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# GEOLOGY OF THE WEST-CENTRAL SEAL LAKE GROUP, CENTRAL LABRADOR (INCLUDING PARTS OF NTS MAP AREAS 13K/4, 5 AND 12, AND 13L/1, 8 AND 9)

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## ABSTRACT

*The Mesoproterozoic Seal Lake Group is a supracrustal sequence of predominantly clastic sedimentary rocks and amygdaloidal basalt flows intruded by gabbro sills. The rocks are disposed in a regional-scale, doubly plunging syncline, of which the southern limb has been variably deformed and overturned to the north, adjacent to several southward-dipping Grenvillian thrust faults and ductile shear zones.*

*Strata within the core of the syncline, near the southeast-plunging western closure of the fold structure, are partially overthrust and tectonically overridden by the well-foliated, greenschist-facies rocks found on the overturned southern limb. The southern extent of the Seal Lake Group (in the map area) is marked by a complexly reactivated unconformity with older felsic volcanic and associated rocks of the Mesoproterozoic Letitia Lake Group.*

*In the southern map area, recumbent and north-verging folds, south-dipping mylonitic fabrics and other kinematic indicators affect both basement and multiphase-deformed cover rocks near the inverted sub-Seal Lake Group unconformity. These structures indicate a predominant northwestward movement along several dip-slip thrust faults. The mapped contacts of the Seal Lake Group with granitoid rocks of the late Paleoproterozoic North Pole Brook Intrusive Suite, and the early Mesoproterozoic Red Wine Intrusive Suite, are primarily faults. The original depositional boundaries separating the Seal Lake Group from older intrusive rock units were not observed.*

*Mineralization includes several significant historical copper (± silver) prospects and showings in the upper stratigraphy of the Seal Lake Group. In contrast, elevated radioactivity is recorded from supracrustal rocks found in the stratigraphically lower formations of the group and is a possible indication of uranium mineralization.*

## INTRODUCTION

During June through August, 2010, parts of NTS 1:50 000 map areas 13K/ 4, 5, and 12 and 13L/1, 8 and 9 were mapped using ground, boat, and helicopter traversing. The map area encompasses the west-central Seal Lake–Letitia Lake area and is a continuation of 1:50 000-scale bedrock-mapping effort completed in the eastern Seal Lake area (van Nostrand, 2009; van Nostrand and Lowe, 2010). The map area is located approximately 150 km northwest of the town of Happy Valley–Goose Bay, Labrador, and 60 km east of a hydroelectric access road connected to the town of Churchill Falls (Figure 1). The area is best accessed by float plane or helicopter from Goose Bay. The physiography of the map area is dominated by Seal Lake, Adeline Lake and Letitia Lake. Elevations range from 590 m in the northern plateau to 212 m at Seal Lake. The generally narrow, east-trending intervening valleys are occupied by thick alder, spruce forests and intermittent swamps. The major ice-flow direction was to the northeast, followed by a later northeast to east-southeast direction (McCuaig and Smith, 2005). Striae directions in the map area are a dominant northeast trend ($060^0$–$070^0$) and a weaker east-northeast trend ($080^0$–$090^0$).

## PREVIOUS INVESTIGATIONS

Initial geological investigations of the Seal Lake area began in the mid-1940s and led to the discovery of native copper occurrences in the Adeline Lake area (Halet, 1946; Smith, 1946). Throughout the 1950s, extensive base-metal prospecting and geological mapping of the Seal Lake area resulted in the defining of the stratigraphy, recognition of the synclinal form of the rocks and the discovery of more than 250 mineral occurrences (Scott and Conn, 1950; Evans, 1951, 1952; Christie *et al*., 1953; Brummer, 1957; Robinson, 1953, 1956; Fahrig, 1959; Brummer and Mann, 1961).

Work continued through the 1970s and 1980s, including field studies of the more significant mineral occurrences (Gandhi, 1971, 1972; Gandhi and Brown, 1975), and detailed- and regional-scale geological mapping (DeGrace, 1969; Knight, 1972; Marten and Smyth, 1975; Hibbs, 1980; Calon and Hibbs, 1980; Thomas, 1981; Ryan, 1984; Nunn, 1993). Petrochemical studies of the Seal Lake Group igneous rocks were completed by Baragar (1981) and Wilton (1989b), and Wilton (1989a, 1996) described some of the significant copper occurrences and suggested an epigenetic origin for the mineralization. Cadman *et al*. (1993, 1994) carried out comparative geochemical and geochronology studies of the mafic dykes of the Mesoproterozoic Harp Lake Complex (Figure 2) and the igneous rocks of the Seal Lake Group.

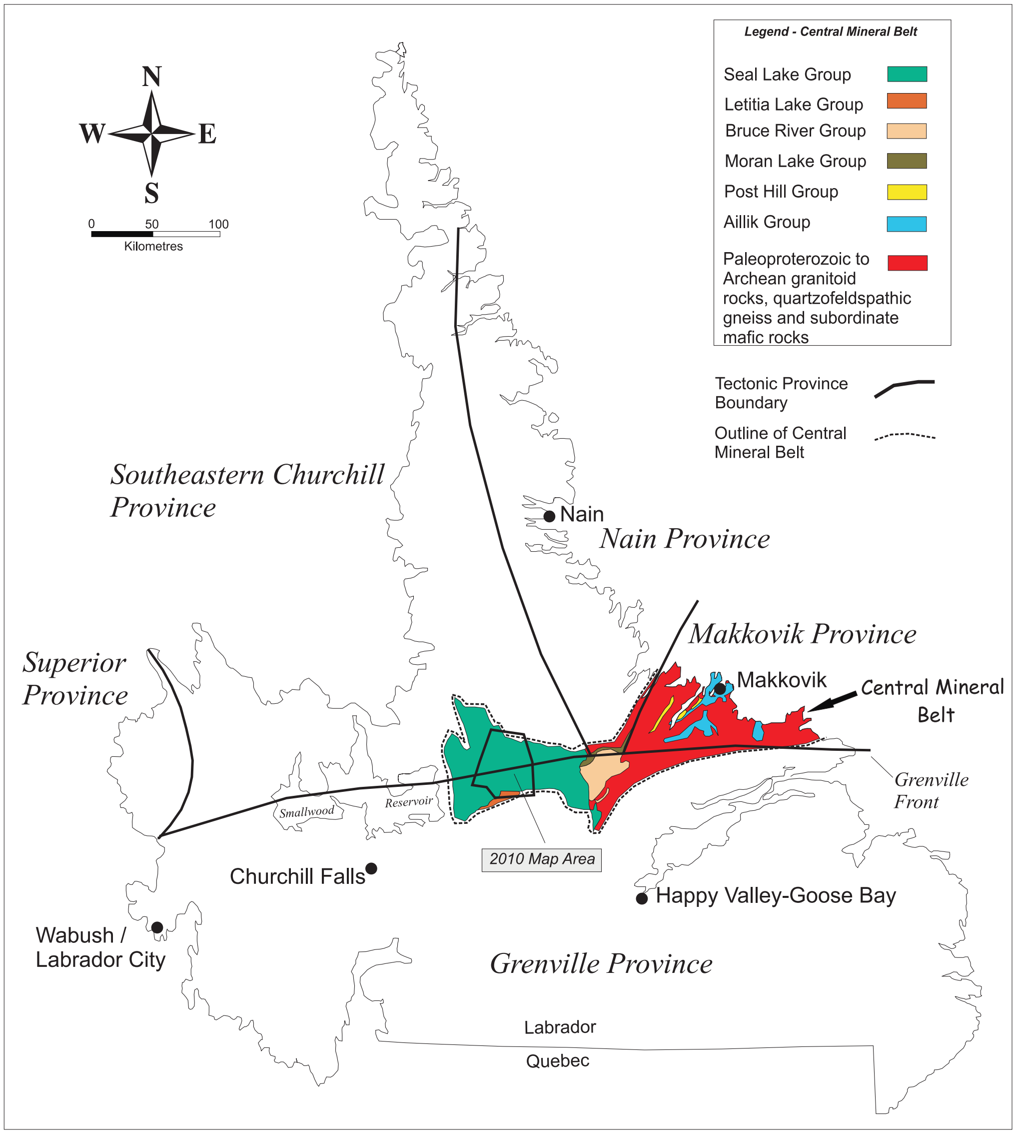



**Figure 1.** *Location of the Central Mineral Belt (outlined in dashed line), which comprises the Mesoproterozoic Seal Lake and Letitia Lake groups, the Paleoproterozoic Bruce River, Moran Lake, Post Hill and Aillik groups and Paleoproterozoic to Archean granitoid rocks, quartzofeldspathic gneiss and mafic rocks. Also shown are the location of the 2010 map area and position of the tectonic provinces of the Canadian Shield in Labrador.*

More recently, Silver Spruce Resources Limited (2006) and Capella Resources Limited (2007) completed airborne geophysical surveys of their Seal Lake area claims and Kilfoil (2008) released shaded-relief, 1:250 000-scale airborne magnetic and gravity compilations that include the Seal Lake area.

Lately, parts of NTS map areas 13K/3, 13K/4, 13K/5 and 13K/6 were systematically mapped at 1:50 000 scale (van Nostrand 2009; van Nostrand and Lowe, 2010).

## REGIONAL GEOLOGY

The Mesoproterozoic Seal Lake Group (Figure 1) is the youngest of the volcano-sedimentary sequences comprising the Central Mineral Belt in Labrador. The group unconformably overlies rocks of the Mesoproterozoic Letitia Lake Group to the southwest, the Paleoproterozoic Bruce River Group to the east, the Mesoproterozoic Harp Lake Complex to the north and Paleoproterozoic Churchill Province gneisses to the west. To the south, the Seal Lake Group is in thrust contact with Paleoproterozoic granitoids of the North Pole Brook Intrusive Suite, part of the Trans-Labrador batholith.

The group is also in thrust contact with, i) an intrusion of strongly foliated porphyritic granite that intrudes granitoid rocks of the North Pole Brook Intrusive Suite (Thomas, 1981), and ii) a small syenite pluton of the Red Wine Intrusive Suite (Miller, 1987).

## GEOLOGY OF MAP AREA

The oldest rocks in the map area are Paleoproterozoic granitoid intrusions and include, i) two small bodies of strongly foliated K-feldspar porphyritic granite southeast of Bessie Lake, ii) quartz monzonite to granite of the North Pole Brook Intrusive Suite (Figure 3), and iii) fine-grained biotite granite. These rocks underlie the southern map limit and are included in the Grenville Province. Mesoproterozoic rocks include anorthosite of the Harp Lake Complex in the northern map area, a small intrusion of the Red Wine Intrusive Suite and rocks of the Letitia Lake Group in the southwest. The youngest rocks in the map area are of the Seal Lake Group (Figure 3).

### DESCRIPTION OF ROCK UNITS

#### Paleoproterozoic Granitoid Rocks

***Subunit P1gp–K-feldspar Porphyritic Granite***

Strongly foliated K-feldspar porphyritic granite occurs southeast of Bessie Lake as an elongate body in thrust contact with the southern limit of the Seal Lake Group. A small inlier, located 2.3 km northwest of the foliated granite intrusion, is enclosed by quartz-sericite schist and is tentatively correlated with subunit P1gp (Figure 3). Thomas (1981) reported that this granite (subunit P1gp) is intruded by quartz monzonite to granite (subunit P2qm) of the North Pole Brook Intrusive Suite (*see* below).

***Subunit P2–North Pole Brook Intrusive Suite***

Granitoid rocks of the North Pole Brook Intrusive Suite (Thomas, 1981) underlie part of the southern edge of the map area (Figure 3). Two main rock types of this granitoid suite in the map area include biotite+hornblende quartz monzonite to granite (subunit P2qm) and fine-grained biotite granite (subunit P2gr)

***Subunit P2qm***

Hornblende + biotite quartz monzonite to granite is the dominant granitoid rock in the map area and is in contact with sedimentary rocks of the Seal Lake Group, along several originally arcuate-shaped or subsequently folded thrust faults. The rock ranges from pink-, white- to red-weathering, fine- to medium-grained, commonly K-feldspar porphyritic, recrystallized, and exhibits a weakly foliated to mylonitic fabric (Plate 1A). In a few localities, K-feldspar phenocrysts exhibit rotated 'tail' features and suggest a predominant dextral shear sense associated with the thrust contact (*see* Structure). Thomas (1981) noted the presence of a 10-m-long xenolith of subunit P1gp within subunit P2qm, approximately 3 km to the east of the subunit P1gp intrusion.

***Subunit P2gr***

Biotite ± hornblende granite is a relatively minor rock type and occurs as fine-grained, pink- to white-weathering, weakly to strongly foliated, recrystallized veins and m-scale intrusions intruding subunit P2qm. Subunit P2gr is not depicted on Figure 3 due to the small size of its intrusions and veins.

***Unit MH1–Anorthosite***

A small portion of the map area immediately north of the Kanairiktok River is underlain by anorthositic rocks of the Harp Lake Complex (Emslie, 1980; Figure 3). Only a few exposures of this unit were mapped and due to the extensive glaciofluvial sediments in the area, the contact with Seal Lake Group sedimentary rocks was not observed. The rocks consist of greyish white-weathering, homogeneous, medium-grained, massive anorthosite (Plate 1B). Plagioclase, pyroxene, olivine, magnetite and minor ilmenite are present

#### Red Wine Intrusive Suite

***Unit MRs–Syenite***

A small syenite intrusion of the Mesoproterozoic (*ca.* 1327 Ma) peralkaline Red Wine Intrusive Suite (Thomas, 1981; Curtis and Currie, 1981; Miller, 1987) occurs along the southern margin of the Seal Lake Group. The intrusion, referred to as the Two Tom syenite (Miller, 1987), intrudes felsic volcanic rocks at the eastern edge of the Letitia Lake Group and is in fault contact with quartz-sericite schist at the base of the Seal Lake Group (Figure 3). The syenite is host to the Two Tom Lake REE showing and Miller (1987) reported riebeckite, aegerine and feldspar as the main mineral phases.

#### Letitia Lake Group-Unit ML

Rocks of the Mesoproterozoic Letitia Lake Group underlie the southwestern margin of the map area (Figure 3). The Letitia Lake Group was originally described by Brummer and Mann (1961) as being dominated by felsic volcanic rocks. Subsequent mapping by Marten (1975), Thomas

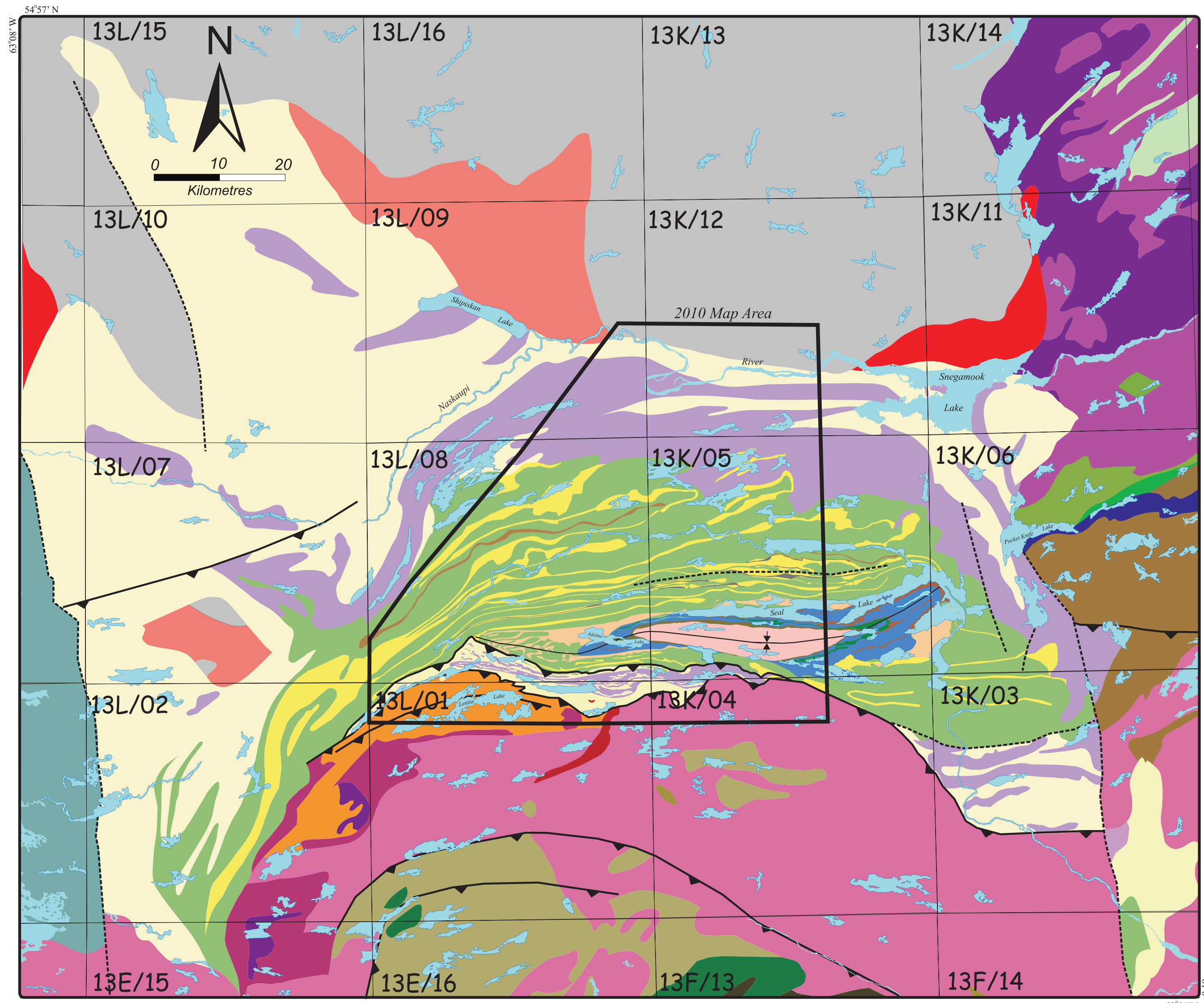



**Figure 2.** (Legend on opposite page.) *Regional geology of the Seal Lake Group and surrounding rocks. Black outline is the present map area. Geology after Wardle et al. (1997); Roscoe and Emslie (1973); Fahrig (1959); Brummer and Mann (1961); Thomas (1983); Ryan (1984); van Nostrand (2009) and van Nostrand and Lowe (2010).*

(1981, 1983) and Miller (1987, 1988) subdivided the group into three main units:

1) a basal quartz-feldspar porphyry,
2) a middle unit of rhyolite crystal tuff and ignimbrite tuff, and
3) an upper unit interpreted to be a paleoweathered 'regolith' surface of underlying units.

Only the extreme northern margin of the Letitia Lake Group was mapped in this study and two main rock units were encountered: these include moderate to strongly deformed, variably porphyritic rhyolite and intercalated felsic volcanic rocks (subunit MLr), and a banded unit consisting of complexly intercalated and deformed felsic volcanic rocks and associated sedimentary rocks, fine-grained tuff, quartz-rich schist and conglomerate (subunit MLrg).

***Subunit MLr–Rhyolite to Trachyte***

Rhyolite and associated felsic volcanic rocks are grey-, green-, to cream-weathering, fine to medium grained, variably porphyritic and complexly sheared and folded. In several areas, the rhyolite is intercalated with volcaniclastic and probable sedimentary rocks. The main rhyolitic rock consists of quartz, K-feldspar, plagioclase, clinopyroxene, aegerine and minor biotite and magnetite. Blue-grey quartz and pink feldspar phenocrysts comprising up to 10% of the rock are present in several areas (Plate 1C).

***Subunit MLrg–Regolith - Porphyritic Rocks, Fine-grained Tuff, Sericite Schist***

A part of the upper unit of the Letitia Lake Group, in the

## Legend for Figure 2

# Middle Mesoproterozoic

### **Seal Lake Group (***ca. 1270 to 1225 Ma***)**

*Upper Red Quartzite Formation*

- M6q Red-, to pink-weathering quartzite and quartzofeldspathic quartzite

*Adeline Island Formation*

- M5 Grey-, green-, red- to maroon-weathering slate, quartzite, sandstone and phyllite intercalated with variably altered basalt flows and thin gabbro sills. Sedimentary rocks in this formation are the primary host for the most significant copper prospects within the Seal Lake Group

*Salmon Lake Formation*

- M4g Fine-, to medium-grained ophitic and equigranular gabbro
- M4b Moderate to strongly foliated, massive and amygdaloidal basalt flows
- M4ms Maroon-weathering slate

*Whiskey Lake Formation*

- M3ms Thinly bedded to laminated slate, quartzite and siltstone

*Wuschusk Lake Formation*

- M2q White-, grey-, to red-weathering quartzite and quartzofeldspathic quartzite. Commonly interbedded with slate, siltstone, and shale layers
- M2st Brown-weathering, thinly bedded to laminated siltstone
- M2bs Fine-grained, black-, to grey-weathering shale. Locally record anomalous radioactive signatures
- M2g Fine-, to very coarse-grained, ophitic to equigranular gabbro sills and minor intrusions

*Majoqua-Bessie Lake formations (stratigraphically equivalent formations)*

- M1q White-, grey-, to red-weathering, massive to well-bedded quartzite and quartzofeldspathic quartzite
- M1qs White-, to light-grey-weathering, strongly foliated to mylonitic quartz - sericite schist. Stratigraphically equivalent to subunit M1q
- M1b Green-, grey-, brown-, to red-weathering basalt flows. Exhibit massive and homogenous textures to amygdaloidal, vesicular, porphyritic and locally pillow features

### **Letitia Lake Group** (*ca. 1327 Ma*)

- White-, to grey-weathering, strongly foliated rhyolite and locally trachyte. Intercalated with fine-grained felsic volcanic and probable sedimentary rocks Includes well-banded and complexely folded felsic vocanic rocks, volcanic derived sedimentary rocks of the Letitia Lake Group and quartz- and feldspar-rich rocks of the basal unit of the Seal Lake Group

### **Red Wine Intrusive Suite** (*ca. 1337 Ma*)

- MRt Peralkaline granitoids and syenite intrusions
- MR Alkaline syenite and metamorphic equivalent rocks

# Early Mesoproterozoic

### **Harp Lake Intrusive Suite** (*ca. 1450 Ma*)

- MH1 Anorthosite and associated layered mafic rocks
- MH2 Associated adamellite to granite intrusions

# Late Paleoproterozoic

### **Late Labradorian rocks** (*1660-1650 Ma, reworked during Grenvillian orogeny*)

North Pole Brook Intrusive Suite (*Trans-Labrador batholith, ca. 1650 Ma*)

- Pqm Fine-, to medium-grained, strongly foliated to mylonitic, biotite-hornblende quartz monzonite to granite. Locally K-feldspar porphyritic

Bruce River Group (*ca. 1650 Ma*)

- Intermediate to felsic volcanic rocks
- Volcaniclastic sandstone and conglomerate

### **Early Labradorian rocks** (*1680 - 1660 Ma, reworked during Grenvillian orogeny*)

- Pelitic, migmatitic metasedimentary gneiss and minor psammitic gneiss
- Mafic Intrusive Suites
- K-feldspar megacrystic granitoid rocks
- Mafic gneiss, probably of supracrustal origin

# Middle Paleoproterozoic

Moran Lake Group (*ca. 1800 Ma.*)

- Shale and sandstone
- Pillow basalt, basaltic pyroclastic rocks. Minor siltstone and greywacke

# Archean

### **Reworked Archean and Churchill Province Rocks**

- Undifferentiated gneiss (southeastern Churchill Province)
- Metatonalite and tonalite gneiss (2682 Ma to 2675 Ma) and Paleoproterozoic granitoid and mafic rocks

### **Southern Nain and Makkovik Province**

- Granodiorite and tonalite orthogneiss and abundant mafic intrusions
- Granodiorite, tonalite and minor granite (Kanairiktok Intrusive Suite, ca. 2800 Ma)
- Mafic volcanic and volcaniclastic rocks

*Symbols*

- Thrust fault
- Major and intermediate strike-slip fault
- Regional syncline axis

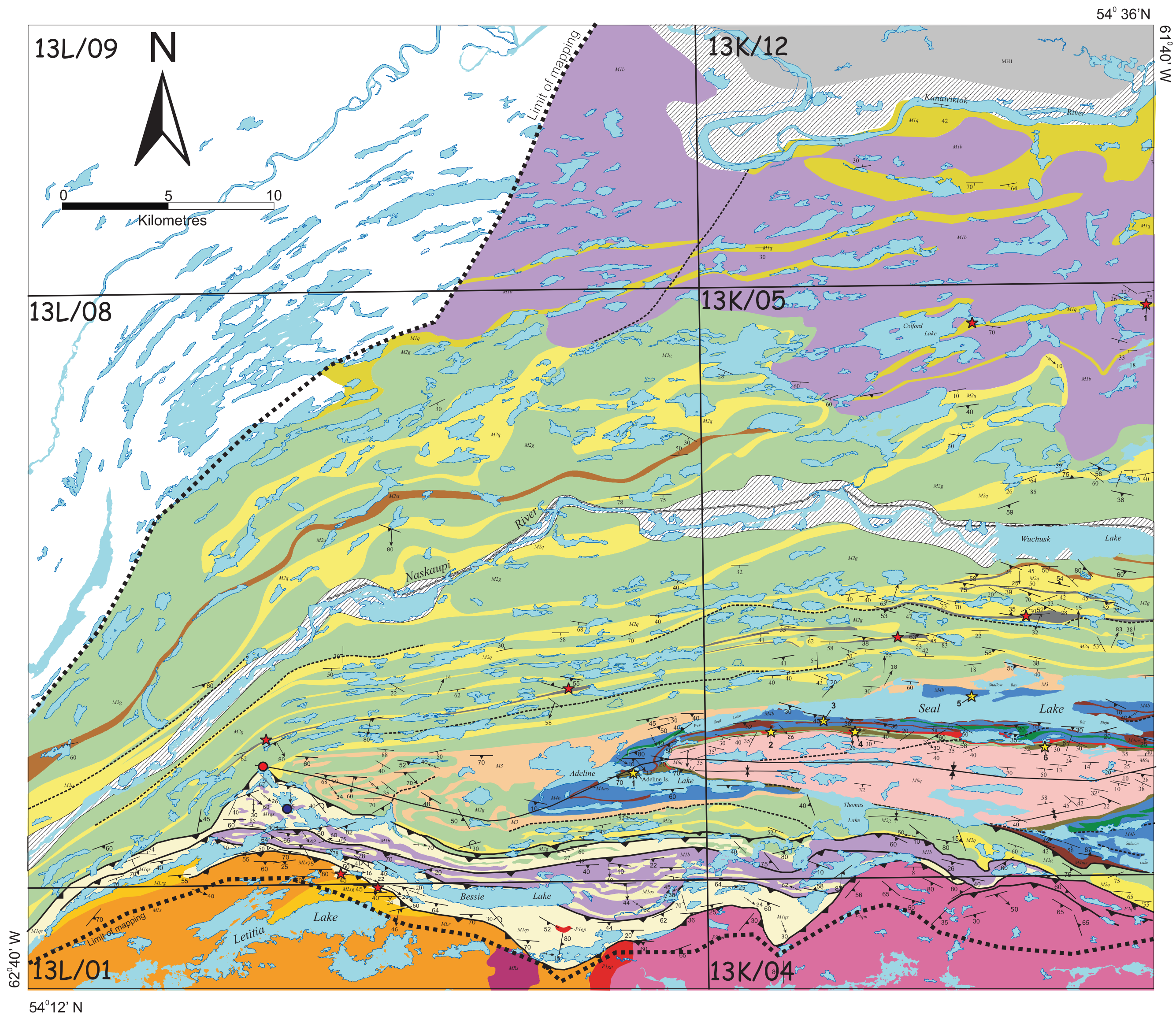



**Figure 3.** (Legend on opposite page.) *Geology of the west-central Seal Lake–Letitia Lake area, includes parts of NTS map areas 13K/4, 5 and 12 and 13L/1, 8 and 9. Geology to the south of southern mapping limit after Brummer and Mann (1961); Thomas (1981, 1983); Miller (1987).*

Bessie Lake area, was termed 'regolith' by Marten (1975) and consists of a series of light- and dark-weathering, well-banded, deformed felsic volcanic and sedimentary rocks (Plate 1D).

The bands consist of intercalated rhyolite, felsic and mafic tuff layers and quartz-, and feldspar-rich sedimentary rocks. Hematite alteration was observed as fine-grained, metallic-grey specularite, locally along layer contacts. These folded rocks are in sheared contact with the rhyolitic unit (subunit MLr) and with strongly foliated quartzite and quartz-rich schists of the Seal Lake Group (*see* discussion of Seal Lake Group–Letitia Lake Group Unconformity).

## Geology of the Seal Lake Group

Rocks of the Mesoproterozoic Seal Lake Group have been divided into six formations (*see* Robinson, 1953; Brummer, 1957; Brummer and Mann, 1961). The stratigraphic subdivision has been slightly modified based on more recent mapping by Gandhi and Brown (1975), Baragar (1981), van Nostrand (2009) and van Nostrand and Lowe (2010) and the present study. From oldest to youngest, the rocks have been divided into:

i) A division that includes both the Majoqua Lake Formation and the Bessie Lake Formation of previous workers;

# Legend for Figure 3

*Glacio-fluvial deposits*

- Unconsolidated sand and gravel
- Esker

## Mesoproterozoic

### Seal Lake Group (ca. 1270-1225 Ma)

*Upper Red Quartzite Formation*

- M6q Red-, to pink-weathering quartzite and quartzofeldspathic quartzite

*Adeline Island Formation*

- M5g Fine-, to medium-grained gabbro
- M5b Fine-grained, foliated basalt flows
- M5sl Grey-, green-, and maroon-weathering slate with pervasive cleavage.
- M5ph Grey-, to green-weathering phyllite and slate. Host to main copper sulphide occurrences in the Seal Lake Group
- M5q Red-, to pink-weathering quartzite and feldspathic quartzite

*Salmon Lake Formation*

- M4g Fine-, to medium-grained ophitic and equigranular gabbro
- M4b Moderate to strongly foliated, massive and amygdaloidal basalt flows
- M4sl Green-, and grey-weathering slate
- M4ms Maroon-weathering slate

*Whiskey Lake Formation*

- M3ms Thinly bedded to laminated slate, quartzite and siltstone

*Wuschusk Lake Formation*

- M2g Fine-, to very coarse-grained, ophitic to equigranular gabbro sills and minor intrusions
- M2q White-, grey-, to red-weathering quartzite and quartzofeldspathic quartzite. Commonly interbedded with slate, siltstone, and shale layers.
- M2st Brown-weathering, thinly bedded to laminated siltstone
- M2bs Fine-grained, black-, to grey-weathering shale. Locally record anomalous radioactive signatures

*Majoqua-Bessie Lake Formations (stratigraphically equivalent formations)*

- M1q White-, grey-, to red weathering, massive to well-bedded quartzite and quartzofeldspathic quartzite. Refers to rocks on the northern limb of regional syncline
- M1qs White-, to light grey-weathering, strongly foliated to mylonitic quartz - sericite schist. Stratigraphically equivalent to subunit M1q. Refers to rocks on southern limb of syncline.
- M1b Green-, grey-, brown-, to red-weathering basalt flows. Exhibit massive and homogenous textures to amygdaloidal, vesicular, porphyritic and locally pillow features. This subunit is variably deformed throughout map area, ranging from moderate to strongly foliated on southern limb of regional syncline to essentially undeformed on northernmost portion of northern syncline limb.

### Letitia Lake Group (ca. 1330 Ma)

- MLr White-, to grey-weathering, strongly foliated rhyolite and locally trachyte. Intercalated with fine-grained felsic volcanic and probable sedimentary rocks.
- MLrg Well banded, and complexly folded felsic volcanic rocks, volcanic derived sedimentary rocks of the Letitia Lake Group and may include quartz-feldspar-rich sedimentary rocks of the overlying Seal Lake Group.

### Red Wine Intrusive Suite (ca. 1330 Ma.)

- MRt Medium-grained, white-weathering syenite (Two Tom syenite)

### Harp Lake Complex (ca.1450 Ma)

- MH1 Medium-grained, massive, olivine-bearing anorthositic rocks

## Paleoproterozoic

### North Pole Brook Intrusive Suite (ca. 1650 Ma.)

- P2qm Weakly foliated to mylonitic, locally K feldspar porphyritic, hornblende + biotite quartz monzonite to granite. Not shown on Figure 3 are small intrusions and veins of subunit Pgr.

### Unassigned Granite (pre-North Pole Brook Intrusive Suite)

- P1gp Strongly foliated, fine-grained K feldspar porphyritic granite (intrudes Subunit P2qm).

***Symbols***

- Bedding (tops unknown)
- Bedding (tops known)
- Bedding (overturned)
- Foliation (1st generation, limited to southern margin of Seal Lake Group)
- Foliation (2nd generation, predominant fabric throughout Seal Lake Group.
- Fold axis of primarily recumbent fold structures associated with the southern margin of the Seal Lake Group
- Fold axis of open to tight, commonly north-verging fold structures observed throughout the Seal Lake Group.
- Mineral lineation
- Thrust fault, based on presence of ductile features such as mylonitic fabric, C-S relationships and rotated phenocrysts, and in part on aeromagnetic signatures. Direction of 'teeth' indicate presumed dip of thrust fault.
- Strike-slip fault, based on presence of brittle fault breccia and in part on aeromagnetic signatures.
- Major syncline structure of southern Seal Lake Group (referred to in text as Seal Lake syncline)
- Intermediate and minor syncline structures associated with main syncline structure.
- Main copper sulphide and native copper occurrences within the map area (prospects/showings: 1 - Adeline Island; 2 - Ellis; 3 - Seal Lake main; 4 - Brian; 5 - 13K/Cu/011; 6 - Duck Lake east)
- Anomalous and elevated radioactive signatures within the map area (1 - Spriggs Lake showing, non-numbered stars are unnamed elevated scintillometer readings)
- Anomalous Uranium in till sample (4 ppm U)
- Anomalous Uranium in lake sediment sample (213 ppm)
- Limit of mapping during 2010 field season

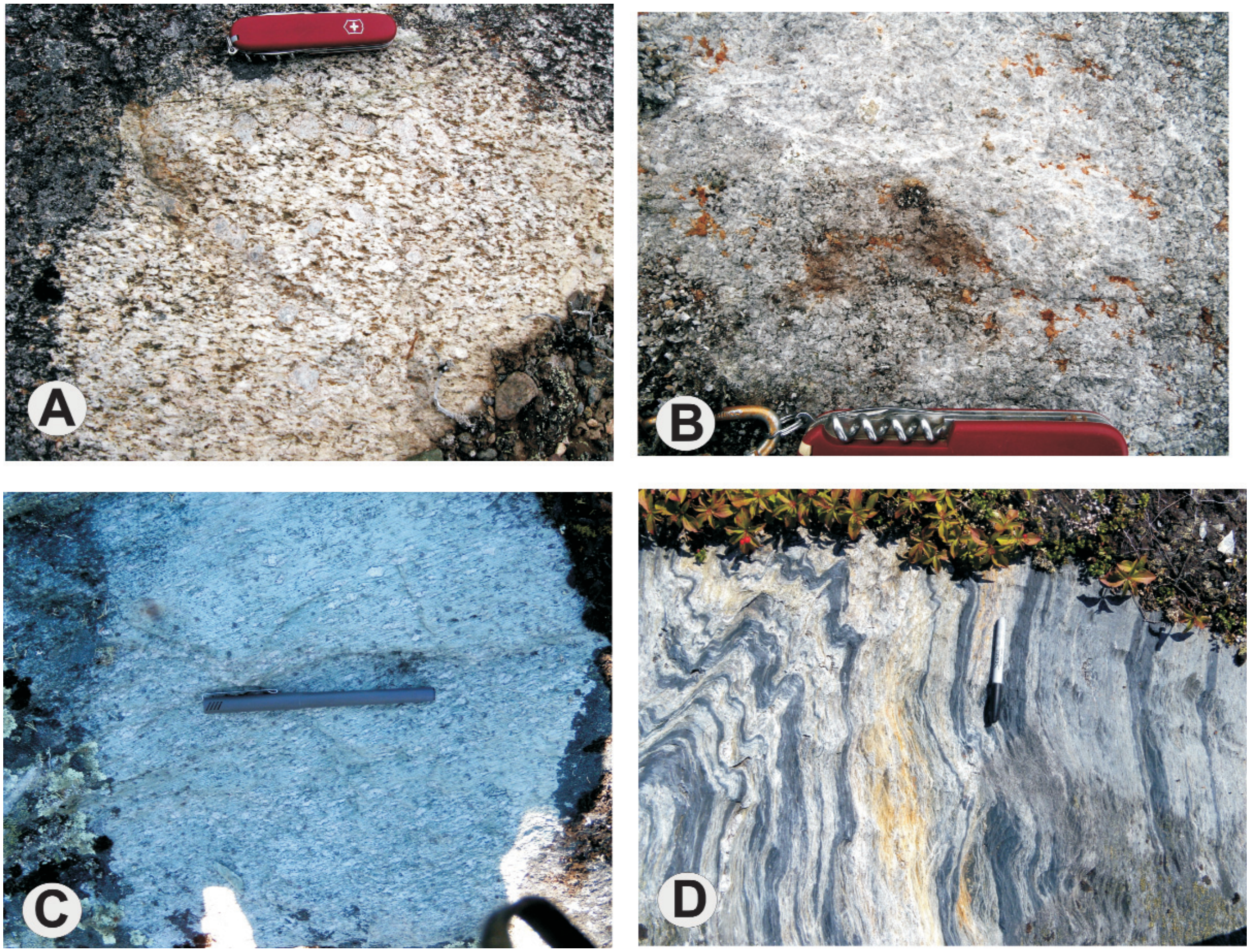



**Plate 1.** *A) Strongly foliated K-feldspar megacrystic hornblende + biotite quartz monzonite to granite (subunit P2qm) of the North Pole Brook Intrusive Suite. This unit is variably deformed along the thrust contact with sedimentary rocks of the southern extent of the Seal Lake Group. B) Grey-weathering, medium-grained, massive and homogeneous anorthosite of the Harp Lake Complex (Unit MH1), immediately north of unexposed contact with sedimentary rocks of the northern Seal Lake Group. Rusty-weathering grains are altered olivine crystals. C) Strongly foliated, K-feldspar porphyritic, medium-grained rhyolite to locally trachyte (Unit MLr). These rocks occur in contact with quartz-rich schists of the Majoqua–Bessie Lake formations, southwest of Bessie Lake. D) Well-banded 'regolith' unit consisting of intercalated layers of dark-weathering, fine-grained rhyolite ± tuffaceous rocks and light-grey to white-weathering quartz-sericite schist, and other sedimentary rocks, probably derived from felsic volcanic rocks (subunit MLrg).*

ii) Wuchusk Lake Formation;
iii) Whiskey Lake Formation;
iv) Salmon Lake Formation;
v) Adeline Island Formation; and
vi) Upper Red Quartzite Formation.

Sedimentary rocks, including quartzite, feldspathic quartzite, sandstone, siltstone, phyllite, shale, slate and minor chert and calcareous rocks, indicate a general subaerial to shallow-marine transition from lowest to highest stratigraphic levels. Basalt flows are predominantly subaerial in nature although pillow features are observed in some areas. Gabbro sills intrude rocks of the four middle formations and occur as intrusions ranging from small, 10s of m-scale, discontinuous bodies to tabular-shaped sills up to 250 m thick. The group is folded into a doubly plunging syncline, of which the southern limb has been strongly deformed and overturned to the north as a result of thrusting of older volcanic and granitoid rocks from the south. A gradational decrease in deformation and metamorphism from south to north reflects the diminishing affects of north-directed thrusting along the southern margin of the Seal Lake Group.

Widespread hematite alteration in all formations, suggests most rocks have had prolonged exposure to terrestrial, oxidizing conditions.

Numerous, historical native copper and copper sulphide occurrences are associated with the margins of basalt flows, clastic sedimentary rocks and gabbro sills of the Salmon Lake and Adeline Island formations. Only a small proportion of copper occurrences are hosted in the Majoqua–Bessie Lake, Wuchusk Lake and Whiskey Lake formations. No mineralization has been reported from the Upper Red Quartzite Formation. Elevated and anomalous levels of radioactivity are recorded from quartzite, conglomerate, shale and fine-grained tuffaceous units in the two lowest stratigraphic formations.

## DESCRIPTION OF SEAL LAKE GROUP ROCK UNITS

The stratigraphic nomenclature applied to the following description of rocks types has been modified from van Nostrand (2009) and van Nostrand and Lowe (2010). The reader should refer to Figure 3 for unit locations.

### Unit M1–Majoqua–Bessie Lake Formations

The term Majoqua Lake Formation was coined by Frobisher Limited geologists (Robinson, 1953; Brummer, 1957) to distinguish undeformed and relatively unaltered basalt flows and sedimentary rocks on the northern limb of the Seal Lake syncline from moderate to strongly deformed and altered rocks on the southern limb (Bessie Lake Formation). Subsequent mapping by several authors, including Brummer and Mann (1961), Gandhi and Brown (1975), Baragar (1981) and van Nostrand (2009) and van Nostrand and Lowe (2010) report that the rocks included in these two formations are stratigraphically and lithologically equivalent units. As some units can be traced from the northern limb to the southern limb, it would seem prudent to describe the two formations as a single division. Thus, for the purpose of this report, the two basal formations (on both the north and south limbs) of the Seal Lake Group are described collectively as the Majoqua–Bessie Lake formations. The two formations consist of extensive basalt flows and subordinate volcaniclastic rocks (subunit M1b) and intercalated sedimentary rocks, including: quartzite and feldspathic quartzite (subunit M1q), quartz-sericite schist (subunit M1qs), conglomerate (subunit M1c) and siltstone (subunit M1st).

#### *Subunit M1b–Basalt Flows*

Basalt flows in the Majoqua–Bessie Lake formations are green-, grey-, maroon-, and red-weathering, aphyric to medium grained. Basalts on the northern limb vary from having a predominant fine-grained, homogenous and nondescript appearance to rocks exhibiting amygdaloidal, vesicular, porphyritic, brecciated and locally pillow textures (Plate 2A, B and C); these are generally only weakly altered and deformed. Most of flows on the southern limb are strongly foliated schists to locally banded rocks (Plate 2D), and igneous textures are only locally preserved as strongly altered, attenuated remnants of amygdules and phenocrysts.

Igneous assemblages are relatively uniform throughout all the basalt flows and consist of plagioclase + clinopyroxene (augite) + magnetite ± olivine ± ilmenite. Plagioclase is saussuritized to varying degrees and chlorite ± tremolite ± epidote assemblages replace clinopyroxene and olivine with the most extensive alteration occurring south of Bessie and Thomas lakes. Hematite alteration is widespread and varies from slight alteration of grain boundaries, fractures and amygdules to a pervasive alteration of all phases and features in the rock.

Polygonal cooling joints on horizontal surfaces are common in flows in the northern map area; less commonly preserved in the southern basalts. In many outcrops, hematite forms maroon-weathering mantles up to 15 cm wide along joint traces (Plate 3A), and columnar jointing is well displayed in several areas, in particular, on a vertical cliff face on the south shore of Big Bight, central Seal Lake (Figure 3; Plate 3B).

#### *Subunit M1q–Quartzite, Feldspathic Quartzite, Arkose*

Mature quartzite and feldspathic quartzite are the dominant sedimentary rock in the basal formation and vary from white-, pink-, to red-weathering, fine to medium grained, and are well bedded to massive. Potassium feldspar ranges from less than 1 up to 20% of the total rock.

Crossbedding is common, and a range of attitudes suggest that several paleocurrent directions were active during sedimentation (Plate 3C).

#### *Subunit M1qs–Quartz-sericite (± Muscovite) Schist*

Subunit M1qs is stratigraphically equivalent to subunit M1q and is limited to the southern limb of the regional syncline. The rocks are white-, cream-, to light-grey-weathering, fine-, to coarse-grained, exhibit a pervasive schistose to mylonitic fabric and contain quartz, K-feldspar, minor plagioclase, magnetite, fine-grained sericite ± coarse-grained muscovite (Plate 3D). The schists are commonly intercalated with conglomerate, siltstone and volcanic rocks. Several generations of quartz veins occur throughout as boudined, folded and sheared remnants to undeformed crosscutting veins. These rocks underlie a significant portion of the

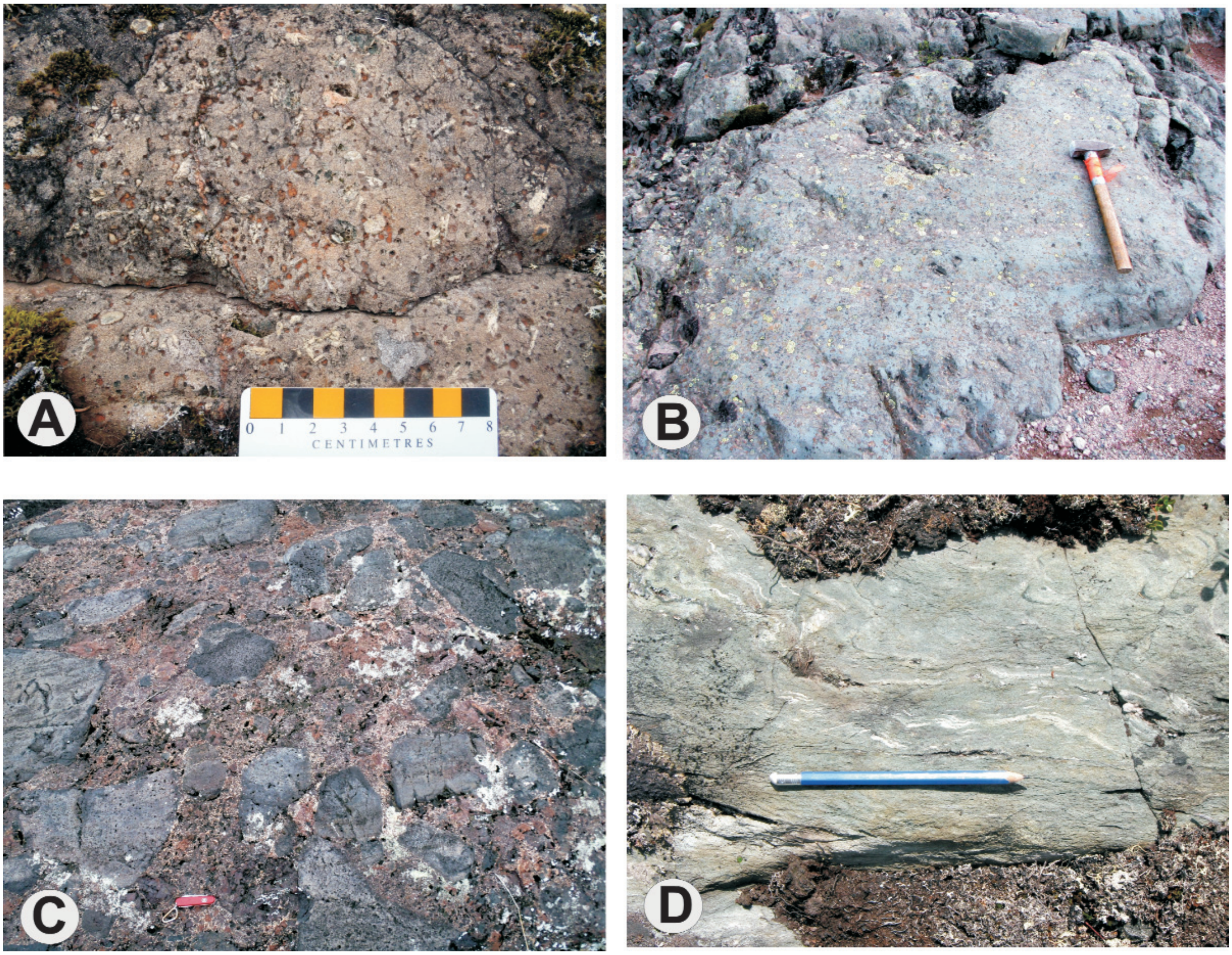



**Plate 2.** A) *Massive, porphyritic basalt of Majoqua–Bessie Lake formations on the northern limb of the regional Seal Lake syncline. Phenocrysts consist of plagioclase and altered olivine.* B) *Fine-grained, massive, homogeneous basalt flow, northern limb of regional syncline, just south of Kanairiktok River. The massive, non-descript appearance of the basalt is very common in the Majoqua–Bessie Lake formations.* C) *Strongly altered, brecciated, probable relict pillow structures in basalt flow, northern extent of Majoqua–Bessie Lake formations. Grey-weathering subangular blocks are fine-grained, massive basalt and the brown-weathering matrix surrounding the blocks consists of small fragments of strongly hematite-altered basaltic material, fine-grained basaltic material and irregular patches of quartz ± calcite.* D) *Fine-grained, strongly foliated to locally banded basalt of Majoqua–Bessie Lake formations on the southern limb of the regional Seal Lake syncline, north of Bessie Lake. Note mm- to cm-wide plagioclase-rich layers concordant to strong schistose fabric and secondary folds of this schistosity.*

southern margin of the Seal Lake Group in contact with older volcanic and granitoid rocks (Figure 3)

***Subunit M1c−Conglomerate***

Conglomerate consists of rocks containing 1 to 5 cm in diameter, 5 to 20% subrounded quartz ± feldspar ± volcanic rocks clasts in a very fine-grained quartz, feldspar, sericite, clay mineral matrix. Conglomerates on the northern limb of the syncline commonly preserve crossbedding and graded bedding and clasts are rounded and undeformed. On the southern limb, these rocks are usually strongly sheared and altered although sedimentary features are locally preserved.

***Subunit M1st–Siltstone***

Siltstone is a relatively minor rock type and occurs as m-scale layers interbedded with quartzite and feldspathic quartzite to 10s of m-scale layers intercalated with basalt flows.

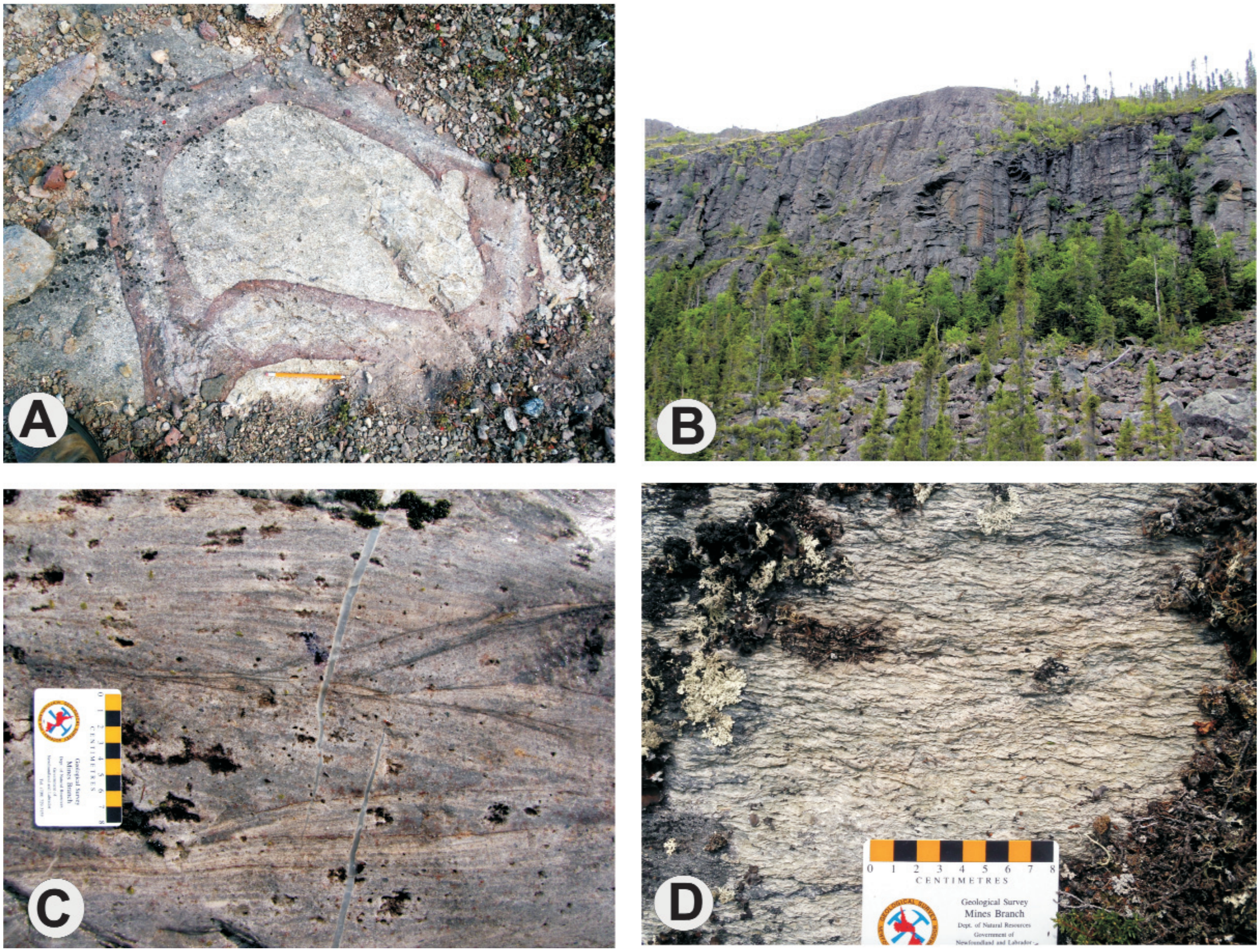



**Plate 3.** *A) Polygonal cooling feature in homogeneous to locally porphyritic, massive basalt flow. The maroon-weathering, hematite alteration mantles on cooling joints are a common feature in basalts in the Majoqua–Bessie Lake formations on the northern limb of the syncline. B) Well-developed, columnar jointing in thick sequence of massive to foliated basalts of the Salmon Lake Formation (subunit M4b). These basalt flows are capped by a 5- to 8-m-thick, fine-grained gabbro sill (subunit M4gf). Height of cliff face is approximately 50 m from top of talus slope. South shoreline of Big Bight, central Seal Lake. C) Herringbone crossbedding in quartzite to quartzofeldspathic quartzite, cut by* en echelon *quartz veins (subunit M1q) in the Majoqua–Bessie Lake formations. D) Strongly foliated quartz-sericite schist (subunit M1qs) in the Majoqua–Bessie Lake formations on the southern limb of the regional Seal Lake syncline.*

***Unit M2–Wuchusk Lake Formation***

The Wuchusk Lake Formation overlies the Majoqua–Bessie Lake formations and consists of extensive ophitic-textured gabbro and leucogabbro sills, quartzite, feldspathic quartzite, siltstone and minor shale, slate and subordinate calcareous layers and volcaniclastic rocks.

***Subunit M2g–Gabbro***

Gabbro is the predominant rock type in the Wuchusk Lake Formation and occurs primarily as south-dipping, tabular-shaped sills ranging from 5 m up to 250 m in thickness. Gabbroic rocks exhibit a wide variety of grain sizes and textures ranging from fine to very coarse grained, ophitic to equigranular and are melanogabbroic to leucogabbroic in composition. Gabbros on the northern limb are essentially undeformed, except locally foliated along fault zones. On the southern limb, adjacent to closely spaced thrust faults, a few sills form deformed mega-boudins and the gabbro exhibits a moderate to strong foliation; in other areas the gabbro appears relatively undeformed. Mineral phases include variable proportions of plagioclase, clinopyroxene (specifically augite), olivine, magnetite and ilmenite. Fine-grained, disseminated pyrite is a near-ubiquitous accessory phase ranging from less than 1 up to 3% of the total rock.

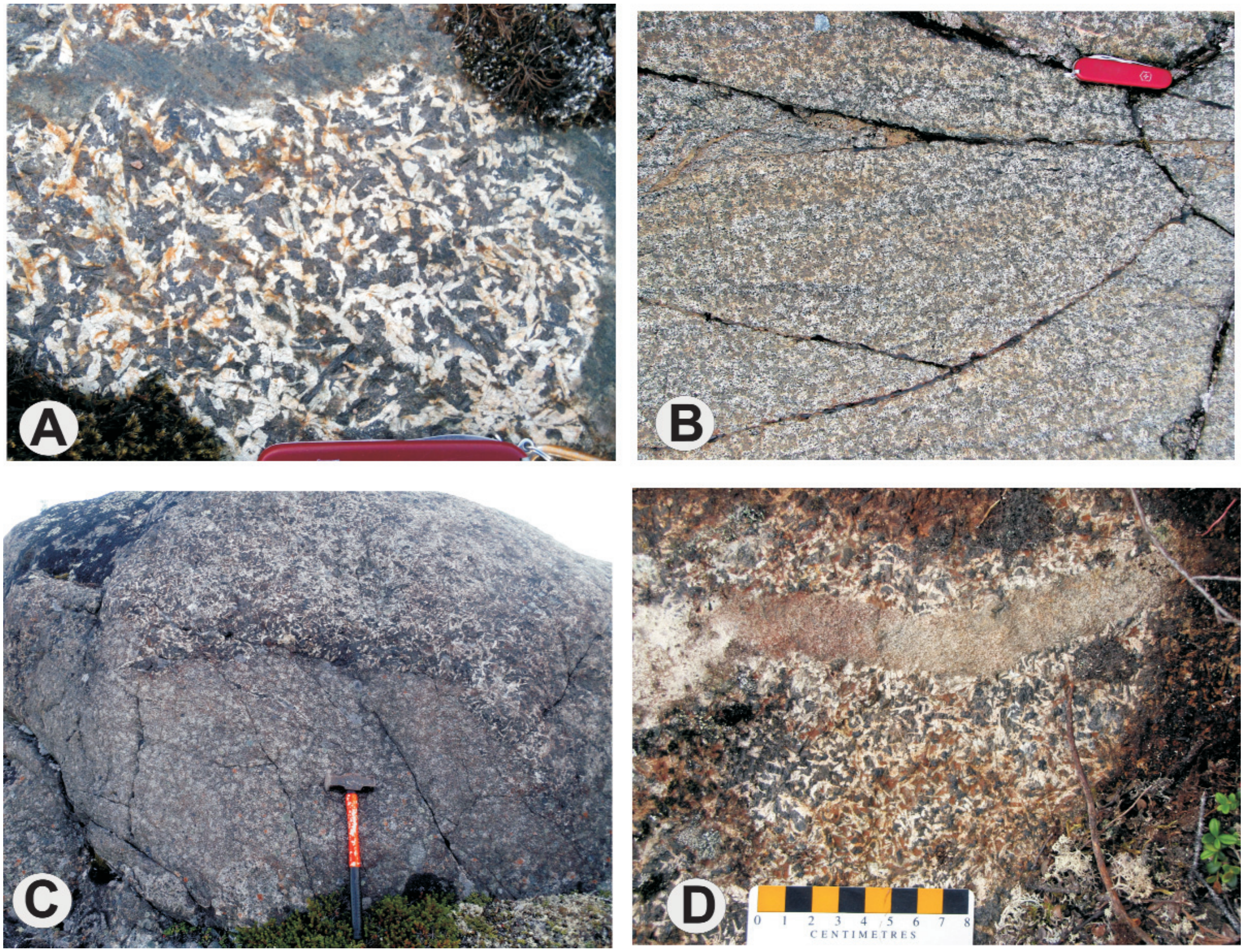



**Plate 4.** *A) Coarse-grained, massive, ophitic-textured gabbro of the Wuchusk Lake Formation. Gabbro consists of subhedral to euhedral plagioclase laths enclosed within anhedral clinopyroxene crystals. Dark layer in upper portion of photograph is composed of clinopyroxene and magnetite. B) Medium- to fine-grained, massive, homogeneous 'leopard spot' texture common in marginal zones of gabbro sills in the Wuchusk Lake Formation. The texture consists of plagioclase-rich glomerocrysts within a slightly more mafic-rich matrix. C) Coarse- to very coarse-grained, massive ophitic gabbro intruding fine- to medium-grained, massive 'leopard spot' gabbro. This is the only unequivocal crosscutting relationships of gabbro sills in the Wuchusk Lake Formation. Note thin vein of coarse-grained gabbro cutting fine- to medium-grained 'leopard' gabbro just to the left of hammer head. Hammer handle is approximately 50 cm in length. D) Medium-grained, massive, ophitic gabbro intruded by small fine-grained gabbro vein. The vein could be an apophysis of an adjacent, crosscutting gabbro sill in the Wuchusk Lake Formation.*

The interiors of most sills consist of medium- to very coarse-grained, ophitic to subophitic gabbro in which plagioclase laths up to 4 cm in length are enclosed within subhedral clinopyroxene grains ranging up to 5 cm in diameter (Plate 4A). Olivine is a common mineral phase and occurs as anhedral, rusty-weathering grains within and surrounding clinopyroxene aggregates. Magnetite is ubiquitous, ranging from fine-grained, disseminated crystals comprising less than 5% of the rock to coarse aggregates up to 3 cm in diameter, comprising up to 15% of the rock. Ilmenite is a common phase and occurs as 1 to 5%, disseminated grains and as local cm-scale layers

Gabbro sill margins vary from having fine-grained, homogeneous ophitic and equigranular textures to a 'leopard spot' appearance in which plagioclase-rich, subrounded glomerocrysts are present within a more mafic-rich matrix (Plate 4B). In some examples, the plagioclase aggregates occur as raised white-weathering 'knobs' on outcrop surfaces.

The only locality where crosscutting gabbros were observed is 7 km west of Adeline Lake, where a coarse-, to very coarse-grained ophitic gabbro clearly intrudes a fine-grained, 'leopard spot' equigranular gabbro to leucogabbro (Plate 4C). North of Shallow Bay, on the north shore of Seal Lake, a fine-grained, 2 to 4 cm-wide, fine-grained gabbro vein intrudes a massive, medium-grained ophitic gabbro (Plate 4D). The vein could be a small apophysis off a separate sill intruding the latter medium-grained gabbro. Thus, in some areas of apparently thick individual gabbro sills as depicted on Figure 3, the map units may be composed of more than one intrusion and be composite gabbroic bodies.

***Subunit M2q–Quartzite, Feldspathic Quartzite and Minor Sandstone***

On the northern limb, subunit M2q consists of quartzite, feldspathic quartzite and sandstone, commonly intercalated with slate, siltstone and shale horizons and minor basalt flows. Quartzite ranges from white-, pink- to red-weathering, fine to medium grained, well-bedded to massive and contains greater than 90 percent quartz and less than 10% K-feldspar with minor magnetite, hematite, and minor muscovite. Feldspathic quartzite containing up to 25% K-feldspar occurs in several areas as a gradational component of the quartzite unit. Subordinate sandstone interbedded with the quartzite layers contain greater than 25% feldspar.

On the southern limb, most of the sedimentary rocks are absent with only remnant segments of primarily deformed quartzite layers. These rocks are weak to moderately foliated, but do not have the pervasive schistose fabric as the layers of quartz-sericite schists (subunit M1qs) found farther south, and are isolated from subunit M2q strata by a thrust fault (Figure 3).

***Subunit M2st–Siltstone***

Siltstone in the Wuchusk Lake Formation occurs as 10- to 25-m-wide layers interleaved between gabbro sills and as cm- and m-scale layers interbedded with other sedimentary subunits. The rocks are light-brown-weathering, fine grained and well-bedded to laminated.

***Subunit M2sl–Slate***

Slate within the Wuchusk Lake Formation is a relatively minor rock type and occurs as maroon- to red-weathering, mm-, to cm-scale laminations interbedded with quartzite, shale and siltstone.

***Subunit M2bs–Shale***

Shale in the Wuchusk Lake Formation occurs as several 10- to 50-m-wide, east-trending units interleaved between gabbro sills and as cm-, to m-scale layers interbedded with quartzite and siltstone. The shale varies from black-, brown- to grey-weathering, fine grained, commonly contains concordant quartz veinlets and is very fissile (Plate 5A). North of Seal and Adeline lakes, several shale layers record local, elevated radioactive signatures. These units, to the east of the present map area (van Nostrand and Lowe, 2010), although poorly exposed in low-lying valleys, can be traced intermittently for up to 20 km along strike and serve as distinct marker horizons (*see* Anomalous Radioactivity).

***Unit M3–Whiskey Lake Formation***

The Whiskey Lake Formation was defined by Robinson (1953) and revised by Brummer and Mann (1961) to group a sequence of interbedded to laminated slate, shale, sandstone and quartzite overlying the Wuchusk Lake Formation. One of the criterion used by these authors for the designation of these rocks as a separate formation is the absence of intercalated basalt flows. However, this in itself would seem to be an insufficient basis for distinguishing a separate formation. Baragar (1981) had suggested that this sequence of sedimentary rocks could be grouped within the Salmon Lake Formation, as a basal sedimentary unit. However, observations made during 2010 suggest that this sequence of rocks is distinct from sedimentary rocks in other formations in that they exhibit ubiquitously interlaminated to thinly interbedded slate, siltstone, sandstone and quartzite that rarely exceed cm-scale bedding thicknesses (Plate 5B).

***Unit M4–Salmon Lake Formation***

The Salmon Lake Formation consists predominantly of weakly to strongly deformed and altered basalt flows and maroon-weathering slate. Subordinate quartzite, siltstone, sandstone, shale and calcareous rocks are also present. Gabbro is a relatively minor rock type consisting of tabular-shaped sills ranging from 5 to 75 m thick, and small, irregular-shaped intrusions.

***Subunit M4b–Basalt Flows***

Basalt in the Salmon Lake Formation occur as variably deformed and altered flows, which in most areas exhibit a moderate to strong, pervasive foliation delineating these rocks as chlorite ± epidote schists. In several areas, amygdules, vesicles and very local pillow features are preserved in these rocks and quartz veining is extensive along contacts with sedimentary rocks (Plate 5C).

***Subunit M4ms–Maroon Slate***

Maroon- to red-weathering slate is the predominant

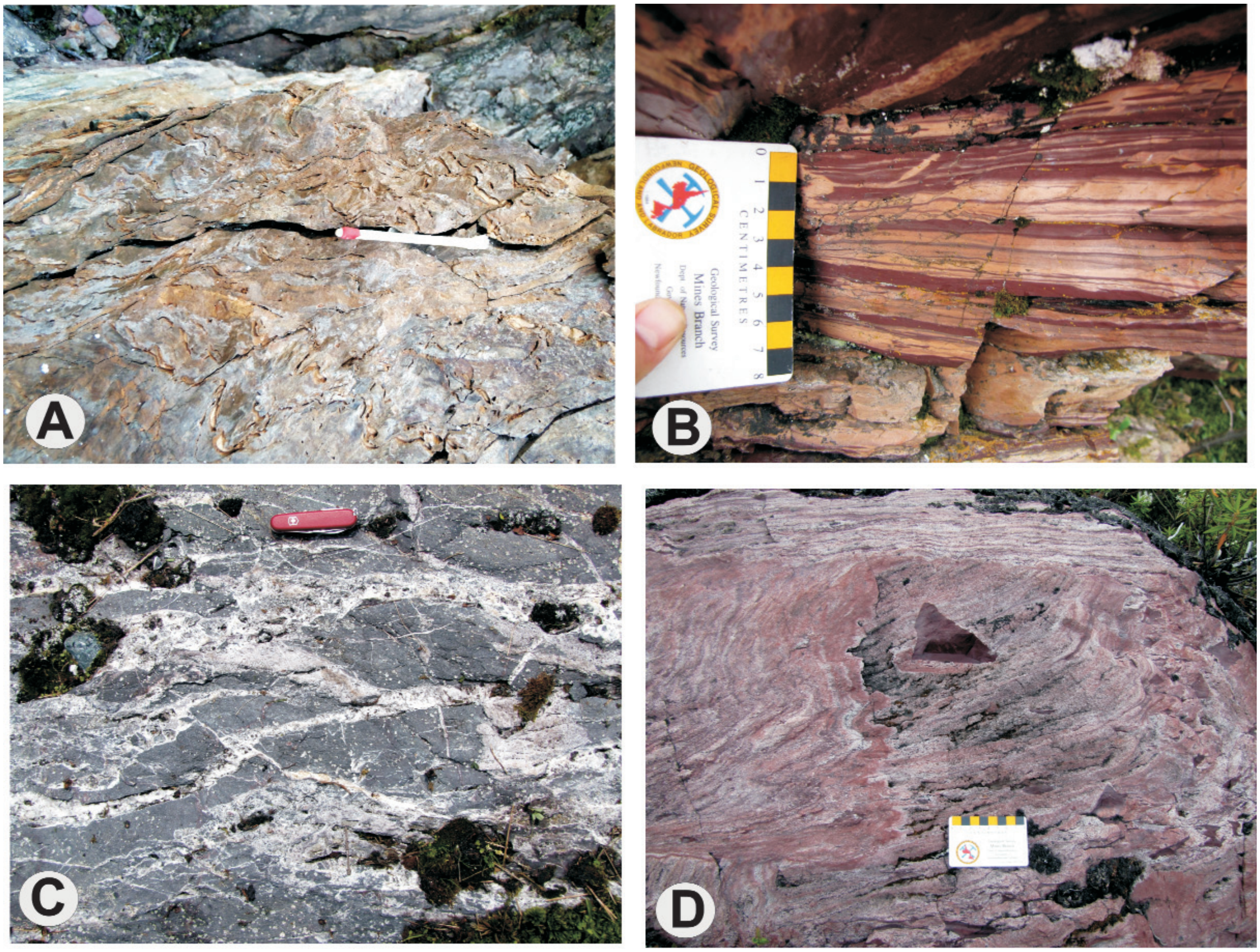




**Plate 5.** *A) Fine-grained shale (subunit M2bs) exhibiting small-scale folding. This unit locally records anomalous radioactive signatures. B) Thin-bedded to laminated slate-siltstone-sandstone of the Whiskey Lake Formation (Unit M3ms). C) Net-veined, strongly altered, amygdaloidal basalt flow (subunit M4b) of the Salmon Lake Formation. This unit is host to several native copper and copper sulphide occurrences. D) Crossbedded quartzite at the base of the Upper Red Quartzite Formation (Unit M6q). Small angular maroon slate fragment is a possible rip-up clast derived from underlying Adeline Island Formation (subunit M5sl). E) Well-developed ripple marks in quartzite near the base of the Upper Red Quartzite Formation. Slight asymmetry of ripple marks suggests a north-northwest paleocurrent direction.*

sedimentary rock in the Salmon Lake Formation and occurs as 10s of m-scale layers intercalated with basalt flows and as cm-, to m-scale interbeds with quartzite, shale and siltstone units.

***Subunit M4q–Quartzite***

Quartzite is a relatively minor rock type in the Salmon Lake Formation and varies from white-, to red-weathering, fine, to medium grained, massive to well-bedded and consists of quartz, K-feldspar and minor, very fine-grained clay mineral phases.

***Subunit M4g−Gabbro***

Gabbroic rocks in the Salmon Lake Formation occur as relatively thin, resistant sills overlying thick sequences of sedimentary rocks and basalt flows. A predominant sill, overlying basalt flows and quartzite–slate layers can be traced along the northern limb of the syncline (just south of Seal Lake) for approximately 8 km and varies from 5 m to 25 m thick along its length. These sills are generally finer grained and more equigranular-textured than sills in the Wuchusk Lake Formation, however, they have very similar composition and mineral assemblages. Contact relationships vary from sharp, chilled margins and hornfels to a diffuse zone of country rock xenoliths within sill margins.

***Unit M5–Adeline Island Formation***

The Adeline Island Formation consists of interbedded slate, phyllite and quartzite having subordinate calcareous rocks, basalt flows and thin gabbro sills. This formation hosts some of the most significant copper sulphide occurrences within the Seal Lake Group (*see* Mineralization). Rocks of this formation exposed on the northern limb of the syncline can be traced around the western fold closure, however, on the southern syncline limb these rocks are mostly absent due to extensive thrusting along several faults zones.

***Subunit M5sl–Grey to Maroon Slate***

Slate is the dominant rock type in the Adeline Island Formation and ranges from grey-, black-, green-, red-, to maroon-weathering, is fine grained and varies from having recognizable local bedding-cleavage relationships to completely transposed fabrics. Previous workers, mapping mostly at 1 inch to 200 feet scale, have subdivided the slates into two main units: a stratigraphically lower, red-, to purple-weathering slate, and an upper green-, to grey-weathering slate (Gandhi, 1972; Gandhi and Brown, 1975).

***Subunit M5ph–Grey-green Phyllite and Slate***

Phyllite and associated slate exhibit a distinct silver-grey-weathering sheen and occur as m-scale layer(s) interbedded with maroon- and grey-weathering slate and quartzite in the upper levels of the formation, near the base of the Upper Red Quartzite Formation. This unit, although described primarily as a slate in much of the literature, it is referred to here as being composed of phyllite and slate and is host to most of the copper sulphide mineralization within the Adeline Island Formation. The grey-weathering phyllite–slate layer can be traced intermittently along strike on the northern limb and becomes thinned out on the southern limb (Figure 3, *see* Mineralization).

***Subunit M5q–Quartzite and Feldspathic Quartzite***

Quartzite and feldspathic quartzite are red-, to pink-weathering, fine to medium grained, well-sorted and are well-bedded to massive, and contain less than 1 up to 20 percent K-feldspar. Gandhi and Brown (1975) referred to this unit as the Adeline quartzite and, in keeping with their model for mineralization, they defined the Adeline Island Formation stratigraphy, such that this quartzite layer always underlies the mineralized grey-green phyllite–slate unit (subunit M5ph). The authors were not able to verify whether the 'Adeline quartzite' of Gandhi and Brown (*op. cit.*) does, in fact, always underlie the mineralized phyllite layer, as several, very similar, albeit thin, quartzite layers are recognizable within this formation, both above and below the phyllite layer. And although the quartzite layers can be traced intermittently along strike for considerable distances, a positive correlation of individual quartzite layers could not be made between widely spaced mineralized occurrences.

***Subunit M5b–Basalt Flows***

Basalt is a relatively minor rock type in the Adeline Island Formation and occurs as thin, m-, to 10s of m-scale flows intercalated with sedimentary rocks.

The basalts are green-, grey-, to red-weathering and vary from homogenous and massive to amygdaloidal, vesicular and weak to moderately foliated. These rocks are host to minor sulphide mineralization where they are adjacent to mineralized sedimentary layers.

***Subunit M5g–Gabbro***

Gabbro is a relatively minor rock type within the Adeline Island Formation and occurs as 10s of m-thick sills and small irregular-shaped intrusions, intruding basalt flows and sedimentary rocks. Most of these are too small to depict on Figure 3. Gandhi and Brown (1975) had suggested that sills in the Adeline Island Formation were younger than gabbros in the underlying formations. However, although finer grained they have similar assemblages and geochemistry of sills in the other formations and would suggest they are of the same age (Wilton, 1996).

***Unit M6–Upper Red Quartzite Formation***

The Upper Red Quartzite Formation is exposed in the central core or hinge zone of the regional syncline and is the youngest formation of the Seal Lake Group (Figure 3).

The rocks in this formation are homogenous throughout and consist of red-, to pink-weathering, fine- to medium-grained, bedded to massive quartzite and minor feldspathic quartzite. Subordinate maroon slate horizons are present along the northern contact of the formation in a few areas. It is not clear whether these slate horizons are part of the Upper Red Quartzite Formation or if they are correlative with rocks of the underlying Adeline Island Formation. However, small, angular fragments of slate in several areas in the lower portion of the formation may be rip-up clasts of slate (subunit M4ms) derived from the upper stratigraphic levels of the Adeline Island Formation (Plate 5D).

Quartz and K-feldspar grains are pervasively coated with fine-grained hematite, and yields the ubiquitous red- to pink-weathering of the rocks in this formation.

Crossbedding and ripple marks observed in several areas and flute casts noted in a few localities indicate variable paleocurrent directions including probable sourcing from the west, east and north and south (Plate 5E). No dominant flow direction was measured in the map area, although a comprehensive paleocurrent analysis was not carried out during this study.

## STRUCTURE

The structure of the map area is dominated by fabrics associated with the southeast-plunging fold hinge of the western part of the regional syncline and several ductile fault zones transecting the southern margin of the group (Figure 3).

Fabrics are best developed in supracrustal units adjacent to fault zones and are dominated by a moderate to strong, east- to northeast-striking, south-dipping cleavage, foliation or banding. Bedding, where tops can be determined, associated with these fabrics are commonly overturned toward the north.

On the southern limb, units of all formations are increasingly displaced by thrusts to become tectonically rather than stratigraphically stacked, thereby forming a lithotectonic sequence of stratified rocks. Rocks of the Whiskey Lake and Salmon Lake formations are completely absent in the Thomas Lake area (Figure 3).

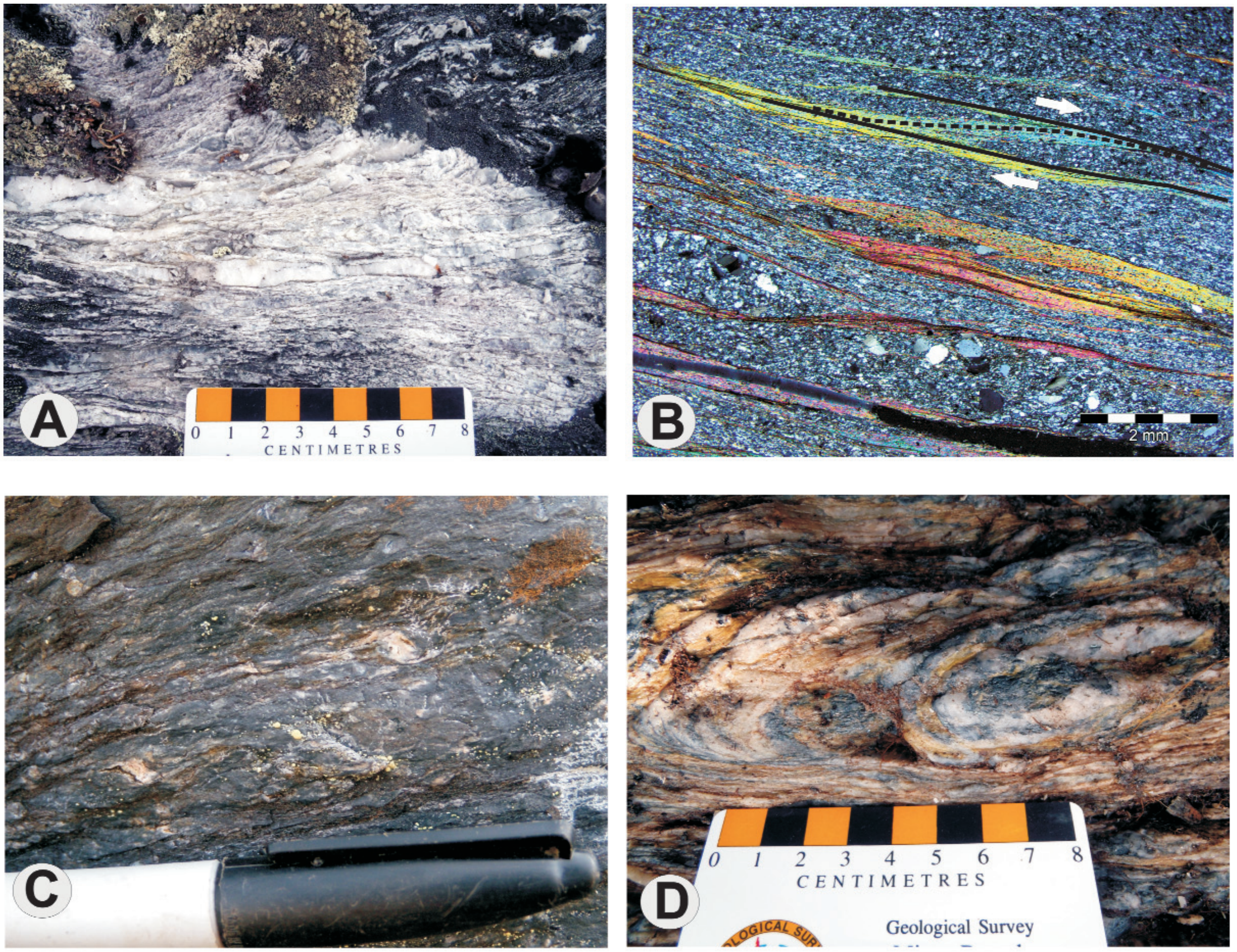
Rocks in the fold hinge west of Adeline Lake are affected by south-, to southeast-plunging folds and are overridden along a thrust fault by a hangingwall sequence represented by the overturned Majoqua–Bessie Lake formations stratigraphy of the southern limb. The contact is strongly deformed, and lineations in quartz-rich schists have a predominant south-southeast plunge direction, indicating a predominant dip-slip reverse movement; gabbroic rocks are strongly foliated in a few areas, immediately north of the quartz schist unit.

The predominant rock types along the southernmost margin of the Seal Lake Group include quartz-sericite schist (subunit M1qs), locally intercalated with strongly foliated basalt flows. Conglomerate is locally present and contains deformed quartz and feldspar pebbles and felsic volcanic rock clasts (Plate 6A). The fabric in these rocks is defined by fine-grained, strongly aligned and/or attenuated, recrystallized quartz and feldspar grains alternating with thin, fine-grained sericite schleiren (Plate 6B). Locally observed, rotated quartz and feldspar grains, C–S fabrics and predominant south-, to southeast-plunging lineation attitudes indicate a dextral (south over north) sense of hangingwall up movement along the interpreted thrust contacts. Similar textures and kinematic structures are observed in interleaved volcanic rocks of the uppermost Letitia Lake Group (Plate 6C).

Detailed structural examination of rocks immediately north of Letitia Lake (Hibbs, 1980; Calon and Hibbs, 1980) identified three stages of folding in the basal Seal Lake formations. Structural observations made during this study corroborate these findings to some extent, although the complex structures associated with the unconformity made correlating different fold generations ambiguous in several areas.

All folds are assumed to be the result of Grenvillian deformation. The earliest recognizable folds (F1) are gently inclined to recumbent structures and are observed in strongly deformed to mylonitic sedimentary rocks of the extreme southern Seal Lake Group, particularly southwest of Bessie Lake (Plate 6D). These reclined folds have an associated shallow, south-dipping axial-planar fabric. Second-generation structures are open to tight, recumbent to asymmetric north-verging folds (Plate 6E). These structures are prevalent, throughout much of the Seal Lake Group and are interpreted as the same generation as the regional Seal Lake syncline. In general, these folds are progressively more open toward the north and the associated, predominant east-trending fabric defines the regional trend observed throughout most of the Seal Lake Group (van Nostrand, 2009; van Nostrand and Lowe, 2010). The open to tight fold structures on the northern limb of the regional syncline are interpreted to be second-generation structures (Figure 3).

Very weakly developed, cm-scale upright F3 crenulated folds were observed on the limbs of some F2 folds in some areas, although no associated cleavage could be discerned in the field.



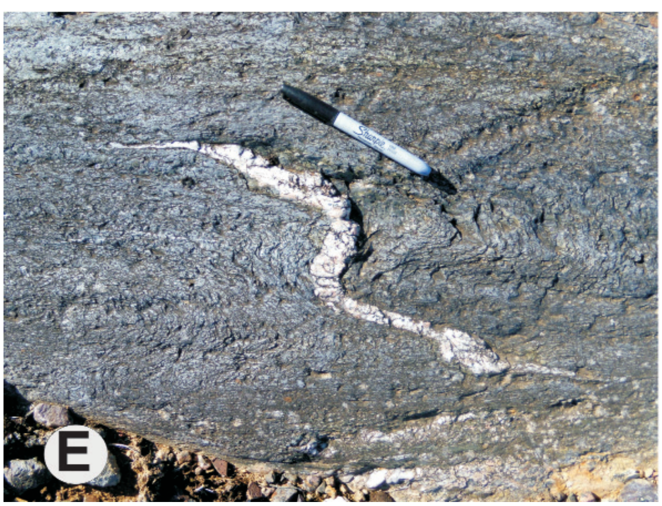




**Plate 6.** *A) Strongly foliated to mylonitic quartz-sericite schist to conglomerate (subunit M1qs, c) containing remnant quartz veins and small tectonic fragments of felsic volcanic rocks. Occurs along contact with Letitia Lake Group rocks, southwest of Bessie Lake. B) Microphotograph (in crossed nicols) of mylonitic fabric in quartz-sericite schist (subunit M1qs) along southern contact of Seal Lake Group. Strongly recrystallized quartz + K-feldspar + fine-grained sericite matrix alternates with thin sericite-rich schleiren. Note asymmetric sericite-rich schleiren in upper portion of photograph suggesting a dextral sense of shear. C) Strongly deformed K-feldspar porphyritic rhyolite (subunit MLr) along southern contact with Seal Lake Group rocks. Note dextrally rotated K-feldspar phenocrysts. D) Recumbent, first-generation fold developed in coarse-grained quartz ± sericite schist (subunit M1qs) in thrust contact with rhyolites (subunit MLr) of the Letitia Lake Group, southwest of Bessie Lake. E) North-verging, second-generation fold of remnant quartz + feldspar vein in strongly foliated tuffaceous rhyolite (subunit MLr) along southern thrust contact with Seal Lake Group quartz-sericite schist.*

## SEAL LAKE GROUP – LETITIA LAKE GROUP UNCONFORMITY

Early studies of the depositional contact of the Seal Lake Group with the older Letitia Lake Group placed the unconformity at the base of conglomerate layers of the Majoqua–Bessie Lake formations, which contain clasts derived from felsic volcanic rocks of the Letitia Lake Group (Brummer and Mann, 1961). Subsequent workers (Marten, 1975; Curtis and Currie, 1981) placed the unconformity, and the upper limit of the Letitia Lake Group, at the base of a regolith unit, underlying the conglomerate layers, which they interpreted as a paleoweathered surface. According to these workers, most of the regolith unit would belong to the Seal Lake Group. The interpretation as a regolith surface was based, in part, on the presence of specularite within this unit. Other studies (Hibbs, 1980; Thomas, 1981) supported the original interpretation of Brummer and Mann (*op. cit.*) and suggested that volcanic-derived rocks in the regolith unit were part of the Letitia Lake Group, and that this surface marked a minor unconformity. They also interpreted a second erosional surface that was developed at the base of the basal conglomerate, and this marked the lowermost extent of the Seal Lake Group. More recently, Wilton (1996) reported specularite in this regolith unit, which is developed locally as concentric selvages around small quartz veins, and suggested this may indicate a hydrothermal rather than a paleoweathering (oxidizing) origin for the unit.

Observations made during this study could not substantiate (nor dispute) either of the aforementioned interpretations regarding the unconformity, however, as Hibbs (1980) indicated, presumable volcanic-derived rock clasts observed within coarse-grained conglomerate of the Majoqua–Bessie Lake formations suggest that a subsequent erosional event occurred after the deposition of volcanic-derived Letitia Lake Group sediments, and this later unconformity marks the lowermost base of the Seal Lake Group.

## METAMORPHISM

Metamorphic grade within the map area varies from greenschist-facies assemblages associated with synfoliation thrust faults along the southern margin to weakly metamorphosed and unmetamorphosed rocks on the northern limb of the regional syncline. A similar transition reported by van Nostrand and Lowe (2010) in the eastern Seal Lake area is present in the current map area. This includes chlorite–epidote alteration in mafic rocks and muscovite–sericite-bearing assemblages in sedimentary rocks on the southern limb, through tremolite-bearing mafic rocks and clay mineral replacement in sedimentary rocks immediately south and north of Adeline Lake. These assemblages may not be solely due to the regional Grenvillian metamorphism. Pumpellyite-bearing mafic rocks north of the Naskaupi River were reported by Baragar (1981) and van Nostrand and Lowe (2010) in the eastern Seal Lake area, however, they have yet to be identified in the present map area. Rocks in the northernmost map area are very weakly altered to unaltered and exhibit weak saussuritization and epidotization. The exceptions are thin marginal hornfels of sedimentary rocks in contact with intrusive gabbro sills.

Preliminary investigation of alteration assemblages indicates that metamorphic isograds are approximately parallel to structures developed along the southern margin of the Seal Lake Group and outline the progressive decrease in grade from south to north.

## MINERALIZATION

Mineralization within the map area includes, i) several historical, well-documented copper and copper–silver prospects and showings (with minor, local molybdenite), ii) numerous minor copper and iron sulphide indications, and iii) anomalous radioactivity associated with clastic sedimentary rocks in the two lower formations.

### Copper Mineralization

The most significant occurrences within the map area are: i) the Adeline Island prospect, ii) the Ellis prospect, iii) the Brian prospect iv) the Duck Lake showings, and v) the Seal Lake main showing (Figure 3). The MODS occurrence 13K/05/Cu011 is also noteworthy. As these prospects and showings have been extensively described in the literature, a comprehensive synthesis will not be attempted here. However, cursory examination and sampling were carried out as part of this study and some general characteristics of the mineralization are discussed below; *see* Gandhi and Brown (1975) and Wilton (1996) for detailed descriptions of these occurrences.

Four of the aforementioned occurrences are hosted in slate, phyllite and to a lesser extent, quartzite, of the Adeline Island Formation. The Seal Lake main and 13K/05/Cu 011 showings are hosted in basalt flows and slates of the Salmon Lake Formation.

### Adeline Island Formation Mineralization

Prospects and showings hosted in clastic sedimentary rocks of the Adeline Island Formation consist of malachite ± azurite + chalcocite ± bornite mineralization as disseminated grains, lenses, layers and selvages occurring along bedding, fractures, and cleavage surfaces as well as in concordant and discordant quartz ± calcite veins. Previous investigators have noted the presence of covellite and

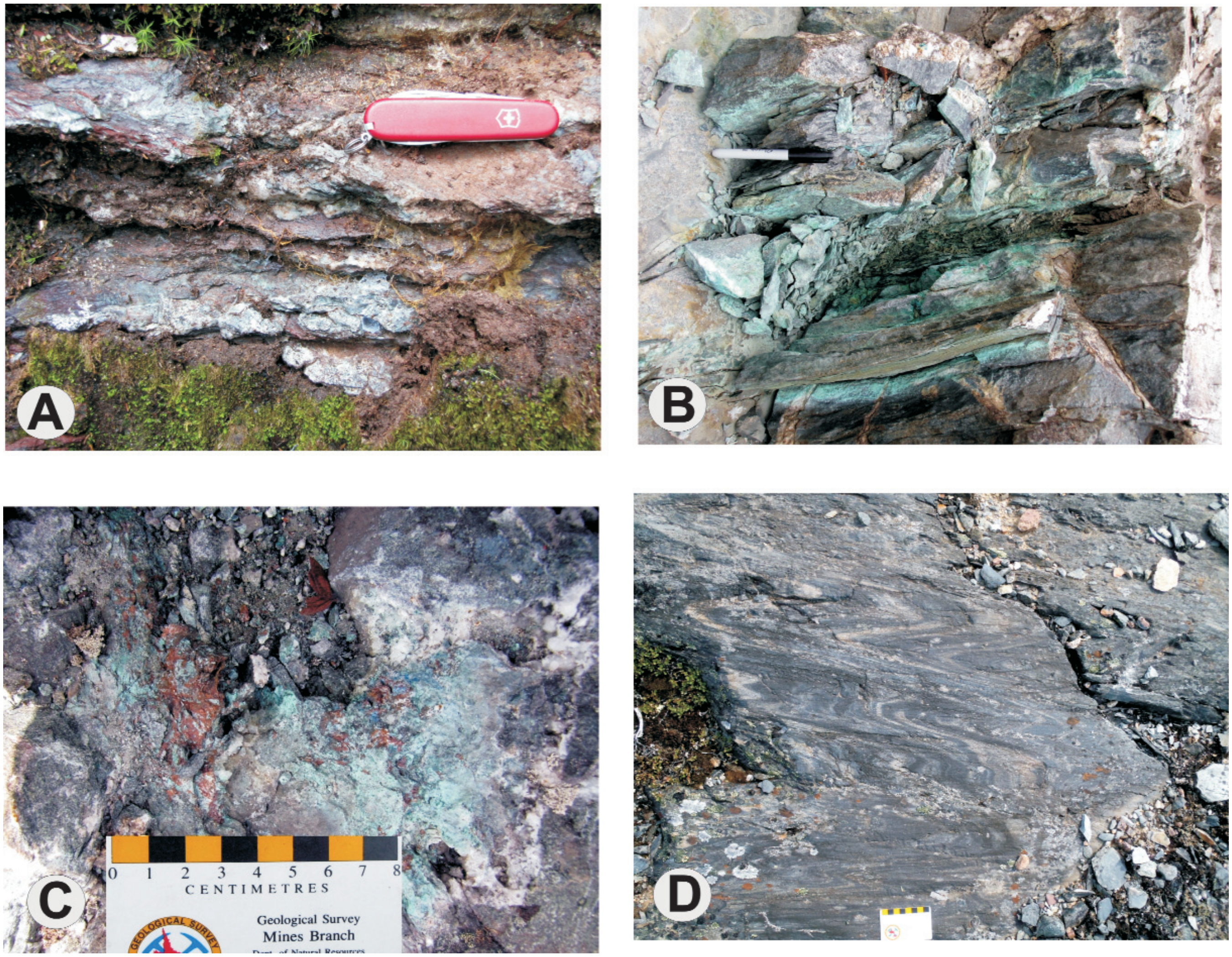



**Plate 7.** *A) Malachite + chalcocite mineralization hosted in grey-green phyllite–slate layer (subunit M5ph) of the upper Adeline Island Formation. Duck Lake east showing, south of Seal Lake. B) Malachite–chalcocite–bornite mineralization hosted in strongly altered phyllite–slate (subunit M5ph) at the Ellis prospect, upper Adeline Island Formation. C) Malachite–azurite–native copper–chalcocite mineralization hosted in strongly altered amygdaloidal basalt flow (subunit M4b) of the Salmon Lake Formation. MODS Occurrence No. 13K/05/Cu011, north shoreline of Seal Lake. D) Fine-grained tuffaceous rocks (part of subunit MLrg) of the 'regolith' layer of the upper Letitia Lake Group, illustrating tight F2 folding of a strong F1 foliation. This unit locally recorded anomalous radioactive signatures up to a maximum of 1200 cps. Southwest of Bessie Lake, along contact with quartz-sericite schists of the Majoqua–Bessie Lake formations.*

cuprite, however these phases were not positively identified in this study. Wilton (1996) noted minor molybdenite associated with a few of the prospects within the Adeline Island Formation. The main host rock is a grey-, to green-weathering, fine-grained phyllite to slate having a pronounced cleavage and present in all the main occurrences (subunit M5ph, Plate 7A and B). The phyllite to slate layer varies from 1 to 10 m thick where measured, and is interbedded with red to maroon slate and quartzite.

### Salmon Lake Formation Mineralization

Mineralization in the Salmon Lake Formation consists of malachite ± azurite ± native copper ± chalcocite ± bornite and is hosted predominantly in sheared quartz ± calcite veins along contacts of deformed basalt flows and slate layers.

At the Seal Lake main showing, on the south shore of Seal Lake, malachite, azurite, native copper and bornite occur in quartz ± calcite veins cutting basalt flows and underlying slate layers. On the north shore of Seal Lake (MODS occurrence 13K/05/Cu011) malachite, azurite, native copper and bornite are hosted in deformed (presumably syntectonic) quartz veins cutting strongly epidotized and brecciated basalt flows (Plate 7C).

A few new, minor indications were noted during the 2010 field season, although these are localized concentrations of disseminated pyrite and malachite and small gossan zones and appear to be insignificant occurrences. In some cases, these, apparently 'new' indications could quite possibly be previously reported occurrences as listed in MODS, some of which were originally sourced from old, sometimes inaccurate assessment reports, and may not necessarily be the precise location of the original discovery

### Mode of Mineralization

The mode of mineralization hosted in the Salmon Lake and Adeline Island formations has proponents for a syngenetic origin (Gandhi, 1972; Gandhi and Brown, 1975) and an epigenetic origin (Wilton, 1996) with respect to the host rocks. Gandhi and Brown (*op. cit.*) suggested that the copper mineralization associated with clastic sedimentary rocks of the Adeline Island Formation is analogous to 'strataform ore' of the Nonesuch shale horizon of the White Pine deposit of northern Michigan (White and Wright, 1954). For the Seal Lake Group mineralization, they suggested a syn- to slightly post-diagenetic model whereby copper, derived from a underlying copper-bearing mafic volcanic series, is transported to overlying shales along redbed aquifers and then deposited within favourable pyritic, grey (reduced) shales by replacement of original iron sulphides. They note several discrepancies of Seal Lake Group mineralization and the style of mineralization at the White Pine deposit but suggested the differences may be a result of post-mineralization effects (*i.e.*, Grenvillian deformation and metamorphism) of the Seal Lake Group host rocks.

In contrast, Wilton (1996) interpreted all the Seal Lake copper mineralization to be a result of epigenetic processes noting that i) ore-fluid flow was likely deformation related because the mineralization is closely associated with zones of structural weakness, in particular, sheared rocks along lithological contacts; ii) the association of native copper with hematized basalt flows, and red slates, indicates a presumed link with a postdepositional hematite alteration; and iii) most of the redbed sequences, within the host formations, are not conglomeratic but are impermeable quartzite and shale units and likely do not possess sufficient porosities to act as aquifers (as suggested by Gandhi and Brown, 1975).

Based on cursory observations of mineral occurrences during the present study, the ubiquitous association of mineralization with sheared lithological contacts, deformed (presumably syntectonic) quartz veins and extensive hematite alteration would suggest an epigenetic origin of the mineralization.

### Anomalous Radioactivity

Most visited outcrops were spot checked for radioactive signatures using a RS-120 or GR-110 hand-held scintillometer. Cursory prospecting was carried out in areas where anomalous readings were recorded and anomalous U in lake-sediment values are present.

Gabbroic rocks and basalt flows recorded the lowest readings ranging from 25 cps to 100 cps. No anomalous values were noted in these rock types.

Sedimentary rocks yield a higher average range of 100 to 200 cps, with quartz-rich conglomerate and fine-grained shales recording the higher readings.

Slightly elevated readings ranging from 300 to 500 cps were recorded from quartzite and quartz conglomerate in the northern Majoqua−Bessie Lake formations. In particular, an interbedded quartzite and quartz conglomerate unit on strike with the Spriggs Lake showing (Baragar, 1969; van Nostrand and Lowe, 2010). The elevated readings can be detected intermittently along strike of the layers and appear to correlate with the presence of coarse-grained K-feldspar pebbles and felsic volcanic rock clasts.

Elevated scintillometer readings were recorded from a black to grey shale (subunit M2bs) within the upper stratigraphic levels of the Wuchusk Lake Formation on the north limb of the syncline (Plate 5A). These units are western extensions of the shale horizons described to the east of the map area (van Nostrand and Lowe, 2010). Readings along strike of these units in the map area range from 350 cps up to the maximum recorded of 610 cps. The shale units are very poorly exposed, but can be traced intermittently in low-lying valleys, and serve as a distinct marker horizon to extrapolate stratigraphic position along strike. The shale is interbedded with quartzite, laminated siltstone and locally calcareous layers.

In the western fold hinge area, a very anomalous U in lake-sediment value of 213 ppm is present from a small lake, located 12.5 km west of Adeline Lake (Friske *et al.*, 1993), and a elevated value of 4.1 ppm U in till is located 1 km southwest of this lake (Batterson and Taylor, 2005). Cursory prospecting failed to reveal any significant radioactive signatures in the area although slightly elevated readings up to 320 cps were recorded from a black shale layer located 1 km north of the anomalous lake-sediment value. It is noteworthy that both the anomalous U in lake sediment and U in till values are located in the hinge area of the regional syncline, which is overridden by a thrust-bounded portion of the southern limb. Further detailed examination of this area is warranted to locate the source of this very significant U in lake-sediment anomaly.

Southwest of Bessie Lake, elevated signatures are recorded locally along the Seal Lake–Letitia Lake groups unconformity. A black-weathering, fine-grained tuffaceous rock intercalated with strongly foliated quartz-sericite schist and conglomerate of the Seal Lake Group and rhyolite of the Letitia Lake Group recorded a maximum value of 1200 cps from one locality (Plate 7D).

Elevated readings up to 510 cps were recorded from adjacent quartz pebble conglomerate layers and intercalated porphyritic rhyolitic rocks.

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