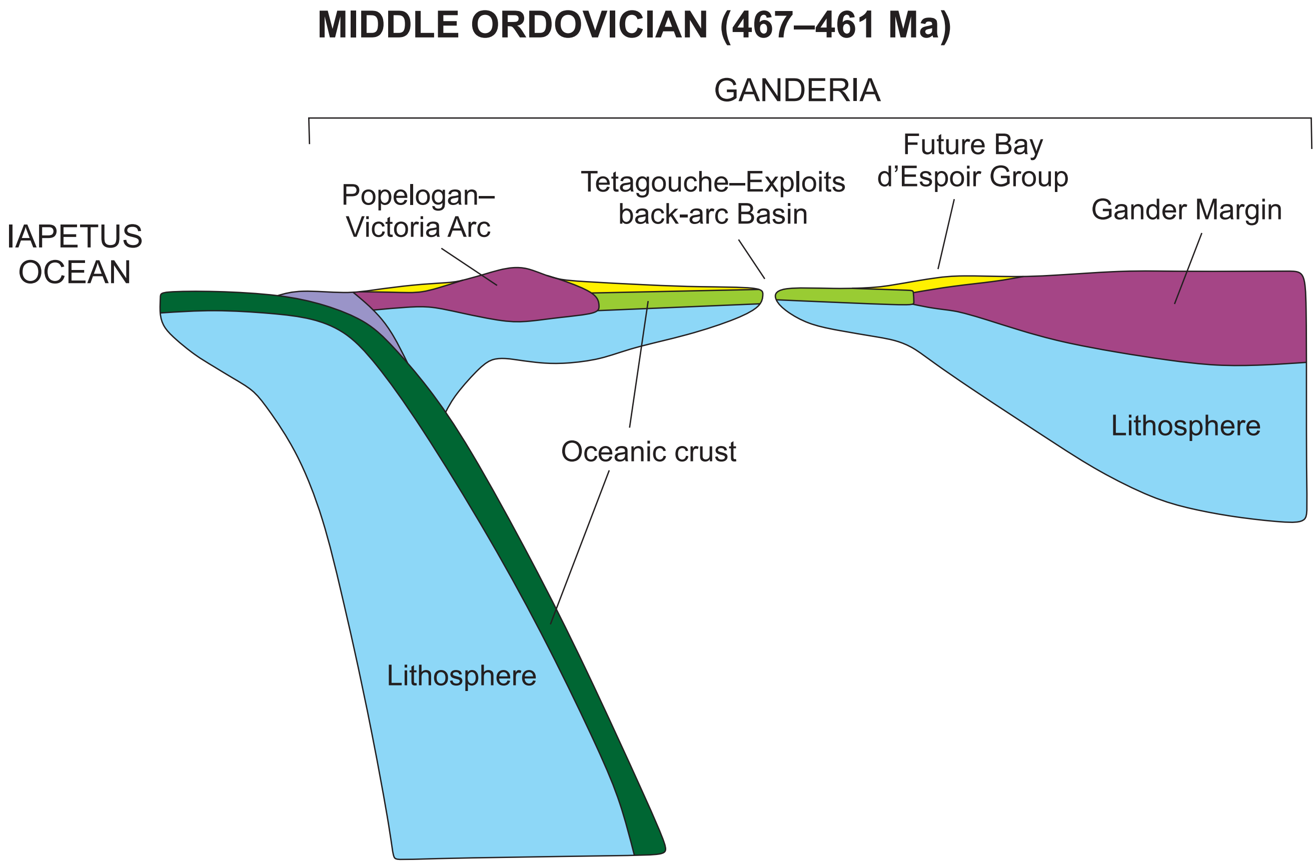


Figure 2. *Tectonic setting of the Bay d'Espoir Group. Deposition of the Bay d'Espoir Group likely took place in the passive side of the Tetagouche–Exploits back-arc basin, unconformably overlying the Gander Group (modified after van Staal* et al.*, 2021.*

GEOLOGY OF THE TWILLICK BROOK AREA

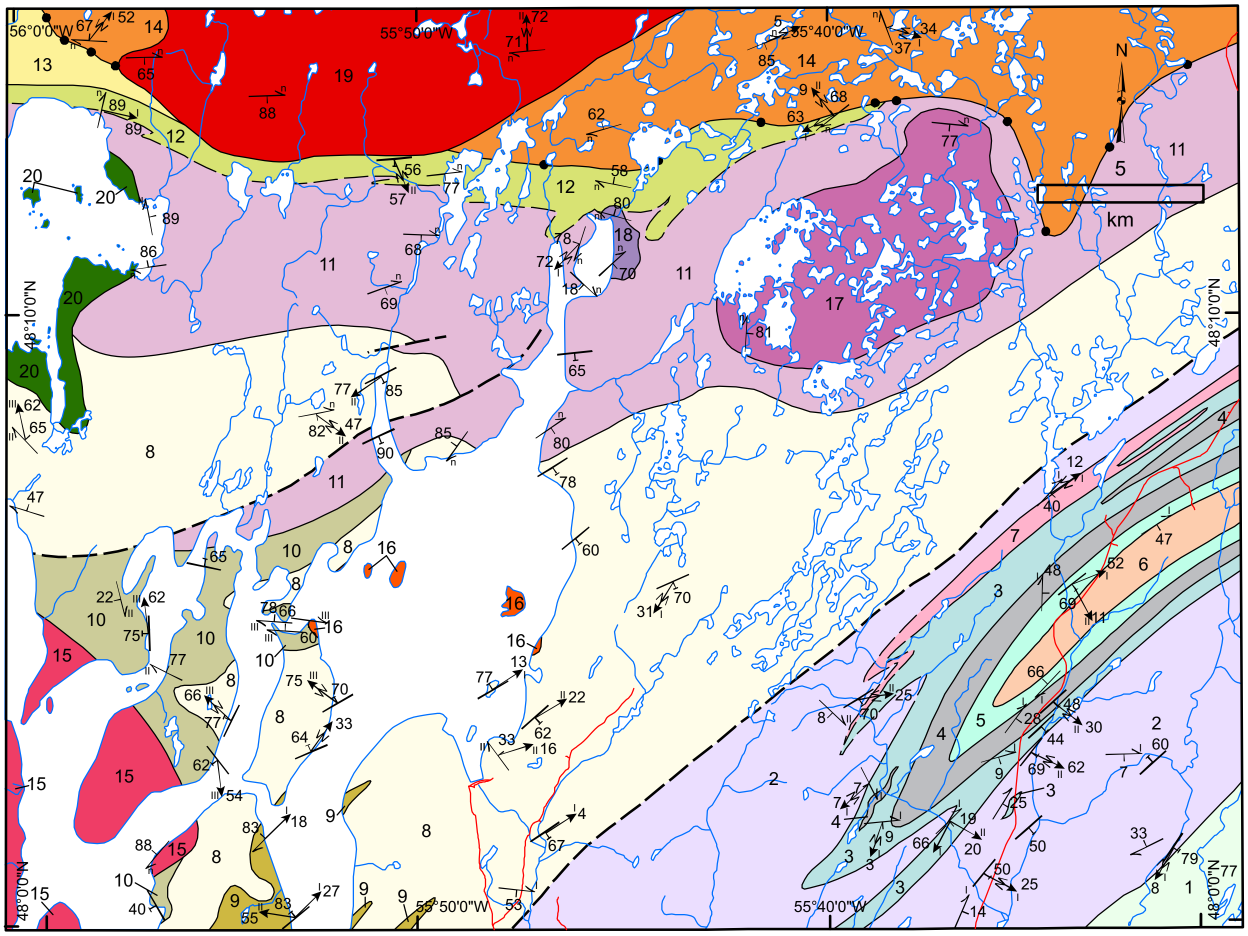
BAY D'ESPOIR GROUP

The Bay d'Espoir Group in the Twillick Brook map area is divided, from southeast to northwest, into the Riches Island Formation, St. Joseph's Cove Formation, Salmon River Dam Formation and North Steady Pond Formation (Colman-Sadd, 1980a; Figure 3). Paleontological and geochronological constraints for the Bay d'Espoir Group are relatively limited. Boyce *et al.* (1993) reported deformed trilobite pygidium in a shale from the Riches Island Formation suggesting a 470–467 Ma age range. Colman-Sadd *et al.* (1992) reported a U–Pb TIMS date of 468 ± 2 Ma age for a rhyolite from Twillick Brook Member of the Riches Island Formation. Working in the St. Alban's area just south of Twillick Brook, Westhues (2022) reported U–Pb TIMS dates of 442.12 ± 0.55 Ma for a felsic metavolcanic sample in the St. Joseph's Cove Formation, and 466.70 ± 0.46 Ma for a dacite in the Riches Island Formation. It is unclear if the felsic metavolcanic sample or the dacite dated by Westhues (2022) are intruding or if they are part of the Riches Island Formation.

Metamorphism in the Bay d'Espoir Group does not exceed greenschist facies. Chlorite is the most widespread index mineral. Unit 2 preserves chloritoid porphyroblasts, up to 2 mm long, in outcrops along Twillick Brook. Field descriptions of the map units in the Bay d'Espoir Group, exposed in the Twillick Brook map area, are presented. All colour descriptions refer to fresh surfaces unless explicitly stated otherwise.

Riches Island Formation (Unit 1)

The Riches Island Formation outcrops in a small area in the southeast corner of the Twillick Brook map area (Figure 3). It mainly consists of a light-green to light-blue, strongly cleaved phyllite (Unit 1), which appears light grey in strongly weathered outcrops (Plate 1A). Disseminated euhedral pyrite grains, up to 1-mm wide, are common. This unit also contains beds of light-blue, fine-grained meta-arenite that can constitute up to 30% of the unit. These arenite beds are



LEGEND

Post Ordovician Intrusive Rocks

Round Pond Composite Pluton

20	Composite intrusion. Medium-grained, equigranular to sub-ophitic olivine gabbro, with green amphibole partially replacing clinopyroxene. Fine-grained, equigranular biotite–tonalite. Light-pink, foliated, medium-grained biotite–granodiorite, with abundant euhedral titanite grains up to 2 mm long

Partridgeberry Hills Granite

19	Light-orange, medium-grained, equigranular leucocratic biotite syenogranite. Locally megacrystic, with K-feldspar megacrysts up to 5 cm long in a medium-grained groundmass of K-feldspar, quartz, plagioclase and biotite

Rocky Bottom Tonalite

18	Weakly foliated, medium-grained, equigranular biotite–tonalite

Matthews Pond Granodiorite

17	Medium-grained, equigranular biotite–monzogranite to granodiorite

Missing Island Granodiorite

16	Light-yellow, isotropic, fine- to medium-grained leucocratic-biotite–granodiorite

North Bay Granite Suite

15	White to pink, megacrystic biotite monzogranite. K-feldspar forms megacrysts up to 7 cm long in a medium-grained groundmass of quartz, K-feldspar, plagioclase and biotite

Ordovician

North Steady Pond Formation

14	Light-grey to light-orange, porphyritic metadacite, with euhedral quartz and plagioclase phenocrysts reaching up to 30% of the rock
13	Dark-blue, medium-grained meta-arenite. Contains up to 20 cm thick beds of a a coarse-grained meta-arenite and cm-scale strongly cleaved dark-blue meta-argillite
12	Light-green, strongly foliated slate
11	Light-blue to light-green, slate and phyllite interbedded with light-blue, fine-grained meta-arenite

Salmon River Dam Formation

10	Light-grey, locally rusted, biotite-rich, fine- to medium-grained meta-arenite. Interbedded with light-grey garnet schist
9	Rusted to grey, metasiltstone and meta-arenite interbedded with rusted meta-argillite
8	Light-blue, fine-grained meta-arenite interbedded with light-blue meta-argillite

St. Joseph's Cove Formation

7	Strongly crenulated, dark-green chlorite schist and white muscovite schist
6	Dark-grey porphyritic metarhyolite, with up to 20% rounded quartz and minor K-feldspar phenocrysts.
5	Light-green to white, fine- to medium-grained meta-arenite
4	Dark-grey, graphitic phyllite, with abundant disseminated pyrite and minor chalcopyrite
3	Light-blue, fine-grained meta-arenite, with subordinate light-green metasiltstone
2	Light-blue, interbedded slate and fine-grained meta-arenite

Riches Island Formation

1	Light-green to light-blue, strongly cleaved phyllite. Contains up to 30% of a light-blue fine-grained meta-arenite

SYMBOLS

Contact (defined, approximate)....................................

Unconformity (approximate, inferred)............................

Faults...

Bedding (transposed)...

Cleavage (S_1, S_2, S_3, S_n).. I, II, III, n

Lineation (L_{c1}, L_{c2}, L_{c3}).. I, II, III

Lineation (L_{f1}, L_{f2}, L_{f3})... I, II, III

Figure 3. *Preliminary geological map of the Twillick Brook map area (NTS 2D/04), showing selected structural observations.*

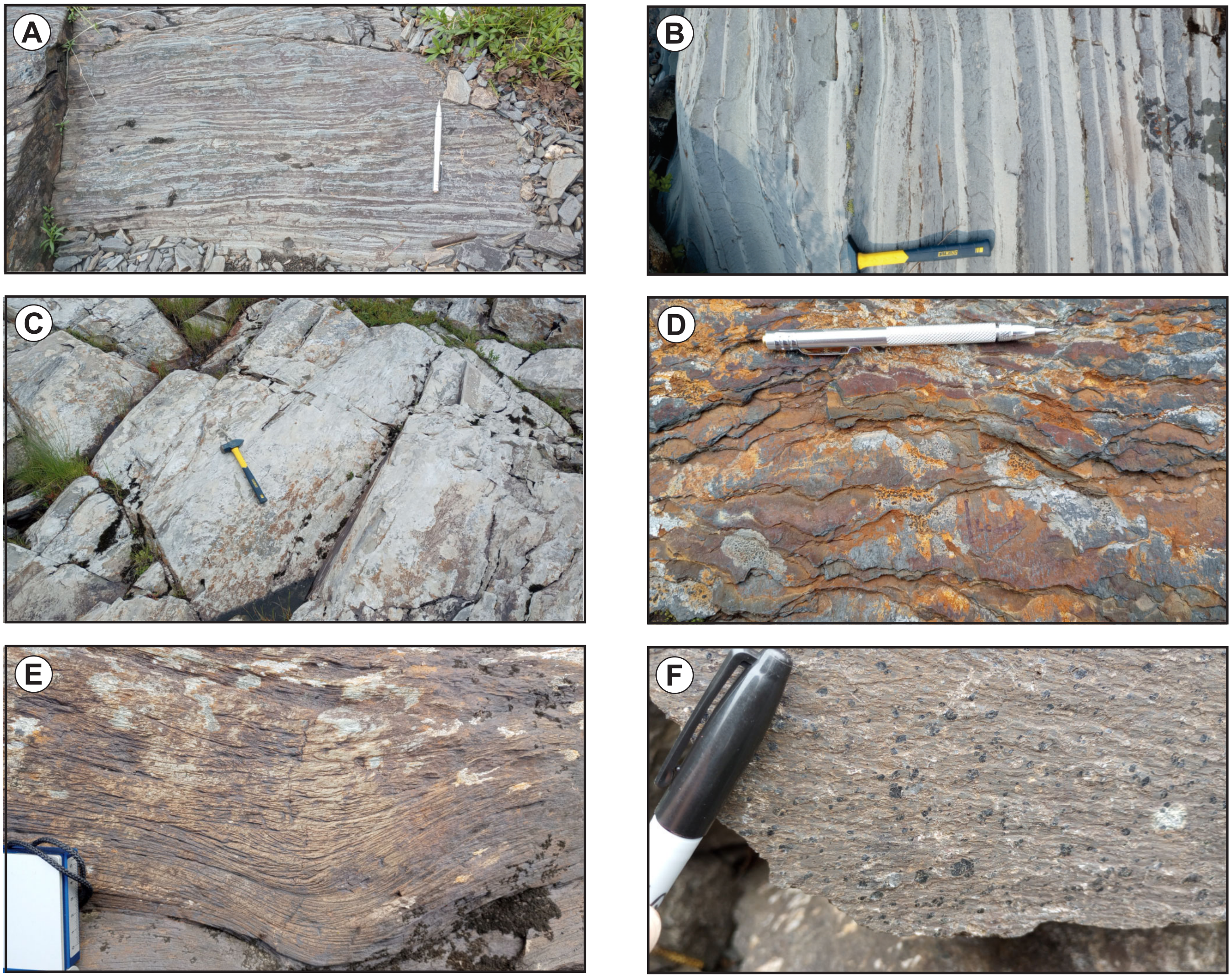


Plate 1. *The Riches Island and St. Joseph's Cove formations. A) Representative fresh, light-blue phyllite, with beds of fresh, crosslaminated meta-arenite (lighter colour), Riches Island Formation; B) Interbedded, cleaved, blue meta-argillite and light-blue meta-arenite; C) Light-blue, fine-grained arenite; D) Rusted graphitic slate showing a well-developed cleavage and crenulation lineation; E) Light-grey, medium-grained, crosslaminated meta-arenite; F) Porphyritic rhyolite, and rounded dark quartz phenocrysts (~2 mm); G) Crenulated muscovite schist, cut along the cleavage by quartz veins ~0.5 cm wide.*

up to 1.5 cm thick, and in one recorded outcrop preserves parallel- and crosslaminations.

St. Joseph's Cove Formation (Units 2–7)

The St. Joseph's Cove Formation outcrops northwest of the Riches Island Formation (Figure 3), and is well exposed along Conne River, Twillick Brook and Bernard Brook. It mainly consists of meta-argillite and slate interbedded with fine-grained meta-arenite. The formation also contains one unit of felsic metavolcanic rocks. Similar to the Riches Island Formation, primary sedimentary structures in the meta-arenites in the St. Joseph's Cove Formation are rarely preserved.

Unit 2 of the St. Joseph's Cove Formation is a light-blue, interbedded slate and meta-arenite, with slate forming between 20 and 90% of the sequence in any given outcrop (Plate 1B). Beds of slate and meta-arenite are respectively up to 10 and 15 cm thick, but are typically in the 2–7 cm range for both lithologies. Meta-arenite beds commonly show sharp basal contacts, and are fine grained, with moderate- to well-sorted grains. Meta-arenite beds are typically massive, but locally are planar- and crosslaminated. Slates show well-developed cleavage, and meta-arenite beds show weak to absent penetrative deformation. Unit 3 is well exposed along Twillick Brook and Bernard Brook, and consists of a light-blue, fine-grained meta-arenite, with subordinate light-green metasiltstone (Plate 1C). Quartz veins reaching 5 cm in thickness forming up to 25% of the outcrop are widespread in this unit. Cleavage is better developed in the meta-siltstone than in the meta-arenite.

Unit 4 is a dark-grey, graphitic phyllite (Plate 1D). Disseminated pyrite and minor chalcopyrite reach up to 10% of the rock, giving this unit a distinctive yellow to orange staining. Pyrite grains are euhedral and up to 2-mm wide. Cleavage is more strongly developed in this unit compared to other units in the St. Joseph's Cove Formation. Quartz veins are ubiquitous. This graphitic phyllite also appears as lenses up to 100-m long and 20-m wide in units 2 and 3 (Figure 3).

Unit 5 is a light-green to white, fine- to medium-grained meta-arenite (Plate 1E) and is poorly exposed. This unit shows a poorly developed cleavage. Grains in the meta-arenite are rounded. The meta-arenite contains massive beds up to a metre thick. Less typical crosslaminated beds up to 40 cm thick were also observed.

Unit 6 is a porphyritic metarhyolite, and it corresponds to the Twillick Brook member defined by Colman-Sadd (1980a). Rounded, dark-grey quartz phenocrysts, up to 2 mm in diameter, form about 20% of the rock (Plate 1F). Locally, euhedral plagioclase is also present as phenocrysts in similar size and proportion as quartz phenocrysts. The metarhyolite shows a weak foliation that anastomoses around the phenocrysts and contains meta-argillite xenoliths up to 2 cm long.

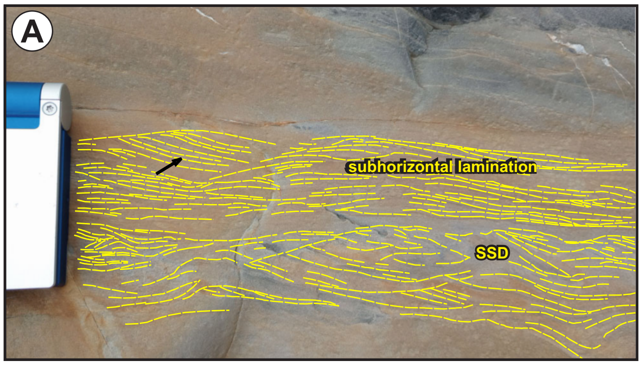
Unit 7 consists of strongly crenulated dark-green chlorite schist and white muscovite schist (Plate 1G). It contains euhedral rusted pyrite grains, and is locally cut by quartz veins. The quartz veins are up to 2-cm wide, and form 5–10% of the outcrop. Exposure of this unit is limited to the headwaters of both Twillick Brook and Bernard Brook.

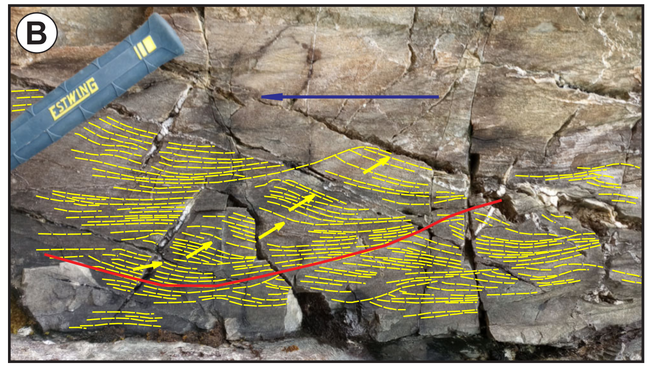
Salmon River Dam Formation (Units 8–10)

The Salmon River Dam Formation mainly comprises interbedded meta-arenite and meta-argillite. This formation has the best-preserved primary sedimentary structures in the Twillick Brook area.

The dominant facies in the Salmon River Dam Formation is a light-blue, fine-grained meta-arenite (Plate 2A) interbedded with a light- to dark-blue meta-argillite (Unit 8), where the proportion of meta-argillite ranges between 30 and 70% in any given outcrop. Meta-arenite and meta-argillite beds are respectively 15 and 10 cm thick, with the meta-arenite beds typically 1–3 cm thicker than the meta-argillite beds in the same outcrop. The meta-argillites show a well-developed cleavage, with penetrative deformation weakly developed in the meta-arenite. Clasts in the meta-arenite are rounded and well sorted. Subhorizontal laminations, crosslaminated beds (Plate 2A), and climbing ripples are widespread. Soft sediment deformation (SSD) structures, such as disrupted beds and slump folds, are also characteristic of this unit. One outcrop preserves centimetre-scale, crosslaminated bedforms stacked over each other, implying a relatively high sediment concentration within the flow (Plate 2B). Notably, these bedforms are migrating on an inclined erosional surface, closely resembling supercritical bedforms migrating against the prevailing flow direction (*e.g.*, Cartingny *et al.*, 2014).

An interbedded grey metasiltstone (Plate 2C) and fine-grained meta-arenite (Unit 9) outcrops in the southwestern corner of the Twillick Brook area. Rusted euhedral pyrite grains, up to 3 mm wide, gives this formation its characteristic orange staining. Beds of the meta-arenite reach up to 10 cm in thickness, and preserve widespread planar and cross-laminations. Crosslaminated sets are commonly covered by thin layers of meta-argillite and are interpreted as starved ripples. The distinctive orange weathering and the high magnetic signature associated with this unit in the aeromagnetic survey (Figure 4) makes it an excellent structural marker within the Salmon River Dam Formation.





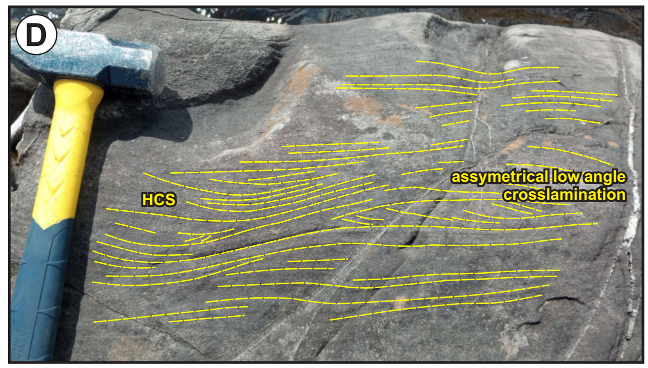


Plate 2. *The Salmon River Dam Formation. A) Light-blue, fine-grained meta-arenite showing climbing ripples (black arrow), subhorizontal lamination, and soft-sediment deformation (SSD) structures typical of Unit 8; B) Stacking of asymmetrical bedforms (yellow arrows) migrating over an inclined erosive surface (red line) seemingly against the predominant flow direction (blue arrow); C) Grey-rusted meta-siltstone, showing open D_1 or D_2 S-folds, Unit 9; D) Hummocky cross-stratification (HCS) in a grey, medium-grained meta-arenite in Unit 10; E) Interbedded, grey, medium-grained meta-arenite and chloritoid schist.*

Outcropping in the northwestern corner of the Salmon River Dam Formation, Unit 10 consists of a light-grey, biotite-rich, fine- to medium-grained meta-arenite, interbedded with a grey meta-argillite (Plate 2D, E). The meta-arenite shows slight rust-weathering. Aligned biotite grains define a weak foliation. The meta-argillite contains chloritoid porphyroblasts up to 4 mm long. Primary sedimentary structures are generally not well preserved. One outcrop with meta-arenite beds up to 40 cm thick preserves hummocky cross-stratification (HCS; Plate 2D). In close proximity to younger intrusions (*see* below), this meta-arenite becomes a quartzite or a biotite schist, depending on the proportion of biotite in the outcrop. In the area west of the contact between this unit and the Missing Island Granodiorite, this unit preserves complex fold interference patterns.

North Steady Pond Formation (Units 11–14)

The North Steady Pond Formation, which covers the northern half of the Twillick Brook map area, is composed of slates, phyllite, felsic to intermediate metavolcanic rocks and subordinate meta-arenites. It is the most poorly exposed formation in the area, with the best outcrops in the north-eastern arm of Jeddore Lake and on the eastern margin of North Steady Pond.

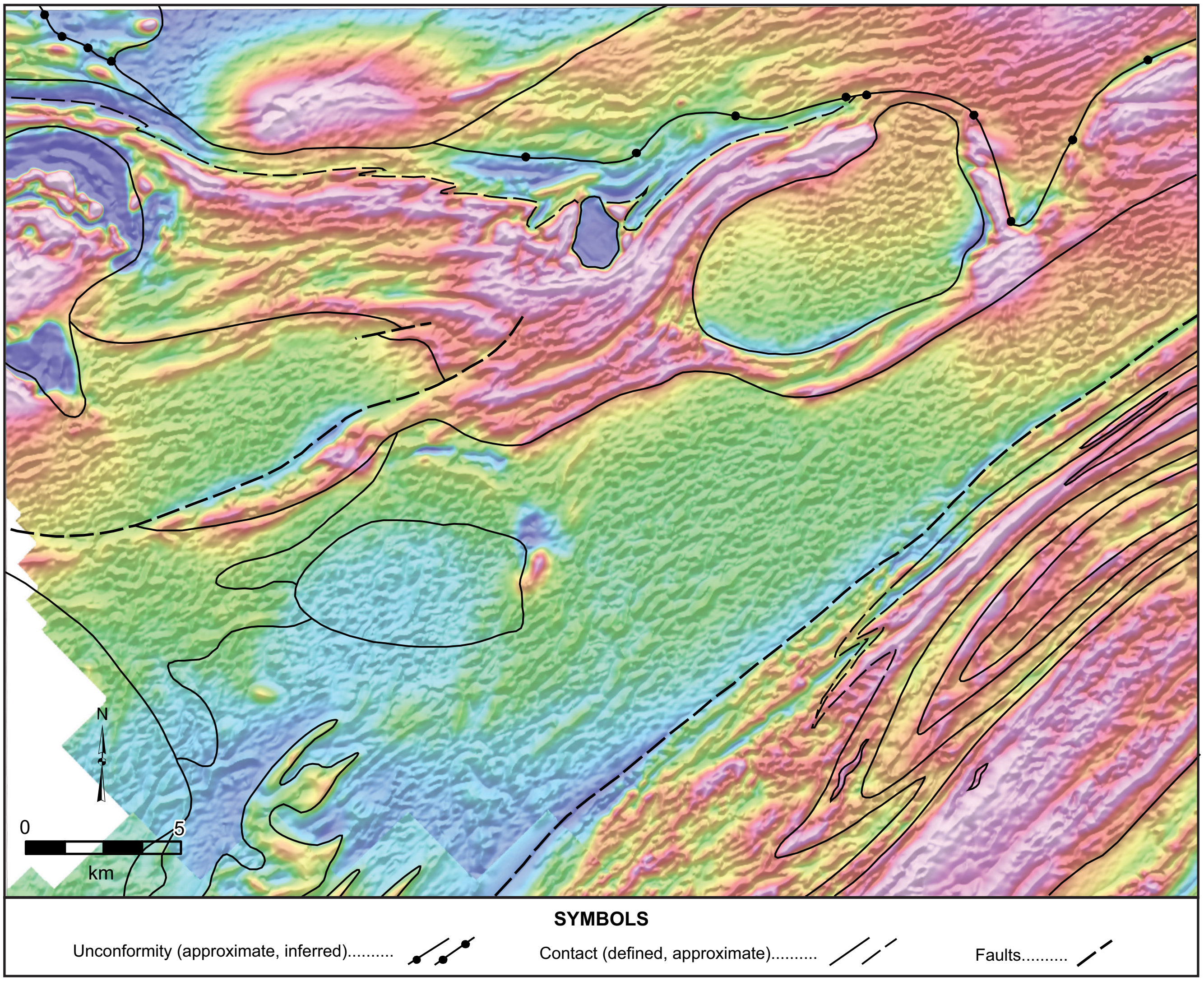


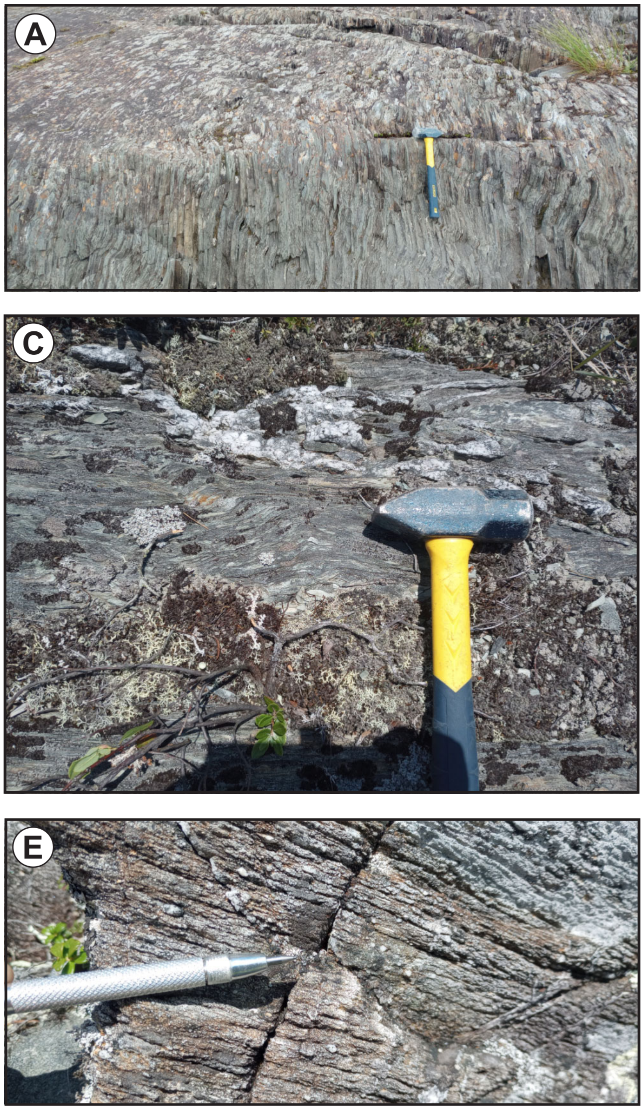
Figure 4. *First vertical derivative of the aeromagnetic survey draped over 10° magnetic tilt in the grey scale for the Twillick Brook area (Kilfoil, 2019).*

A light-blue to light-green slate and phyllite (Plate 3A, B) interbedded with light-blue, fine-grained meta-arenite (Unit 11) is the dominant lithology in the North Steady Point Formation (Figure 3). Beds vary from 1- to 5-cm thick, but typically are in the 1.5–2.5 cm range. The proportion of meta-arenite in an outcrop ranges between 30–60%.

Unit 12 is a light-green, strongly foliated slate (Plate 3C). The slate contains 0.5–1-cm-thick layers that are slightly coarser and more quartz-rich than the dominant light-green strongly foliated slate. A rare, dark-green chlorite slate is also present. All lithologies in this unit show strong penetrative deformation, with multiple generations of well-developed cleavage.

Exposed in a small area in the northwest corner of the map area (Figure 3), Unit 13 is of a dark-blue, medium-grained meta-arenite (Plate 3D). A dark-blue, meta-argillite having a strong foliation forms up to 10% of the described outcrops. Beds up to 20 cm thick of a coarse-grained arenite, with poorly sorted and subangular clasts, form up to 10% of this unit.

Metavolcanic rocks (Unit 14) are present in the northern edge of the Twillick Brook area (Figure 3). Best exposed on the western slope of the Partridgeberry Hills, Unit 14 comprises a light-grey to light-orange porphyritic metadacite (Plate 3E) having a well-developed foliation. Dark-grey, euhedral quartz and plagioclase phenocrysts, up to 2 mm long, form up to 20% of the unit. The groundmass in the metadacite has a welded texture. Based on the distribution of outcrops and the structural trends observed in the aeromagnetic surveys of the area (Figure 4), the contact between the metadacite and units 11, 12 and 13 is likely an unconformity.



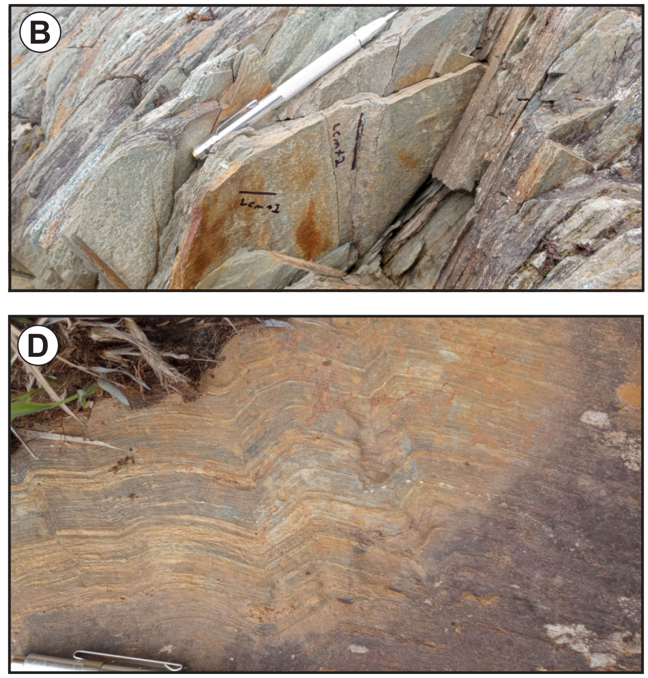


Plate 3. *The North Steady Pond Formation. A) Light-green phyllite, interbedded with fine-grained meta-arenite, showing centimetre-scale Z-folds and a well-developed crenulation; B) Detail on the outcrop presented in A, highlighting a shallow D_1 or D_2 crenulation axis and a younger, steeply plunging, likely D_3 crenulation axis; C) Green, strongly crenulated chlorite slate, cut by quartz veins; D) Light blue, slightly rusted, fine-grained meta-arenite, showing D_3 kink bands; E) Foliated, grey, porphyritic metadacite, with quartz (<2 mm) and plagioclase (<1 mm) phenocrysts.*

INTRUSIVE ROCKS

In the study area, plutonic rocks intrude the Salmon River Dam and the North Steady Pond formations (Figure 3). The North Bay Granite Suite and the Missing Island Granodiorite intrude the Salmon River Dam Formation in the southwest corner of the map. The Matthews Pond Granodiorite, Rocky Bottom Tonalite, Partridgeberry Hills Granite and Round Pond composite pluton intrude the North Steady Pond Formation in the north. No observed plutonic rocks intrude the Riches Island and the St. Joseph's Cove formations. Similar to the Bay d'Espoir Group, available geochronology constrains for the intrusive rocks are limited. Using a sample collected outside of the study area, Dunning *et al.* (1990) provided a U–Pb TIMS zircon date for the North Bay Granite at 396 +6/-3 Ma. Colman-Sadd *et al.* (1992) provided a 474 +6/-3 Ma U–Pb TIMS zircon date for the Partridgeberry Hills Granite. Similar to the Bay d'Espoir Group, colour descriptions refer to fresh surfaces unless stated otherwise.

North Bay Granite Suite (Unit 15)

The North Bay Granite Suite (Unit 15) intrudes units 9 and 11 of the Salmon River Dam Formation, and mainly comprises a white to pink megacrystic biotite monzogranite (Plate 4A). K-feldspar forms euhedral megacrysts (3–7 cm), typically displaying concentric zoning. The groundmass is medium grained, and comprises quartz, K-feldspar, plagioclase and biotite. A fine- to medium-grained equigranular variety of the monzogranite occurs in the northern edge of the North Bay Granite Suite, near the contact with Unit 11. The granite contains ellipsoidal mafic to intermediate enclaves up to 30 cm long. These mafic enclaves contain

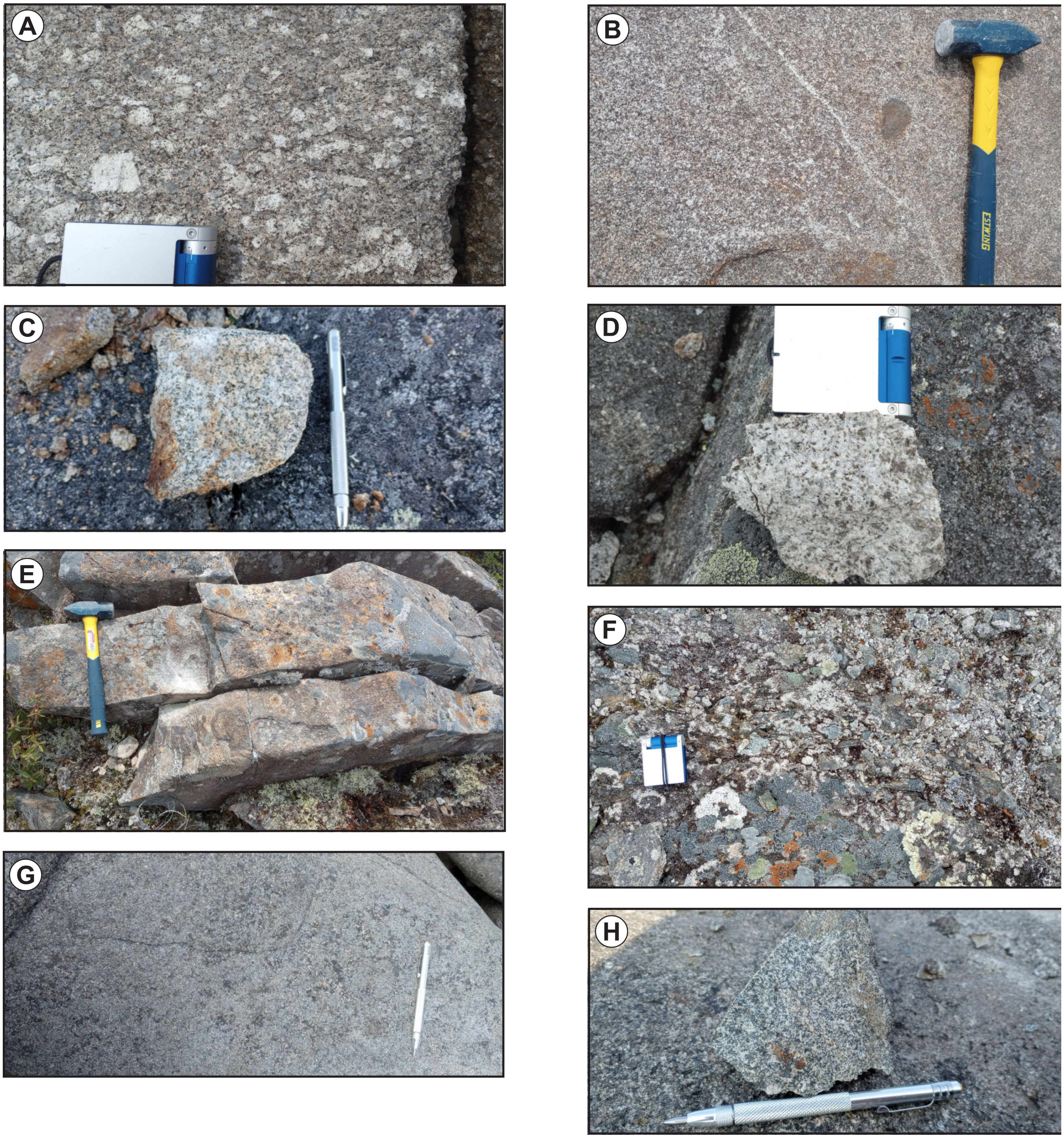


Plate 4. *Plutonic units intruding the Bay d'Espoir Group. A) Megacrystic, biotite monzogranite. K-feldspar megacrysts (<2.5 cm) occurs in a medium-grained seriate groundmass of plagioclase, K-feldspar, quartz and biotite, North Bay Granite Suite; B) Unfoliated, medium-grained, equigranular, biotite granodiorite of the Missing Island Granodiorite. Note the ~4 cm wide rounded mafic enclave; C) Medium-grained, equigranular, biotite monzogranite in the Matthews Pond Granodiorite; D) Fine- to medium-grained biotite tonalite, Rocky Bottom Tonalite; E) Medium-grained, leucocratic, biotite syenogranite, the dominant facies of the Partridgeberry Hills Granite in the map area; F) Megacrystic biotite syenogranite facies of the Partridgeberry Hills Granite; G) Fine- to medium-grained, locally sub-ophitic gabbro, the dominant facies of the Round Pond composite pluton; H) Medium-grained equigranular biotite tonalite.*

xenocrysts of quartz and plagioclase. A weak foliation defined by aligned K-feldspar megacrysts, elongated enclaves, and quartz aggregates is present in a few of the described outcrops of this granite.

Missing Island Granodiorite (Unit 16)

The Missing Island Granodiorite is a light-yellow, unfoliated, fine- to medium-grained, leucocratic biotite granodiorite (Plate 4B). The unit contains mafic enclaves up to 5 cm long forming 5–10% of the rock. The granodiorite is intruded by 2–3 cm wide aplitic dykes. Outcropping in a few islands on Jeddore Lake, the Missing Island Granodiorite intrudes units 9 and 11 of the Salmon River Dam Formation. An observed intrusive contact with Unit 11 clearly shows the grey meta-arenite forming a biotite-rich hornfels. In the eastern margin of Jeddore Lake, several boulders of the granodiorite and a hornfels of Unit 9 are present, also suggesting an intrusive contact. However, no outcrops of the granodiorite were observed on that shore.

Matthews Pond Granodiorite (Unit 17)

The Matthews Pond Granodiorite intrudes Unit 12 of the North Steady Pond Formation. This unit consists of a medium-grained, equigranular, biotite monzogranite to granodiorite (Plate 4C). Outcrops on the edges of the intrusion are finer grained than that in the centre, and also show a weak foliation defined by aligned biotite and stretched quartz grains. This foliation is parallel to the one observed in adjacent outcrops in Unit 12 and to lineaments visible in the aeromagnetic survey (Figure 4), and therefore is interpreted as tectonic. The best exposures of the intrusion are on the southern and eastern margins of Matthews Pond.

Rocky Bottom Tonalite (Unit 18)

The Rocky Bottom Tonalite outcrops along the contact between units 12 and 13 of the North Steady Pond Formation (Figure 3). It is a weakly foliated, medium-grained, equigranular biotite tonalite (Plate 4D). Aligned biotite grains and biotite aggregates define the foliation in the tonalite. Decimetre-scale xenoliths of folded metasedimentary rocks, likely belonging to Unit 12, are present along the southern edge of the intrusion and in an outcrop located along the northeastern edge of Jeddore Lake, indicating an intrusive contact with the already deformed metasediments of the North Steady Pond Formation.

Partridgeberry Hills Granite (Unit 19)

The Partridgeberry Hills Granite in the map area is a medium- to fine-grained, typically leucocratic, equigranular, biotite syenogranite (Plate 4E). Towards the interior of the intrusion, the granite becomes coarse grained and locally megacrystic (Plate 4F), with K-feldspar megacrysts (<5 cm) forming between 10–40% of the exposure. Although its contacts are not exposed, the grain size of the granite decreases to fine grained close to the contact with units 14 and 15 in the southwestern corner of the intrusion, suggesting an intrusive relationship.

The granite is cut by several east- and northeast-striking shear zones. These shear zones range in thickness between 20 cm to 5 m, and are marked by sheared quartz and biotite grains, anastomosing around plagioclase and, more typically, K-feldspar porphyroclasts. Chloritization of biotite and saussurite alteration of feldspar is pervasive in the wider shear zones, giving the granite a green colour. Sigmoidal feldspar and quartz aggregates are consistent and sinistral kinematics are present in decimetre-wide shear zones in the southwestern part of the intrusion.

Round Pond Composite Pluton (Unit 20)

Outcropping in the northwest edge of the map area, the Round Pond composite pluton is a composite intrusion, mainly comprising a medium-grained, equigranular to subophitic gabbro (Plate 4G), where green amphibole partially replaces clinopyroxene. This unit contains centimetre-scale enclaves of finer grained olivine gabbro with edges marked by clinopyroxene schlieren. Xenoliths of metasediments range from 5 to 20 cm in width. A gabbroic pegmatite intrudes the gabbro, with plagioclase and clinopyroxene grains reaching up to 6 cm in length. The other major lithology included in this unit is a grey, fine-grained, equigranular tonalite (Plate 4H), preserving a weak foliation in one outcrop. The tonalite contains disseminated pyrite and a few centimetre-scale mafic enclave and decimetre-scale xenoliths of a medium-grained melagabbro, with green amphibole replacing clinopyroxene, indicating an intrusive relationship between the two major lithologies of the Round Pond composite pluton.

A light-pink, weakly foliated, medium-grained biotite granodiorite occurs in the peninsula that marks the southeastern shoreline of Round Pond. Aligned biotite laths define the foliation, forming up to 10 to 40% of the sample. This sample contains abundant euhedral titanite grains (1–2 mm), forming approximately 2% of the granodiorite. The relationship between this granodiorite and the gabbro and tonalite described above is unclear, as no contacts are exposed.

STRUCTURAL FEATURES

Given the variability in structural styles, the Twillick Brook map area divides into three distinct structural panels

(Figure 5A). Panel I encompasses the Riches Island and the St. Joseph's Cove formations in the southeast corner. Panel II contains the Salmon River Dam Formation in the centre, and Panel III comprises the North Steady Pond Formation in northern Twillick Brook.

The structural fabric of Panel I is dominated by northeast-striking transposed beds (Figure 5B). This transposed bedding (S_n) is best preserved in the interlayering of meta-argillite and meta-arenite in Unit 2. Metre-scale isoclinal folds with axial planes parallel to S_n indicate transposition (deformation event D_1). This S_n foliation contains centimetre- to decimetre-scale parasitic S- and Z-folds with axis (F_n) shallowing plunging northeast. F_n is parallel to the widespread crenulation axis (L_{cn}) observed in the area. The slates of Unit 2 and phyllites of Unit 4 in Panel I also preserve a well-developed cleavage (S_{n+1}). The strike of this S_{n+1} (Figure 5C) cleavage forms a small angle (<15°) with the better-preserved S_n foliation, and tends to have shallower dips. Isoclinal folds with axial plane parallel to S_{n+1} occur in the shales of the Riches Island Formation, suggesting a second isoclinal folding event with fold axis (F_{n+2}) having a similar orientation to F_{n+1} (deformation event D_2) It is unclear whether D_1 or D_2 is responsible for the isoclinal folding observed at map scale. A weak, third-generation foliation (S_{n+2}) striking north to northwest, with shallow to moderate dips to west and southwest occurs in units 3 and 4 on Bernard's Brook. This foliation is associated with a steep,

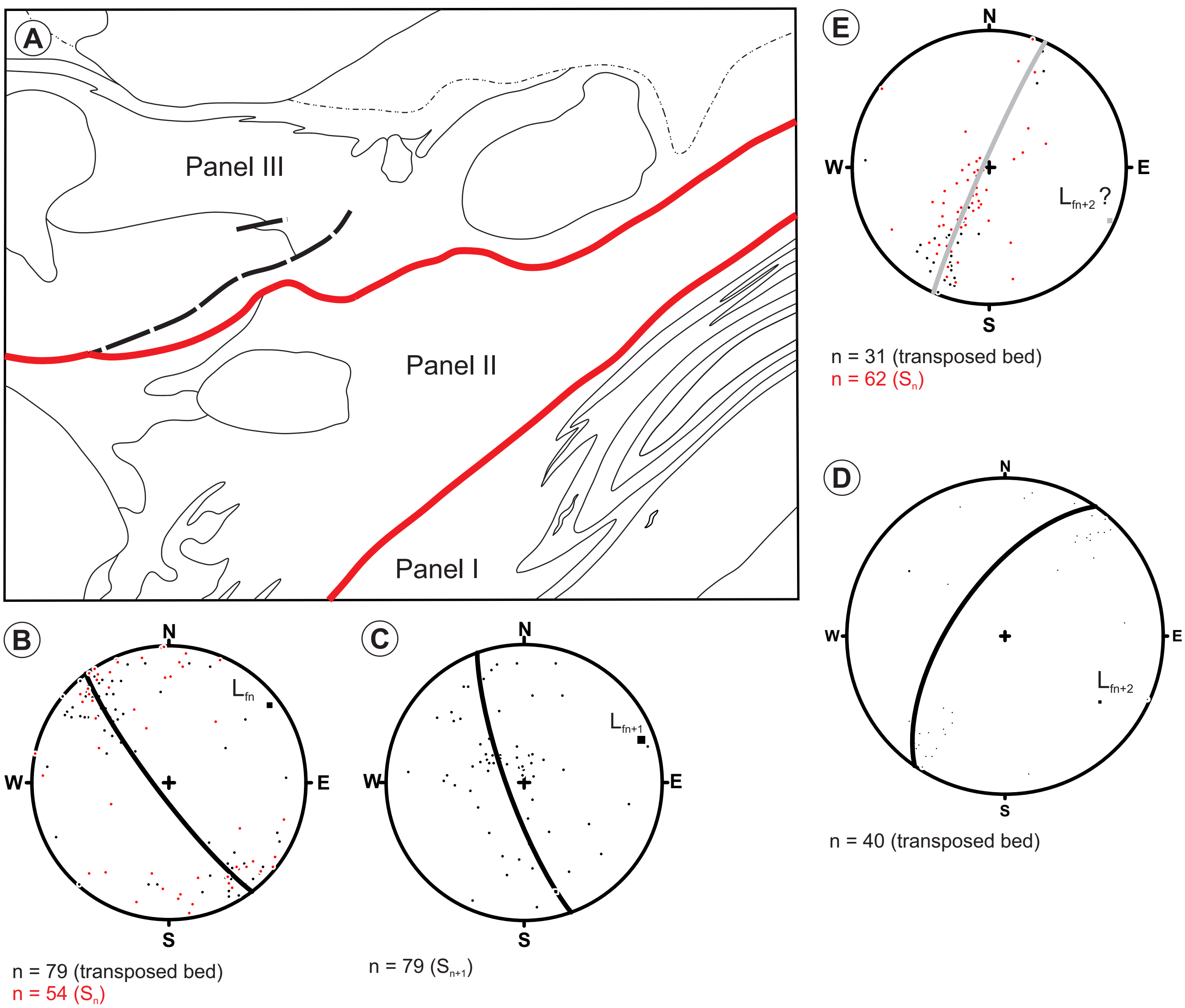


Figure 5. *Preliminary structural interpretation of the Twillick Brook map area. A) Structural subdivisions of the Twillick Brook map area; B) Transposed beds and S_n foliation of Panel I; C) S_{n+1} foliation of Panel I; D) Transposed beds of Panel II; E) Transposed beds and S_n foliation of Panel III.*

northwest-plunging crenulation axis (L_{cn+2}). This third folding (deformation event D_3) event produced open folds with an amplitude of approximately 20 km, visible on both the map pattern distribution of units and on the aeromagnetic survey (Figure 4) data in Panel I.

In Panel II, the D_1 transposed foliation and D_2 cleavage are well preserved in the interlayering of the blue meta-arenite and meta-argillite of Unit 8 of the Salmon River Dam Formation. This unit also preserves excellent F_1 folding. The major difference between panels I and II is the geometry of D_3 structures. F_3 folds in Panel II are close to isoclinal, in contrast with the open F_3 folds in Panel I. Foliation and the L_{cn+2} crenulation (Figure 5D) associated with D_3 in Panel II are preserved as a weak northwest-striking cleavage in the meta-argillites of Unit 8 and a foliation in the meta-arenites of Unit 10. D_3 M-folds in Unit 10 preserve older F_1 or F_2 folds in their hinges. These F_3 folds can also be observed in the aeromagnetic signature of Unit 9 (Figure 4), where isoclinal F_1 or F_2 folds are themselves folded by a close F_3 fold. A fourth generation foliation (S_{n+3}) is preserved in Unit 10 close to the contact with the Missing Island Granodiorite. This steeply dipping east–west striking foliation forms the most recent axial plane in the complex fold interference patterns of the grey meta-arenite of this unit (deformational event D_4).

Due to limited exposure, the structural fabric of Panel III is not as well constrained as panels I and II. Well-exposed outcrops of Unit 11 (blue meta-arenites and slates) preserve a similarly transposed bedding–cleavage relationship, reflecting the D_1 and D_2 relation recorded in the St. Joseph's Cove Formation in Panel I. Both measured bedding and cleavage planes show a major D_3 influence (Figure 5E); however, a major east–west deflection in the structural fabric is discernible on the aeromagnetic data (Figure 4), similar to the S_{n+3} foliation observed immediately south in Panel II. The extent, if any, of the limited D_4 in the structural history of Panel III remains unconstrained. The structural fabric may be deflected around the Partridgeberry Hills Granite, Rocky Bottom Tonalite and the North Bay Granite (Figure 4).

The preliminary geological interpretations provided here place the igneous units of the area in a structural context. The metarhyolites of Unit 6 show similar deformation style as the metasedimentary units of the St. Joseph's Cove Formation. Combined with the presence of metasedimentary xenoliths, the 468 ± 2 Ma, Twillick Brook member (Colman-Sadd *et al.*, 1992) likely postdates the deposition of the other units of the St. Joseph's Cove Formation and predates the events of D_1 and D_2. Foliation in the North Bay Granite Suite was observed in two outcrops, both close to the edge of the intrusion. Although both occurrences are interpreted as magmatic foliations in the field, their northeast strikes with steep dips to the southeast are similar to the D_1 and D_2 foliations. More detailed mapping of the intrusion outside of the current map area would be required to further constrain this interpretation. The Missing Island Granodiorite is massive, showing no evidence of magmatic or tectonic fabrics. The intrusive contacts with the host metasedimentary preserving the D_1–D_4 deformation indicates that this unit postdates all deformation events in the area, making it key for dating the minimum age of deformation.

In Panel III, both the Rocky Bottom Tonalite and Matthews Pond Granodiorite show tectonic foliations. Foliation is pervasive though the Rocky Bottom Tonalite, with deformation in the Matthews Pond Granodiorite restricted to the edges of the intrusion. The measured foliations in both intrusions are parallel to the foliation in the surrounding metasedimentary rocks, in outcrop and in the aeromagnetic data (Figure 4). However, the limited structural knowledge in Panel III renders tectonic interpretations ambiguous.

The relationship between the 474 +6/-3 Ma Partridgeberry Hills Granite and the surrounding units is more complex. In the area, the grain size of the granite decreases from megacrystic to medium grained towards its edge. However, the contact between the granite and the host metavolcanic and metasedimentary rocks was not observed. Both the medium-grained and megacrystic phases preserve centimetre to decimetre-thick east–west shear zones. Based on these features, the intrusion of the Partridgeberry Hills Granite likely predates the formation of the dominant structural fabric of Panel III.

FUTURE WORK

1) A detrital zircon study on the Bay d'Espoir Group would provide constrains to the late Penobscot and Salinic events in south-central Newfoundland. Furthermore, it would allow the Bay d'Espoir Group to be correlated with other metasedimentary units in the northern Appalachians.

2) Geochemical, geochronological, and isotopic investigations of the plutonic rocks intruding the Bay d'Espoir Group are of paramount importance for the understanding of the tectonic history of south-central Newfoundland. They would provide further constrains on the age, source and tectonic setting of late Penobscot and Salinic magmatism in south-central Newfoundland.

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