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GEOLOGY OF THE NORTHEASTERN ASHUANIPI COMPLEX, WESTERN LABRADOR (PARTS OF NTS 1:50 000-SCALE MAP AREAS 23J/6, 7, 10, 11, 14 AND 23O/3)

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ABSTRACT

The Ashuanipi Complex is a granulite-facies, sedimentary-plutonic subprovince of the Archean Superior Province, and is one of the largest high-grade gneiss terranes in Canada. The complex, in Labrador, consists of older sequences of migmatitic paragneiss intercalated with pre-tectonic tonalite to granodiorite, and subordinate diorite, gabbro and ultramafic intrusions. These rocks predate the development of extensive diatexite migmatite, variably deformed granitoid intrusions and late granitic pegmatite. The eastern margin of the Ashuanipi Complex is unconformably overlain by siliciclastic sedimentary rocks of the Proterozoic New Québec Orogen (Labrador Trough). Orthopyroxene–garnet-melt assemblages indicate granulite-facies conditions were attained, but some pyroxene-bearing assemblages in granitoid and ultramafic rocks are interpreted as igneous relicts. Structures are dominated by a west-northwest-striking S_1 regional fabric and moderately plunging F_2 fold patterns.

The region has potential to host gold and base-metal mineralization associated with sulphide-bearing gossan zones, in gneissic units and mafic and ultramafic rocks. The latter two rock types also have the potential for hosting platinum-group elements (PGEs).

INTRODUCTION

The northeast portion of the Ashuanipi Complex of the Superior Province, western Labrador was examined during July through August 2013. The surveyed area includes parts of NTS 1:50 000-scale map areas 23J/6, 7, 10, 11, 14 and 23O/3 (Figures 1 and 2), and the 2013 project was the first year of a new multi-year, 1:50 000-scale bedrock mapping program to evaluate the geological evolution and mineral potential in the area.

Ground traverses were carried out at approximately one to two kilometre spacing over well-exposed areas, complemented by helicopter traversing and some boat work along the western shoreline of Lake Menihek.

The surveyed area was previously investigated at 1:125 000-scale by Percival (1987, 1993) who carried out ground traversing in the southern part and mapped extensively in the region surrounding Howell Lake. Those parts not already examined by Percival (*op.cit.*) were mapped during the 2013 survey, as was the northwest-trending prong of Labrador territory northwest of Schefferville.

LOCATION, ACCESS AND PHYSIOGRAPHY

The centre of the map area is located about 30 km southwest of the town of Schefferville, Québec, and 180 km north of Labrador City (Figure 1). Most regions are best accessed by helicopter or float-plane either from Schefferville or Labrador City. Gravel roads in the Shefferville area, constructed for mining, provide access to parts of NTS map area 23J/14 and 23O/3. The western shore of Lake Menihek can be accessed by boat from the hydroelectric dam at Menihek, which connects to Schefferville by a 45-km-long, rough gravel road.

Bedrock exposure is fair to good; however, most of the exposures are extensively lichen-covered. The topography is of moderate- to high-relief, characterized by rounded to flat, barren hilltops, broad valleys and moss and coniferous tree-covered slopes (Plate 1). Elevation ranges from a maximum of 760 m above sea level in the highlands to the west and northwest of Lake Menihek to 525 m in the southern part of the map area.

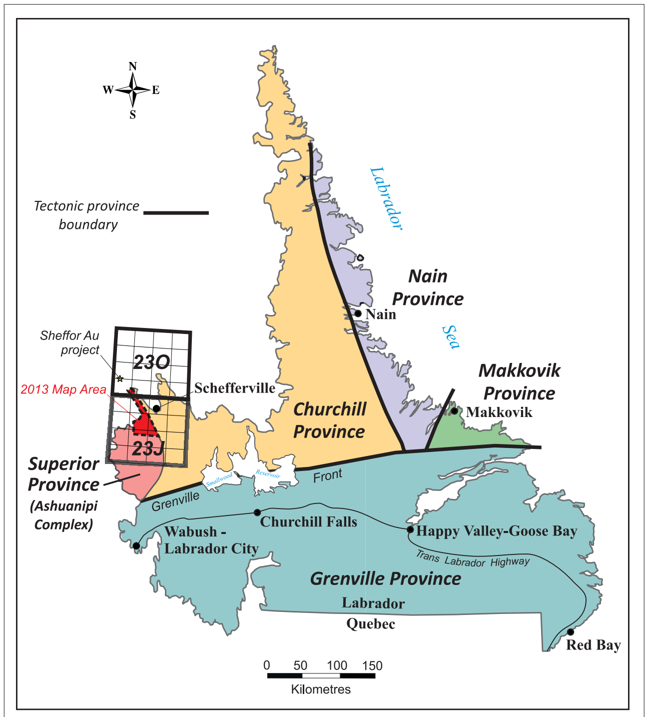


Figure 1. *Tectonic provinces of Labrador, extent of the Ashuanipi Complex in western Labrador and the location of the 2103 survey area (outlined by black border) in the Archean Superior Province. The location of the Sheffor gold project northwest of Shefferville in Québec, referred to in the text, is also shown.*

PREVIOUS INVESTIGATIONS

BEDROCK MAPPING SURVEYS

The first reconnaissance surveys by Kidd (1950) and Perrault (1951) produced 1 inch to one-half mile scale maps, along the main waterways, immediately south of the map area, in the McPhayden River area.

Parts of three, 1:253 440-scale (1 inch to 4 miles) geological maps include the present map area. Frarey (1961) and Stevenson (1963) mapped the east and west parts, respectively, of NTS map area 23J, and Baragar (1967) produced a regional map of 23O and an accompanying memoir.

Wardle (1982a, b) included rocks of the Ashuanipi Complex, the unconformity and Proterozoic rocks on 1:100 000-scale bedrock map compilations of the south-central Labrador Trough. Percival (1987, 1989, 1993) produced a 1:125 000-scale map of NTS map areas 23J/3, 4, 5, 6, 11 and 12 and parts of 23J/2, 7 and 10. In addition to the mapping, Percival (1987, 1991a, b), Percival and Girard (1988) and Percival *et al.* (1992, 2003) reported on the geology, geochemistry and geochronology of the Ashuanipi Complex.

GEOCHEMICAL AND GEOPHYSICAL SURVEYS

The map area is covered by regional lake-sediment geochemistry surveys of NTS map areas 23J (Geological Survey of Canada, 1982) and 23O (Hornbrook *et al.*, 1983). Detailed lake-sediment, lake-water and stream-geochemical surveys were completed over all regions of the map area (Butler and McConnell, 1989; McConnell, 2009, 2012a, b). The map area is included in a report on the glacial history and till geochemistry of Labrador (Klassen and Thompson, 1990).

A 1:1 000 000-scale residual total-field aeromagnetic map (Geological Survey of Canada, 1984), and 1:50 000-scale magnetic line contour maps have been compiled as a colour, shaded-relief map (Kilfoil, 2013), and a 1:500 000-Bouger gravity anomaly map (Earth Physics Branch, 1975). Parts of NTS map areas 23J/7 and 23J/10 are included in 1:50 000-scale airborne geophysical survey maps of the Lake Attikamagen–Schefferville region (Dumont *et al.*, 2010a, b).

The area was included in a survey of heavy mineral concentrates from esker sand and gravel collected over rocks of the Ashuanipi Complex and the Proterozoic Labrador Trough (Brushett and Amor, 2013).

EXPLORATION EFFORTS

Thomas and Butler (1987) carried out a bedrock-sampling survey of the Ashuanipi Complex in Labrador, to determine the potential for gold mineralization, based on anomalies detected by an earlier regional lake-sediment sampling program (Geological Survey of Canada, 1982). The survey delineated elevated gold values in several occurrences in gossan zones in gneissic rocks.

Subsequent gold exploration programs focused on bedrock and some soil, rock and stream sampling, in the vicinity of these and other gossan zones (McConnell *et al.*, 1987, 1989; Dimmell, 1989; Graves, 1992; Simpson, 2010).

In adjacent Québec, LaPointe (1986), Chevè and Brouillette (1992), LaPointe and Chown (1993) and Ivanov (2012) reported significant gold occurrences hosted in Archean Algoma-type, metamorphosed iron formation, intercalated with migmatitic gneisses northwest and east of the map area (Figures 1, 3B and 4B; *see* later section on Mineralization).

REGIONAL GEOLOGY

The Superior Province is an Archean craton that is divided into two main domains, and are further subdivided

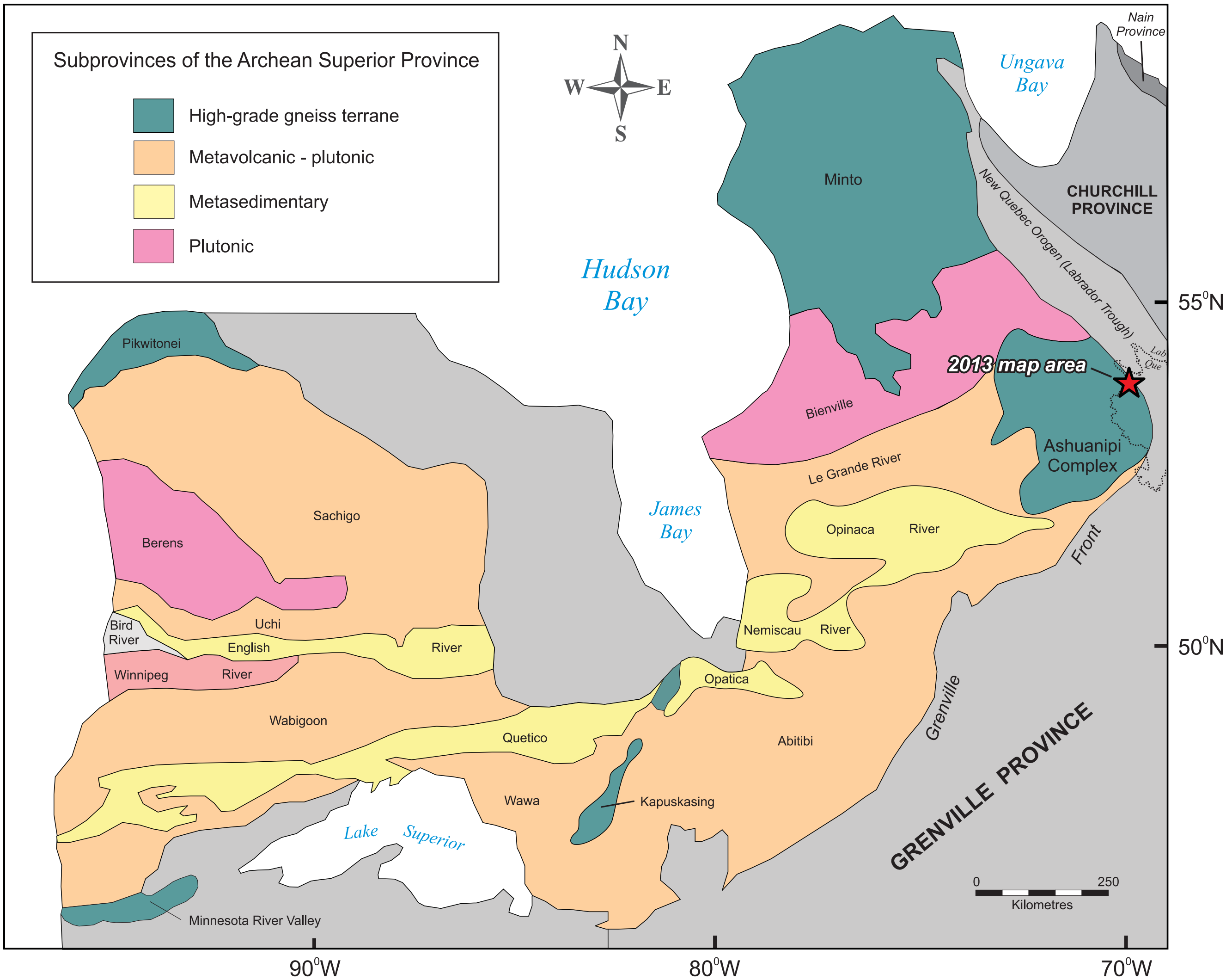


Figure 2. *Main subdivisions of the Archean Superior Province (modified from Card and Ciesielski, 1986). Location of the 2013 map area shown by red star.*

into several subprovinces (Card and Cieleski, 1986; Stott, 1997). The rocks in the northern domain are predominantly of continental affinity, have ages of 2.75 to 2.65 Ga, and contain crustal vestiges as old as 3.0 Ga (Percival *et al.*, 2003).

The southern domain consists of linear metavolcanic, metaplutonic and metasedimentary subprovinces (Card and Cieleski, 1986). The metavolcanic subprovinces contain sequences of low-grade volcanic rocks intruded by tonalite to granite plutons; collectively known as 'granite-greenstone' terranes. The metaplutonic subprovinces are distinguished on their lack of supracrustal rocks. The metasedimentary subprovinces comprise an approximately 2100-km-long belt that stretches across the southern Superior Province, and consist predominantly of metagreywacke sequences intruded by granite and tonalite. Most of the Superior Province formed between 3.0 and 2.65 Ga and the subprovinces demarcate amalgamated volcanic arcs, sedimentary prisms and composite terranes that were accreted, progressively, from north to south between 2.75 and 2.70 Ga. A subgreenschist- to granulite-facies transition from west to east, exposing the high-grade and deeper level Minto and Ashuanipi subprovinces in the east, is attributed to a wide-scale crustal tilting (Card and Cieleski, 1986; Percival and Williams, 1989; Card, 1990; Percival *et. al.,* 1992).

Percival and Williams (1989) proposed that the Quetico, Nemiscau, Opinaca and Ashuanipi subprovinces are remnants of a single, late, Archean accretionary prism, based on similarity of rock types and sedimentary features. Age relationships and lithological associations in the Ashuanipi Complex suggest a correlation with the predominantly amphibolite-facies Opinaca subprovince to the west (Figure 2).

Plate 1. *Typical physiography of the Ashuanipi Complex within the study area, showing well-exposed, rounded hill-tops and partially vegetated slopes and broad valleys.*

GEOLOGY OF THE ASHUANIPI COMPLEX

The Ashuanipi Complex is a granulite-grade sub-province of the eastern (Archean) Superior Province, approximately 90 000 km^2 in area (Card and Ciesielski, 1986; Figure 2). The complex is bounded by Proterozoic rocks of the New Québec Orogen (Labrador Trough) to the east, and by Archean rocks of the Le Grande, Bienville and Opinaca subprovinces to the west, north and southwest, respectively. To the southeast, the Ashuanipi Complex is bounded by the Grenville Front, but its reworked continuation extends into the Grenville Province.

The geology of the Ashuanipi Complex is dominated by migmatitic metasedimentary rocks derived from a predominantly psammitic protolith. The metasedimentary rocks are intruded by tonalite, granodiorite, quartz diorite, diorite and gabbro plutons, interpreted as a fractionated series of adakitic intrusive rocks, referred to as the Desliens igneous suite (Percival, 1991a; Percival *et al.*, 2003). Granulite-facies metamorphism produced orthopyroxene-bearing assemblages and migmatitic fabrics, and resulted in the intrusion of predominantly sedimentary-derived, syn-, to late-metamorphic stage diatexite (Percival, 1991b; James, 1997). Mafic and ultramafic rocks occur as isolated intrusions, sills, thin layers or dykes within the gneiss, the granitoid rocks and the diatexite. Leucogranite plutons are later intrusions that crosscut fabrics in other units. Pre-, to post-tectonic granite, alkali-feldspar granite and alkali-feldspar quartz-syenite veins, and pegmatite also intrude most units. The eastern margin of the Ashuanipi Complex is unconformably overlain by siliciclastic sedimentary rocks of the Proterozoic Knob Lake Group of the Labrador Trough, of the New Québec Orogen; these include primary iron formations (taconites) that are currently of exploration interest (Simpson, 2006). Percival (1987, 1991a, b) and Percival and Girard (1988) have described the regional geology of the Ashuanipi Complex in some detail, including the regional structural, metamorphic and geochronological relationships, and the reader is encouraged to consult these reports for additional information.

GEOCHRONOLOGY OF THE EASTERN ASHUANIPI COMPLEX

No age data have been reported from the map area, but, several U–Pb ages of monazite and zircon are available from related units in adjacent areas of Labrador and Québec. A summary of pertinent geochronological data is listed below.

Summary of Pertinent U–Pb geochronological data for the eastern Ashuanipi Complex

- 3.4 to 2.7 Ga: age range of detrital zircons from metasedimentary rocks; indicates that deposition of sedimentary rocks and minor volcanic rocks completed by *ca.* 2.7 Ga (Mortensen and Percival, 1987)
- 2.7 and 2.68 Ga: intrusion of tonalite, granodiorite, diorite and mafic rocks of the Desliens igneous suite (Percival, 1991a)
- 2.68 to 2.65 Ga: high-grade metamorphism, development of S_1 migmatitic fabric or foliation and intrusion of syn- to late-metamorphic garnet ± orthopyroxene-bearing granite and granodiorite diatexite (Mortensen and Percival, 1987)
- 2.65 to 2.63 Ga: post peak metamorphic cooling (Mortensen and Percival, 1987)
- 2.65 Ga: intrusion of posttectonic granite pegmatites and leucogranite (Percival *et al.*, 1992)
- 2.65 to 2.6 Ga: post-metamorphic thermal event resulting in new zircon crystallization in diatexite and new monazite growth in older gneisses (Chevè and Brouillette, 1992)

GEOLOGY OF THE MAP AREA

The geology of the Ashuanipi Complex within the map area is shown in Figures 3A and B. Part of the southern area outlined by the bold dashed line in Figure 3A, is compiled primarily from Percival (1993). The rocks include older migmatitic metasedimentary gneiss (paragneiss) intruded by pretectonic foliated to gneissic tonalite, granodiorite and diorite intrusions of the Desliens igneous suite. The rocks of the Desliens igneous suite occur as km-scale, west-north-west-striking, deformed sills or oblate-shaped intrusions, as smaller intrusions on a scale from 1 m to 100 m, and as abundant enclaves within diatexite and granitoid rocks (Fig-

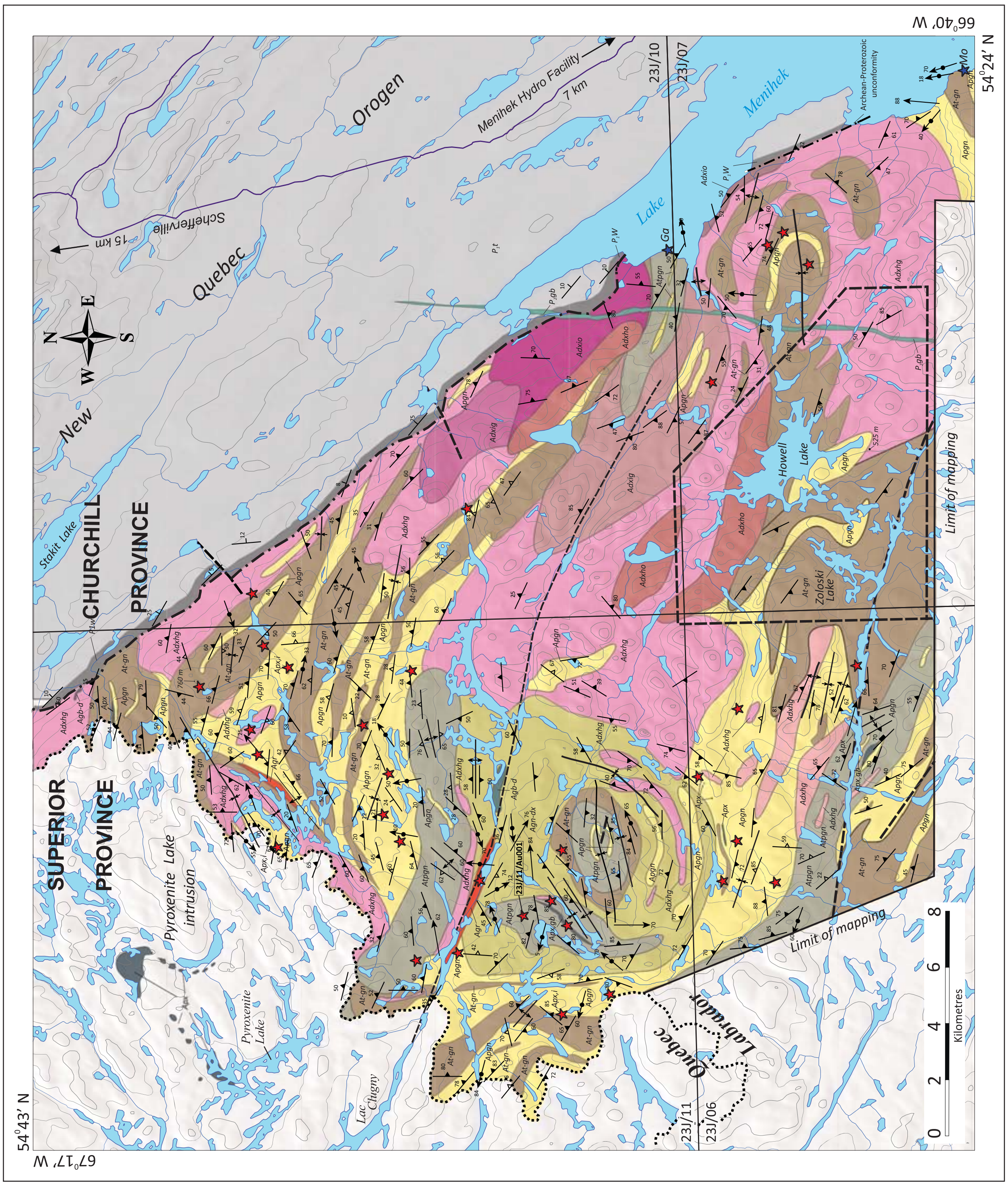


Figure 3A. *Map of the southern part of the Ashuanipi Complex in the map area, compiled from field data collected during the 2013 survey and from earlier work by Wardle (1982a) and Percival (1993). The area enclosed by the bold dashed line has been examined in 2013 only by helicopter reconnaissance, the geological patterns here being compiled from Percival (1993). The geology shown in the Pyroxenite Lake area in Québec is also compiled from Percival (ibid.)*

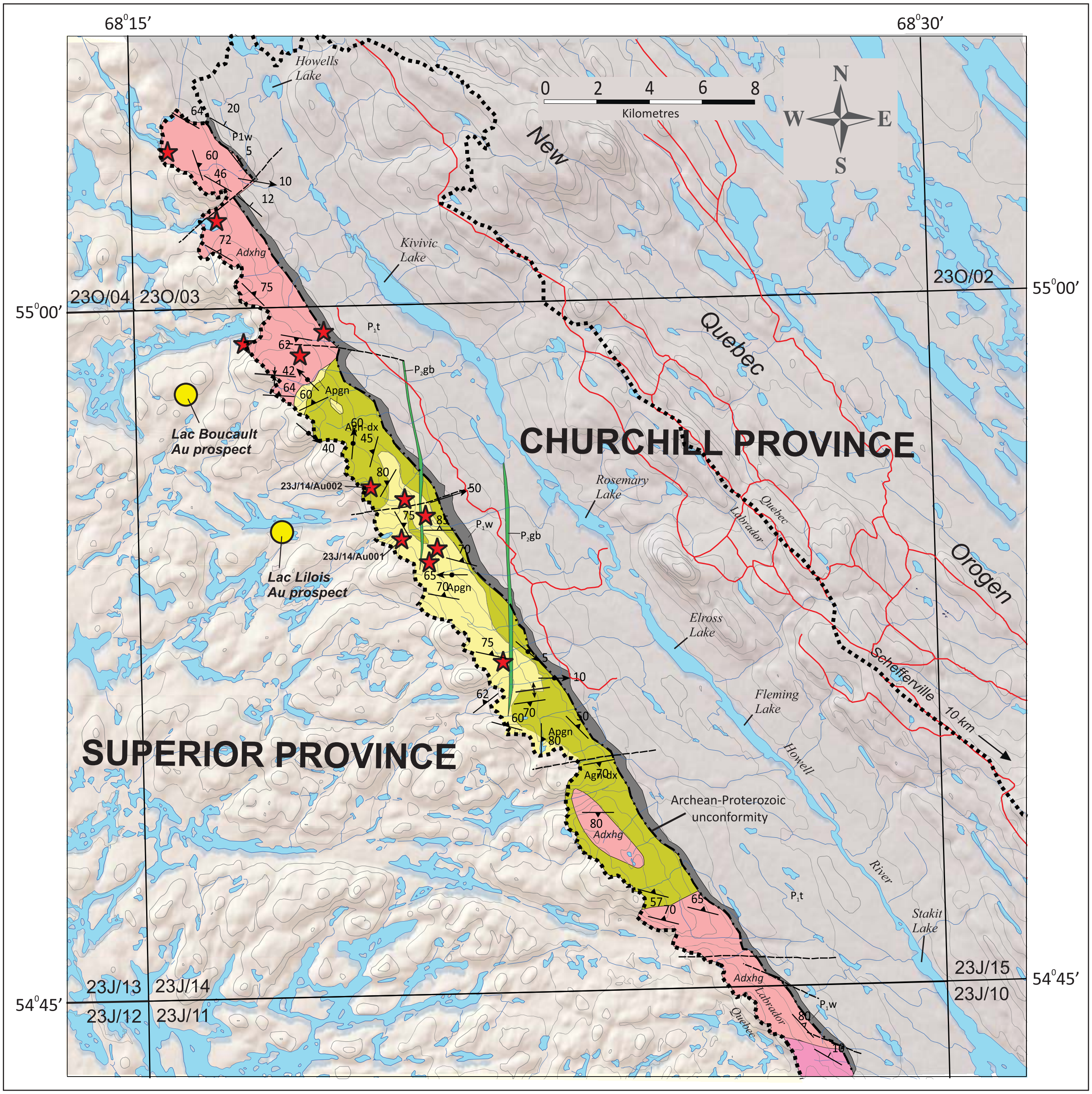
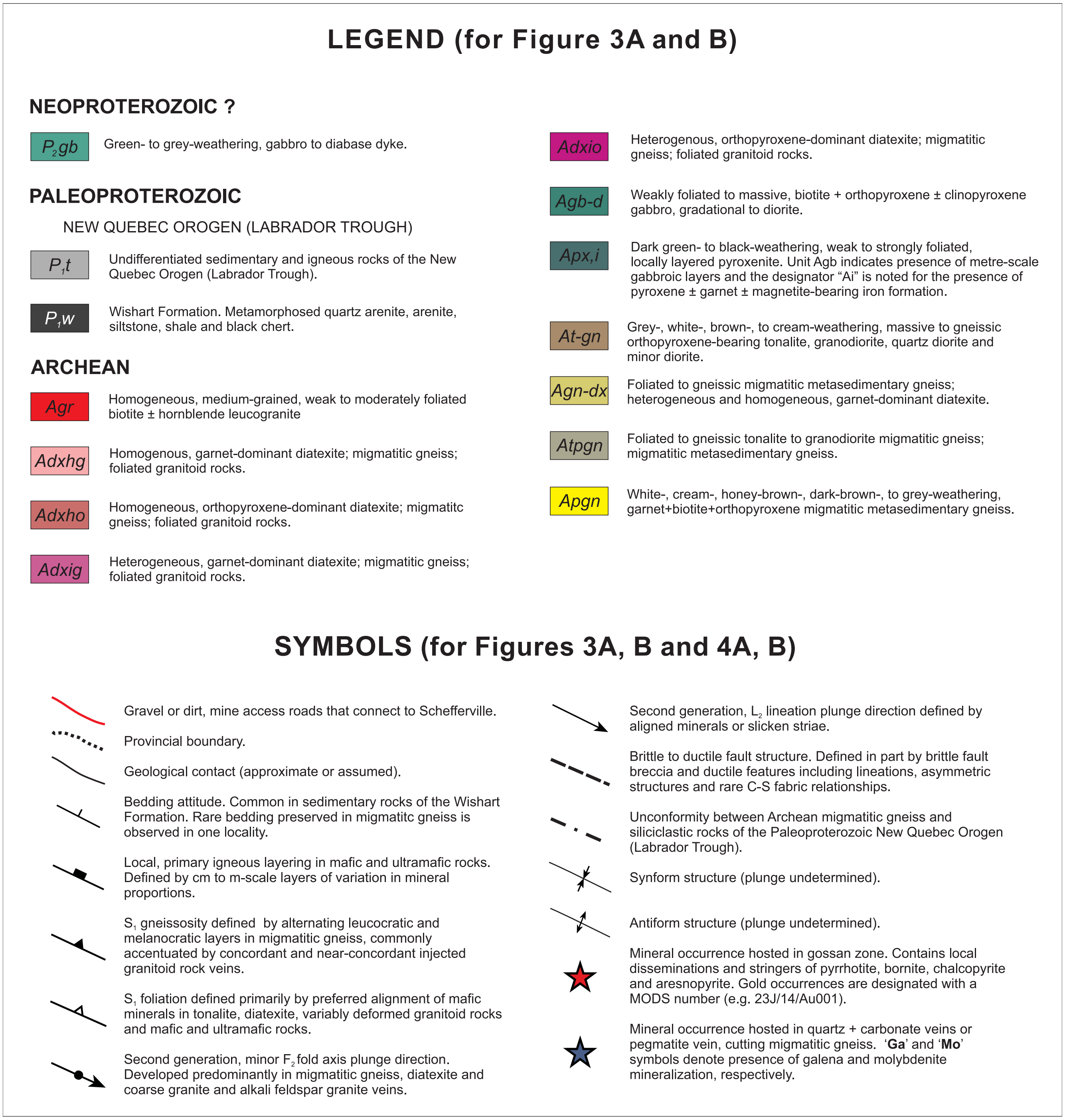


Figure 3B. *Map of the northern part of the Ashuanipi Complex in the map area, compiled from field data collected during the 2013 survey and from earlier work by Wardle (1982b).*

ure 3A). Gabbro and pyroxene-rich ultramafic rocks occur as small intrusions, sills and layers and may be related end members of the Desliens igneous suite. Granite to granodiorite diatexite is the dominant rock type, occurring as 10s of km-scale bodies in the eastern map area and as abundant outcrop-scale, syn- to late tectonic veins and concordant layers throughout the map area. Diatexite is subdivided into four units, based on proportion of older enclaves, and the dominance of either garnet- or orthopyroxene-bearing assemblages (Percival 1987, 1991a; Brown 1973). Later syn- to posttectonic granite and alkali-feldspar quartz-syenite pegmatite veins intrude most units. Fine-grained, metre-scale, northeast-striking gabbro dykes intrude gneissic rocks and diatexite in a few areas. Three, 100- to 200-m-wide, north-northeast-striking gabbro dykes postdate the deposition of the Proterozoic rocks of the Labrador Trough.



The dominant structural fabric is a west-northwest-striking, S_1 migmatitic layering in gneiss, and a weak to strong foliation in granitoid rocks and mafic rocks that are folded about steeply plunging F_2 axes. Granulite-facies conditions are inferred throughout the map area, based on widespread orthopyroxene–garnet–melt assemblages in the Archean migmatitic gneiss, but some granitoid and gabbroic rocks preserve remnants of primary pyroxene (Percival, 1991a). Quartz arenite, arenite, chert and siltstone of the Wishart Formation of the Labrador Trough, unconformably overlying the Archean gneiss and diatexite units along the eastern margin of the map area, have been affected only by a greenschist-facies overprint.

Several mineral occurrences are hosted in gossanous, migmatitic gneiss, foliated granitoid rocks, gabbro, pyroxenite and probable local zones of pyroxene-bearing, iron formation. These rocks have potential for hosting gold, copper and, in the case of ultramafic rocks, platinum-group-element (PGE) mineralization. Local, vein-hosted galena and molybdenite occur in gneissic rocks and/or pegmatite, immediately below the Archean–Proterozoic unconformity.

MIGMATITES – BACKGROUND AND TERMINOLOGY

Migmatites will be briefly discussed here because most rock units in the map area exhibit some degree of migmatization and some definitions and textural terms are pertinent to the descriptions.

Migmatite, as used in this report, is a medium- to high-grade metamorphic rock consisting of two of more petrographically different parts. The neosome (‘new rock’) is formed by partial melting and contains rocks that are petrogenetically related to each other and to their protolith, and consists of a leucosome (felsic-rich neosome) and may or may not contain a melanosome (mafic-rich neosome). A paleosome (’old rock’) component, which is unaffected by partial melting, may also be present (Sawyer, 2008).

The two-fold division of migmatites are metatexite and diatexite (Brown, 1973; Sawyer, 2008). Metatexite is heterogeneous at the outcrop scale, but primary structures in the paleosome and possibly, in the melanosome, are variably preserved. Diatexite refers to a migmatite, in which the neosome, derived from partial melting, is dominant and is distributed throughout the rock. Paleosome components may be present as rafts or schollen.

Migmatite Textures

The migmatitic rocks of the Ashuanipi Complex have been discussed in detail in several studies (Percival, 1991b; Guernina and Sawyer, 2003; Guernina, 2007; Sawyer, 2008) and the reader is referred to these to augment the following descriptions.

Migmatites within the map area exhibit a wide range of morphologies and textures and a brief discussion of these types follows.

Metatexite textures are predominantly stromatic, defined by a near-pervasive alternation of cm-, to m-scale, neosome and paleosome components (Plate 2). Patch and nebulitic migmatites consist of massive to foliated neosome incorporating paleosome remnants having diffuse contacts, and may indicate the proximity to a ’melt-in’ isograd (Plate 3).

Dilation-structured migmatites are characterized by the neosome occurring in low-pressure structural sites, such as between boudins, and imply a competency contrast between lithologically different layers (Sawyer, 2008; Plate 4)

Diatexite exhibits a range of textures. A dominant type is a massive, coarse-grained, homogeneous, granitic-textured rock (Plate 5). Also present are schleiric-textured rocks, defined by thin, trains of platy minerals in a homogeneous neosome (Plate 6), as well as schollen-structured (enclave-bearing) diatexite in which rafts of paleosome occur in the neosome (Plate 7). The last type is an atypical texture in these rocks; however it is an indication of a transition from metatexite to diatexite morphologies (Sawyer, 2008).

Metatexite–Diatexite Transitions

Apparent metatexite to diatexite transitions are present locally. For example, a stromatic-textured metatexite gneiss (Plate 8) may pass gradationally through to a patch or nebulitic migmatite characterized by small zones of paleosome within a granite neosome (Plate 9), to a final partial melt stage of coarse-grained, massive, homogeneous, granitic-textured, neosome-dominant diatexite (Plate 10). Percival (1991b) did not record migmatitic transitions of this nature within the map area and this apparent absence partially supported his interpretation that the metatexite units are inherently older because they occur consistently as enclaves within the diatexite units. However, the localized transition, from metatexite to diatexite outlined above and illustrated in the accompanying plates, suggest that some diatexite may be locally derived from metatexite country rocks, resulting from variable degrees of partial melting on the outcrop-scale. This gradation is also supported by the presence of other migmatite transition ’indicators’ such as schollen-textured diatexite (Plate 7). But Guernina (2007) indicated that migmatite transitions in the Ashuanipi Complex may also result from the intrusion of anatectic granite into dilatant structural sites and the subsequent interaction of that granite with the wall rocks.

The differentiation between *in situ* leucosome melt and later injected, concordant granitic veins is not always readily apparent in the migmatitic rocks. Diffuse contact relationships between leucosome (± melanosome) and paleosome components support a petrogenetic and protolithic link indicating *in situ* melt generation. Alternatively, sharp, and locally chilled contacts of felsic veins, which may be very slightly discordant to the fabric, indicate a lack of petrogenetic relationship and, thus imply these veins are later, injected material, not related to the initial partial melting (Sawyer, 2008; Plate 11).

Plate 2. *Orthopyroxene-bearing tonalite gneiss (metatexite, Unit At-gn) exhibiting the typical stromatic (layered) texture defined by cm-scale alternations of light-weathering leucosome and dark-weathering pre-partial melt paleosome.*

Plate 3. *Nebulitic to patch diatexite migmatite consisting of predominantly, garnet-bearing granite neosome with small, pre-melt, orthopyroxene–biotite paleosome patches (left of scale card).*

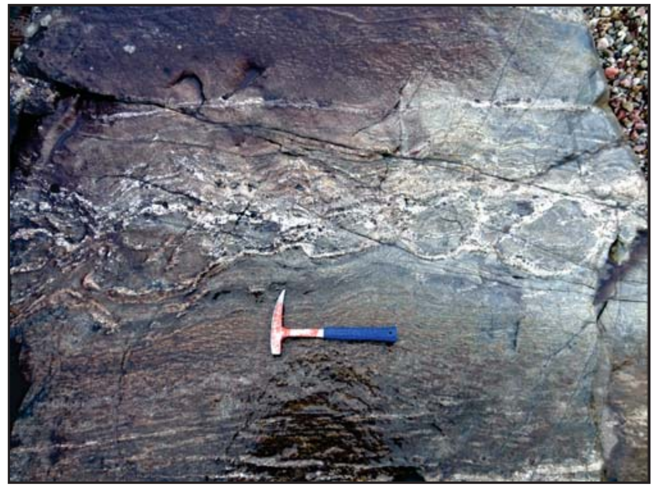


Plate 4. *Dilation-textured migmatite in which orthopyroxene-bearing granite neosome occurs in dilatant (low pressure) sites in between boudinaged layers. Texture is indicative of a competency difference between compositional layering.*

Plate 5. *Typical coarse-grained, homogeneous, massive garnet-bearing diatexite migmatite (Unit Adxhg). This unit is primarily granodiorite in composition although is locally gradational to granite.*

DESCRIPTION OF ROCK UNITS

All rock types have been described previously, in some detail, by Percival (1987, 1991a, b), Percival and Girard (1988) and Percival *et al.* (1992). The salient features of the rock units shown in Figure 3A and B are discussed below. The reader is referred to the aforementioned studies for additional descriptions pertaining to both the map area and the regional geology of the Ashuanipi Complex. All igneous rocks described below, except late gabbro dykes, are metamorphic and should be prefixed by meta-, but, for simplicity, igneous terminology is retained.

UNIT Apgn – MIGMATITIC PARAGNEISS

The oldest rock unit, based on field relationships, is migmatitic paragneiss. Rocks of this unit are white-, cream-, grey-, tan-, to honey-brown-weathering, fine-, to medium-grained, biotite + garnet ± orthopyroxene psammitic to semi-pelitic gneiss. Bulk compositions of these rocks resemble typical Archean greywacke with a maximum depositional age of 2.7 Ga (Percival, 1991b). The paragneiss exhibit a dominant stromatic structure, where mm- to cm-scale melanosome ± paleosome layers alternate with granite

Plate 6. *Garnet-bearing, granite to granodiorite diatexite exhibiting a schleiric texture. Fabric is defined by thin aligned lenses of biotite (± orthopyroxene) in a predominant quartzofeldspathic neosome.*

Plate 7. *Raft- or schollen-textured migmatite consisting of lenses of orthopyroxene–biotite–garnet paleosome in a coarse-grained granodiorite neosome. Texture suggests transition between metatexite and diatexite and may indicate the proximity to a 'melt-in' isograd.*

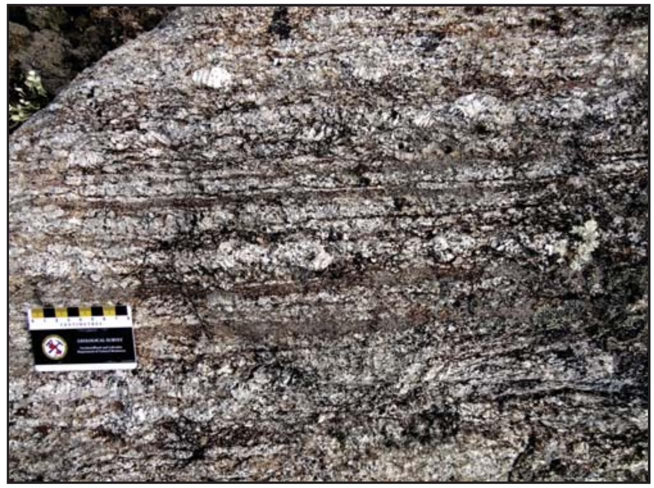


Plate 8. *Initial metatexite stage of apparent migmatite transition occurring on the local outcrop scale. Here stromatic-textured, orthopyroxene–garnet paragneiss, with well-developed layering of leucosome and paleosome components.*

Plate 9. *Intermediate stage of transition with the development of patch or nebulitic migmatite showing predominant granitic neosome component with irregular-shaped, diffusely bounded paleosome 'patches'. The texture is indicative of a partial melting transition (*cf. *Sawyer, 2008).*

to granodiorite leucosome. Concordant granite and alkali-feldspar granite veins accentuate the layering, the latter of which varies from a dominant 'straightened' appearance to variably folded (Plates 12 and 13). Patch and nebulitic metatexites are the other widespread migmatitic paragneiss textures. Garnet porphyroblasts are near ubiquitous and vary from red, maroon, orange, brown to pink, are anhedral to subhedral and range from 1 mm to several cm in diameter, and comprise up to 10% of the total rock. Feldspars, quartz, pyroxene, biotite and magnetite inclusions are common. Orthopyroxene occurs as dark-brown to black-weathering, anhedral to subhedral, commonly 'blocky' porphyroblasts, ranging from 1 mm to 1.5 cm in diameter and locally comprising up to 10 % of the total rock.

Relict sedimentary bedding was recorded at only one location, as a 25-cm-wide layer of psammitic composition intercalated with semi-pelitic paragneiss (Plate 14).

Desliens Igneous Suite: Tonalite–Diorite–Gabbro

Percival (1987, 1991a) and Percival *et al.* (2003) proposed the name Desliens igneous suite for a 500-km-long

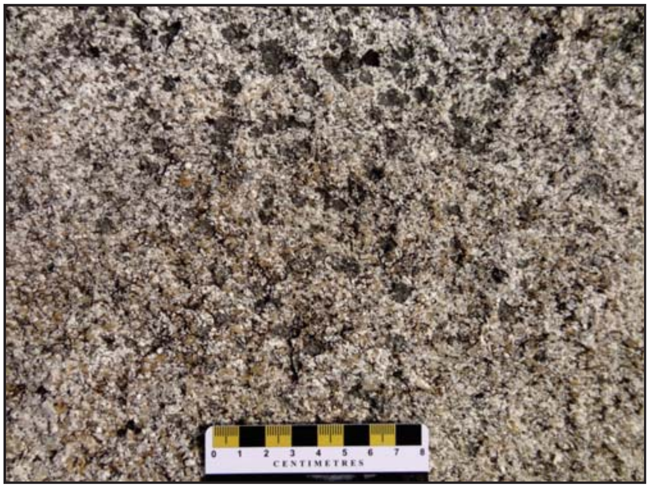


Plate 10. *Final stage of migmatite transition with the formation of a massive, homogeneous, granitic-textured orthopyroxene–garnet-bearing neosome, with no evidence of a pre-existing paleosome component.*

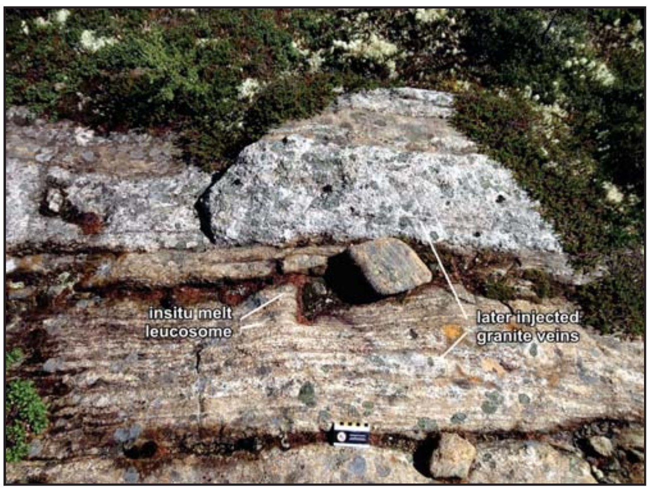


Plate 11. *Garnet + orthopyroxene paragneiss (Unit Apgn) illustrating the distinction between early in situ partial melt leucosome (the thin cream-weathering quartzofeldspathic layers alternating with biotite ± orthopyroxene paleosome) and later injected granite veins, which may not be derived from local source material.*

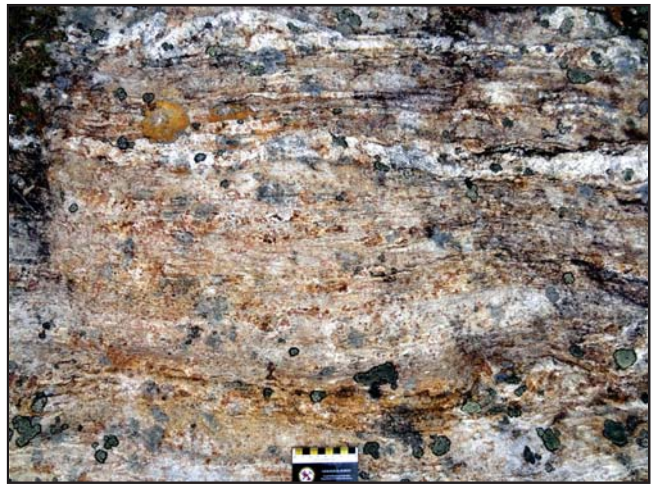


Plate 12. *Garnet + minor orthopyroxene-bearing, locally semi-pelitic, migmatitic paragneiss (Unit Apgn), showing the dominant "straightened" stromatic texture typical of these gneisses. The migmatitic layering is accentuated by later, concordant granite to alkali feldspar granite veins.*

Plate 13. *Folded stromatic migmatitic texture in garnet–orthopyroxene–biotite paragneiss (Unit Apgn). The rusty-weathering zones are common in the paragneiss unit due to fine-grained pyrite and biotite alteration.*

belt of pretectonic tonalitic to mafic intrusions, characterized by adakitic geochemical affinities, in the eastern Superior Province. These rocks, and their sedimentary host rocks, were variably deformed and metamorphosed at granulite facies and subsequently intruded by felsic granitoid diatexite. Field relationships within the map area indicate that the tonalite, diorite, gabbro and ultramafic rocks are the oldest plutonic units in the map area. Percival (1991a) proposed, on the basis of textural, geochemical and geochronological attributes, that these units are a fractionated igneous series of mafic–ultramafic through tonalitic compositions, a compositional spectrum common in magmatic suites of all ages (Arth *et al.*, 1978).

Although rocks of the Desliens igneous suite are similar to other Archean gneissic, tonalite–trondhjemite suites with respect to the pretectonic timing of intrusion and their presence in a high-grade metamorphic terrane, Percival (1991a) noted that the tonalitic to mafic rocks in the Ashuanipi Complex differ in having an apparent primary anhydrous mineralogy and in their association with texturally similar rocks of more mafic composition.

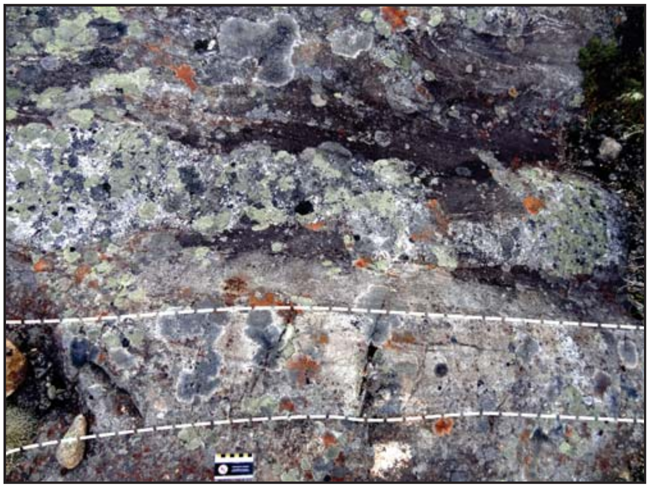


Plate 14. *Rare example of a relict sedimentary psammitic bed (outlined by dashed lines) intercalated with migmatitic gneiss in which, local, very thin neosome layers, alternate with thicker zones of paleosome.*

Plate 15. *Medium-grained, massive to weakly foliated tonalite of the Desliens igneous suite. Irregular brown patches are sieve-textured, inclusion-rich orthopyroxene, interpreted as relict igneous oikocrysts.*

UNIT At-gn – FOLIATED TO GNEISSIC TONALITE, GRANODIORITE AND DIORITE

The pretectonic tonalitic to dioritic rocks (Unit Amt of Percival, 1993) occur as i) km-scale northwest-striking belts, ii) irregular, oblate-shaped bodies, iii) layers on a scale of metres or tens of metres intercalated with gneissic rocks, and iv) enclaves within younger diatexite. The rocks of this unit are predominantly tonalite but include granodiorite, quartz diorite and diorite. They vary from white-, green-, brown-, to grey-weathering, fine- to coarse-grained and massive to gneissic. The dominant mineral assemblage is biotite + orthopyroxene ± clinopyroxene ± garnet ± amphibole. Percival (1987) noted the absence of a leucosome component in the foliated tonalite and interpreted these rocks as less-deformed equivalents of the tonalite gneiss.

A characteristic feature of the foliated tonalite is the presence of brown-, grey-, to black-weathering, anhedral to subhedral, inclusion-filled, orthopyroxene crystals up to 3 cm in diameter (Plate 15). Percival (1991a) interpreted these sieve-textured orthopyroxenes as a relict igneous phase overprinted by granulite-facies-metamorphic assemblages and the migmatitic S_1 fabric. James (1997), however, reported the presence of resorbed, sieve-textured metamorphic orthopyroxenes in metasedimentary gneiss in the southern part of the northeastern Ashuanipi Complex, bringing into question the igneous origin of the orthopyroxenes in the tonalitic rocks.

The gneissic equivalent of this unit exhibits diffuse-, to well-layered cm-scale alternations of leucosome (± melanosome) and paleosome. The gneisses are finer grained than the foliated tonalitic rocks. The inclusion-rich oikocrystic orthopyroxenes are not as evident in the strongly deformed rocks, where pyroxene occurs more commonly as subhedral porphyroblasts (Plate 16).

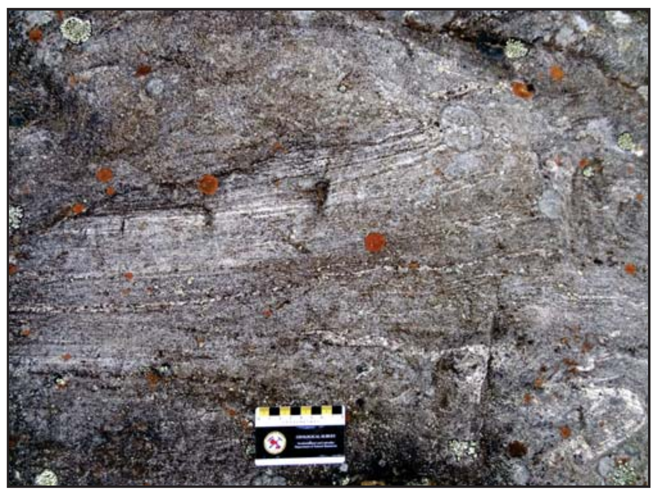


Plate 16. *Fine-grained, stromatic-textured, orthopyroxene-bearing migmatitic tonalite gneiss of the Desliens igneous suite. Interpreted as a gneissic equivalent of the massive to foliated, oikocrystic tonalite shown in Plate 15.*

Mafic and Ultramafic Rocks of the Desliens Igneous Suite

Mafic and ultramafic rocks are a subordinate unit within the map area and occur as boudinaged, map-scale bodies and as metre- and 10s of metre-scale lenses and layers of massive to layered pyroxenite, gabbro and minor diorite. Percival (1991a) proposed that these rocks are the fractionated mafic end members of the Desliens igneous suite. He based this correlation on close similarities between the two, using features such as analogous field relations, comparative textures, relative ages with respect to adjacent rocks and the presence of relict igneous orthopyroxenes.

UNIT Agb-d – GABBRO–DIORITE

Mafic rocks, ranging from dioritic to gabbroic in composition, occur as minor intrusions, dykes and probable deformed sills intercalated with gneissic units and diatexite. Two map-scale bodies occur in the southern map area (Figure 3A). The largest is a gabbro to diorite intrusion located along the northwest-striking fault that runs through the central part of the map area. A smaller gabbro body occurs in the northern part, adjacent to the Archean–Proterozoic unconformity (Figure 3A).

Metre-scale lenses of gabbro (and subordinate diorite) are locally intercalated with gneissic rocks, foliated tonalite and some pyroxenite bodies throughout the map area.

UNIT Apx – PYROXENE-RICH ULTRAMAFIC ROCKS AND ASSOCIATED GABBRO

Ultramafic rocks, primarily pyroxenite in composition, are a subordinate unit in the map area occurring as bodies up to 200-m wide as well as metre-scale layers and lenses intercalated with paragneiss and foliated to gneissic granitoid rocks (Figure 3A). The protolith of these rocks is equivocal, but their elongate and tabular shape, concordant and sharp contacts and rare, chilled margins with the enclosing rocks, suggest they are probable sills. Such an origin was suggested by Percival (1987) for some of these rocks within the current map area and Percival (*ibid*) and Morisset (1988) likewise interpreted similar rocks north of the map area in the Pyroxenite Lake area in Québec as sills (Figure 3A).

The rocks exhibit a variety of textures ranging from massive and containing very coarse-grained pyroxene crystals (oikocrysts ?) to fine-grained and locally layered to strongly foliated (Plates 17 and 18).

Igneous layering is developed within mafic and ultramafic rocks in a few areas, defined by diffuse variations in the proportions of constituent minerals and by metre-scale gabbroic layers.

One of the largest ultramafic bodies is located in the western part of the map area, enclosed by a unit of undifferentiated paragneiss and tonalite gneiss. The intrusion is approximately 150 m wide and can be traced for approximately 1.5 km in a north-northeasterly strike direction (Figure 3A). The sill, and enclosing rocks, are associated with a very strong aeromagnetic high (Figure 4A). The intrusion

Plate 17. *Very coarse-grained, massive to weakly foliated pyroxenite. Large anhedral green-grey-weathering crystals are orthopyroxene (oikocrysts ?) in a medium-grained matrix of pyroxene, olivine and amphibole. White areas are lichen-covered patches.*

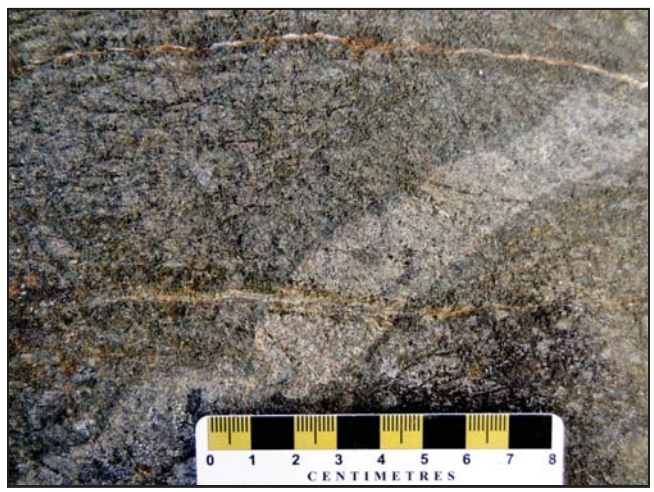


Plate 18. *Medium-grained, green-weathering, massive to foliated pyroxenite (Unit Apx) with a leucocratic plagioclase–pyroxene layer, which are both cut by thin serpentinite veins.*

consists predominantly of dark-green- to black-weathering, medium- to coarse-grained, moderately to strongly foliated pyroxenite, grading locally to olivine gabbro, harzburgite and probable minor dunite. Thin, mm-scale, cream-weathering sepentinite (?) veins crosscut the fabric in several areas and a strongly foliated, coarse-grained pyroxenite, in the central part of the body, appears to be truncated at a low angle by a younger medium-grained mafic intrusion (Plate 19). It is not yet known if there is a genetic relationship between the two intrusions.

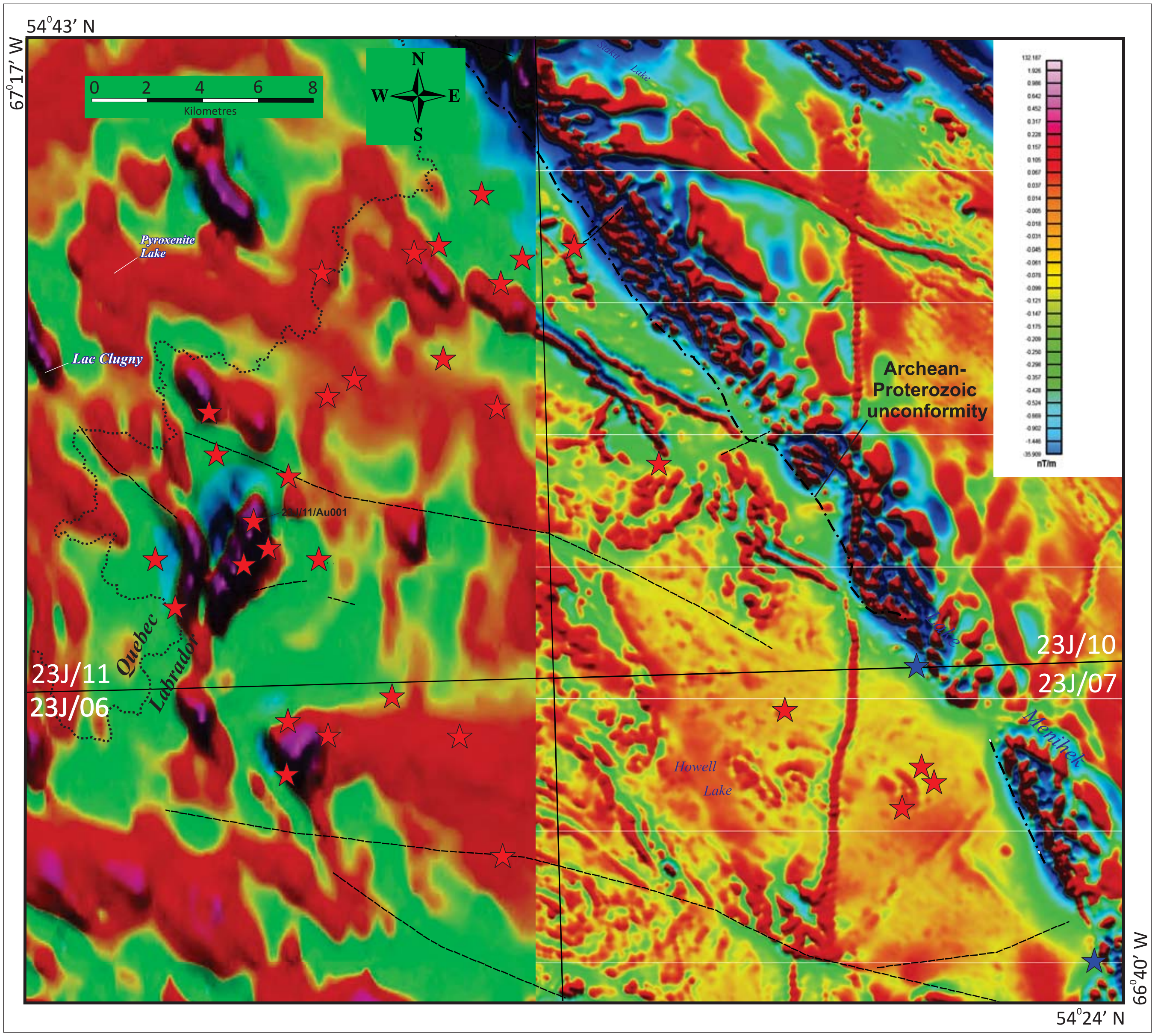


Figure 4A. *Regional and detailed aeromagnetic compilation covering southern part of the map area and surrounding region (same scale as Figure 3A). A 1:50 000-scale aeromagnetic survey covers parts of NTS 23J/07 and 23J/10 (Dumont* et al.*, 2010a, b) and a regional compilation covers parts of NTS 23J/11 and 23J/06 (Geological Survey of Canada, 1984; Kilfoil, 2013). Dashed lines are fault structures.*

OTHER PRETECTONIC ROCK UNITS

UNIT Ai – PROBABLE IRON FORMATION ROCKS

This unit is of interest from the perspective of economic geology. It consists of rare, strongly altered, cm-, to 10s of cm-scale, pyroxene ± garnet ± magnetite-bearing lenses that are intercalated with gneissic and foliated granitoid rocks (Thomas and Butler, 1987). The lenses are massive to locally diffusely banded, are very dense, appear to be concordant with the fabric in surrounding rocks and contain local, disseminated pyrrhotite and minor chalcopyrite and rare arsenopyrite (Plate 20). Although the protolith of these rocks is equivocal, partly due to the strongly altered state and the similarity to intrusive pyroxenites of Unit Apx, some of these lenses resemble auriferous, pyroxene–garnet–magnetite iron formation rocks intercalated with migmatites in adjacent Québec (LaPointe and Chown, 1993; Ivanov, 2012; *see* section below on Mineralization).

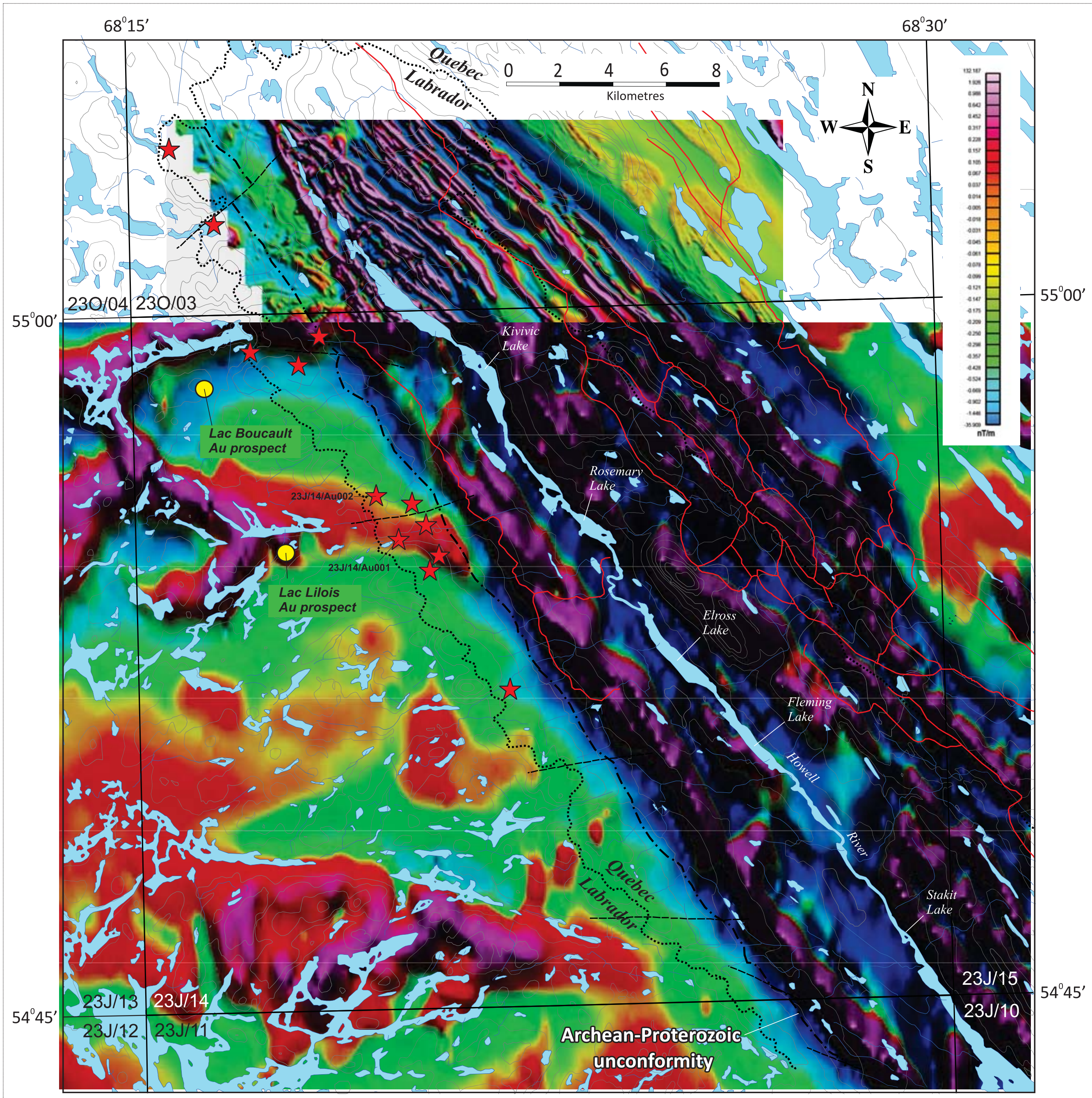


Figure 4B. *Aeromagnetic compilation for the northern map area. A 1:50 000-scale survey covers part of 23O/03 (D'Amours and Intissar, 2013) and a regional-scale compilation covers parts of NTS 23J/10, 11, 12, 13, 14 and 15 (Geological Survey of Canada, 1984; Kilfoil, 2013).*

UNIT Atpgn – UNDIFFERENTIATED METATEXITE

Extensive regions in the southern map area (Figure 3A), are underlain predominantly by paragneiss and tonalite intrusions that are intercalated on scales of 10s and 100s of metres and are not subdivided at the present scale of mapping. The contacts of this undifferentiated unit and the tonalite (Unit At-gn) and paragneiss (Unit Apgn) units are gradational.

UNIT Agn-dx – UNDIFFERENTIATED METATEXITE AND DIATEXITE

This is a diverse unit consisting primarily of

Plate 19. *Strong foliation in dark-weathering pyroxenite (Unit Apx) appears to be truncated at a low angle, by a fine-grained, weakly foliated mafic intrusion. The later intrusion may be one of the fine-grained dykes that intrude metatexite units in some areas (as in Plate 26) or it may have a genetic link to the host pyroxenite unit.*

Plate 20. *Strongly altered, thinly layered 10-cm-wide zone of pyroxene + minor magnetite rock (Unit Ai) containing minor pyrrhotite mineralization.*

garnet–orthopyroxene paragneiss and intruded, on a scale of metres to 10s of metres, by subordinate, foliated to gneissic tonalite and by coarse-grained, predominantly garnet–diatexite (*see* below). This unit has not been subdivided on Figures 3A and B.

Diatexite Rocks

Diatexite is a product of the advanced stages of anatexis (partial melting) of older gneisses, in which a neosome component is distributed throughout the rock (Sawyer, 2008). Diatexite is a predominant rock type, occurring as map-scale bodies containing older gneiss and foliated granitoid rock enclaves, and as metre- to 10s of m-scale veins and bodies intruding metatexite units.

The diatexites are divided into two compositional types and two textural types, namely i) homogeneous and heterogeneous garnet–diatexite and ii) homogeneous and heterogeneous orthopyroxene diatexite. Homogeneous and heterogeneous are used to characterize diatexite having, respectively, less and more than 25% enclaves (Brown, 1973). These subdivisions were recognized by Percival (1991a, 1993) and used to delineate individual map-scale bodies, and they are applied to the present study. Diatexites have been described in some detail elsewhere (Percival, 1987, 1991b) and only the pertinent features of these units will be discussed below.

Unit Adxhg – HOMOGENEOUS GARNET–DIATEXITE

The predominant type in this unit is a homogeneous, enclave-poor, garnet-dominant granodiorite to granite diatexite (Plate 21). This is a white-, grey-, and pink-weathering, medium- to coarse-grained, and massive to moderately foliated unit. It exhibits a range of migmatite types, but is dominated by a coarse-grained, homogenous and massive texture indicative of high degrees of partial melting (*cf.* Sawyer, 2008). Garnet porphyroblasts comprise 5 to 15% of the rock. The garnets are pink-, red-, and orange-weathering, subhedral to anhedral, commonly fractured and inclusion-filled are range from 1mm to 3 cm in diameter. The diatexite also contains up to 10% subhedral, ‘blocky’ orthopyroxene porphyroblasts.

UNIT Adxig – HETEROGENEOUS GARNET–DIATEXITE

This unit, having a predominant granodiorite composition, is a variant of Unit Adxhg. It has similar mafic mineral contents and differs only in the proportion of older enclaves. The mafic mineral contents appear to be proportional to the percentage of enclaves present (Plate 22).

UNIT Adxho – HOMOGENEOUS ORTHOPYROXENE–DIATEXITE

Orthopyroxene–diatexite in which the proportion of enclaves ranges approximately 5 to 15% of the total outcrop, occurs primarily as two map-scale intrusions north of Howell Lake and as a marginal phase of a heterogeneous orthopyroxene–diatexite unit northwest of Menihek Lake (Figure 3a). The diatexite is coarse grained, massive, predominantly granite in composition, and contains 5 to 10% subhedral orthopyroxene, 5 to 10% biotite and subordinate garnet (Plate 23).

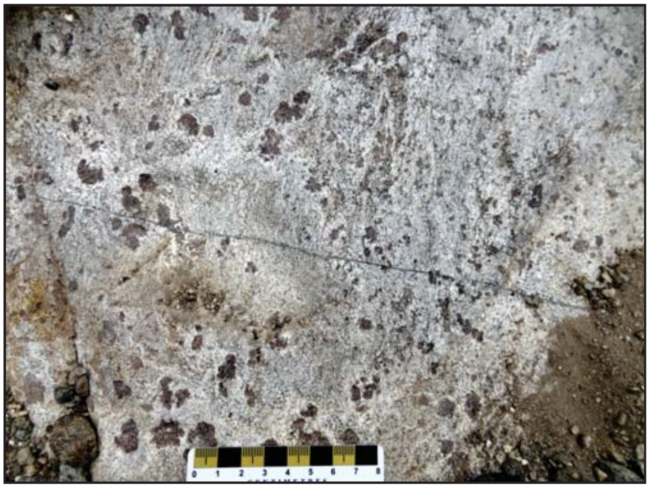


Plate 21. *Homogeneous, medium-grained, garnet–diatexite migmatite (Unit Adxhg) exhibiting a local fabric in central part of photo and mafic-depleted haloes surrounding garnet porphyroblasts.*

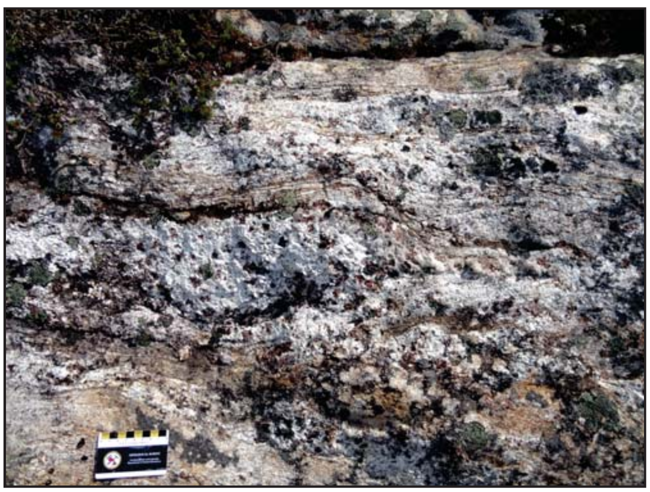


Plate 22. *Heterogeneous garnet–diatexite migmatite (Unit Adxig) veins intruding, and containing small enclaves of, thinly banded garnetiferous migmatitic paragneiss (Unit Apgn).*

UNIT Adxio – HETEROGENEOUS ORTHOPYROXENE–DIATEXITE

Heterogeneous orthopyroxene–diatexite occurs along the eastern edge of the map area and is gradational to the adjacent intrusion of Unit Adxho. The diatexite is characterized by abundant, (25% or more) enclaves of foliated to gneissic tonalite and paragneiss. The orthopyroxene occurs as subhedral to locally euhedral dark-brown-, and black-weathering porphyroblasts having sharp grain boundaries and comprising 2 to 15% of the rock. Biotite is a minor phase, ranging up to 5% of the total rock (Plate 24).

Plate 23. *Homogeneous, medium-, to coarse-grained orthopyroxene-dominant diatexite (Unit Adxho).*

Plate 24. *Heterogeneous, orthopyroxene–garnet diatexite (Unit Adxio) with abundant enclaves of fine-grained, locally oikocrystic tonalite (Unit At-gn) of the Desliens igneous suite (outlined by dashed lines).*

LATE- to POSTTECTONIC IGNEOUS ROCKS

UNIT Agr – LEUCOGRANITE

These rocks are very minor and are limited to 100- to 200-m-wide, elongate intrusions of massive to weakly foliated, leucocratic biotite ± hornblende granite. Only two bodies are depicted on Figure 3A, one located in the western area, along a north-northwest-striking fault, and a second intrusion is located in the northwestern map area, near the Labrador–Québec border.

Plate 25. *Two generations of alkali-feldspar granite veins intruding a strongly foliated to locally migmatitic tonalite (Unit At-gn). Pre- to syntectonic parallel veins are concordant to the S_1 fabric in the tonalite. These are cut by a late, D_2 open-folded vein intruded perpendicular to the S_1 fabric.*

Plate 26. *Fine-grained, northeast-striking, 1-m-wide mafic dyke intruding foliated tonalite (8-cm-size scale card in bottom centre of photograph). The dyke margins are delineated by white lines.*

GRANITE AND ALKALI-FELDSPAR GRANITE PEGMATITE VEINS

Coarse-grained to pegmatitic granite, alkali-feldspar granite and alkali-feldspar-quartz syenite are widely distributed rock types and thus are not depicted on Figure 3A and B. They occur as pre- to posttectonic, cm-, to 10s of m-wide veins and minor intrusions (Plate 25). Pre- and syntectonic veins enhance the overall migmatitic fabric in many rocks, particularly in metatexite units where the vein margins are concordant with pre-existing leucosome and paleosome. The veins in extensively veined migmatites are commonly difficult to distinguish from an *in situ* partial melt phase.

FINE-GRAINED GABBRO DYKES

Concordant to slightly discordant, northeast-striking gabbro dykes intrude gneissic and foliated rocks in several localities. The dykes are fine-grained, massive, homogeneous, appear fresh, and contain plagioclase, clinopyroxene as well as minor olivine and possibly amphibole. The dykes range from one to five metres in width, appear undeformed and have local, well-developed chilled margins (Plate 26). Percival (1987) reported several, northerly striking mafic dykes, all less than 30 m wide and suggested they are of tholeiitic origin. James (1997) reported three sets of mafic dykes intruding rocks of the Ashuanipi Complex in the Labrador City area. He proposed that dykes that have a northeast-striking (050°) orientation may be related to the Paleoproterozoic Preissac dyke swarm, which occur elsewhere in the Superior Province (Fahrig and West, 1986). A similar interpretation may apply to the fine-grained dykes in the map area.

PROTEROZOIC ROCKS

UNIT P_1w – WISHART FORMATION (LABRADOR TROUGH)

The Wishart Formation, which is the basal unit of the Paleoproterozoic Knob Lake Group of the Labrador Trough (Harrison, 1952; Wardle *et al.*, 2002), unconformably overlies Archean migmatitic gneiss and diatexite at the extreme eastern margin of the map area (Figure 3A and B). The Wishart Formation consists of white-, cream-, and grey-weathering, medium-grained, planar- and crossbedded quartz arenite (referred to as orthoquartzite, Wardle, 1982a), arenite, grey shale and black chert (Plate 27). The base of the formation, in contact with Archean gneisses, is marked in some areas by a cobble to pebble conglomerate. The conglomerate contains angular to subrounded quartz and rare quartz arenite fragments in a fine-, to medium-grained arenaceous matrix, locally occurring as cm-thick veneers within shallow depressions on the paleosurface (Plate 28).

UNIT P_2gb – GABBRO DYKES

Three, north-northeast-striking dykes crosscut the Archean–Proterozoic unconformity and rocks of the Labrador Trough at the eastern margin of the map area (Figure 3A and B). Wardle (1982a, b) referred to such undated dykes as “Mary Jo diabase”. The dykes are poorly exposed, but the extent of one dyke in the southern map area can be delineated by a strong, positive, linear aeromagnetic signature (Figure 4A). The width of the dykes could not be confidently determined, but based on the documented exposures, topography and aeromagnetic signatures, they are between 150 and 250 m wide. The gabbro is grey- to brown-

Plate 27. *Thinly bedded quartz arenite of the basal Wishart Formation, Labrador Trough (Unit P_1w). Note low-angle crossbedding shown by black arrow, in central-top of photograph.*

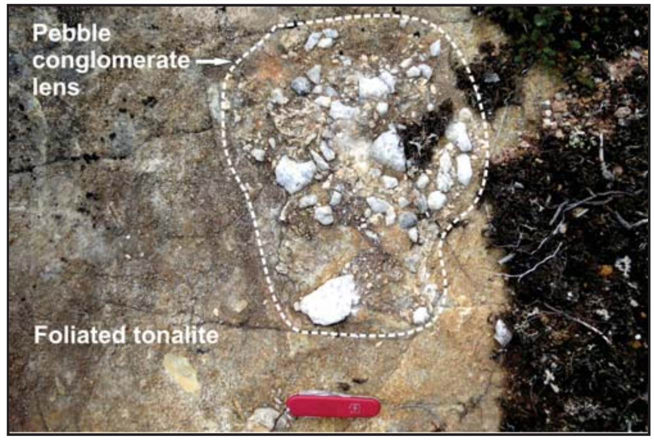


Plate 28. *Thin lens of pebble to cobble conglomerate overlying foliated granitoid rocks, marking the Archean–Proterozoic unconformity. Fragments consist of subangular to rounded quartz and rare quartz arenite.*

weathering, fine to medium grained, massive, homogeneous and subophitic textured. The minerals present are plagioclase, orthopyroxene and magnetite, with and without clinopyroxene and amphibole.

STRUCTURE

Horizontal to shallow-dipping bedding (S_o) is only well developed in quartz arenite, arenite and chert of the Wishart Formation, which unconformably overlie gneissic rocks and diatexite of the Ashuanipi Complex along the eastern margin of the map area. Primary structures in rocks of the Ashuanipi Complex include: local igneous layering developed in some mafic and ultramafic rocks, rare igneous flow features in some granitoid rocks, and relict sedimentary bedding in paragneiss.

The dominant structural feature is a west-northwest-striking regional fabric. It is defined by i) a syn-metamorphic S_1 migmatitic layering and/or schleiren-texture in gneissic rocks, ii) a weak to strong alignment of primarily biotite in gneiss and foliated granitoid rocks (including diatexite) and iii) aligned pyroxene (± plagioclase) grains in gabbroic and ultramafic rocks.

The D_1 fold structures were not recorded in the map area; however, macroscopic D_2 structures are developed in most rock units, with the exception of some late, granite and alkali-feldspar granite veins and late gabbro dykes. These D_2 structures are tight to isoclinal, predominantly southwest-plunging folds of earlier S_1 fabrics (Plate 29). The S_1 fabric within individual outcrops commonly has a highly variable strike and dip as a result of the superposed younger folding.

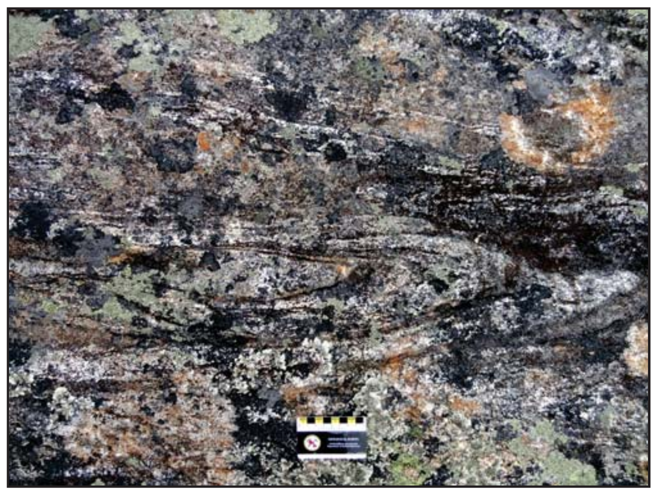


Plate 29. *Steeply plunging, isoclinal F_2 fold of pre- to syn-D_2 granite vein in diffusely banded migmatitic gneiss.*

Diatexite bodies postdate gneissic fabrics (S_1) but are open to tightly folded about F_2 axes (Plate 30). This indicates, as Percival (1991b) noted that the diatexite postdates D_1 deformation and the S_1 fabric and was emplaced or developed prior to D_2 deformation.

Two significant west-northwest-striking, late-stage faults transect the southern map area (Figure 3A). Fault breccia, chlorite and hematite alteration and local attenuated and granular garnet porphyroblasts occur locally within these structures. Map-unit offsets were not documented across these faults, but local asymmetric structures and sub-horizontal stretching lineations suggest a dextral, predominantly strike-slip movement (Plate 31).

Plate 30. *Late D_2 stage coarse-grained, garnet diatexite intruding stromatic-textured, migmatitic garnetiferous paragneiss. The diatexite is folded about a steeply dipping F_2 axis and postdates the S_1 migmatitic fabric, supporting the interpretation that the diatexite units are inherently younger than the metatexite units.*

Plate 31. *Localized shearing of anastomosing quartz veins in strongly deformed garnet–orthopyroxene granodiorite gneiss. Displacement of quartz veins and shallow-plunging stretching lineations (not shown) indicate dextral slip movement along a major strike-slip fault within the map area.*

Several, west-southwest-striking faults transect the unconformity of migmatitic gneisses of the Ashuanipi Complex and sedimentary rocks of the Wishart Formation of the Labrador Trough (Figure 3A and B). Although the amount of offset is difficult to establish along most of these structures, dextral slip offsets of approximately 1 km and 0.5 km are indicated in the extreme northern map area, northwest of Kivivik Lake, whereas the other fault northwest of Menihek Lake appears to have undergone 0.5 km dextral movement (Figure 3A and B).

METAMORPHISM

Petrographic analyses have not yet been completed as part of this study, but, Percival (1991b), Percival and Girard (1988) and James (1997) have described microstructural relationships in the main rock units and reported on the metamorphic evolution of the northeastern Ashuanipi Complex.

The presence of widespread orthopyroxene–leucosome melt-bearing assemblages in metatexite units is indicative of granulite-facies conditions. Percival (1991b) and James (1997) reported minimum metamorphic and igneous emplacement conditions of 700 to 800°C and 5 to 6.5 kbar, using several geothermometers and geobarometers.

Percival (1991b) proposed that some orthopyroxenes in tonalitic, granodioritic and mafic/ultramafic rocks of the Desliens igneous suite are relict oikocrysts that have been overprinted by regional granulite-facies, pyroxene-bearing assemblages and the regional S_1 fabric. Percival (1991b) and James (1997) discussed the presence of anhedral, inclusion-rich orthopyroxene in granitoid rocks, particularly tonalite units, and suggested that the pyroxene is a relict igneous phase derived from an anhydrous mantle melt source.

In contrast, subhedral, 'blocky' orthopyroxene crystals show sharp grain contacts with other constituents and commonly having mafic-depleted haloes of feldspar and quartz, are interpreted as a peak metamorphic mineral phase.

Localized alteration of biotite, garnet and pyroxenes to chlorite, particularly associated with late fault zones, indicates some retrogression of the granulite-facies assemblages.

AEROMAGNETIC SIGNATURES – BEDROCK GEOLOGY CORRELATIONS

Colour-shaded compilations of three aeromagnetic surveys covering the southern and northern map areas are shown in Figure 4A and B (Geological Survey of Canada, 1984; Dumont *et al.*, 2010a, b; D'Amours and Intissar, 2013; Kilfoil, 2013).

Some direct correlations of the bedrock geology and aeromagnetic signatures are evident and highlighted below.

The north-striking series of magnetic highs in the western map area (Figure 4A) correlates, in part, with migmatitic gneiss and foliated tonalite that contain ultramafic boudins and layers. In particular, a very strong magnetic high in the southern part of map area 23J/11 coincides with a paragneiss belt containing a pyroxenite intrusion approximately 200 m wide and 2 km long (Figure 3A). A gold showing (MODS No. 23J/11/Au001) and other minor gossan zones are also associated with this signature. A smaller, albeit poorly exposed, pyroxenite body seems to correlate with a second magnetic high, immediately to the west. The intensity and lateral size of these magnetic highs might indicate that the ultramafic sills are more extensive at depth.

The two parallel, northwest-striking magnetic highs to the northwest of Lake Menihek are correlated, in part, with deformed, mafic-rich tonalite sills (?) intercalated with migmatitic paragneiss.

The prominent north-northeast-striking linear magnetic signature west of Lake Menihek (Figure 4A) delineates a 150-m-wide late gabbro dyke that postdates the Archean–Proterozoic unconformity. Immediately to the east of this magnetic signature, a second, less intense, northeast-striking, magnetic high also appears to demarcate a dyke transecting the unconformity. The two linears intersect at a point along a northwest-striking fault (Figure 4A).

There is no bedrock exposure coincident with the less intense magnetic signature, but, considering the correlation of the gabbro and the north-northeast-striking magnetic signature, the proposition that the northeast-striking linear signature likewise marks a dyke, seems justified. A more obvious aeromagnetic correlation evident from Figures 3A and 4A is the strong magnetic gradient associated with the Archean–Proterozoic unconformity where the magnetic high signatures are unquestionably related to iron formation of the Labrador Trough.

Correlations between bedrock units and aeromagnetic signatures are not as evident in the northern map area (compare Figures 3B and 4B), aside from the gradient across the unconformity. This weak correlation may be a function of the compilation being of a lower resolution than for part of the southern map area. However, several anomalously auriferous sulphide-bearing gossan zones in Labrador (including two MODS occurrences) correlate with the extension of a horseshoe-shaped magnetic anomaly, evident in Québec and closely allied with two gold prospects in the Lac Lilois and Lac Boucault area (*see* section on Mineralization).

MINERALIZATION

GOLD POTENTIAL OF THE ASHUANIPI COMPLEX

The discovery of gold mineralization hosted in Algoma-type Archean iron formation of the northeastern Ashuanipi Complex, northwest of Schefferville, Québec, in 1986 (LaPointe, 1986), has led to numerous exploration ventures in the region (Thomas and Butler, 1987; Dimmell, 1989; Graves, 1992; Chevè and Brouillette, 1992; Lapointe and Chown, 1993; Simpson, 2010; Ivanov, 2012). The discovery was noteworthy because Archean iron formation is a major global source of gold (Kersill, 1995) and the recognition of such mineralization in the Ashuanipi Complex significantly elevated the regional gold potential of northern Québec.

The most advanced gold prospects are located 30 km northwest of the northern limit of the map area at the Sheffor Project (Figure 1), which consists of numerous gold showings and several, weakly mineralized zones hosted by boudinaged iron formation. The iron formation is intercalated with migmatitic gneiss and granitoid rocks of the Riviere du Sable Complex (Chevè and Brouillette, 1992). Ivanov (2012) described anomalous gold mineralization associated primarily with arsenopyrite and pyrrhotite in pyragmite, a orthopyroxene + garnet ± amphibole ± clinopyroxene facies of the iron formation, as well as being ‘free grains’ in quartz veins. Diamond drilling confirmed the presence of a broad, near-surface mineralized zone, and revealed gold contents such as 1.42 g/t over 8.34 m (Ivanov, *ibid*) and 5.5 g/t Au over 7.1 m (Chevè and Brouillette, 1992).

Chevè and Brouillette (1992) interpreted local shear zones and a granulite- to amphibolite-facies transition as two of the main controls on gold distribution. Moritz and Chevè (1992) used fluid-inclusion data to propose that the gold was deposited during post-peak metamorphic cooling and uplift.

Two other iron formation-hosted gold prospects, the Lac Lilois and Lac Boucault occurrences (LaPointe and Chown, 1993), are located just 5 km west of the Labrador–Québec border in the northern map area (Figures 3B and 4B). Assay values of 1.45 g/t Au over 3.8 m of drill-core and local grades up to 50 g/t Au in surface samples have been reported from the Lac Lilois occurrence (Chevè and Brouillette, 1992). These two occurrences are spatially associated with a horseshoe-shaped aeromagnetic anomaly, which extends eastward into Labrador. The magnetic anomaly is coincident with several gossan zones occurring in migmatitic rocks containing rare, thin zones of pyroxene-rich rock and may be related to the rocks hosting the gold prospects in Québec (Figures 3B and 4B).

Thomas and Butler (1987) and McConnell *et al.* (1987, 1989) defined several areas of anomalous gold in western Labrador, on the basis of numerous boulder and bedrock assays of samples collected from sulphide-bearing gossan zones in gneissic and mafic rocks. Subsequent exploration efforts focused on these and other potential areas, and additional elevated gold (and base-metal) contents were reported (Dimmell, 1989; Graves, 1992; Simpson, 2010), but no further substantial exploration was undertaken. In light of previous work and the potential for iron formation host rocks in the map area, like the ones in Québec, a concerted effort was made during this study to locate such rocks. The northern area was specifically targeted because the eastward extension of the aeromagnetic pattern over the Québec occurrences raised the possibility of iron formation occurring in the northern survey block (Figures 3B and 4B). Our preliminary results indicate that thin (10s of cm-, to 1 m-scale), strongly altered pyroxene-bearing layers, intercalated with gneissic rocks, in a few of the gossan zones in the northern area, may have an iron-formation protolith, although further analyses of these rocks is required.

PLATINUM-GROUP ELEMENT POTENTIAL

The PGE potential may lie with the larger pyroxenite intrusions in the western and southern map areas. Although no elevated PGE values are reported, Percival and Girard (1988) reported a 70 ppb Pt assay from a sample collected from the base of a 80-m-thick ultramafic sill in the Pyroxenite Lake area, Québec (Figure 3A), associated with disseminated pyrrhotite and arsenopyrite. This ultramafic sill was visited by the first author, and it was observed to have many similarities with pyroxenite sills in the map area and further investigation of these bodies for their PGE potential is deemed warranted.

MINERAL OCCURRENCES

Several mineral occurrences listed in the Geological Survey's database, the Mineral Occurrence Database System (MODS), were examined in the map area (Figures 3A, B). These include m-, to 10s of m-scale, primarily limonitic gossan zones in paragneiss, orthogneiss, granitoid rocks, and mafic and ultramafic rocks. Some occurrences consist of several closely spaced, strongly altered boulders and probable frost-heaved blocks, where bedrock sources are not always evident. Mineralization includes pyrrhotite, bornite, arsenopyrite and chalcopyrite as disseminations, fine-grained coatings on fracture surfaces, thin stringers and irregular layers and lenses (Plate 32). Pyrite is usually present, and graphite, ranging from 1 to 5%, is found in some gossan zones.

GOLD OCCURRENCES

Three gold occurrences are listed in the MODS database for the map area, including 23J/11/Au001 (Figure 3A) and 23J/14/Au001 and 23J/14/Au002 (Figure 3B).

The MODS occurrences 23J/14/Au001 and Au002 are located near the Labrador–Québec border in the northern map area (Figure 3B) and are spatially associated with the eastern part of a horseshoe-shaped magnetic high that is evident in Québec (Figure 4B). At both occurrences, a rusty-weathering gossan zone in migmatitic gneiss contains thin, cm- to 10s of cm-scale lenses of strongly altered pyroxene-rich rock. These pyroxene-bearing rocks may be similar to the iron-formation host rocks 5 km to the west in adjacent Québec (LaPointe and Chown, 1993). Several altered and sulphide-bearing boulders are also present in the area, and Thomas and Butler (1987, Appendix II) reported an assay of 4000 ppb Au from a mafic-rich rock at occurrence 23J/14/Au001 and 400 ppb Au from the gossan at occurrence 23J/14/Au002.

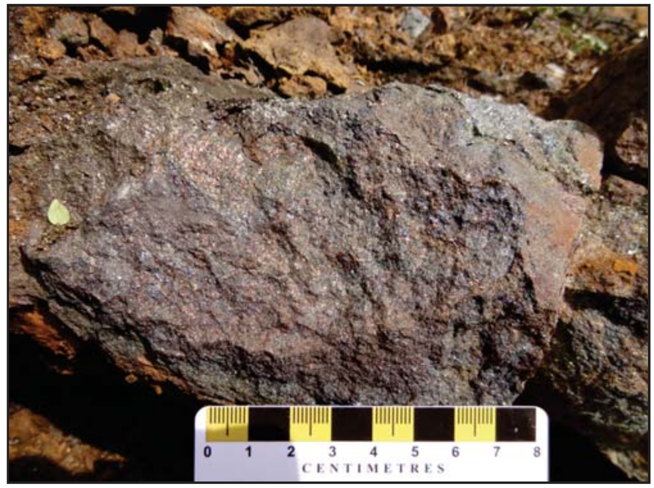


Plate 32. *Bornite and chalcopyrite-rich "block" of dense gossanous material, possibly ultramafic rock. Occurring as part of a 1-m-wide by 4-m-long boudin within a strongly altered gossanous zone in migmatitic paragneiss.*

The MODS occurrence 23J/11/Au001 is located in the western part of the southern map area (Figure 3A), coincident with a strong magnetic high (Figure 4A). At this locality, two, metre-scale, limonitic, sulphide-bearing gossan zones occur in garnet+biotite+orthopyroxene-paragneiss. One of these zones, within a east-trending valley, is strongly altered and contains thin concordant, sheared quartz veins (Plate 33). The sulphide mineralization occurs as localized disseminations of bornite and pyrrhotite and trace chalcopyrite. Thomas and Butler (1987) reported an assay of 410 ppb Au from one of these gossan zones.

GOSSAN ZONES NOT CURRENTLY LISTED IN MODS AND NEW DISCOVERIES

There are several gossan zones within the map area that do not yet appear in the MODS on-line database, but are plotted on mineral-assessment report maps (Dimmell, 1989; Graves, 1992; Simpson, 2010) and on geological bedrock maps (Thomas and Butler, 1987; Percival, 1989, 1993). Most of these unreported gossans are metre-scale zones consisting of limonite-altered migmatitic gneiss containing

Plate 33. *One of two gossan zones, hosting disseminated pyrrhotite and bornite mineralization in migmatitic paragneiss (MODS Occurrence 23J/11/Au001). The gossan lies in a minor east-striking fault zone and contains thin, concordant and slightly discordant quartz veins.*

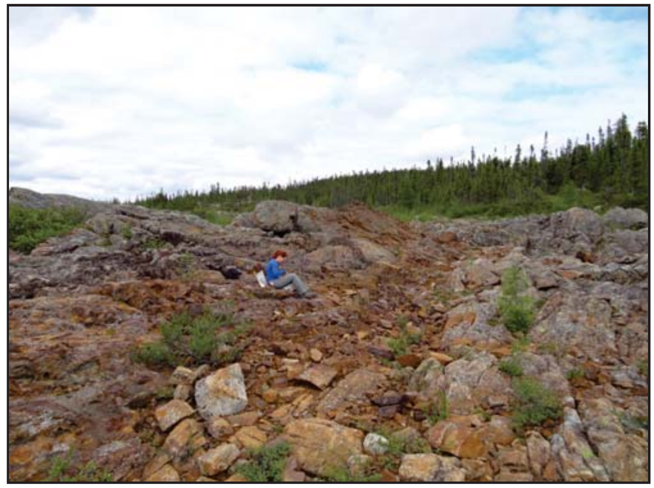


Plate 34. *Gossan zone in migmatitic garnetiferous paragneiss. The gossan contains local disseminations and stringers of pyrrhotite, minor bornite and trace chalcopyrite.*

pyrite ± minor pyrrhotite ± minor chalcopyrite. At least two of these zones contain strongly altered, centimetre-scale, pyroxene-bearing lenses. Whether these pyroxene-rich lenses are boudinaged pyroxenitic sills of Unit Apx or whether they are iron formation similar to those rocks described at the Lac Lilois prospect to the west in Québec (LaPointe and Chown, 1993; Ivanov, 2012), has not yet been determined. Some of the unreported mineralized localities warrant an indication designation in the MODS database. Examples of these include 10s of m-scale, strongly altered, sulphide- and graphite-bearing gossans in metatexite (Plate 34) and metre-scale mineralized gossans in ultramafic and mafic rocks (Plate 35).

BASE-METAL MINERAL OCCURRENCES

Two base-metal mineral occurrences were discovered on the western shoreline of Lake Menihek (Figure 3A). These occur within Archean gneisses below the unconformity with sedimentary rocks of the Proterozoic Wishart Formation.

Marina galena indication: Mineralization here comprises 2 to 3% galena as crystals, small aggregates, stringers and disseminations hosted in two, late quartz + calcite vein sets crosscutting a mixed zone of well-banded metatexite, diatexite and late pegmatite (Plate 36). The veins range from 3 to 12 cm wide, strike north and northeast and can be traced along strike for approximately 5 m. Some veins in the two sets, not all of which are mineralized, extend below the water line of Lake Menihek.

Plate 35. *Gossan zone in moderately foliated and layered gabbro boudin within pyroxenite intrusion in western map area (Unit Apx) The altered zone hosts disseminated pyrrhotite, bornite and trace chalcopyrite and thin stringers of pyrrhotite in the dark-weathering core zone. Pyroxenite unit is exposed in the background. Hammer is 1 m long.*

Katelyn molybdenite indication: The second base-metal mineral occurrence is also located on the western shoreline of Lake Menihek, just south of the galena indication (Figure 3A). Here, molybdenite is hosted along the contact of migmatitic paragneiss and an alkali-feldspar granite pegmatite. The molybdenite occurs as 2 to 3% disseminated grains and thin stringers along a 2-m-long section of the contact (Plate 37). A 10-cm-wide limonitic gossan zone adjacent to the pegmatite contains trace chalcopyrite and records anomalous radioactive readings (*see* below).

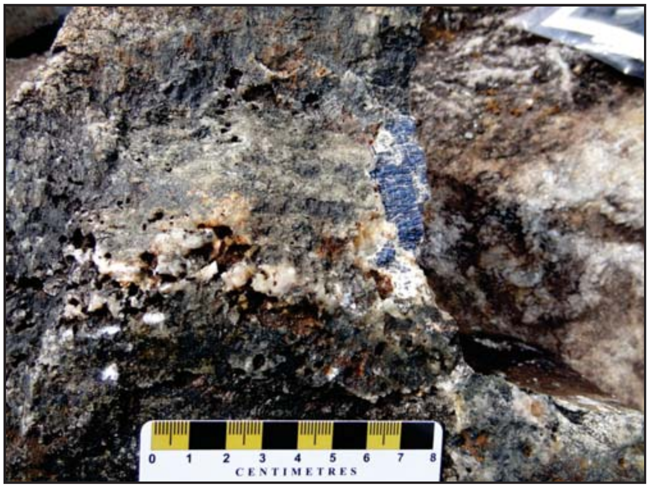


Plate 36. *Marina galena indication. Subhedral galena crystal hosted in late, quartz-carbonate vein cutting migmatitic paragneiss and tonalite gneiss. Mineralization is hosted in two vein-sets, north and northeast striking. The veins contain individual blue-grey galena crystals and 2% small aggregates, thin stringers and disseminations along 2- to 7-m-long vein strike lengths.*

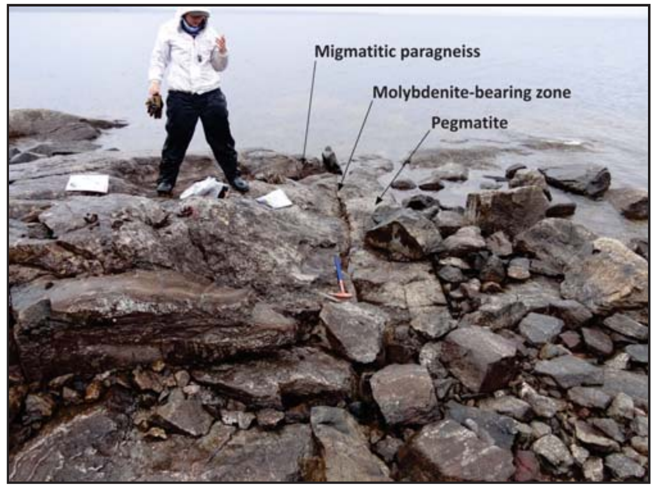


Plate 37. *Katelyn molybdenite indication. Alkali-feldspar granite pegmatite vein intruding migmatitic paragneiss. Local molybdenite and trace chalcopyrite mineralization occur as small aggregates and disseminations along contact of gneiss and pegmatite. The pegmatite records up to 2500 total counts per second radioactivity.*

INDICATIONS OF RADIOACTIVITY

Most outcrops visited during the 2013 survey were examined with a portable Radiation Solutions hand-held scintillometer (either a RS-120 or RS-230 BGO model). Readings were collected as total counts per second (tcps) radiation.

Most of the rock units show little or no evidence of elevated radioactivity. General background readings span a spectrum from 70 tcps in ultramafic rocks up to 300 tcps in some coarse-grained diatexites. Elevated readings were obtained from numerous syn- to late-tectonic coarse-grained to pegmatitic granite, alkali-feldspar granite, and alkali-feldspar-quartz syenite veins. Radioactive signatures recorded at several outcrops of these rocks range up to 3500 tcps. In one locality, the Katelyn Mo indication, an alkali-feldspar granite pegmatite vein yielded radioactivity readings up to 2500 tcps.

SUMMARY AND DISCUSSION

The map area consists of granulite-facies i) migmatitic rocks derived from sedimentary and igneous protoliths, ii) foliated tonalite, granodiorite and diorite intrusions, iii) variably deformed, sedimentary-derived diatexite, and iv) boudinaged sills of mafic to ultramafic composition. The migmatitic paragneiss were derived primarily from psammitic sedimentary rocks deposited in an accretionary wedge (Percival 1991b). He also interpreted the pretectonic intrusive rocks to be part of a fractionated suite having adakitic affinities of tonalite to diorite, and possibly gabbro and ultramafic rocks. These rocks underlie a 500-km-long tract of the northeastern Ashuanipi Complex. Percival (*ibid*) also interpreted some orthopyroxene-bearing assemblages as being of igneous origin, overprinted by granulite-facies metamorphism and an S_1 regional fabric.

Percival (1991b) showed that geochemical signatures of peraluminous garnet–diatexites and garnetiferous paragneiss are virtually identical, and proposed that the diatexites formed through complete partial melting of the paragneiss. This anatexis must have occurred at a lower crustal level than the present erosion surface, and did not entail *in situ* melting of surrounding country rock, because field relations indicate that paragneiss and granulite-facies assemblages occur as enclaves within the diatexite (James, 1997). However, apparent metatexite–diatexite transitions may be an indication that localized outcrop-scale, *in situ*, differential partial melting has occurred. Orthopyroxene-dominant diatexites, although equivocal in origin, are suggested to have formed through a similar, yet less-extensive melting process (Percival, 1991b).

The mineral potential of the region, although assessed previously through several geochemical and exploration surveys, remains largely untested. The discovery of significant gold mineralization, in adjacent Québec, just 5 km west of the map area, suggests that the Labrador part of the Ashuanipi Complex, requires further investigation.

The gossan zones in the map area, a few containing rare pyroxene-bearing lenses, some with elevated gold values, and the numerous zones that have assayed above-background gold content, imply an auriferous environment (Thomas and Butler, 1987; McConnell *et al.*, 1987; Dimmell, 1989). Drilling and ground geophysical surveys have yet to be carried out on these zones and only cursory exploration programs have been completed. Further detailed investigation of these zones in the map area is warranted, considering i) the significant gold mineralization hosted in pyroxene-bearing iron-formation rocks and anomalous gold in some gneissic rocks in adjacent Québec, ii) the local elevated gold contents in some gossans within the map area, iii) the largely untested potential of ultramafic and mafic rocks for gold and PGE mineralization, and iv) possible correlations of mineralized zones with magnetic highs, in particular a horseshoe-shaped magnetic high underlying prospects in Québec and extending into Labrador.

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