

MAFIC IGNEOUS ROCKS IN WESTERN LABRADOR: A REGIONAL ASSESSMENT OF POTENTIAL FOR MAGMATIC Ni–Cu ± PGE MINERALIZATION

A. Kerr
Mineral Deposits Section

ABSTRACT

This report provides a review of two mafic intrusive suites in western Labrador that provide exploration targets for Ni–Cu ± PGE mineralization, briefly describes known sulphide mineralization, and assesses their wider potential as hosts to magmatic sulphides.

The ca. 1450 Ma Shabogamo Gabbro intrudes sedimentary rocks of the Kaniapiskau Supergroup in the Churchill Province foreland, and their metamorphosed equivalents in the Gagnon Terrane of the Grenville Province. These sheet-like olivine–gabbro bodies host magmatic sulphide mineralization in several locations, but only one such site has been drill-tested, where preliminary results suggest that the mineralizing systems are potentially large. The mineralization is disseminated and low-grade (<0.7% combined Ni and Cu), but the sulphide metal contents suggest potential grades of 2% to 3% combined Ni and Cu. If the parental magmas to the Shabogamo Gabbro contained >100 ppm Ni (a reasonable estimate), significantly higher grades are possible if sulphide liquids reacted with larger relative quantities of magma elsewhere. The extensive occurrence of sulphide-bearing country rocks in the Gagnon Terrane creates many potential settings for magmatic sulphide formation. The Shabogamo Intrusive Suite also intrudes granitoid gneisses in the adjacent (deeper-level) Molson Lake Terrane, but these country rocks contain few external sources for sulphur.

The ca. 1640 Ma Ossok Mountain Intrusive Suite intrudes paragneisses in the allochthonous Lac Joseph Terrane of the Grenville Province, and consists of heterogeneous gabbro, norite, gabbronorite, pyroxenite, peridotite and anorthosite. Pyroxenitic boulders in one area are anomalous in PGE (up to 1.4 g/t combined Pt, Pd and Au), and appear to have a local bedrock source. However, mineralization in bedrock is harder to confirm, and there is some evidence that it is, in part, epigenetic and/or hydrothermal. Assuming that the potential for PGE mineralization is highest in pyroxenitic rocks, further exploration in the suite is dependent on the identification of larger and more continuous units of this type for more detailed evaluation.

INTRODUCTION

PROJECT DESCRIPTION

The discovery of the Voisey's Bay Ni–Cu deposit about ten years ago inspired unprecedented exploration in Labrador, but this activity declined five years later due to poor market conditions and low commodity prices. The recent development of the Voisey's Bay deposit into a producing mine, coupled with rising prices for nickel (and most other mineral commodities), has led now to a resurgence of interest. Much of this activity remains focused within 100 km of the Voisey's Bay deposit, but there has also been significant activity in western Labrador.

The Geological Survey completed a short metallogenic studies program in western Labrador during 2003, and

expanded this project in 2005 (Kerr, 2003, 2005); some additional field work was completed in early 2006 (Kerr, 2006). This article is the first report on this work, and it has three main objectives. The first objective is to review and assess the petrological and geochemical characteristics of two mafic igneous suites that represent potential host rocks. The second objective is to provide basic descriptive information about known magmatic sulphide mineralization within these suites and the third objective is to outline work that might assist in their future evaluation and exploration. Overall, it is hoped that this overview will raise the profile of western Labrador area as a grass-roots target area for magmatic sulphide deposits, and attract further exploration.

MINERAL EXPLORATION DEVELOPMENTS

The western Labrador area is one of the most important

producers of iron ore in the world and, by the standards of northern regions of Canada, it has good infrastructure and access. Since the 1950s, sedimentary and metasedimentary rocks have been explored intensely for iron ore, but there has been less exploration for other commodities.

Magmatic sulphide mineralization has been known in adjacent regions of Québec since the 1950s, when Ni–Cu sulphides were discovered in a deformed sill of unknown age at Rivière Pekan, south of Fermont (summarized by Indares, 1993). Northeast of Schefferville, mafic–ultramafic sills within sedimentary rocks at Lac Retty contain magmatic sulphide accumulations, some of which are quite substantial in size and PGE-enriched (summarized by Clark and Wares, 2005). Mafic sills occur in the same setting in Labrador, but the minor sulphide concentrations in these sills are metal-poor (Findlay *et al.*, 1988). Elsewhere in western Labrador, a few small chalcopyrite and pyrrhotite indications were reported in mafic rocks during early mapping and exploration (*see* later discussion).

The Voisey's Bay discovery drew wider attention to the potential for Ni in western Labrador. The late Karl Krats and several associates commenced work in the Evening Lake area, some 90 km northeast of Labrador City, where they found gabbro boulders containing disseminated pyrrhotite and chalcopyrite, and traced them to a possible source on a local hillside (the Krats showing). Other possible magmatic sulphide occurrences were recognized around Evening Lake, and also along the Esker Road. The mafic host rocks in these areas were assigned to the ca. 1450 Ma Shabogamo Gabbro (SG; Ware and Wardle, 1979; Rivers, 1985a, b, c) and were later pinpointed as a potential environment for magmatic sulphides by Ryan *et al.* (1995). Karl Krats and his colleagues eventually optioned claims to BHP-Billiton in late 2001, and the latter conducted reconnaissance work that confirmed this suggestion (Muntanion, 2002). BHP-Billiton acquired additional ground, and then entered a joint venture with Gallery Resources, who conducted subsequent exploration, commencing with airborne magnetic-EM surveys. In late 2004, drilling of an airborne conductor located about 9 km east of the Krats showing intersected sulphides in gabbroic rocks. In 2005, a similar mineralization was intersected up to 1500 m along strike, suggesting a mineralized zone of significant dimensions. The grades are low (<0.7% combined Ni and Cu), but the mineralization is disseminated in nature (Gallery Resources, Press Releases, November 26, 2004; August 26, 2005; *see also* Janes *et al.*, 2005). Work was suspended in July 2005 and the property is presently dormant.

In the early 1990s, the Geological Survey mapped the Lac Joseph area, where a routine sample of gabbro from an aggregate quarry contained 200 ppb Pd (James,

1994). A few years later, this result sparked exploration interest in the host rocks, assigned to the ca. 1650 Ma Ossok Mountain Intrusive Suite (OMIS). Buchans River Ltd. found some greater local Pt and Pd enrichment (up to 1.4 g/t combined Pt, Pd and Au), but mineralization was sporadic and largely confined to pyroxenite boulders. Sampling of nearby pyroxenite outcrops (Kerr, 2003) did not reveal significantly anomalous PGE, but suggested that mineralized boulders were likely of local origin. A subsequent lake-sediment geochemistry survey (McConnell, 2005) revealed anomalies for Pt and Pd around this area and elsewhere in the OMIS. Brilliant Mining Inc. subsequently acquired several claim blocks (including the former Buchans River ground), and completed airborne geophysics and prospecting. Pyroxenitic rocks anomalous in PGE were later reported by the company (Brilliant Mining, Press Release, August 22, 2005).

Prospecting activity continues in several areas of interest, including the Mount Fyne area, southwest of Churchill Falls, where troctolites are abundant in the SG and the survey of McConnell (2005) revealed Pt and Pd anomalies. Minor amounts of sulphide have been detected in troctolites, but richer concentrations such as those at Evening Lake have yet to be uncovered.

REGIONAL GEOLOGICAL FRAMEWORK

Western Labrador contains parts of three structural provinces of the Canadian Shield, *i.e.*, the Superior Province, the Churchill Province and the Grenville Province (Figure 1). This section presents only a summary of information pertinent to the present subject and readers are referred to other sources for more detailed information and interpretation. Figure 2 presents a simplified geological map of the region, based upon the 1:1-million-scale compilations (Wardle *et al.*, 1997).

SUPERIOR PROVINCE

The oldest rocks of the region are high-grade orthogneisses, paragneisses and less abundant granitoid plutonic rocks of the Ashuanipi Metamorphic Complex (Figure 2), which represent the eastern extremity of the Superior Province. Geochronological data (mostly from Québec) indicate a complex sequence of igneous and metamorphic events between about 2700 Ma and 2625 Ma (reviewed by James, 1997). Metamorphosed iron formations in Québec host gold mineralization of possible mesothermal affinity (Lapointe and Chown, 1993), and there are surficial gold anomalies within the Labrador portion of the complex. Metapyroxenites occur locally, and James (1997) noted that these may have potential for Ni–Cu mineralization.

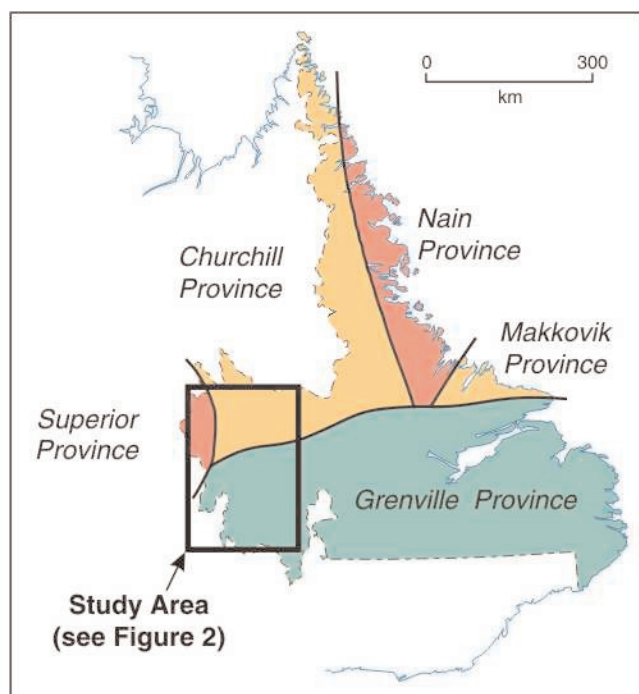


Figure 1. Generalized location map of western Labrador, showing major structural provinces.

CHURCHILL PROVINCE

Archean and Paleoproterozoic rocks of the Churchill Province underlie most of the region west and north of the Smallwood Reservoir (Figure 2). This region exhibits strong geological contrasts from west to east. In the west, it is dominated by Paleoproterozoic sedimentary and volcanic rocks of low metamorphic grade, whereas in the east it is dominated by high-grade metamorphic rocks and granitoid suites. The western section is termed the "Labrador Trough", and is now considered part of a wider orogenic belt known as the New Quebec Orogen (Hoffman, 1988). The Labrador Trough is divided into two sections that represent contrasting shallow-water and deep-water settings, separated by a zone of west-verging thrust faults (Figure 2). These two areas are termed the Schefferville and Howse zones. The sedimentary rocks in each are assigned to the Kaniapiskau Supergroup (Frarey and Duffell, 1964), which itself represents three cycles of sedimentation and volcanism. The stratigraphic terminology for these rocks varies along the length of the Labrador Trough, and is a subject of debate, with revisions most recently proposed by Clark and Wares (2005). The details of the subdivision of the Kaniapiskau Supergroup are not discussed further in this report.

In the Schefferville Zone, arkosic rocks pass upward into interbedded shales, dolostones and cherts, and then into quartzites, ironstones, shales and arkoses, which include the

iron deposits of the Schefferville area (Sokoman Formation). Above the ferruginous interval, there is a thick sequence of shales known as the Menihék Formation. These are associated with surficial Zn anomalies, and typically contain minor amounts of sulphides; they have been suggested as a possible SEDEX exploration target (Swinden *et al.*, 1991). Sulphide-bearing sedimentary rocks also occur lower in the sequence, in the Attikamagen Formation. The youngest rocks in the Kaniapiskau Supergroup are arkoses and conglomerates of the Tamarack River Formation. The eastern part of the Labrador Trough (the Howse Zone) contains some representatives of all the above rock types, but is dominated by turbiditic sandstones, siltstones and shales, interbedded with submarine mafic volcanic rocks. It also contains numerous gabbroic sills that are presumed to be synvolcanic. The rocks of the Howse Zone are presumed to be of the same general age as those of the Schefferville Zone, but developed in a more distal, deep-water setting. Mylonite zones juxtapose the sedimentary rocks of the Kaniapiskau Supergroup against reworked Archean gneisses and Paleoproterozoic igneous rocks of the Rae Province (Hoffman, 1988) to the east. In this area, James *et al.* (1993) delineated two belts of gneissic rocks, separated by a wide zone of plutonic rocks that represent the southern end of the ca. 1850 Ma De Pas batholith.

The folded sedimentary rocks of the Kaniapiskau Supergroup are overlain unconformably by arkose and quartzite of the undated Sims Formation, which form several outliers west of the Smallwood Reservoir (Figure 2). Both the Kaniapiskau Supergroup and the Sims Formation are cut by mafic rocks of the SG. These are the youngest igneous rocks within this part of the Churchill Province, and are assumed to be of ca. 1450 Ma age, but they have not actually been dated in this area. In central and eastern Labrador, plutonic rocks of both mafic and felsic composition dated at ca. 1650 Ma intrude the older foreland region north of the Grenville Front, and mafic rocks of this age certainly exist within the Churchill Province east of the Smallwood Reservoir (Gower and Krogh, 2003). It is possible that some of the mafic rocks in the west could be of this same general age.

The sedimentary rocks of the Kaniapiskau Supergroup contain important iron-ore deposits, located in the Schefferville area; the continuation of this belt into the Grenville Province (*see below*) hosts major iron-ore deposits in the Labrador City, Wabush and Fermont areas. Sedimentary rocks in the Howse Zone contain syngenetic sulphide deposits, and may have potential for SEDEX or Besshi-type mineralization (Swinden *et al.*, 1991). As previously indicated, mafic sills in the latter area also contain minor magmatic sulphide concentrations.

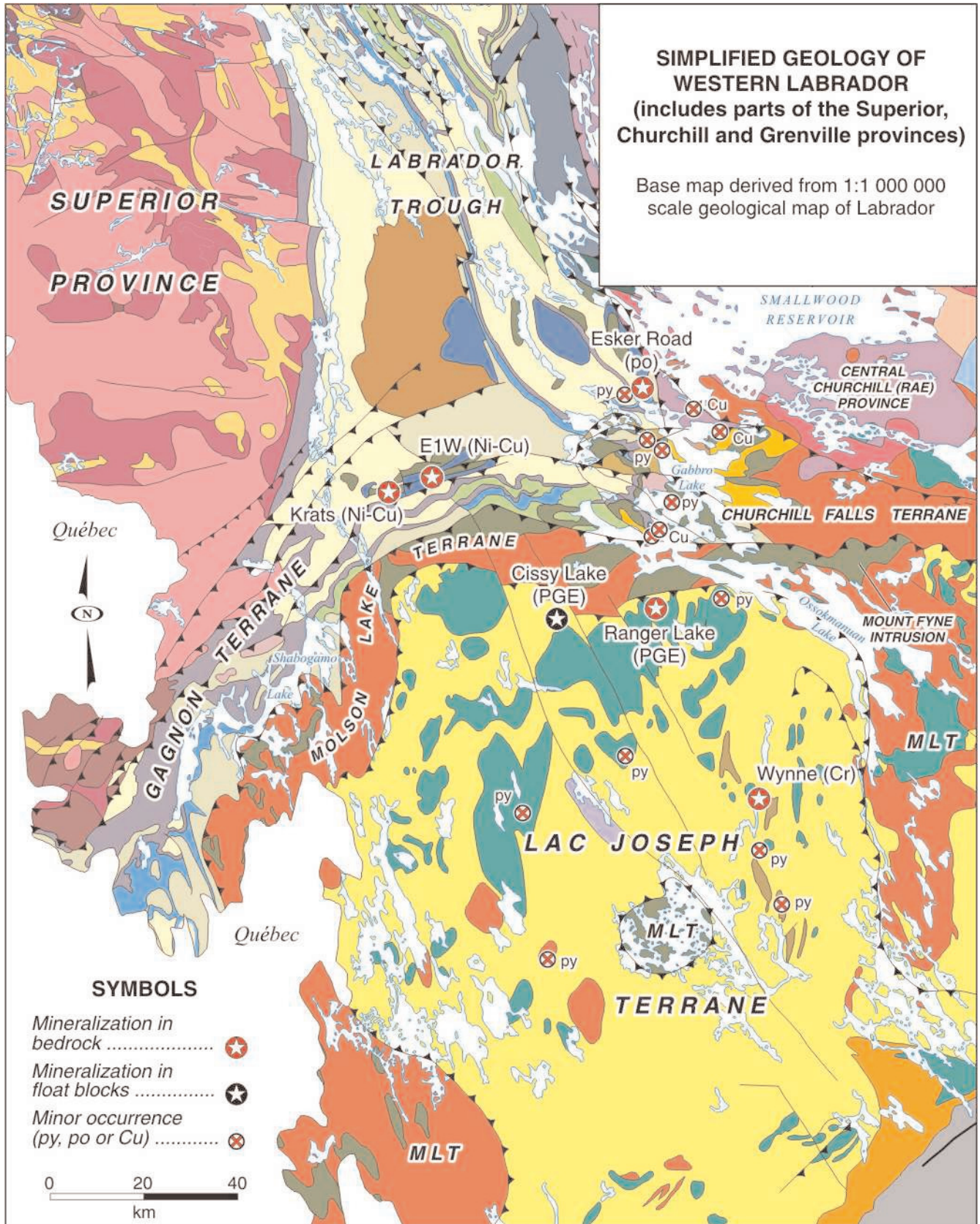


Figure 2. Regional geological map of western Labrador, based upon the 1:1 000 000 scale map of Labrador, showing the areas discussed in this report.

LEGEND

GRENVILLE PROVINCE (OTHER AREAS)




 Granites and syenites  Anorthosites

GRENVILLE PROVINCE (LAC JOSEPH TERRANE)


 Granitoid rocks  OSSOK MOUNTAIN INTRUSIVE SUITE
 Mafic gneisses and amphibolites  Gabbros, norites and gabbro-norites;
 Paragneisses and granitoid gneisses  minor pyroxenites and anorthosites

GRENVILLE PROVINCE (GAGNON AND CHURCHILL FALLS TERRANES)

BLUEBERRY LAKE GROUP

 Felsic volcanic rocks
 Sedimentary rocks
 Undivided granitoid rocks





SHABOGAMO GABBRO

 Olivine gabbro to monzonite

GRENVILLE PROVINCE (MOLSON LAKE TERRANE)


 Granitoid rocks and granitoid gneisses  SHABOGAMO GABBRO
 Recrystallized olivine gabbro and gabbro

CHURCHILL PROVINCE (INTERIOR REGION)


 Granitoid rocks
 Seal Lake Group
 Charnockitic granitoid rocks
 Granitoid gneisses

CHURCHILL PROVINCE (LABRADOR TROUGH) AND GRENVILLE PROVINCE (GAGNON TERRANE)








SIMS FORMATION

 Arkoses and quartzites

SHABOGAMO GABBRO

 Olivine gabbro to monzonite

KANIAPISKAU SUPERGROUP

 Arkoses and conglomerates
 Arkoses and sandstones
 Mafic volcanic and pyroclastic rocks
 Dolostones and marbles
 Siltstones, shales and schists
 Iron formations and quartzites
 Undivided sedimentary rocks

SUPERIOR PROVINCE (ASHUANIPI COMPLEX)





 Gneisses reworked during Grenvillian events
 Paragneisses
 Tonalite and metatonalite
 Migmatic granitoid gneisses

Figure 2. Legend for map on opposite page.

GRENVILLE PROVINCE

The area south of the Smallwood Reservoir is here assigned to the Grenville Province, although the exact position of its northern boundary (the "Grenville Front"), depends upon its definition. There are structural components such as folds and thrusts that record Grenvillian deformation, although the ca. 1000 Ma thermal overprint recorded by K–Ar ages from muscovites is, in part, absent (Gower, 2003). The Grenville Province in this region is divided into four major terranes (Figure 2), which contain different rock types and exhibit contrasting structural and metamorphic patterns. These terranes were assembled into their present positions during the ca. 1080–985 Ma Grenvillian Orogeny, but the geological history of each is different.

Gagnon Terrane

The Gagnon Terrane consists of older rocks of the Superior and Churchill provinces that experienced variable amounts of deformation and metamorphism during the Grenvillian Orogeny (Figure 2). In the west, it consists of reworked equivalents of the Ashuanipi Complex, and metasedimentary rocks derived from the Kaniapiskau Supergroup. The Gagnon Terrane contains numerous sheet-like mafic intrusions assigned to the ca. 1450 Ma SG, which also intrude deformed equivalents of the Sims Formation (Figure 2). However, as discussed above, the presence of older mafic rocks amongst these cannot be discounted on the basis of available geochronology. The Gagnon Terrane is essentially a fold-and-thrust belt, verging to the northwest, and its structural and metamorphic pattern is discussed by Connelly *et al.* (1996). Metamorphic grades vary from sub-greenschist in areas close to the Grenville Front, to upper amphibolite facies in the southeast, where it adjoins the Molson Lake Terrane (*see below*). Metamorphism and deformation in the Gagnon Terrane are believed to be related to emplacement of the Molson Lake Terrane above it during the Grenvillian Orogeny. The western part of the Gagnon Terrane contains the important iron-ore deposits of the Labrador City–Wabush–Fermont area, and also industrial-mineral commodities such as quartzite and dolostone.

Churchill Falls Terrane

The eastern end of the Gagnon Terrane is not precisely defined on the basis of geological features, and its equivalent east of Gabbro Lake is termed the Churchill Falls Terrane (Figure 2). The Churchill Falls Terrane similarly represents rocks of the Churchill Province that experienced Grenvillian deformation. It consists mostly of deformed granitoid rocks that were originally part of the Trans-Labrador batholith, a major plutonic belt emplaced across central Labrador about 1650 Ma ago. These plutonic rocks

are associated with volcanic and metavolcanic rocks of the Blueberry Lake Group, which likely represent part of their extrusive carapace (Figure 2). Remnants of older gneisses occur locally, and there are numerous mafic intrusions assigned to the SG; however, older mafic rocks could also be present, as discussed above. In the extreme east, around Churchill Falls, biotite-bearing gabbroic rocks (Unit 10 of Wardle, 1985) were distinguished from rocks viewed as SG equivalents.

Molson Lake Terrane

The parautochthonous Molson Lake Terrane structurally overlies the Gagnon Terrane and the Churchill Falls Terrane (Figure 2). It forms a narrow belt located immediately north of the Lac Joseph Terrane (*see below*), but also occurs in a circular "window" within the latter (Figure 2). The Molson Lake Terrane contains almost no supracrustal rocks and is dominated by granitoid gneisses, dated at ca. 1640 Ma (Connelly *et al.*, 1995), considered to be metamorphosed equivalents of the Trans-Labrador batholith, present in the structurally underlying Churchill Falls Terrane. The Molson Lake Terrane contains variably recrystallized mafic plutonic rocks of 1459–1445 Ma age (Krogh, 1993; James, 1994; Connelly *et al.*, 1996), which are assigned to the SG. These U–Pb ages are extrapolated to the mafic rocks in terranes to the north (*see above*). The metamorphic grades in the Molson Lake Terrane are higher than those in the underlying Gagnon Terrane. Corona structures in the mafic rocks provide important information about pressure-temperature paths during Grenvillian orogenic events. The Molson Lake Terrane appears to have experienced only tectonic and metamorphic events attributable to the Grenvillian Orogeny (Connelly *et al.*, 1996).

Lac Joseph Terrane

The allochthonous Lac Joseph Terrane is the structurally highest terrane within the Grenville Province in western Labrador. It differs from terranes described above in that it is dominated by metasedimentary gneisses of pelitic to psammitic composition, with lesser amounts of mafic gneiss and granitoid rocks. These rocks are accompanied by a varied and complex suite of mafic metaplutonic rocks that form the OMIS (Figure 2). The metasedimentary country rocks are younger than 1900 Ma but older than 1672 Ma; the OMIS is dated at 1640 to 1620 Ma (Connelly and Heaman, 1993; James, 1994). The Lac Joseph Terrane apparently does not contain mafic rocks of the SG, although it does contain mafic dykes of unknown age. The Lac Joseph Terrane was only mildly affected by Grenvillian events, and instead records metamorphism at 1660–1630 Ma (the Labradorian Orogeny). The mafic rocks of the OMIS are variably recrystallized and many contain corona structures, but some retain

their primary igneous textures. Mineral assemblages suggest that metamorphic conditions involved lower pressures and higher temperatures than those recorded at later dates in the underlying Molson Lake Terrane (James, 1994; Connelly *et al.*, 1996). The metasedimentary gneisses of the Lac Joseph Terrane locally contain minor amounts of disseminated sulphides (James, 1994).

SHABOGAMO GABBRO

DEFINITION, EXTENT AND AGE

The term Shabogamo Gabbro (SG) was introduced initially by Frarey and Duffell (1964). The SG probably correlates with the Michael Gabbro intrusions of eastern Labrador, which are compositionally similar and have an analogous geological setting (Gower *et al.*, 1991). The Michael Gabbro intrusions were dated at 1426 ± 6 Ma (Scharer *et al.*, 1986), suggesting that they are younger than the SG, although the age of the latter is far from well constrained (*see below*).

The SG occurs in the Churchill Province foreland, and in the Gagnon, Churchill Falls and Molson Lake terranes of the Grenville Province (Figure 2). However, it is accurately dated only within the Molson Lake Terrane, where ages of 1459 ± 22 Ma (Connelly *et al.*, 1996), $1452 +15/-13$ Ma (James, 1994) and 1445 ± 4 Ma (Krogh, 1993) suggest emplacement ca. 1450 Ma ago. Earlier data (Rb–Sr, Sm–Nd, K–Ar, Ar–Ar) gave less accurate and generally younger ages indicative of a complex cooling history in the northern Grenville Province (Gower *et al.*, 1991; Gower, 2003). The lack of accurate ages from areas north of the Molson Lake Terrane presents a problem in that older (ca. 1650 Ma?) mafic igneous suites could also exist in this area, and Gower (2003) suggests that anomalously old Ar–Ar ages (previously interpreted in terms of excess Ar) may provide direct evidence of such. This presents a difficult problem in assessing and interpreting geochemical patterns amongst these rocks, because it is not known if all these rocks are compositionally/geochemically related. The treatment of geochemistry below is thus very generalized, and restricted to aspects that relate to the overall potential of mafic rocks as hosts to Ni–Cu sulphide mineralization. Ultimately, more detailed assessment of geochemical data in the light of additional geochronology from areas north of the Molson Lake Terrane are required to resolve these issues.

PETROLOGY

Churchill Province

In the Churchill Province, several intrusions are elongated in a northwest–southeast orientation with host rocks

of the Labrador Trough (Figure 2). They intrude the Menihek Formation of the Kaniapiskau Supergroup, and also quartzites of the Sims Formation (Rivers, 1985a, b). These intrusions were not examined under this project because they were not easily accessible. One of the intrusions in this area appears to be associated with the contact between the Sims Formation and older sedimentary rocks, and it is possible that it was, in part, emplaced along the unconformity between the two.

Grenville Province (Gagnon and Churchill Falls Terranes)

The SG is most abundant and best known in the area west of the Smallwood Reservoir towards Shabogamo Lake (Figure 2). The dominant host rocks to intrusions are the Menihek and Attikamagen formations of the Kaniapiskau Supergroup, which both contain dispersed syngenetic sulphides. Locally, gabbros intrude the iron-rich sedimentary rocks of the underlying Sokoman Formation, and also carbonate and volcanic units (Denault Formation and McKay River Formation). In the Evening Lake area, some of the intrusions are spatially associated with the unconformable contact between the Kaniapiskau Supergroup and the younger Sims Formation (Figure 3). The area around Evening Lake and McKay River (Figure 3) provides an illustration of the complexity of the geology in the Gagnon Terrane, the numbers of mafic intrusions, and their widespread juxtaposition with sulphide-bearing country rocks. Some gabbroic units appear to be underlain by the Kaniapiskau Supergroup and overlain by the Sims Formation, suggesting that their emplacement may locally be controlled by the unconformity. However, the exact attitude of most contacts (if indeed they are planar) remains unknown. Around northern Gabbro Lake, sheet-like mafic units occur within the ca. 1650 Ma Blueberry Lake Group (Figure 2), and are broadly conformable with the stratigraphy. However, around southern Gabbro Lake and eastward into the Churchill Falls Terrane, the sheet-like geometry of mafic intrusions is much less evident (Rivers, 1982, 1985b; Figure 2). Such differences likely reflect the contrasts between well-layered sedimentary rocks in the west and more massive metaplutonic rocks in the east (Rivers, 1982).

The SG is lithologically monotonous, and most outcrops consist of dark-grey to black, medium-grained, homogeneous gabbro (Plate 1a). Variably altered olivine, purple-grey pyroxene and grey plagioclase are the dominant constituents visible in the field. Modal layering is rarely visible in outcrops, but olivine-rich melagabbro of probable cumulate origin is locally observed. Pinkish monzonitic rocks containing acicular amphiboles (Plate 1b) are observed locally, and these appear to grade into the dominant gabbro, suggesting that they are genetically related.

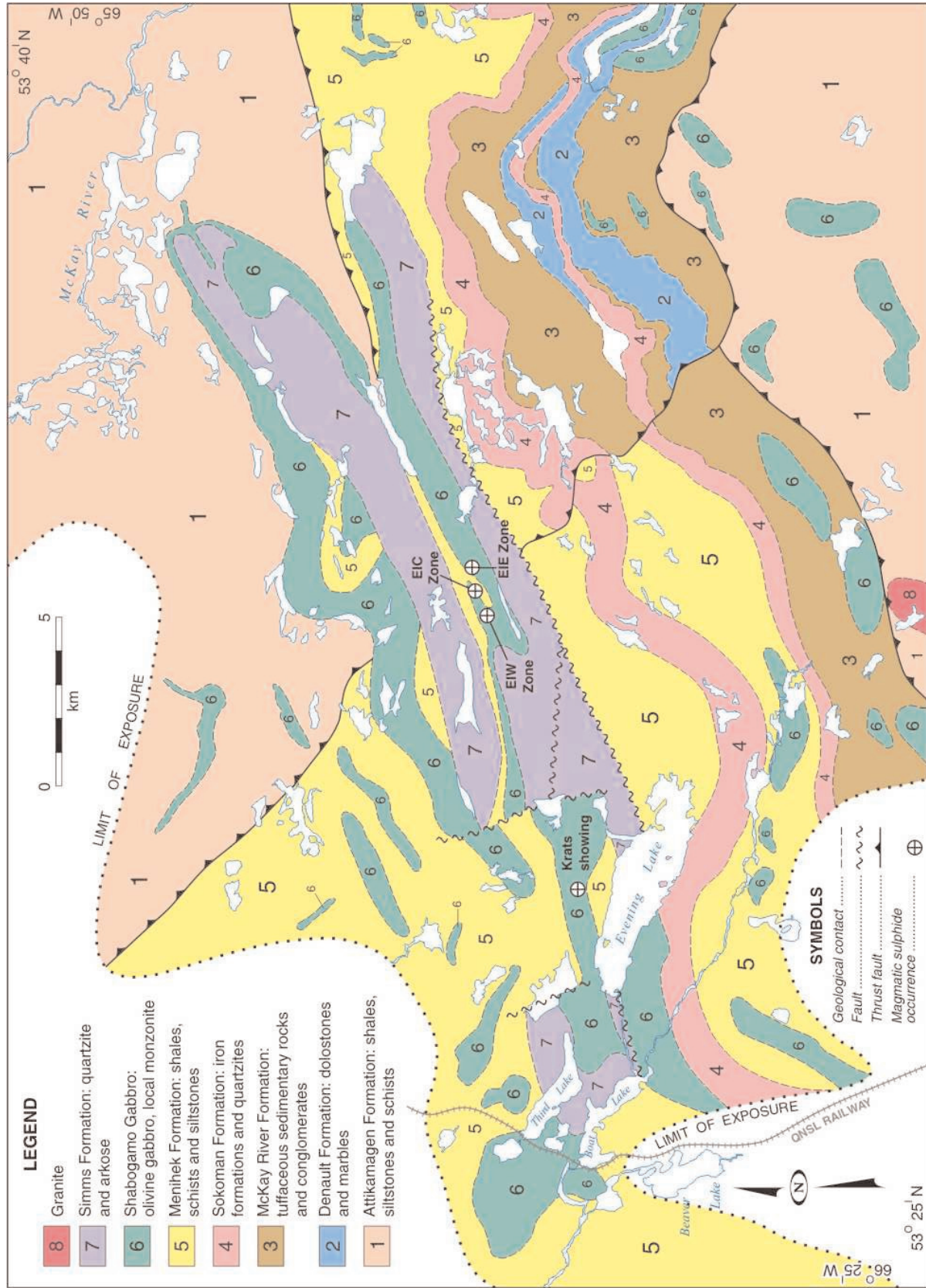


Figure 3. Geological map of the Evening Lake–McKay River area (NTS 12G/09 and 12H/12), showing the distribution of Shabogamo Intrusive Suite mafic rocks, major divisions of their country rocks, and the locations of magmatic sulphide showings. The map illustrates the complexity of Gagnon Terrane geology, the numerous locations where mafic rocks sit within or against sulphide-bearing country rocks, and the possible association of some mafic bodies with the Kaniapiskau Supergroup–Sims Formation unconformity; geology after Rivers (1985a, b, c).

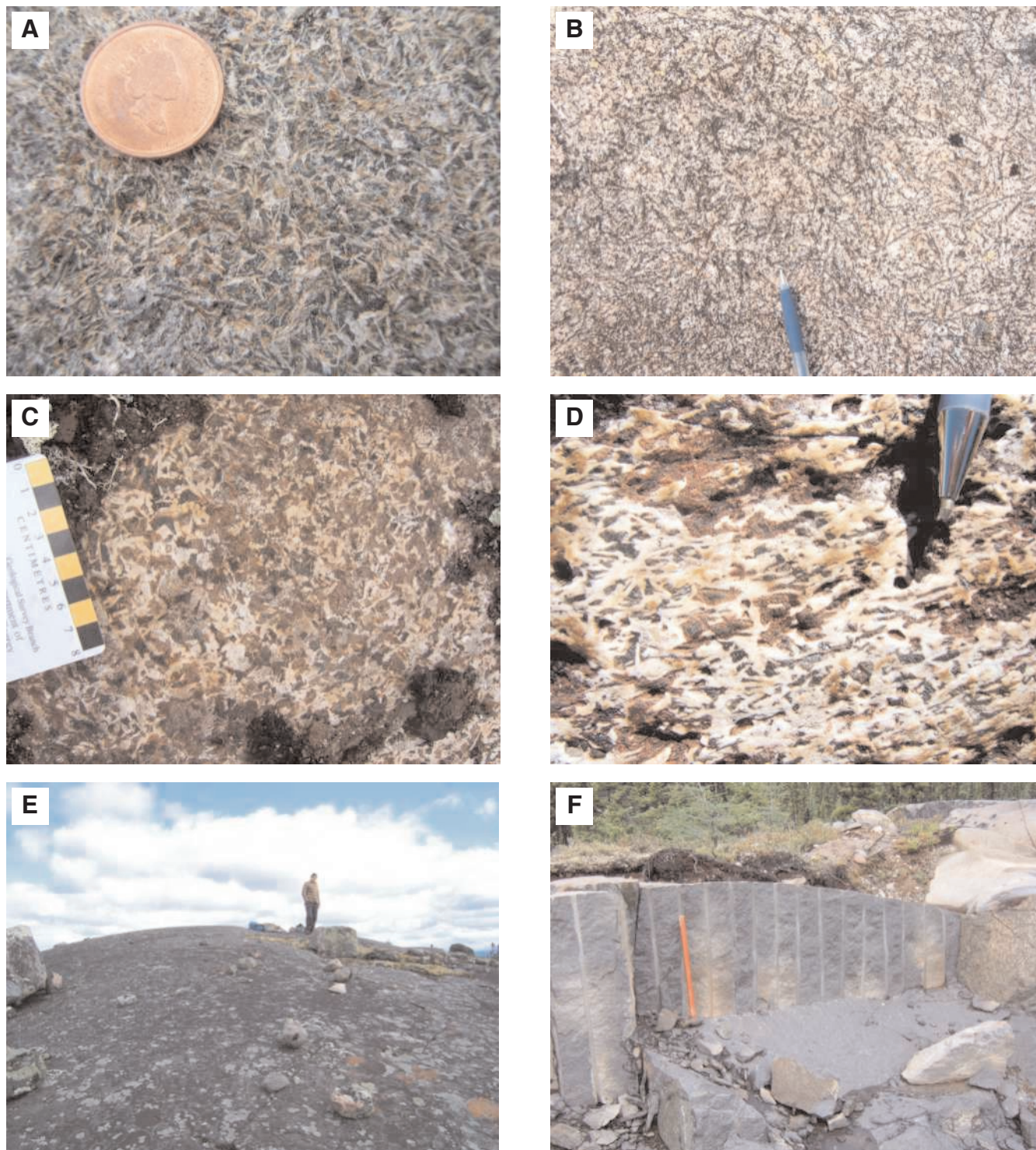


Plate 1. *Shabogamo Gabbro and related rocks. (a) Typical ophitic texture of fine- to medium-grained gabbro. (b) Pinkish "monzonitic" variant; note acicular amphibole crystals. (c) Massive, homogeneous black troctolite outcrops on Mount Fyne. (d) Coarse-grained subophitic texture of a gabbro unit in the western Molson Lake Terrane. (e) Relict igneous texture in recrystallized coarse-grained gabbro in the Molson Lake Terrane. (f) Massive grey olivine gabbro from an area in the Mount Fyne pluton where test dimension-stone blocks were extracted, near the Trans-Labrador Highway.*

Previous descriptions (Ware and Wardle, 1979; Rivers, 1982; Gower *et al.*, 1991) indicate that ophitic- to sub-ophitic-textured olivine gabbro is the dominant rock type; samples collected in 2003 and 2005 confirm this diagnosis. Fresh examples consist of plagioclase, olivine and purple-grey clinopyroxene, with lesser amounts of primary amphibole, primary red-brown biotite, magnetite and euhedral apatite. Olivine is a rounded to subhedral cumulus phase, along with plagioclase that forms euhedral laths and, locally, small phenocrysts. Pinkish monzonitic variants contain larger amounts of K-feldspar, interstitial quartz, and prismatic primary amphiboles. Elsewhere, primary amphibole is uncommon, but red-brown biotite is commonly present as a primary igneous mineral.

Some samples exhibit superb igneous textures, but many are variably altered and/or weakly foliated. Commonality of textures indicates that most were originally the same rock type, and most samples contain at least relict olivine. The alteration probably records the effects of Grenvillian metamorphism and related fluid circulation.

Grenville Province (Molson Lake Terrane)

From west to east, there is a change in the morphology of mafic units assigned to the SG in the Molson Lake Terrane (Figure 2). From Shabogamo Lake southward to the Québec border, a complex outcrop pattern suggests that they are attenuated and folded remnants of larger bodies (Rivers, 1985c). Eastward toward Churchill Falls, larger, more continuous intrusions are defined by regional mapping. The largest of these is termed the Mount Fyne Intrusion (Figure 2), and extends for about 80 km.

There are also lithological contrasts from west to east. In the west, these are coarse-grained to very coarse-grained rocks that retain subophitic textures (Plate 1c). Olivine is less obvious than in the Gagnon Terrane, and metagabbros contain locally obvious corona structures of granular red garnets and brown orthopyroxene. Although the overall igneous textures are well-preserved, the rocks are extensively recrystallized and granoblastic. Corona structures reflect the effects of Grenvillian metamorphism, notably the breakdown of olivine to form orthopyroxene and garnet, described in detail by Rivers and Mengel (1988). The outcrops within the tectonic window in the Lac Joseph Terrane similarly retain spectacular primary igneous textures in spite of the formation of complex corona structures (Plate 1d). In the east, mafic rocks are fine to medium grained, and recrystallization is less pervasive; igneous textures are in general much better preserved in this area. James (1994) notes that the rocks are locally foliated, and display amphibolite-facies metamorphism coupled with greenschist-facies retrogression. In general, such effects are more obvious in the Mol-

son Lake Terrane than in the Gagnon and Churchill Falls terranes to the north. However, igneous textures are well-preserved in many outcrops. Irregular zones of coarse-grained pegmatitic material, possibly representing local volatile concentrations, occur in some areas. The largest and best-known unit in this area is the Mount Fyne Intrusion, which is well-exposed in the upland area that lends the unit its name. At the type locality, the massive, homogeneous, unjointed black troctolite and olivine gabbro may have potential for dimension stone (Plate 1e, 1f). The effects of Grenvillian metamorphism in the Mount Fyne Intrusion are largely confined to the development of narrow orthopyroxene coronas on primary olivine grains, described in detail by Wardle (1985).

MINERALIZATION

Mineral occurrences within, or associated with, rocks assigned to the SG are indicated in Figures 2 and 3. Most of these represent minor instances of sulphides reported during regional mapping and earlier exploration. Locations that have received more detailed evaluation over the last few years are described separately below, based upon public-domain information.

The Krats Showing

This showing was discovered in 1998 by the late Karl Krats and his prospecting colleagues, who were ground-checking anomalous Zn values in lake-sediment data. The showing is located within an elongated body of gabbro that extends some 12 km to the east, and about 5 km to the west (Figure 3). Although the regional mapping suggests that the showing is surrounded by gabbro, it actually lies just to the north of a contact between gabbro and sulphide-bearing metasedimentary rocks that are suspected to belong to the Menihék Formation (Kaniapiskau Supergroup) rather than the Sims Formation, which forms high hills to the east. The showing is described in general terms by Krats (2000, 2001a), and Muntanion (2002); the following is derived from these reports.

At the site, large angular blocks of medium-grained gabbro contain variable amounts of sulphide, ranging from mere traces to about 25%. The most obvious sulphide minerals are pyrrhotite and chalcopyrite. A conductor was detected northwest of the showing by a reconnaissance VLF-EM survey (Krats, 2000, 2001a), but there have been no subsequent detailed ground EM surveys. Samples collected during initial prospecting, which may not be representative, contained up to 0.6% Cu and 0.6% Ni (Krats, 2000, 2001a). Samples of mineralized and unmineralized gabbro from the showing area are medium-grained, altered gabbro, reported to be devoid of olivine (Muntanion, 2002).

E1W Prospect and Related Zones

The E1W prospect is the most significant zone of mineralization yet reported from the SG. It is located approximately 9 km east of Evening Lake, within a gabbro unit that may represent the offset continuation of that hosting the Krats showing (Figure 3). Airborne magnetic and EM surveys outlined a strong conductor over a total strike length of about 3 km in this area, in a narrow gabbro unit that is bounded to the north by metasedimentary rocks of the Menihék Formation, and to the south by quartzites of the Simms Formation (Gallery Resources, Press Release, September 22, 2004). Muntanion (2002) reported a mineralized gabbro boulder containing 0.15% Cu and 0.04% Ni from a nearby location, but there is no surface expression of mineralization in bedrock. General details concerning the subsurface mineralization were released by the company (Gallery Resources, Press Releases, November 26, 2004 and August 26, 2005). Descriptions of mineralization and drill-core logs are provided by Janes and French (2005a, b), but this information remains confidential, and a thesis research project is currently in progress at Memorial University by Kimberly Janes (Janes *et al.*, 2005). The following description is drawn from public domain sources.

Four drillholes were completed at this site in late 2004 and two more in 2005. Disseminated sulphide mineralization is hosted by gabbroic rocks a few metres above a basal contact about 60 to 80 m below surface, below which there are sedimentary rocks. The mineralization consists mostly of pyrrhotite and minor chalcopyrite, and the amount of sulphide ranges from less than 10% to almost 50% locally.

Drillholes were also completed 750 m and 1.5 km to the east along the same conductive zone, and define the E1C and E1E zones (Figure 3), which contain 9 and 12 m of disseminated sulphide mineralization, respectively (Gallery Resources, Press Release, August 26, 2005). The mineralization is at shallow depths (40 to 60 m) and has a similar setting. These results suggest that there may be an extensive zone of sulphide development within this mafic intrusion over a significant strike length.

Assay results from E1W and nearby localities are generally low, reflecting the disseminated mineralization. Nickel and copper both range from <0.1% to about 0.4%, but there appears to be wide variation in Ni/Cu ratios (Gallery Resources, Press Releases, 2005).

Esker Road Showing

The Esker Road showing is located along the old road between Churchill Falls and Esker, about 6 km west of the Gabbro Lake control structure (Figure 2). It may actually be

the same showing as a pyrrhotite occurrence indicated by Rivers (1985b) several hundred metres to the east; the discrepancy probably dates back to the original description by Breau (1957). The showing is described by Krats (2001b) and by Muntanion (2002).

The showing is fairly small, and is hosted by a medium-grained altered gabbro. Sulphide mineralization is sporadically distributed. Locally, the rusty zones seem to define crosscutting, vein-like structures, and Muntanion (2002) suggested that mineralization was hydrothermal, or perhaps remobilized. Descriptions and available assay results suggest that the sulphides are dominantly pyrrhotite; assays reported by Krats (2001b) indicate only a few hundred ppm Ni. Reconnaissance geophysical surveys in the area suggest that there is an associated VLF-EM conductor close to the site (Krats, 2001b).

Other Zones of Mineralization

Several minor occurrences of sulphide mineralization are reported by previous mapping (Figure 2) and by the reconnaissance survey of Muntanion (2002) along the Esker Road and around Gabbro Lake; most were originally depicted by Labrador Mining and Exploration Ltd. (Breau, 1957). The Esker Road #2 showing, located at the Gabbro Lake control structure, appears to consist of disseminated and veinlet-style pyrite and chalcopyrite in quartzofeldspathic gneiss, rather than Shabogamo Gabbro. Muntanion (2002) reported 0.14% Ni and 0.15% Cu from a gabbro containing digested metasedimentary fragments near Ossokmanuan Lake; this appears to correspond with either the Ossokmanuan Lake #1 or #2 showings. Information on these occurrences is sparse, and contained within the MODS database.

Mafic rocks in the Molson Lake Terrane are devoid of mineral occurrences, aside from a narrow quartz vein containing minor pyrite and chalcopyrite on Mount Fyne, documented by Breau (1957). A search for this vein at its reported location was unsuccessful, suggesting that the position is inaccurate. This is a common problem with small mineral occurrences described in old reports prepared before accurate topographic mapping.

GEOCHEMISTRY

Previous geochemical studies of the SG include Gower *et al.* (1991), who presented data from Mesoproterozoic mafic intrusions across central Labrador, and James (1994), who presented data from part of the Molson Lake Terrane. In view of the uncertainties of the presence of older mafic rocks, and an ongoing detailed thesis project in the area of the E1W prospect (*see above*), the following discussion is largely a summary of previous work. More detailed inter-

pretation in the future will require integration of new data with archived and re-analyzed data from Gower *et al.*, 1991.

Broad Major- and Trace-Element Geochemical Patterns

Previous studies (Gower *et al.*, 1991; James, 1994) indicate that the SG has a tholeiitic differentiation trend and straddles the boundary between subalkaline and alkaline compositional fields; it is typically also enriched in TiO₂ and P₂O₅ compared to other Mesoproterozoic mafic suites such as the Seal Lake Group sills, Mealy dykes, Harp dykes and Nain dykes. It most closely resembles the chronologically equivalent Michael Gabbro intrusions of eastern Labrador (Gower *et al.*, 1991). The SG largely falls within the field of within-plate basalts in common trace-element discrimination diagrams (Gower *et al.*, 1991; James, 1994). Rare-earth-element (REE) patterns reported by Gower *et al.* (1991) and James (1994) are closely similar, gently sloping and linear in shape, with LREE abundances of 5 to 60 x chondrite; REE-depleted samples have prominent positive Eu anomalies, indicating that they are plagioclase cumulates, and REE-enriched samples have small negative Eu anomalies indicating the removal of plagioclase. The smoothest REE patterns likely represent samples that are closest to primary magmatic compositions, and these have normalized LREE contents of 20 to 40, which translates to 20 to 40 ppm Ce, as the normalization factor for this element is close to 1.

Gower *et al.* (1991) reported mean values of 127 ± 104 ppm Ni and 38 ± 17 ppm Cu, and James (1994) reported equivalent values of 122 ± 79 ppm Ni and 45 ± 20 ppm Cu. These studies did not involve mineralized samples and they indicate that the bulk of the rocks assigned to the SG contain less than 200 ppm Ni and 100 ppm Cu.

The geochemistry of the SG appears to be typical of transitional calc-alkaline to alkaline mafic suites that are emplaced in rift-related tectonic settings. From the present perspective, the Ni and Cu contents in parental magmas are the most significant parameter. Although mean values are naturally biased by the presence of cumulus olivine in some samples, these would, to some extent, be balanced by the dilution effects of cumulus plagioclase in others, and values of about 125 ppm Ni and 40 ppm Cu are probably reasonable estimates. The Ni value is close to the suggested parental magma composition for the Kiglapait Intrusion (Morse *et al.*, 1991) and slightly less than values suggested for the Pants Lake and Voisey's Bay intrusions in northern Labrador (Kerr, 2003; Li *et al.*, 2000).

Geochemistry of Mineralization

The Ni and Cu contents of mineralized samples from the Krats and E1W showings range from a few hundred ppm

to >3000 ppm of each element (Krats, 2000; 2001a; Gallery Resources, Press Releases, 2005). The "raw" Ni and Cu values are dependent on the amount of sulphide in the sample and, to a lesser extent, on the amount of olivine, which also concentrates Ni. This complication can be removed by recalculating (normalizing) the data to obtain the metal content of the bulk sulphide component, with an appropriate correction for Ni in olivine. The basis of the method is described by Kerr (2003), and simply requires an analysis for sulphur in addition to metals. On this basis, the data of Krats (2000) suggest sulphide metal contents from 1.1% to 1.6% Ni and 0.9% to 1.5% Cu. The generally low Ni and Cu contents from the Esker Road showing (Krats, 2001b) suggest that the mineralization is mostly pyrrhotite.

Nickel and copper data reported from the E1W prospect (Gallery Resources, Press Release, August 26, 2005) are similar to those obtained from the Krats showing, but sulphide metal contents cannot be calculated from them. The results indicate considerable variation in Ni/Cu ratios, perhaps suggesting some disturbance of Cu contents by post-mineralization processes.

OSSOK MOUNTAIN INTRUSIVE SUITE

DEFINITION, EXTENT AND AGE

The term Ossok Mountain Intrusive Suite (OMIS) applies to compositionally-varied mafic intrusive rocks in the central Lac Joseph Terrane (James, 1994). Similar rocks mapped elsewhere in the terrane by Nunn and Christopher (1983) and Rivers (1985c), are now also included in the suite. The OMIS forms several discrete "plutons" within metasedimentary gneisses (Figure 2), but the true depth extent of such bodies is unknown, as both they and their host rocks are allochthonous. James (1994) suggested that most extend less than 2 km below the surface. Mafic rocks are most abundant in the northern part of the Lac Joseph Terrane (Figure 2), where they coincide with high-pressure metamorphic assemblages in the host gneisses, implying a paleodepth control (James, 1994). The OMIS intrudes surrounding paragneisses, and contain paragneiss inclusions near to the inferred contacts. The mafic rocks are in turn cut by granitic rocks, which are locally pegmatitic, and also by mafic dykes of unknown age. The age of the OMIS is defined by U–Pb zircon ages of 1639 ± 2 Ma (James, 1994) and $1623 \pm 7/-5$ Ma (Connelly and Heaman, 1993) from homogeneous gabbro-norites. These ages are believed to indicate crystallization, and are extrapolated to all rocks included within the OMIS. The metasedimentary country rocks yielded a U–Pb zircon age of 1660 ± 6 Ma (James, 1994), indicating the time of metamorphism, rather than deposition. As in the case of the SG in terranes to the north, the assumption of a single intrusive age for all such mafic bodies may be simplistic.

GEOLOGY AND PETROLOGY

Regional mapping was completed by James (1994), and subsequent field work was limited to areas near the Trans-Labrador Highway between 2003 and 2006 (Figure 4), augmented by regional geochemical sampling in more remote areas by helicopter in 2005.

The dominant rock types are gabbro, norite, gabbro and olivine-bearing equivalents of these, accompanied by lesser amounts of pyroxenite and anorthosite (James, 1994). These all exhibit some degree of recrystallization, deformation and metamorphism, and original igneous textures are variably preserved. The OMIS has one definitive, but lamentable characteristic, *i.e.*, it is texturally and compositionally heterogeneous on an outcrop scale (Plate 2a), and the definition of mappable subunits is almost impossible (James, 1994). Relict igneous features, such as primary layering, textural variations and subophitic textures (Plates 2b,c, and d) are locally observed, notably around the margins of some of the larger bodies. Individual outcrops commonly contain at least three different rock types (Plate 2a), and the relationships between these may be ambiguous. Even if time relationships can be established, nearby outcrops may yield contradictory evidence, and it cannot be assumed that a given "phase" is of the same age even within a small area. James (1994) notes that the youngest rock types throughout the area are fine-grained, recrystallized gabbro dykes, which are observed to cut all other mafic rocks as well as the paragneisses. However, no other timing relationships can be established except on the most local scale.

The most abundant rock types are gabbro, norite, which consist largely of plagioclase, clinopyroxene and orthopyroxene, with lesser amounts of biotite, hornblende, oxide (ilmenite), and apatite. This is probably a primary mineral assemblage because it is present in rocks that have well-preserved igneous textures and their strongly recrystallized equivalents. Olivine-bearing rocks are less abundant, and olivine is generally observed where original igneous textures are well preserved. Olivine typically shows well-developed corona structures that have inner sections of orthopyroxene and outer sections of intergrown clinopyroxene and green spinel; in some cases, it is completely transformed. The corona structures are described in detail by James (1994) who suggests that they record isobaric cooling following emplacement of the magma under high-grade metamorphic conditions (after Mengel and Rivers, 1988). James (1994) also reports rocks of troctolitic composition in two localities.

Ultramafic rocks are uncommon, but they are of interest because of sporadic PGE enrichment. The most abundant

is pyroxenite, which occurs on a variety of scales, but rarely forms mappable units. Pyroxenites are best known in the northern part of the OMIS, near the highway (Figure 4) but this simply reflects more detailed knowledge in this area. They are likely present throughout all areas of mafic rock, as they were also observed in locations sampled by helicopter. They occur as discontinuous lenses or layers within the dominant gabbroic rocks and they likely represent disrupted mafic cumulates. An alternative explanation is that they could be transposed and rotated dykes, but this would imply more intense deformation than is generally seen. Pyroxenites are typically massive black to dark-green recrystallized rocks (Plate 2e), consisting of orthopyroxene, clinopyroxene, phlogopitic mica and minor plagioclase. Olivine is present in some examples, and the widespread occurrence of spinel-clinopyroxene symplectites in recrystallized rocks suggests its former presence. Brown amphibole is also present in many samples, and some "pyroxenites" proved to be amphibolites when examined in thin section. Minor amounts of sulphide are locally present in these ultramafic rocks. Brown-weathering melatroctolite to peridotite, containing up to 75% olivine, occurs in outcrops along the Trans-Labrador Highway (Plate 2f), but does not appear to be geographically extensive. Serpentinized ultramafic rocks are also present at the Wynne Showing, in the extreme south part of the Lac Joseph Terrane, where they were included as part of the OMIS by James (1994).

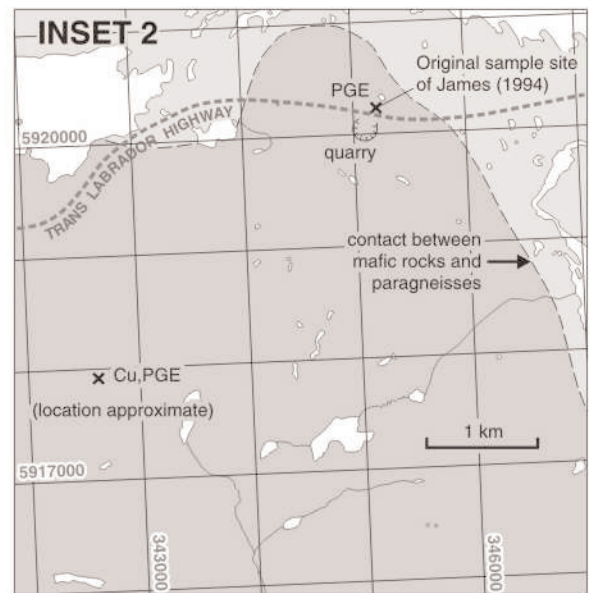
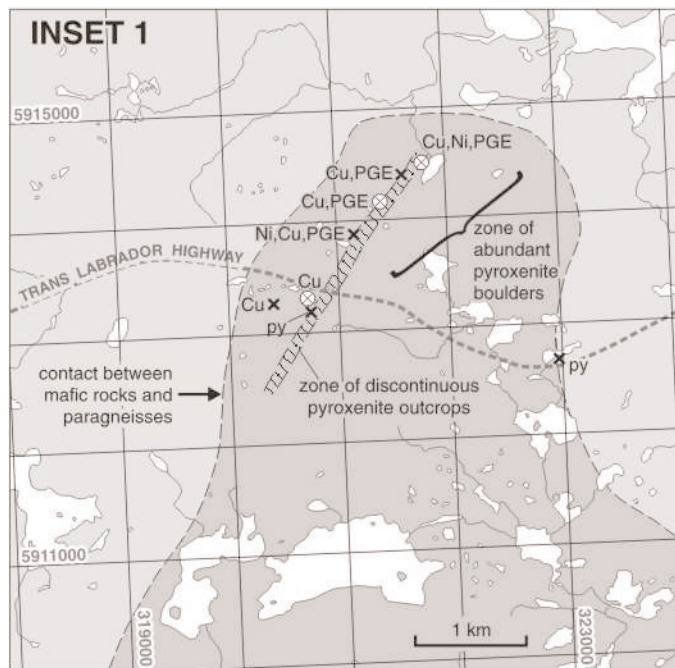
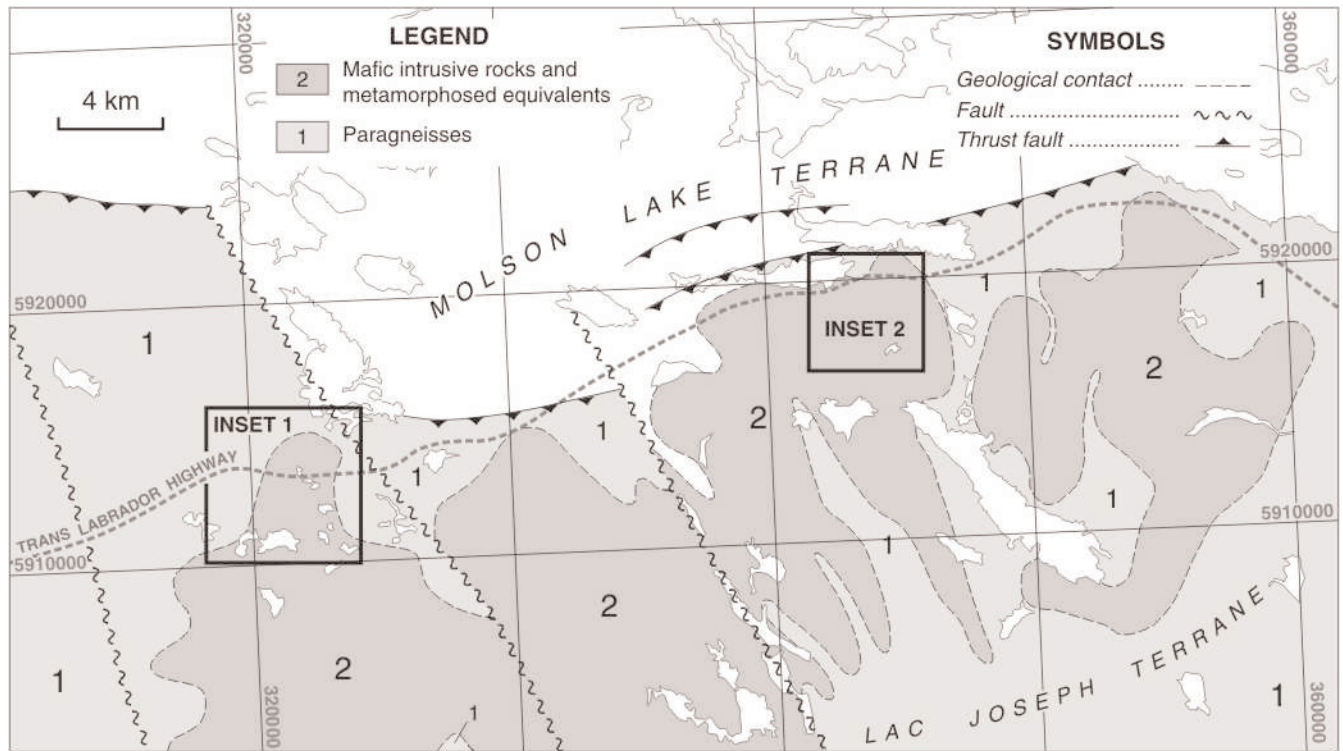
Well-layered mafic rocks occur locally within the OMIS, and were termed "mafic gneiss" by James (1994). The layering is suspected to have originated through cumulate processes. In some areas, the mafic minerals have been partially or completely replaced by granular aggregates of red garnet. The layered rocks are most commonly cut by more massive gabbros, implying that they are earlier (marginal ?) phases of individual intrusions

MINERALIZATION

Wynne Showing

The Wynne showing (MODS # 23A/14/Cu001) is located in the southern part of the Lac Joseph Terrane (Figure 2). It was found by Brinex (Pyke, 1956) and was described as "an altered mineralized zone 1.5 miles in length and 0.5 miles wide" hosted in paragneisses. The original report indicated the presence of Cu (0.1 to 0.5%), along with traces of Cr, Ag, Ni and V. However, the exact location of the showing is difficult to ascertain because the map included with the report is much generalized. Mineral rights are presently held of Altius Minerals.

James (1994) visited the area, and described a dyke-like body of serpentinized troctolite within paragneisses. He ten-



- × Mineralization in outcrop
- ⊗ Mineralization in float blocks

Figure 4. Simplified geological map of the Ossok Mountain Intrusive Suite in the area south of Cissy Lake and Ranger Lake along the Trans-Labrador Highway, showing local geology and the locations where anomalous PGEs have been documented during exploration work. Partly after Saunders et al. (2001a, b), and Carpenter (2005); lake-sediment data from the detailed survey of McConnell (2005).

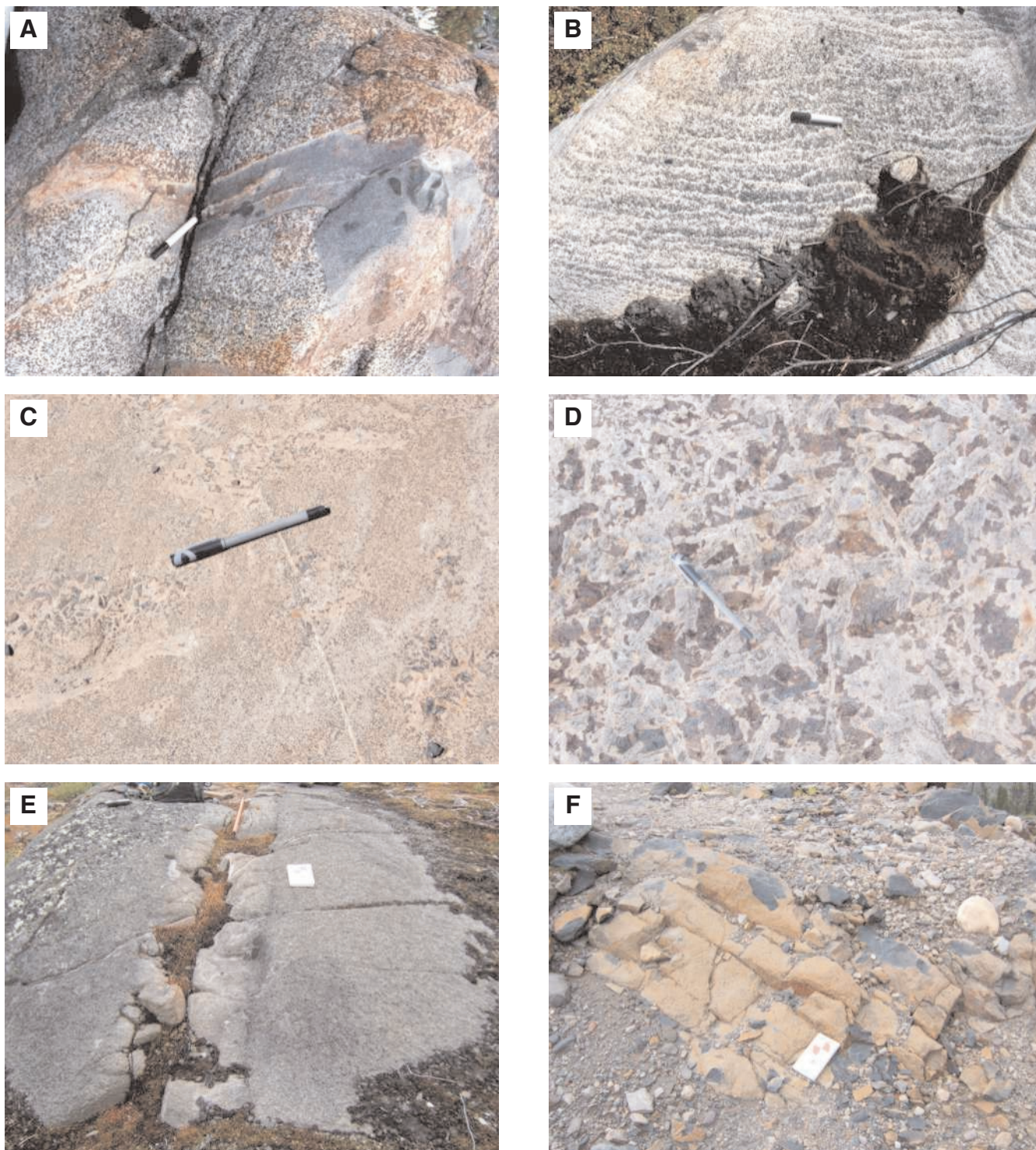


Plate 2. *Ossok Mountain Intrusive Suite and related features. (a) Typical multiphase outcrop of gabbronorite and finer grained phase with uncertain contact relationships. (b) Magmatic layering preserved in coarse-grained gabbronorite. (c) Medium-grained gabbronorite containing coarse-grained pegmatitic patches, (d) Coarse-grained leucocratic gabbronorite showing well-preserved oikocrystic pyroxenes and cumulus plagioclase. (e) Massive pyroxenite outcrop cut by a medium-grained gabbroic dyke. (f) Brown-weathering peridotite.*

tatively correlated the ultramafic rocks with the OMIS, and reported elevated Cr (up to 0.9%) and Ni (up to 0.3%), but no indication of Cu. The area was subsequently explored by Consolidated Viscount Resources Ltd (Van Nostrand and Brewer, 1997) who also described serpentinized troctolites. This work failed to locate any significant mineralization, aside from some small patches of pyrite in paragneisses. A visit in 2005 confirmed the earlier observations, but the ultramafic rocks are likely serpentinized peridotites or dunites that have very little plagioclase. This conclusion is supported by the very high MgO contents (38% to 43%) of samples. These also contained 0.7% to 0.8% Cr, and 0.19% to 0.3% Ni, but were devoid of Cu (<5 ppm). Platinum-group-element abundances were at background levels (<5 ppb). It seems likely that the Ni is hosted by silicate minerals (olivine and serpentine) and the Cr is hosted by chromite. The Wynne showing should probably be redesignated as a chromite occurrence, and perhaps renamed, for it remains possible that the site mentioned by Pyke (1956) is actually elsewhere.

Cissy Lake Area

James (1994) noted that the OMIS might have potential for magmatic Ni–Cu (\pm PGE) mineralization, and reported a value of 200 ppb Pd from a sample of gabbronorite collected along the Trans-Labrador Highway (Figure 4). This result eventually led to some prospecting by Buchans River Ltd., and the discovery of pyroxenitic boulders that are anomalous in PGE. The largest concentration of such boulders is in the area south of Cissy Lake (Figure 4). The rock types in this area are a confusing mixture of gabbronorite, norite and gabbro, cut by pink to grey granitic and pegmatitic dykes. A pyroxenitic unit, which ranges in width from 5 m to >30 m, trends northeast–southwest through the area, across the highway, and locally forms massive outcrops (Figure 4). It is not known if this unit is continuous or actually a series of disconnected lenses, but it is easily traced. The area to the southeast of this unit contains abundant pyroxenitic boulders, but these are comparatively rare to the northwest. This suggests that much, if not all, of the pyroxenitic float is of local origin. Small amounts of sulphide (generally <2%) occur in several outcrops and in loose material, but the PGE content of these varies widely. The best early results came from a 2-m-diameter pyroxenitic block which was sampled twice, giving 850 to 1250 ppb Pd, 200 to 320 ppb Pt, and 100 to 130 ppb Au (Saunders *et al.*, 2001a, b); this block also contained Ni (0.15%) and Cu (0.3%). Most pyroxenitic outcrops and boulders were only weakly anomalous in PGE, although they were locally enriched in Ni and Cu (Saunders *et al.*, 2001a, b). Two mineralized samples examined as part of a consultant report (Wilton, *in* Saunders *et al.*, 2001a) are described as an "olivine-bearing pyroxenite containing both orthopyroxene and clinopyroxene" and a "gabbroic rock".

The sulphide minerals include pyrite, chalcopyrite and pyrrhotite; minor amounts of pentlandite were also observed. Hercynitic spinels in both samples were interpreted as evidence for digestion of country-rock material, as documented in mafic rocks at Voisey's Bay and other localities in Labrador (Wilton, *in* Saunders *et al.*, 2001a). However, given the widespread occurrence of spinel as a metamorphic mineral in the OMIS (James, 1994) it is more likely that this is a regional feature unconnected to mineralization. Numerous pyroxenitic blocks around the location indicated by Saunders *et al.* (2001b) were sampled in 2003, but revealed only weakly anomalous PGE values. Pyroxenitic outcrops in the area contained background levels of PGE or were weakly anomalous. Relocation and sampling of the "best boulder" of Saunders *et al.* (2001) is difficult because its location was not constrained by GPS coordinates.

More recent work in this area by Brilliant Mining has detected additional outcrops and boulders containing sulphides (R. Carpenter, personal communication, 2005). Some of these are anomalous in base metals (notably Cu, up to 0.6%) but only weakly anomalous in PGEs, whereas others have more significant PGE enrichment. The best results were 500 to 760 ppb Pd, 100 to 200 ppb Pt and ~150 ppb Au from a large boulder or small outcrop of pyroxenite, which has malachite staining and contains about 0.3% Cu. This is located along strike to the northeast from the site reported by Buchans River Ltd. A rusty zone of anomalous Cu and Ni in pyroxenite south of the Trans-Labrador Highway (Figure 4) is spatially associated with a pink granitic vein, and a similar relationship was noted at a pyroxenitic outcrop north of the highway that contained ~500 ppb Pd (Figure 4). These observations raise the possibility that there may be a hydrothermal component to some of this mineralization, and that Cu and PGE were locally redistributed from the ultramafic rocks.

Ranger Lake Area

Buchans River Ltd., prospected other areas along the Trans-Labrador Highway, including a block located southwest of Ranger Lake, close to kilometre 139 (Figure 4). Here, hills south of the highway are underlain by medium- to coarse-grained gabbronorite, showing the usual confusing mixture of rock types and relationships. A sample from a small (<1 m²) sulphide-bearing inclusion within gabbronorite yielded 800 ppb Pd, 360 ppb Pt and 240 ppb Au, coupled with 0.4% Cu and 0.06% Ni (Saunders *et al.*, 2001a). However, because the sample site was not constrained by GPS coordinates, it has to date not been located again.

GEOCHEMISTRY

James (1994), discussed the geochemistry of the OMIS, but had only 12 analyses to study. Pyroxenites and other

rock types near the Trans-Labrador Highway were sampled in 2003, and regional sampling elsewhere was completed in 2005; some additional sampling of mineralized rocks was conducted in 2006. The 2003 database is dominated by pyroxenites and is, therefore, not representative; these samples from 2003 were analyzed for PGE and Au only. The database discussed below comprises regional data from the 2005 program, combined with data from James (1994).

Broad Major- and Trace-Element Geochemical Patterns

The previous study of James (1994) indicates that mafic rocks of the OMIS are subalkaline, and do not display clearly tholeiitic or calc-alkaline trends in the AFM ternary plot. In trace-element discrimination diagrams, the OMIS plots within calc-alkaline basalt, within-plate basalt and mid-ocean-ridge basalt fields without a clear preference (James, 1994). The applicability of such diagrams to coarse-grained plutonic rocks is debatable, but the pattern differs from the tighter grouping shown for the SG (Gower *et al.*, 1991). The larger dataset from this study generally confirms these patterns. Rare-earth-element patterns illustrated by James (1994) are varied in shape and slope and many samples have positive Eu anomalies, indicating that they are plagioclase cumulates. The variations in shapes were interpreted in terms of a fractionation relationship by James (1994), but it is also possible that they record more than one parental magma type. James (1994) suggested that the OMIS may represent mafic magmas related to the continental-arc environment envisaged for the Trans-Labrador batholith, which is of broadly equivalent age.

Trace-Element and Ore-Element Variation Patterns

Trace-element variations were assessed using MgO as a differentiation index, and show expected patterns. Chromium, Ni, and Co all show very good positive correlations against MgO (Figure 5a, b and c), suggesting that Cr is controlled by chromite and Ni and Co by olivine. The Ni-enriched samples from the Wynne showing are excluded from the chart for clarity, but they lie on the extension of the MgO–Ni trend. The data for Cu (Figure 5g) do not show a clear pattern, although there is some modest Cu enrichment in pyroxenites, and also in one other sample that contained a vein-like zone with disseminated sulphides and 700 ppm Cu (excluded from chart). The expected inverse correlations against MgO are shown by incompatible trace elements such as Zr, Rb and Sr (Figure 5d, e and f), and also La, Ce and Y. If the high-MgO pyroxenites are excluded, incompatible trace-element abundances have lowest values between about 6% and 10% MgO.

Relationships between Ni and Cu (Figure 5g) indicate a general correlation between the two elements, but illustrate

significant variation in Ni/Cu ratios from 0.1 to 10. Frequency patterns for MgO and SiO₂ illustrate the compositional variability of the OMIS (Figure 6a, b)

James (1994) reported mean values of 192 ± 182 ppm Ni and 59 ± 32 ppm Cu for the OMIS. Frequency histograms for data from the Lac Joseph Terrane (Figure 6c, d) indicate higher mean values of 271 ± 399 ppm Ni and 98 ± 115 ppm Cu, but these figures are biased by samples that have high Ni values and a single sample with elevated Cu. The bulk of the OMIS samples contain less than 400 ppm Ni and 150 ppm Cu, and the mean values (excluding rocks with >500 ppm Ni or Cu), are 116 ± 91 ppm Ni and 82 ± 61 ppm Cu.

Geochemistry of Mineralization

At present, little can be said on this topic, except that PGE enrichment is sporadic, and generally seems to be associated with elevated Cu values, based upon exploration company data (Saunders *et al.*, 2001a, b; R. Carpenter, personal communication, 2005). Additional trace-element analyses of pyroxenites are in progress and the results of these will be published at a later date. Data from regional sampling in 2005 in the OMIS indicate that virtually all samples have Pd and Pt contents below detection limits (<4 ppb Pd and <5 ppb Pt). Data from pyroxenites sampled in 2003 and 2005 are more variable, and partly above detection limits, containing up to 63 ppb Pd and 29 ppb Pt. There is, thus, some indication that the pyroxenitic rocks do contain elevated PGEs compared to other rock types.

DISCUSSION

The two suites of mafic rocks (SG and OMIS) discussed above are both exploration targets for Ni–Cu (± PGE) deposits, but they are distinctly different in character. The exploration of both suites is still at a relatively early stage, and the information presented in this report remains incomplete. In the case of the SG, the ongoing thesis study by Kimberly Janes will ultimately provide more detailed information. This section is intended simply to summarize the main conclusions permitted by existing public-domain data and highlight gaps that remain to be filled.

Ni–Cu POTENTIAL OF THE SHABOGAMO INTRUSIVE SUITE

Ryan *et al.* (1995) identified these rocks as possible hosts for magmatic sulphide deposits, largely on the basis of their olivine-rich nature and the presence of sulphide-bearing country rocks distributed over wide areas. This suggestion was confirmed by the discovery of magmatic sulphide

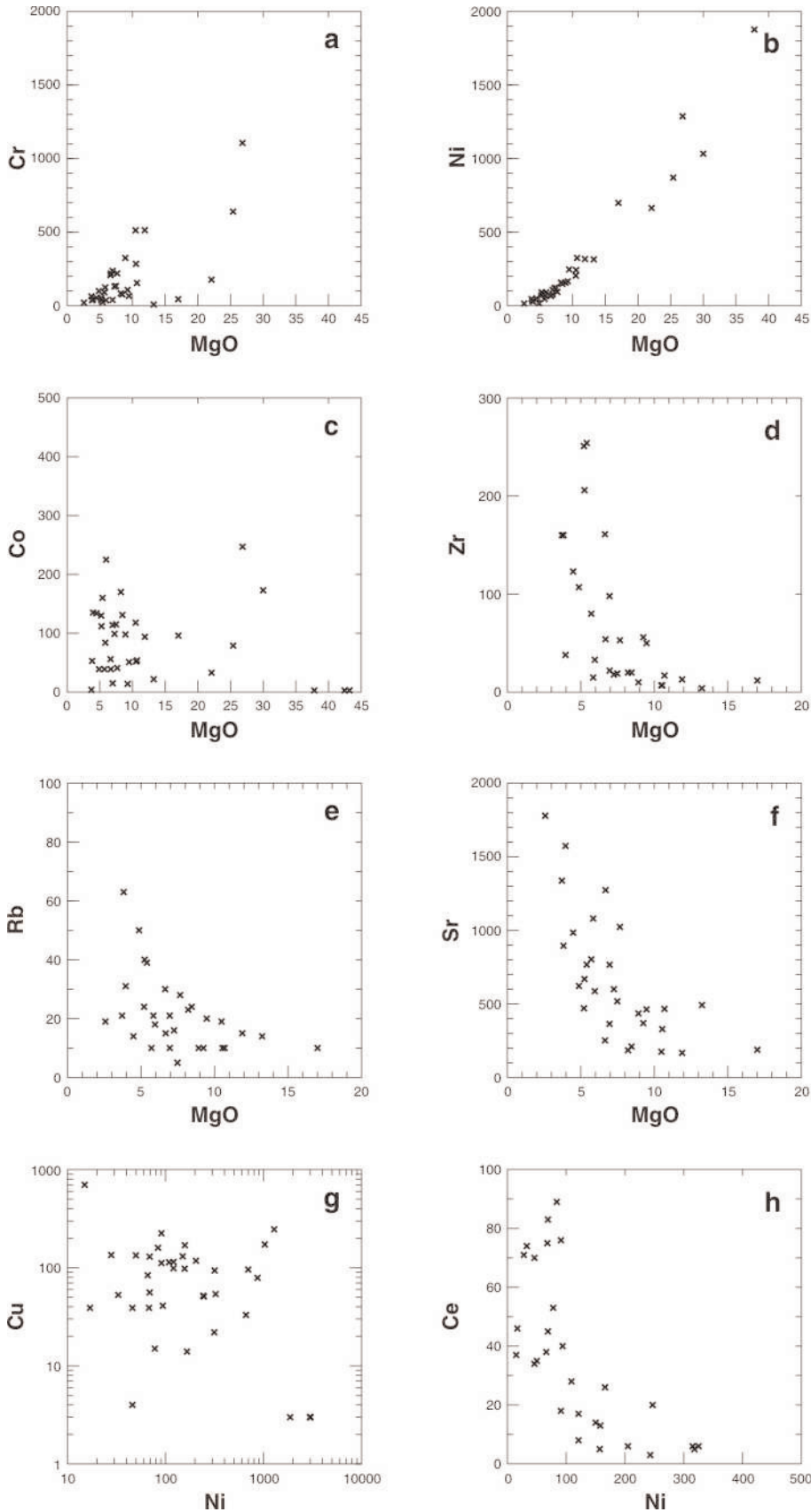


Figure 5. Trace-element variation patterns for the OMIS, using MgO as a differentiation index on the X axis. Note that the axis limits for some charts have been "clipped" in order to avoid excessive crowding of data at low levels; consequently, a few samples with high values for Cr, Ni, Cu and MgO are excluded; see text for further discussion.

mineralization near Evening Lake, and subsequent exploration and drilling at the E1W prospect. The mineralization in both areas is largely disseminated, but the discoveries are significant in that they confirm the potential of this geological setting. In the case of E1W, the recognition of similar mineralization over a strike length of about 1.5 km indicates that mineralizing systems could be of considerable size. The geology of this part of the Gagnon Terrane, as illustrated by Figure 3, indicates many prospective situations where mafic intrusions lie within, or adjacent to, potentially sulphide-bearing country rocks.

Some general evaluation of the capacity of SG parental magmas to generate economic mineralization is possible using general principles. If sulphide liquids developed in a closed system, a magma/sulphide ratio (R-factor) of about 1000 would form sulphide liquids containing over 3% Ni, if the initial magma content was only 100 ppm Ni and the sulphide/magma partition coefficient was about 500. Values of 1.5 to 2.5% Cu in sulphides are certainly possible using reasonable assumptions for parental Cu contents (40 ppm) and partition coefficients (about 800). The observed sulphide metal contents at the Krats showing of 1% to 1.5% Ni and Cu indicate low R-factors (<250), and a twofold increase in the amount of

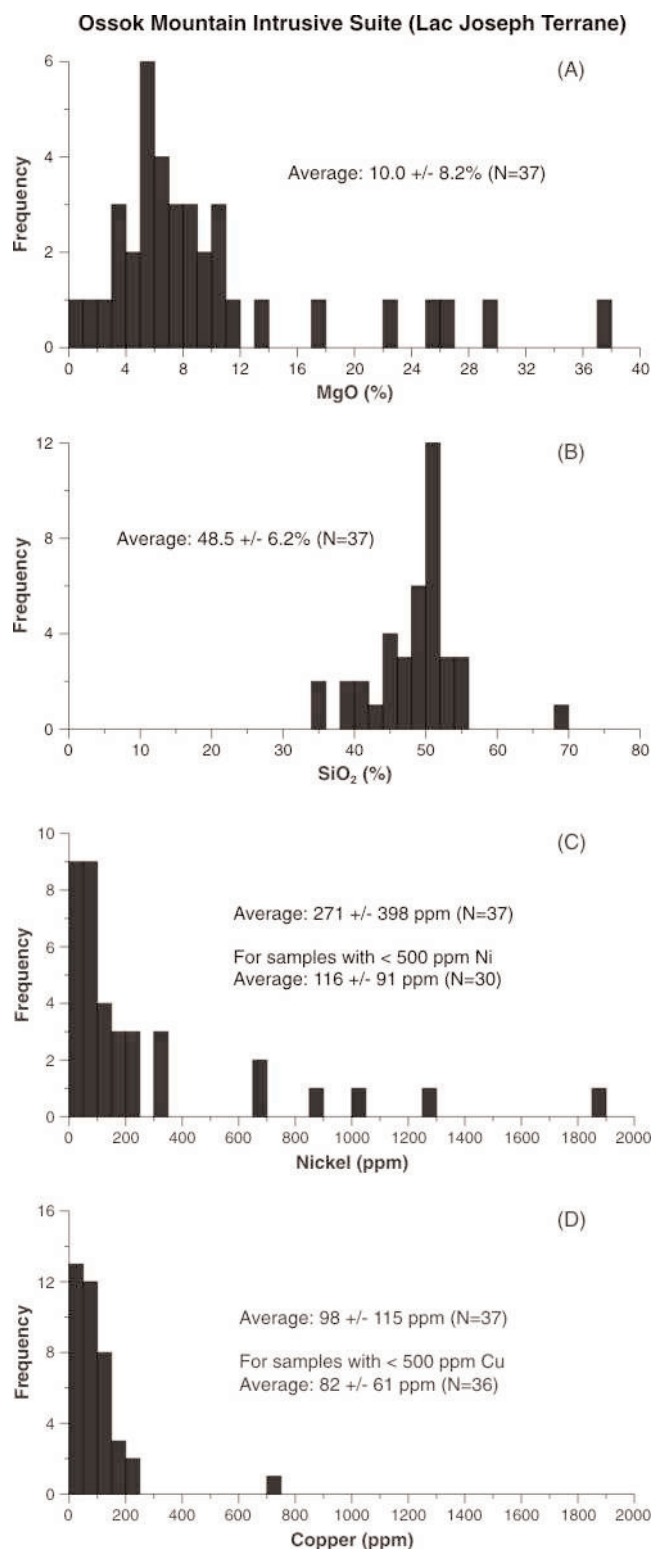


Figure 6. Frequency distribution patterns for Ni and Cu in the OMIS; see text for further discussion. (A) Major element variations indicated by SiO₂. (B) Major element variations indicated by MgO. (C) Nickel variation. (D) Copper variation.

magma processed would bring sulphide metal contents closer to present economic thresholds. Higher initial Ni contents would reduce the amount of silicate magma required to produce such values.

The mafic rocks assigned to the SG within the Molson Lake Terrane probably represent a deeper crustal level compared to those of the Gagnon Terrane. Amongst the former, the Mount Fyne Intrusion stands out by virtue of its olivine-rich troctolites. However, to date, only traces of sulphides have been detected in these mafic rocks. An important difference between the Gagnon and Molson Lake terranes is that the former contains abundant sulphide-bearing country rocks, whereas the latter contains very few. If external sources of sulphur are important in the generation of magmatic sulphides, as is commonly understood, the Molson Lake Terrane may be intrinsically less prospective. However, it is premature to dismiss this area, as it has not received detailed airborne geophysical surveys of the type completed over the Gagnon Terrane. The Mount Fyne area also contains a significant lake-sediment geochemical anomaly defined by Ni, Cu, Pt and Pd (McConnell, 2005) that remains unexplained, unless it is connected to the yet-to-be-relocated Cu-bearing quartz vein of Breau (1957).

Ni–Cu ± PGE POTENTIAL OF THE OSSOK MOUNTAIN INTRUSIVE SUITE

Assessment of the mineral potential of these rocks is more difficult, because they are very varied in composition and texture and mostly well-removed from liquid compositions. The parental magma compositions are harder to estimate, but the general compositions (gabbro versus olivine–gabbro) and higher mean Cu contents, suggest that these rocks are more compositionally evolved than the SG.

The PGE potential is not simple to assess, but there is at least direct evidence for the enrichment of these elements on a local scale. Anomalous PGE results to date have come mostly from pyroxenites, notably in the Cissy Lake area. The character of the small showing south of Ranger Lake remains unknown, as it could not be located again. Strong PGE enrichment, to potential economic levels, has not yet been documented, and the best results so far have come from boulders rather than true outcrops. Platinum-group-element enrichment seems to be associated with Cu enrichment. Sparse evidence from the Cissy Lake area suggests a possible link between sporadic Cu ± PGE enrichment and intersections between pyroxenites and pegmatitic granite veins, implying that mineralization may, in part, be hydrothermal and epigenetic, rather than magmatic and syngenetic.

Assuming that the greatest potential for PGE enrichment is in pyroxenites – irrespective of its mode of origin – the setting and abundance of these host rocks are important considerations. The pyroxenites observed in the Cissy Lake area probably originated as mafic cumulate zones, and their original distribution may have been erratic; their discontinuous nature may also indicate disruption by later deformation. Pyroxenites are not abundant on a regional scale, and most are mappable only on an outcrop scale. Continued PGE exploration in the OMIS is thus dependent upon the definition of larger, more continuous pyroxenitic units that can be systematically assessed. The regional mapping (James, 1994) and sampling conducted under this project seem to rule out the existence of kilometre-scale pyroxenite units in exposed portions of the suite, but smaller bodies with strike lengths below this threshold could be present, although their definition presents a challenge. Detailed airborne geophysical surveys may have potential to define such rocks by virtue of their magnetic signatures; preliminary analysis of such data by Brilliant Mining suggests that the pyroxenitic unit south of Cissy Lake was detected (R. Carpenter, personal communication, 2005). There may also be potential for the use of lake-sediment geochemical data (McConnell, 2005) to target both mineralization and the geochemical signatures of potential host rocks.

OTHER INDICATORS OF MINERALIZATION POTENTIAL

Exploration for heavily disseminated Ni–Cu sulphides is critically dependent upon geophysics, notably EM prospecting. Detailed magnetic–EM surveys were conducted by BHP-Billiton and Gallery Resources over parts of the SG and by Brilliant Mining over parts of the OMIS. These results remain confidential, although numerous conductors were detected within the survey area, most of which is within the Gagnon Terrane (Gallery Resources, Press Releases, September 22, 2004, June 17, 2005). Clearly, most of these still remain untested.

Sulphide-poor PGE mineralization is not easily detectable using EM prospecting, and surficial geochemical techniques may be useful in early-stage exploration. The detailed lake-sediment survey of McConnell (2005) covered much of the southern part of the study area. The behaviour of PGE in the surficial environment is discussed by Cameron and Hattori (2005), who note that there is marked separation of Pt and Pd, because the latter is soluble and more easily dispersed. This tendency is affirmed by the different inter-element correlations and geographic distributions noted for Pt and Pd by McConnell (2005). The distribution of Pd highlights the large area of mafic rocks that includes the Cissy Lake area, and one anomalous sample site is located southeast of the discontinuous pyroxenite unit

(Figure 4). However, the strongest individual Pd anomaly is located in the Mount Fyne area. The pattern for Pt does not coincide strongly with that for Pd, although the Mount Fyne area also hosts the strongest individual anomaly. The large mafic unit south of Cissy Lake is regionally anomalous in Cu, but not in Ni. The strongest anomalies for Ni are instead associated with Mount Fyne and also an area of the OMIS located north of the Trans-Labrador Highway.

The data are not easy to interpret in terms of exploration targets. Cameron and Hattori (2005) note the wide dispersion of Pd compared to Pt, and a possible association of Pd-only anomalies with esker systems, which may provide high permeability surface environments where Pd can be easily leached from mafic rocks. In this context, Pd-only anomalies southeast of Cissy Lake are associated with a very large zone of gravel esker deposits. Such considerations do not, however, explain the wider Cu anomalies associated with this region, or the multi-element Ni–Pt–Pd anomaly near Mount Fyne. Given the association between Cu and PGE in known mineralization, the distribution of Cu may be as valuable as that of Pd or Pt, and this clearly highlights the area southeast of Cissy Lake within the OMIS.

Irrespective of gaps in our knowledge of the behaviour and interpretation of Pt and Pd distribution in surficial environments (Cameron and Hattori, 2005), lake-sediment geochemistry is well established as an exploration technique. In this context, it would certainly be beneficial to have equivalent high-density sampling coverage for the area of the Gagnon Terrane, where many potential environments for magmatic sulphide formation exist (Figure 3). Such data would prove useful in ranking geophysical anomalies for further investigation.

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Plate 3. Karl Krats (1937-2006) at home in the Labrador wilderness, June 2005.

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