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RECONNAISSANCE SAMPLING FOR DIAMOND-INDICATOR MINERALS FROM ESKERS, WESTERN LABRADOR

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ABSTRACT

Western Labrador, in particular the Archean Ashuanipi Complex of the Superior structural province, is a potential target for diamond-bearing kimberlites and lamproites. In 2012, the Geological Survey of Newfoundland and Labrador conducted a reconnaissance regional-scale field program as an initial appraisal of the area. The main objective was to collect sand and gravel samples from esker deposits, to be analyzed for kimberlite-indicator-mineral (KIM) grains as a means of identifying potential areas for diamond exploration. Sample selection was based on favourable bedrock geology and ice-flow history of the area. The survey area encompassed four 1: 250 000 map areas (NTS 23G, 23H, 23I and 23J), over which 156 samples were collected. Results are anticipated to be available in summer 2013.

INTRODUCTION

Following the discovery of diamonds in the Archean Slave Craton in the Northwest Territories (*i.e.*, the Lac de Gras region) in the early 1990s, diamond exploration has expanded to other cratons in North America (Pell, 1997). One of the most important geological constraints on the location of diamond deposits is their association with Archean cratons, typically those tectonically stable for the last 1.5 Ga (Morris and Kaszycki, 1995). The Superior Craton is the largest Archean craton (2.7 Ga), constituting most of eastern Canada and is host to numerous occurrences of diamond-bearing kimberlite and other associated rocks (*e.g.,* lamproite) that have arisen from deep within the lithosphere (vanRythovern *et al.*, 2011). Recent exploration in the Superior Craton has led to several diamond discoveries in the Otish Mountains (*e.g.*, Lynx, Renard, and Hibou), James Bay (Wemendji), and Temisscaminque regions of Québec (Moorhead *et al*., 2000*;* vanRythovern *et al.*, 2011) and the Wawa, Attawapiskat, Kirkland Lake regions of Ontario (McClenaghan *et al.*, 2002; Figure 1a).

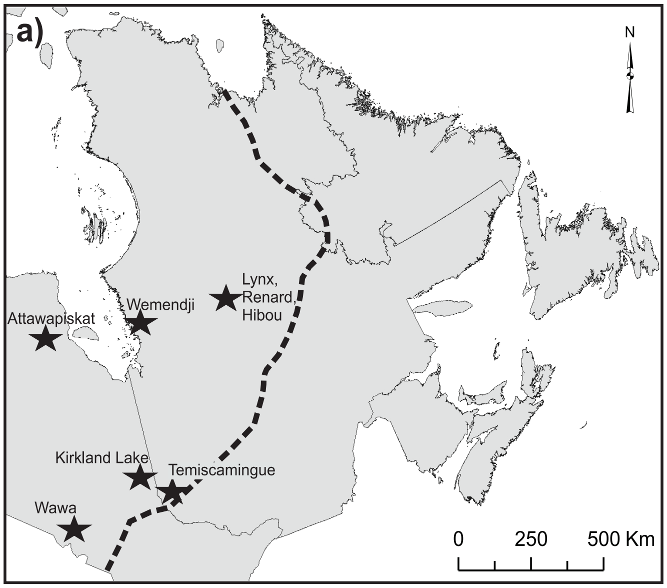
To date, no diamonds have been found in Labrador, although kimberlite has been identified in northern Labrador (Wilton *et al.*, 2002). In eastern Labrador, a kimberlite and lamproite sediment and bedrock sampling program by the Geological Survey of Newfoundland and Labrador was conducted in the mid 1990s (Ryan and McConnell, 1995). The discovery of diamonds in western Greenland, once contiguous with the Canadian Shield of Labrador, provided further reason for diamond exploration in Labrador. River, stream and beach sediment was collected from reworked glaciofluvial and glaciomarine deposits in areas underlain by the Archean Nain Province and reworked Archean crust of the Makkovik Province. Samples were analyzed for kimberlite and lamproite minerals; no indication of either was found (Ryan and McConnell, 1995).

The current project focuses on western Labrador, particularly the Archean Ashuanipi Complex of the Superior structural province, the easternmost extension of the Superior Craton (Figure 1b). Given the favourable geological context and exploration, elsewhere across the Canadian Shield, in areas underlain by Archean cratons, a reconnaissance regional-scale sampling program was conducted as an initial appraisal of the area during the summer of 2012. The main objective was to collect sand and gravel samples from esker deposits to be analyzed for kimberlite indicator minerals (KIMs), as a means of identifying potential areas for diamond exploration. This paper examines kimberlites, the methods used in finding diamonds in glaciated terrain, reviews the geological significance of western Labrador and outlines the methods for sample collection and processing.

DIAMOND EXPLORATION IN GLACIATED TERRAIN

KIMBERLITE AND KIMBERLITE-INDICATOR MINERALS

Diamond exploration in glaciated terrain in Canada focuses on exploration for kimberlite, the primary host rock



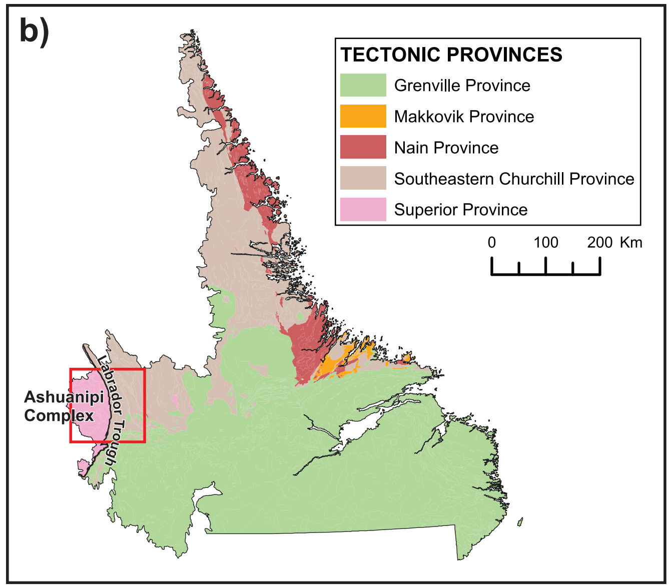


Figure 1. *a) Map showing eastern Superior Craton (west of the dashed line) with kimberlite occurrences mentioned in the text indicated (black stars). The thick dashed line shows the approximate boundary of the Superior Craton. b) Map of Labrador showing study area (red box) and tectonic provinces (taken from Wardle* et al., *1997).*

for diamonds. Kimberlites are small (few hundred metres across) circular point sources. They are relatively soft rocks that have been preferentially eroded by preglacial weathering and glacial scouring to deeper levels than the surrounding bedrock surface and are subsequently buried by glacial sediments or covered by lakes.

Kimberlite hosts a suite of heavy minerals with unique geochemical and physical characteristics that yield discrete dispersal trains in glacial sediments and dispersion fans in stream sediments. Cr-pyrope, eclogitic garnet, Cr-diopside, Mg-ilmentie, Cr-spinel and olivine are the most commonly used KIMs (McClenaghan *et al.*, 1997). These kimberlite indicator minerals are found in few rocks other than kimberlite and are used to identify kimberlite pipes and evaluate their diamond potential. They are coarse grained, visually distinctive, dense (specific gravity >3.2), relatively resistant to weathering and generally able to survive long-distance glacial transport. Because of these properties, KIM dispersal trains tend to be tens of kilometres long, longer than the heavy-mineral geochemical signatures of base-metal dispersal trains in glacial drift, which are generally hundreds of metres (Averill, 2001). Kimberlite indicator minerals are so source specific that only a few grains are needed in glacial sediments to recognize the presence of kimberlite (McClenaghan and Kjarsgaard, 2007).

GLACIAL PROCESSES

Success in tracing indicator minerals back to their source depends on the proper identification of the surficial sediment types collected and an understanding of their transport history and depositional processes. Kimberlite is dispersed primarily through glacial erosion, and can be transported a few tens of metres to tens of kilometres down-ice. As a result, boulder tracing and heavy-mineral sampling using till, glaciofluvial, beach or stream sediments are the most common drift prospecting methods (McClenaghan and Kjarsgaard, 2007). Till is an unsorted mixture of crushed rock and mineral fragments, from boulder to clay-sized, transported by glaciers and blended with reworked sediments. Glaciofluvial sediments result from recycling of till by glacial meltwater (*e.g.*, eskers, outwash, or beaches). The fine fraction washed away from these sediments is transported farther and deposited as silt and clay in glaciolacustrine or glaciomarine environments (Klassen, 1999). Modern streams also have the potential to transport kimberlite material several tens to hundreds of kilometres down-ice; however, these sediments may have undergone several cycles of transport and may be more difficult to trace back to their bedrock source (McClenaghan and Kjarsgaard, 2007).

Typically, the initial reconnaissance-scale survey involves sampling fluvial, glaciofluvial (esker), or beach sediments and having them analyzed for the presence of KIMs. The benefit of sampling these sediments is that a small number of samples represent the bedrock composition of a large area. Systematic follow-up is then undertaken, generally by higher density till sampling and/or airborne geophysical surveys (McClenaghan *et al.*, 1997).

GEOLOGICAL SETTING

The study area lies within the Canadian Shield, spanning three structural geological provinces: Superior to the west, Churchill to the east, and Grenville to the south (Wardle *et al.*, 1997). The field area encompasses four 1: 250 000 map areas (23G, 23H, 23I and 23J) that extends from the Ashuanipi Complex (Superior Province) in the west to the Labrador Trough in the east (southeastern Churchill and Grenville provinces) (Figure 1b).

Bedrock of the Superior Province includes the Archean (2700 to 2650 Ma) Ashuanipi Complex, which comprises granulite-facies gneisses and associated tonalite to granite plutons (James and Mahoney, 1993). The Proterozoic Churchill Province includes the Labrador Trough and is adjacent to the Ashuanipi Complex. The trough, which comprises sedimentary and volcanic rocks in its western part and mafic volcanic and intrusive rocks in its eastern part, is characterized by strong northwest–southeast structural and lithological trends. In the northern part of the Labrador Trough, iron formation and fine-grained, pelitic sedimentary rocks are most extensive, whereas in the southern part, iron formation is less extensive and sedimentary rocks are coarser grained, and include quartzite and arkose. East of the trough, the Churchill Province comprises gneissic and granitic intrusive rocks. South of the Superior and Churchill provinces is the Grenville Province, which includes metamorphic equivalents of the trough and gabbroic intrusive rocks (Wardle *et al.*, 1997).

GLACIAL HISTORY

The study area was covered by the Laurentide Ice Sheet during the late Wisconsinan glaciation, which reached its maximum approximately 20 000 years ago (Grant, 1989). At least four ice-flow directions have been identified from striations, streamlined landforms and distribution of clasts and erratics (Klassen and Thompson, 1987; Figure 2). This variation in ice flow is a result of the area's proximity to the centre of the Labradorean Sector of the Laurentide Ice Sheet, including one or more of its ice divides (Klassen, 1999).

Event 1 (the oldest) was northeastward and southwestward, outward from the axis of the Labrador Trough. Material originating from the trough is common in tills overlying the Ashuanipi Complex and this ice-flow event was an important agent of glacial erosion and transport. All later ice flow across the Ashuanipi Complex was toward the trough (Klassen, 1999).

Event 2 was north to east-northeastward over much of the study area. In the central Labrador Trough, this ice flow was south to southeastward. Evidence for this ice flow includes red porphyritic erratics that have been distributed northwest and south to southeast from their source (Martin Lake porphyry; Figure 2).

Event 3 extended east to southeastward across the southern Ashuanipi Complex into the southern part of the Labrador Trough where it merged with Event 2 trends. This ice-flow event was strongly erosional and marked by well-defined glacially molded bedrock and streamlined landforms. The geological record of this ice-flow event is consistent with the concept of a localized zone of 'fast ice', an ice stream within a more extensive ice sheet.

The youngest ice-flow event (Event 4) was northeastward and is recorded by faint striations in the central part of the Labrador Trough near Schefferville where it crosscuts striations associated with Event 3. Event 4 did not have a major effect on the geomorphology of the area nor was it a significant agent of glacial transport (Klassen, 1999).

SURFICIAL GEOLOGY

The landscape of western Labrador is dominated by glacial and glacially derived sediments deposited by the Laurentide Ice Sheet, which retreated from the region approximately 7500 years ago (Klassen and Thompson, 1990). Till is the most widespread glacial deposit (Figure 3). Till is generally thin (<2 m) to discontinuous in highlands, particularly over the Ashuanipi Complex. Crag-and-tail hills are also common throughout this terrain. Till is thicker in valleys (>2 m) and local areas here are characterized by drumlins, hummocky terrain and ribbed moraine.

Extensive esker systems are present in Labrador, similar to other areas within the Precambrian shield. Eskers are widespread throughout the field area and range from individual shoestring-shaped ridges of glaciofluvial sand and gravel to tree-shaped networks that resemble tributary stream networks (Plates 1 and 2). Eskers, often discontinuous, vary in length from <1 km to hundreds of kilometres and the larger ones commonly have an apron of glaciofluvial sediments on their sides. Within the field area, eskers generally have a northwest–southeast orientation. A study of cobble lithology of eskers in central Labrador by Bolduc *et al.* (1987) suggested that the flow within the eskers, based on the transport directions of indicator erratics, was to the southeast.

SAMPLING AND ANALYSIS

SAMPLE COLLECTION

A total of 156 samples of <4 mm esker material were collected within the study area. Both glacial (striation orien-

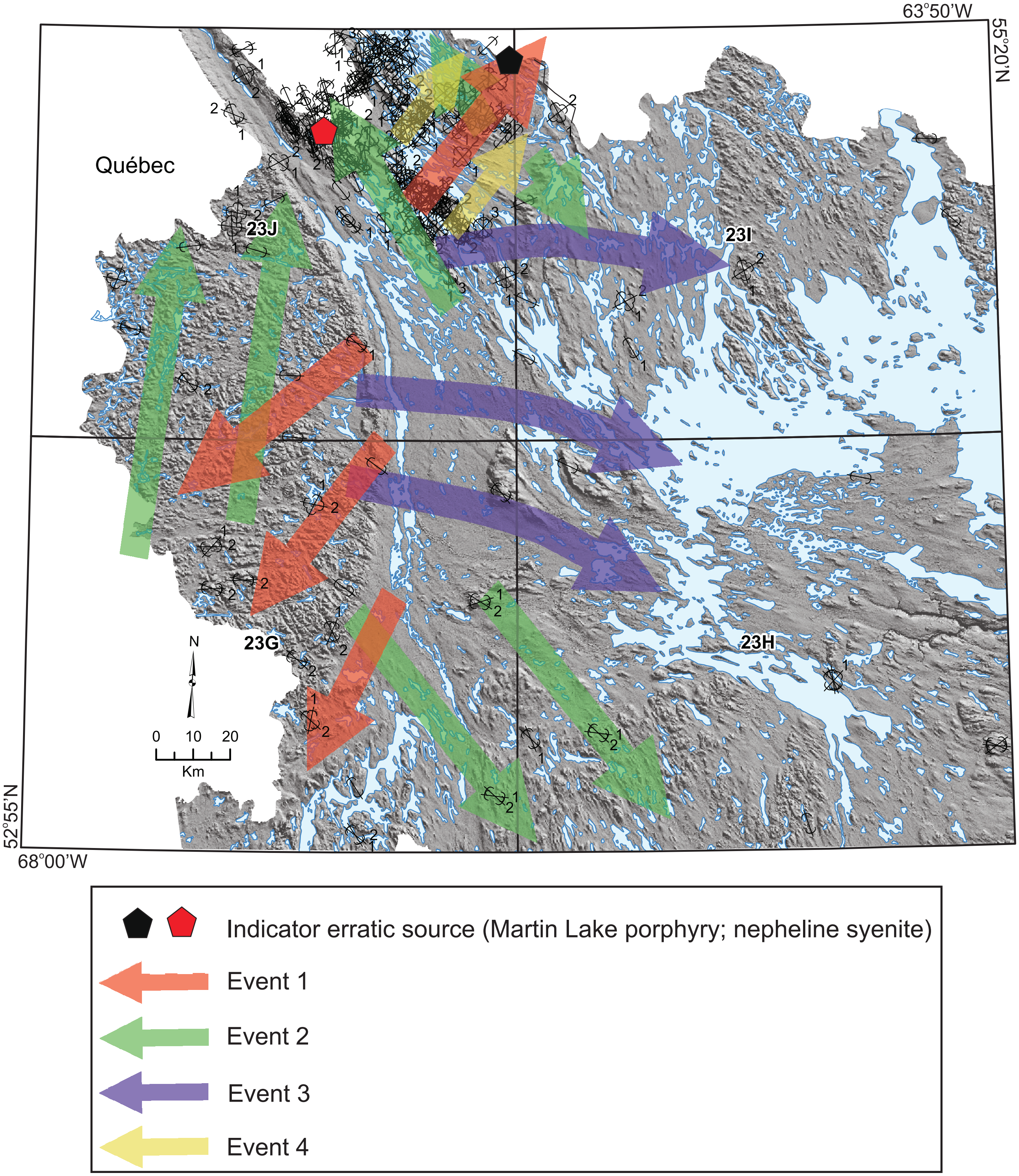


Figure 2. *Ice-flow patterns in western Labrador; numbers indicate the relative age of events with Event 1 being the oldest. Glacial dispersal trains defined by Martin Lake porphyry and by nepheline syenite are also shown (adapted from Klassen, 1999).*

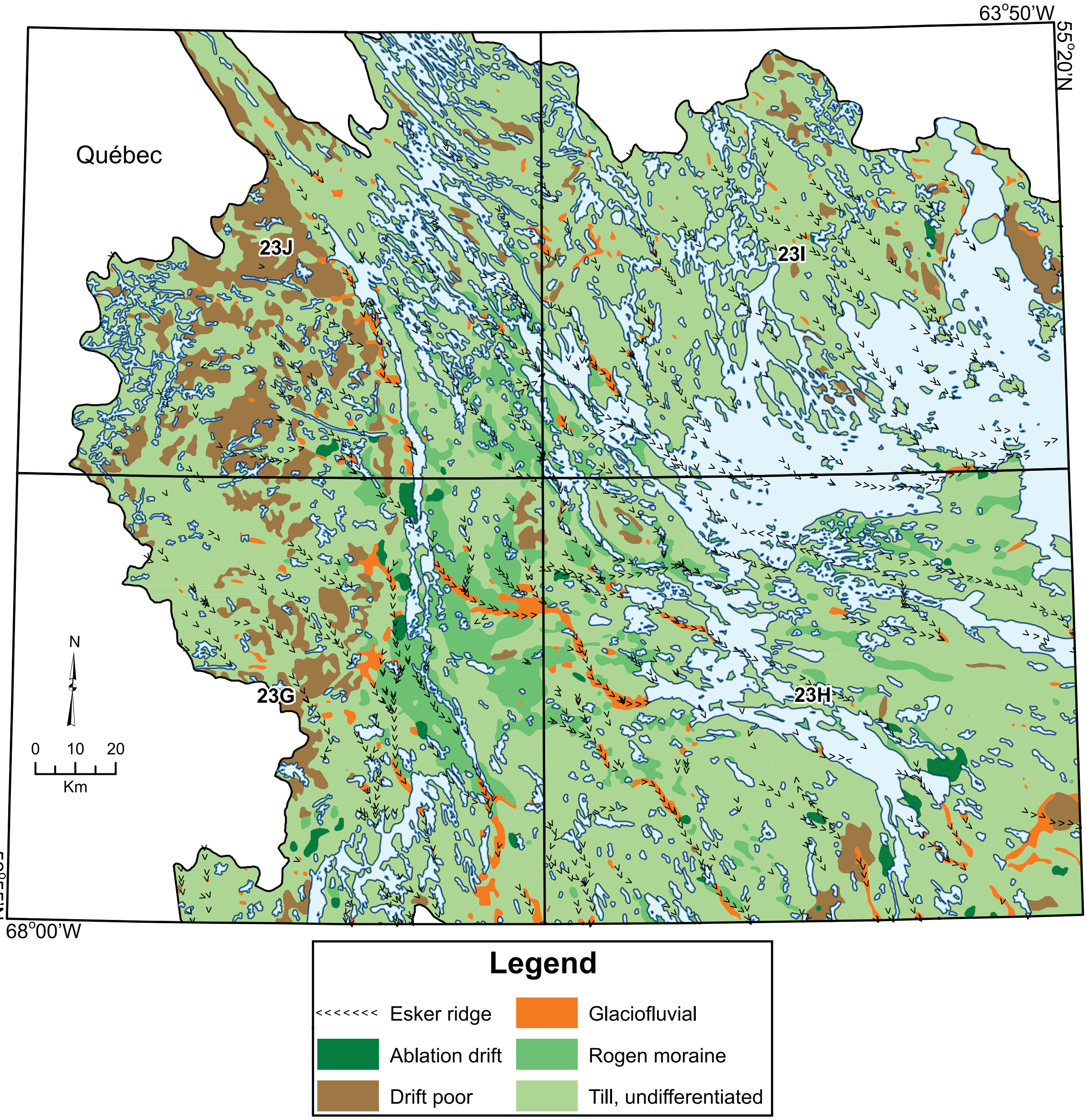


Figure 3. *Surficial geology of western Labrador (adapted from Klassen* et al., *1992).*

tations) and glaciofluvial (esker trends) transport directions were considered when selecting sites for sampling. Sample density was approximately 1 per 16 km^2 and was constrained by the spatial distribution of eskers and accessibility. Most of the survey area has no direct road or lake access so helicopter support was required. Samples were collected from hand-dug pits below the oxidized layer, approximately 60 to 100 cm deep. Samples were sieved on site to <4 mm and stored in heavy plastic sample bags and plastic 4 gallon buckets before being shipped. Each sample ranged from 10 to 15 kg because large samples are needed to obtain a useful and representative number of KIM grains (Averill, 2011).

The following parameters were recorded at each site: UTM coordinates, NTS 1:250 000 map sheet number, sample composition, size class (*e.g.*, silt, sand, gravel), compaction, deposit type (*e.g.*, glaciofluvial, till, esker, glaciolacustrine), exposure type (*e.g.*, stream cut, hand-dug pits,

Plate 1. *This large sharp-crested esker is part of an extensive esker network overlying the Ashuanipi Complex.*

Plate 2. *These eskers are part of a large tree-shaped network northwest of Menihek Lakes.*

lake shore) and thickness, and the presence of any sedimentary structures (*e.g.*, massive, stratified, crossbedded).

SAMPLE PROCESSING AND ANALYTICAL METHODS

Sample processing was carried out by Overburden Drilling Management, which included sieving, and heavy-mineral separation using dense (SG~3.2) liquid and magnetic separation. The resulting 0.25- to 2.0-mm heavy-mineral concentrates were subjected to binocular microscopic examination to identify potential KIM grains that were counted and vialed by size and KIM species for 3 size fractions: 0.25 to 0.5 mm, 0.5 to 1.0 mm, and 1.0 to 2.0 mm. Seven indicator minerals were analyzed for Cr-pyrope garnet, Cr-poor pyrope garnet, eclogitic pyrope-almandine garnet, Cr-diopside, Mg-ilmenite, chromite, and forsteritic olivine.

Selected mineral grains (*i.e.*, any questionable grains of the above indicator minerals) were analyzed for major and minor elements by scanning electron microprobe. Major background minerals constituting more than 15% of either the paramagnetic or nonparamagnetic fraction of the heavy-mineral concentrates were also provided as a guide to the overall provenance of the sample and potential sources of any identified indicator minerals. Counting, measuring and classification of gold grains were also conducted.

SUMMARY

A reconnaissance sediment sampling program was conducted in western Labrador, where the surrounding bedrock geology and exploration suggest the potential for diamond-bearing kimberlites and lamproites. A total of 156 sand and gravel samples, derived mainly from the Archean Ashuanipi Complex, were collected from esker deposits at a density of approximately 1 per 16 km^2. Samples were analyzed for kimberlite indicator mineral grains and it is anticipated that results will be available by summer 2013 on the Newfoundland and Labrador Department of Natural Resources website (http://www.nr.gov.nl.ca/nr/mines/geoscience/publications/ latest_pubs.html).

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