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GEOLOGY AND MINERAL POTENTIAL OF THE ARCHEAN FLORENCE LAKE GREENSTONE BELT, HOPEDALE BLOCK (NAIN PROVINCE), EASTERN LABRADOR[1]

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ABSTRACT

The Hopedale Block, in the southern Nain Province, is an Archean granite – greenstone terrane that includes the Florence Lake greenstone belt. The Florence Lake greenstone belt has been sporadically explored over the past 40 years; mineral exploration, regional mapping and geochemical studies suggest it has the potential to host nickel sulphide deposits, volcanogenic massive sulphide deposits and mesothermal gold. In view of this potential, parts of the Florence Lake greenstone belt were mapped at 1:25 000 scale.

The Florence Lake greenstone belt consists mainly of greenschist- to amphibolite-facies mafic and ultramafic rocks, and lesser amounts of felsic and intermediate volcanic and volcaniclastic sedimentary rocks. The ultramafic rocks commonly occur as composite units that are interlayered with felsic and mafic volcanic rocks and local volcaniclastic sediments. The composite nature of these units and their stratigraphic continuity suggest they are extrusive in origin. The ultramafic rocks have the potential to host komatiite-associated nickel sulphide deposits.

The Florence Lake greenstone belt is multiply deformed, and primary volcanic structures are generally obscured. Volcanic stratigraphy in the belt is undefined.

INTRODUCTION

The Florence Lake greenstone belt is an Archean greenstone belt in the Hopedale Block, southern Nain Province, eastern Labrador (Figures 1 to 3). It is here defined to include several northeast-striking and lenticular-shaped greenschist- to amphibolite-facies sub-belts or volcanic domains (Figure 4) that are intruded and encompassed by Archean granitoid plutons and orthogneiss units of several ages. Detailed geological, geophysical and prospecting studies (e.g., Piloski, 1960, 1962, 1963; Sutton, 1971a and b; Stewart *et al.*, 1983; Wilton, 1987; Brace and Wilton, 1989; Brace, 1990; McLean *et al.*, 1992) and regional-scale geological mapping (Ermanovics, 1993), suggest the Florence Lake greenstone belt has potential for komatiite-associated nickel sulphide mineralization, volcanogenic massive sulphide (VMS) deposits and mesothermal gold (Swinden *et al.*, 1991). In view of the mineral potential and the need for an updated bedrock geology map, parts of the belt were mapped at 1:25 000 scale. The bedrock mapping is in collaboration with more detailed mapping and sampling of known and newly discovered sulphide mineralization (Miller, *this volume*), a soil- and stream-sediment geochemical sampling program (McConnell, *this volume*), and surfical geology studies (Batterson, *this volume*). The data collected in these studies will be combined with non-confidential mineral-industry data currently held in the Newfoundland Department of Natural Resources assessment files. The compilation work is being conducted by L. Nolan, G. Kilfoil and T. Leawood of the provincial Geological Survey. A preliminary report of the 1995 field season is given by James *et al.* (1995).

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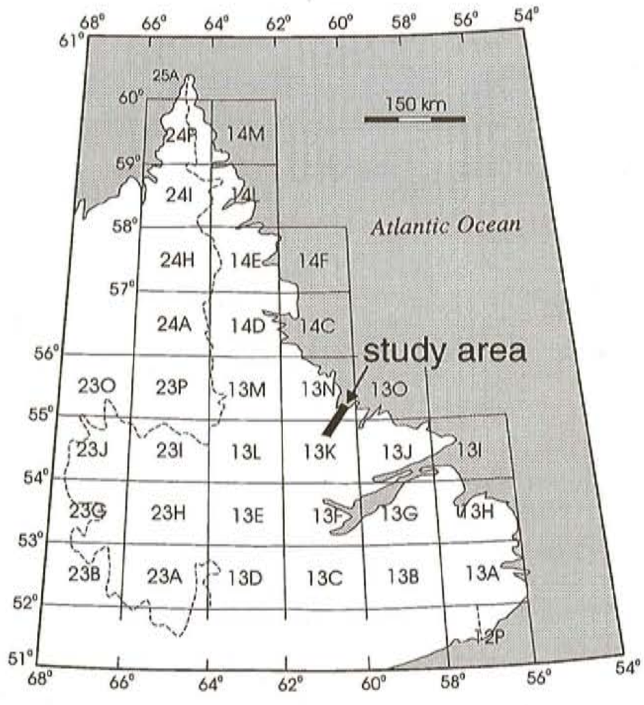

Figure 1. *NTS index map of Labrador showing location of the study area in NTS areas 13K and 13N.*

PREVIOUS WORK

Detailed historical accounts of geological mapping and mineral exploration work in the southern part of Hopedale Block are given by Ermanovics (1993) and Miller (*this volume*), respectively. A short chronological list of some highlights of regional geological studies in the southern Hopedale Block is included below.

1. 1953 – The first geological maps of coastal areas of Labrador in the Makkovik and Hopedale areas are published by the Geological Survey of Canada (Kranck, 1953; Christie *et al.*, 1953).
2. 1959 – Systematic geological mapping of Hopedale Block in the west half of NTS map area 13/K by Fahrig (1959).
3. 1967-71 – Taylor (Taylor 1977, 1979) maps Hopedale Block in NTS areas 13N and 13O at a scale of 1:250 000.
4. 1978-81 – 1:100 000- and 1:50 000-scale mapping of Hopedale Block by Ermanovics (see Ermanovics, 1979, 1980, 1981a and b; Ermanovics and Raudsepp, 1979; Ermanovics and Korstard, 1981; Ermanovics *et al.*, 1982; Grant *et al.*, 1983).

PRESENT INVESTIGATIONS

This report is based on 1:25 000-scale bedrock mapping conducted in 1995 in the Knee Lake, Schist Lakes, Ugjoktok Bay and Adlatok Bay areas, including northeastern parts of NTS map area 13K and southeastern parts of NTS map area 13N (Figure 1). Mapping was conducted by three traversing teams, and was mainly boat-supported from camps on Florence Lake, Knee Lake and Ugjoktok Bay. A minor amount of the work was helicopter-supported from the Florence Lake camp.

The focus was on subdividing the Florence Lake greenstone belt into mappable units, examining the stratigraphic and structural relations between units, and to evaluate the mineral potential of the belt. Contacts between the volcanic rocks and encompassing granitoid plutons and orthogneisses were mapped, although the plutons and orthogneiss units were not examined in any detail.

Very cursory examination of greenstone belts in the Stomach Lake (621000E, 6085000N UTM coordinates) and Canoe Lake (634000E, 6087000N UTM coordinates) areas were made in 1995. The results of these examinations are not reported here. Results of detailed studies of volcanic rocks in the Baikie sub-belt are reported by Miller (1996).

REGIONAL FRAMEWORK

The Archean Nain Province (Stockwell, 1964) is divided into Hopedale and Saglek blocks in the south and north, respectively (see Taylor 1971, 1977, 1979). The Hopedale Block contains crust ranging between 3.3 and 2.8 Ga in age (Ermanovics, 1993), in contrast to the Saglek Block which contains crust between 3.8 and 2.5 Ga (Schiøtte *et al.*, 1993; Connelly and Ryan, 1994). The two blocks are separated by a zone containing voluminous Mesoproterozoic intrusions of anorthosite, troctolite and associated granite belonging to the 1340- to 1290-Ma Nain Plutonic Suite (Connelly and Ryan, 1994; Krogh and Davis, 1973), and perakaline volcanic and plutonic rocks of the ca. 1271-Ma Flowers River igneous suite (Hill, 1982; Brooks, 1982). The Hopedale Block is tectonically bound by Paleoproterozoic shear zones that separate it from reworked Archean and Paleoproterozoic rocks in the eastern Churchill and Makkovik provinces. Locally, Archean rocks in the Hopedale Block are unconformably overlain by deformed and metamorphosed Paleoproterozoic volcanic and sedimentary rocks belonging to the Moran Lake Group (southwest) and Ingrid Group (northwest). The Mesoproterozoic Harp Lake Complex intrudes the southwestern margin of the Hopedale Block (see Wardle, 1993).

The Hopedale Block is a granite – greenstone terrane consisting of northeast-striking and lenticular-shaped, mainly greenschist- to amphibolite-facies volcanic belts that are enveloped by Archean granitoid plutons and orthogneiss units of several ages. Based principally on field relationships, Ermanovics (1993) suggested that rocks in the Hopedale

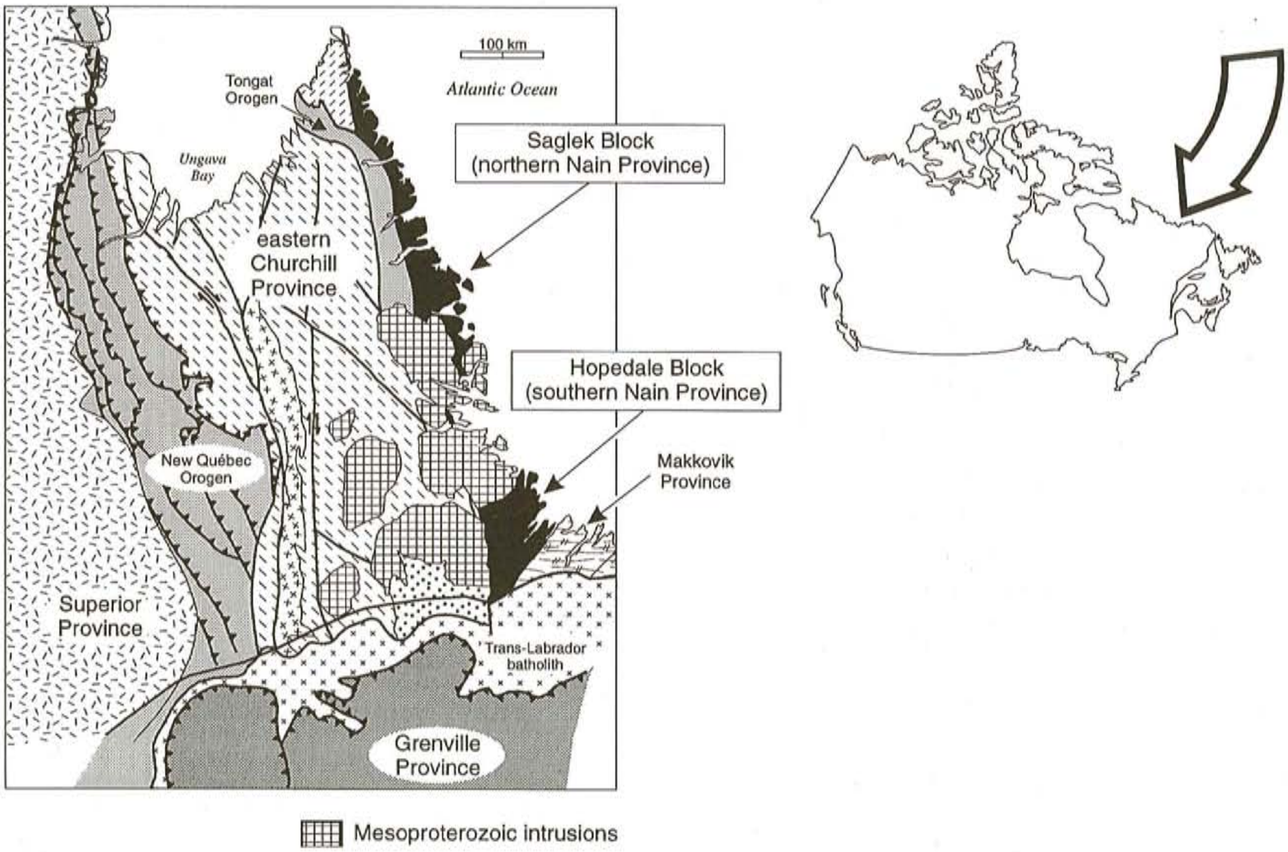

Figure 2. *Principal tectonic elements of northern Labrador and adjacent parts of Quebec.*

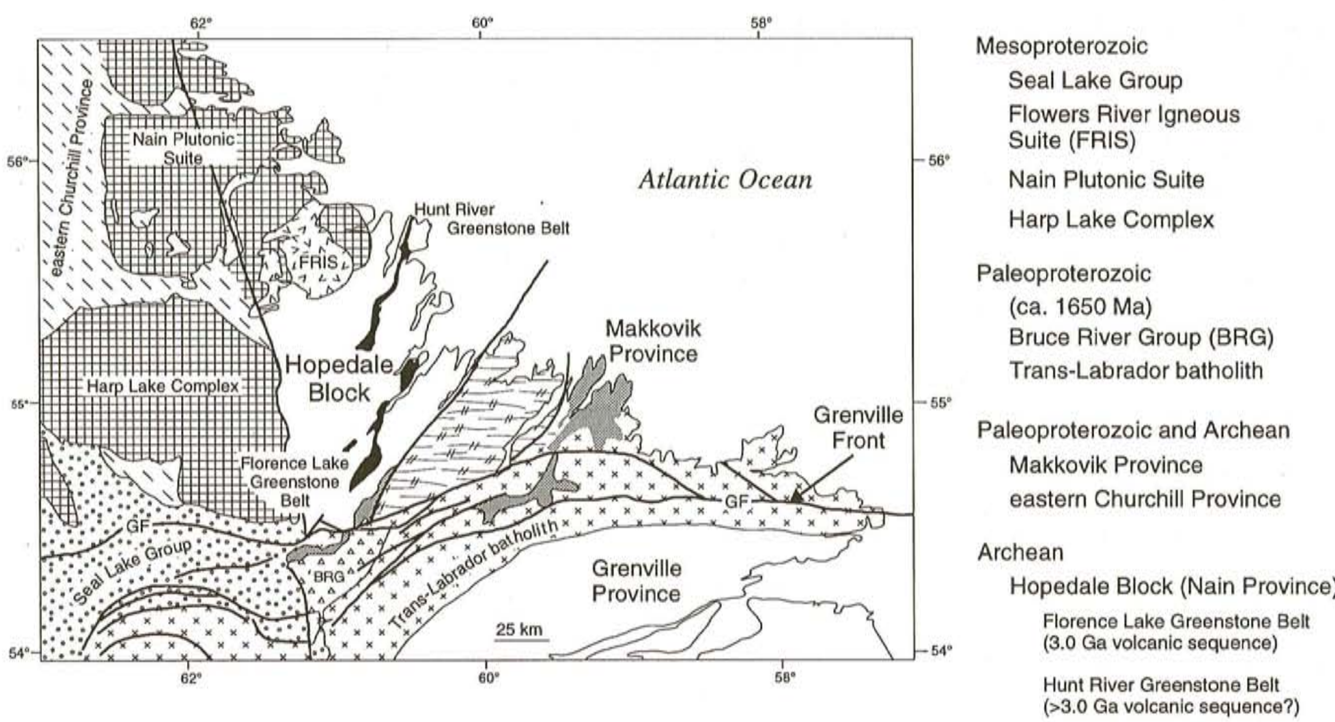

Figure 3. *General geology of eastern central Labrador. The Florence Lake greenstone belt (study area) is in the southern part of the Hopedale Block.*

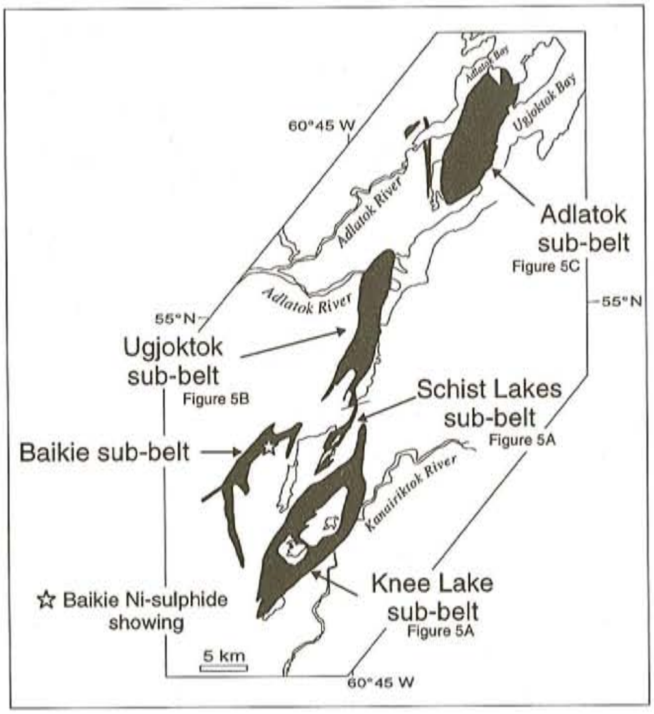

Figure 4. *Subdivision of the Florence Lake greenstone belt.*

Block contain evidence of two volcanic–plutonic episodes, each followed by a period of metamorphism and concomitant deformation (Table 1). The first metamorphic and deformation event, termed Hopedalian, is marked by upper amphibolite- and local granulite-facies metamorphism and north-northwest-trending structures, in contrast to the second event, termed Fiordian, which is marked by greenschist- to amphibolite-facies metamorphism and northeast-trending structures (Ermanovics, 1993). A sample of felsic volcanic rock from the Florence Lake greenstone belt, inferred to be one of the younger volcanic sequences, has been dated to be 3002 ± 2 Ma (Wasteneys *et al.*, 1995). However, volcanic rocks from the older sequence have not been dated directly. The Hunt River greenstone belt is inferred to be one of the older volcanic sequences, although it is only constrained to be older than a ca. 2875-Ma monzodiorite pluton that intrudes it (Wasteneys *et al.*, 1995).

The volcanic sequences are intruded by ca. 2840 Ma plutons (e.g., Loveridge *et al.*, 1987) ranging in composition from tonalite to granite, and defined as the Kanairiktok Plutonic Suite, prior to Fiordian metamorphism and deformation at ca. 2750 Ma (Ermanovics, 1993). However, the ages of Kanairiktok intrusions and Fiordian metamorphism are not tightly constrained by U–Pb geochronological data. Field relations demonstrate that some Kanairiktok Plutonic Suite intrusions have been affected by several events, whereas other intrusions are essentially undeformed. As presently defined on Ermanovics (1993) map, the Kanairiktok Plutonic Suite may include ca. 3.0-Ga subvolcanic intrusions, pre-Fiordian intrusions and late-syn to post-Fiordian intrusions.

The Florence Lake greenstone belt is also in contact with two granitoid orthogneiss units. One is in tectonic contact with volcanic rocks and may represent pre-volcanic basement equivalent to the ca. 3105-Ma Maggo gneiss (Loveridge *et al.*, 1987; Ermanovics, 1993) based on correlation of rock types. In contrast, the other orthogneiss is clearly intrusive into volcanic rocks. Orthogneiss units in the study area have not been dated.

TERMINOLOGY

Ermanovics (1993) has formally subdivided the Florence Lake greenstone belt into formations (Schist Lakes, Adlatok, Lise Lake, and Ultramafic) that are defined to constitute the Florence Lake Group. Ermanovics (*op. cit.*) stratigraphic terminology is not used here for a number of reasons. First, in many places it was impossible to distinguish between the Schist Lakes and Adlatok formations, and in the absence of defined type sections and clearly defined contact relations for either, it was very difficult to assign outcrops to the Schist Lakes or Adlatok formations. Second, mapping in 1995 showed that map units are more complex and have significantly different distributions than shown on Ermanovics 1:50 000-scale map of the Florence Lake greenstone belt. Adopting his terminology in light of these complexities would have required extensive redefinition and revision of the formations, hence new units have been defined. This is the prudent approach to take, in light of the fact that stratigraphic top indicators, detailed geochemical data that could be used to establish a hitherto unrecognized chemostratigraphy, and U–Pb geochronological data are lacking.

DESCRIPTION OF UNITS

Units in the legend for Figure 5 are not listed chronologically because stratigraphic-facing directions could not be determined from field observations. Subdivision of the volcanic rocks into mafic, ultramafic and intermediate units was determined in the field and based mainly on colour and mineralogy, where the latter could be determined. Geochemical studies of volcanic rocks have commenced, and will be reported at a later date.

FLORENCE LAKE GREENSTONE BELT

Mafic Volcanic Rocks (Unit 1)

Unit 1 contains greenschist- and amphibolite-facies mafic volcanic rocks including massive, pillowed and layered

Table 1. Major Archean units and events in the Hopedale Block (summarized and modified from Ermanovics, 1993)

Major Unit/Event	Rock Type
Fiordian Event	High-grade metamorphism and deformation
Kanairiktok Plutonic Suite, ca. 2.84 Ga	Pre-, syn- and post-Fiordian intrusions of granite, granodiorite and tonalite
------------ INTRUSIVE CONTACT ------------	
Florence Lake Greenstone Belt ca. 3.0 Ga	Mafic, ultramafic and felsic volcanic rocks, gabbroic intrusions, clastic sedimentary rocks, sub-volcanic granitoid intrusions
------------ UNCONFORMITY (INFERRED) ------------	
Hopedalian Event	High-grade metamorphism and deformation
------------ HOPEDALE DYKES ------------	
Maggo Gneiss >3.1 Ga	Granitoid orthogneisses
------------ INTRUSIVE CONTACT ------------	
Weekes Amphibolite	Amphibolite, anorthosite, ultramafic rocks (in part equivalent to Hunt River volcanic rocks?)
Hunt River Greenstone Belt	Mafic and ultramafic volcanic rocks, gabbroic intrusions, clastic sedimentary rocks
Pre-Hunt River?	Pre-Hunt River granitoid intrusions?

volcanic rocks (Plates 1 and 2). Massive rocks are most abundant, whereas pillowed and layered volcanic rocks make up minor amounts of the unit. Pillows are generally small (< 1 m), poorly preserved and commonly highly flattened. Layering is defined by colour variations; layers are generally less than 5 cm thick.

The mafic rocks are black- to dark-green-weathering, mainly fine grained, and are variably foliated. They contain variable amounts of chlorite, actinolite, plagioclase and local epidote, or hornblende, plagioclase and local biotite. Garnet occurs locally in amphibolite-grade mafic rocks. Secondary carbonate is widespread in mafic rocks in all parts of the Florence Lake greenstone belt. Secondary specular hematite is common in the northeastern part of the Adlatok sub-belt.

The unit also includes minor medium- to coarse-grained, isotropic to foliated rocks that have local, relic phaneritic textures. These rocks form sheets in the mafic volcanic unit that are generally less than 50 m thick. They cannot be shown on the map because of their small size. On the basis of their texture, composition and distribution, these rocks are inferred to be metamorphosed gabbro dykes and/or sills. The gabbro intrusions may have fed mafic volcanic flows that were higher in the volcanic sequence.

Amphibolites of uncertain protolith make up a minor proportion of the mafic volcanic unit. They mainly occur in the eastern parts of the Adlatok sub-belt. They are fine- to medium-grained rocks consisting of hornblende, plagioclase and local garnet. They could represent metamorphosed gabbro or mafic volcanic flows.

Ultramafic Rocks (Units 2 and 3)

Unit 2 consists mainly of ultramafic schists and minor felsic volcanic rocks, plagioclase-phyric mafic volcanic flows and metasedimentary (pelitic) schists. Unit 2 mainly forms thin (less than 10 m thick) composite layers, including the minor rock types that can sometimes be traced for several kilometres. Thicker layers are uncommon, although a layer of Unit 2 rocks that is locally 1 km thick occurs in the area south of Ujgoktok Bay. These rocks are interlayered with all of the other volcanic and sedimentary units in the Florence Lake greenstone belt.

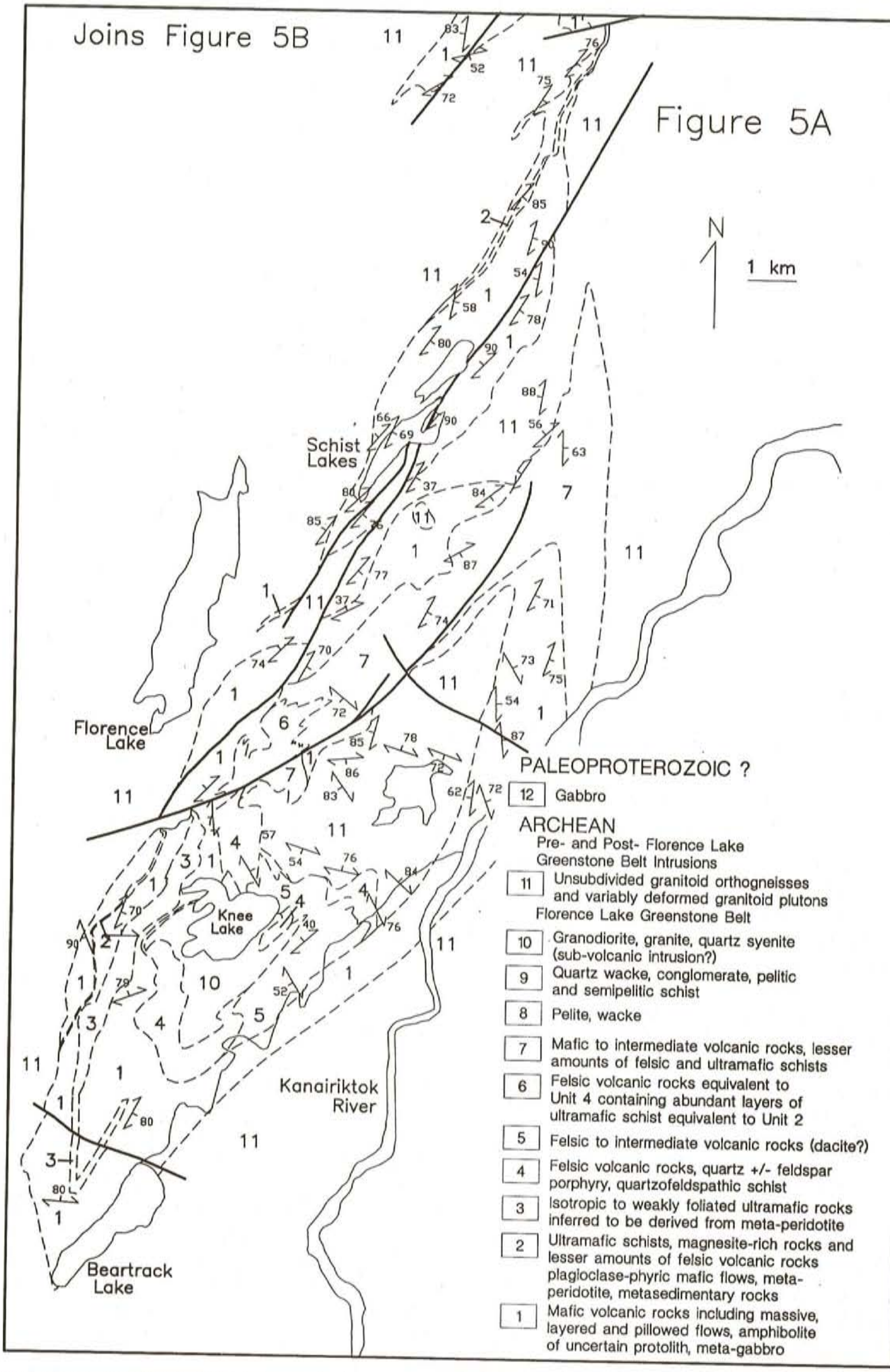

Figure 5. *General geology of the Florence Lake greenstone belt.* **5a,** *Knee Lake and Schist Lakes sub-belts.(See Figure 4 for locations.)*

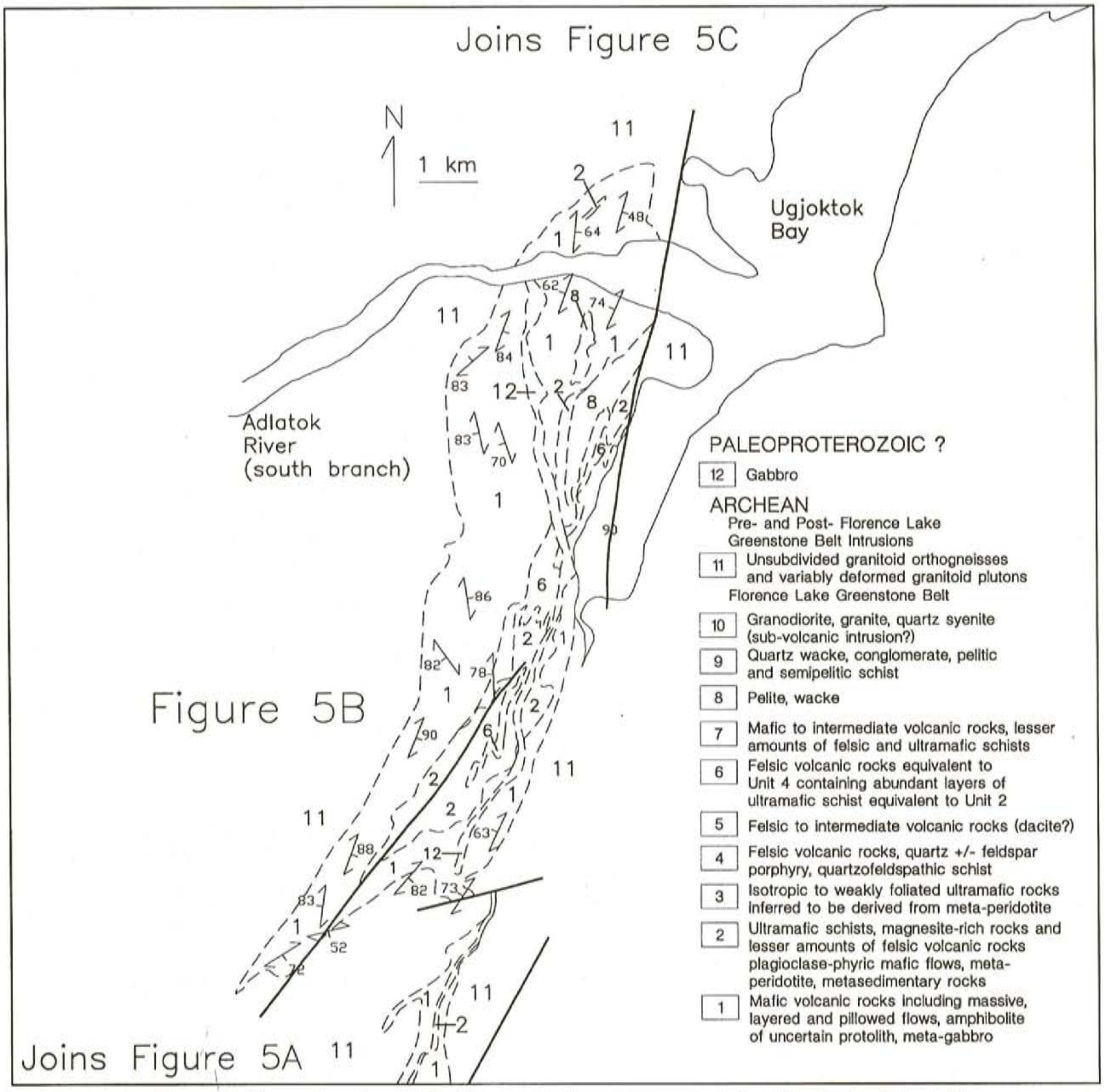

Figure 5. *General geology of the Florence Lake greenstone belt.* **5b,** *Ugjoktok sub-belt. (See Figure 4 for locations).*

The ultramafic schists of Unit 2 include white- to grey-weathering talc schists containing variable amounts of carbonate and magnesite (Plate 3), and dark-green- to black-weathering chlorite and serpentine(?) schists (Plate 4). The talc schists are commonly interlayered with massive, orange-brown-weathering magnesite rocks that commonly contain abundant quartz veins and pods (Plate 5). The magnesite is thought to be the product of metamorphic reactions involving the breakdown of serpentine to magnesite + quartz, or to magnesite + talc. Both reactions occur at extremely small values of X_{CO_2} (Winkler, 1979).

Black- to dark-green-weathering and variably foliated plagioclase-phyric mafic volcanic rocks (Plate 6) are locally interlayered with Unit 2 ultramafic schists. The plagioclase-phyric rocks contain up to 25 percent coarse- to very coarse-grained, equant to elongate plagioclase phenocrysts that sit in a very fine-grained mafic (chloritic?) matrix. The plagioclase-phyric rocks are everywhere associated with Unit 2 ultramafic schists, although the converse is not true. The plagioclase-phyric rocks are interpreted as mafic flows.

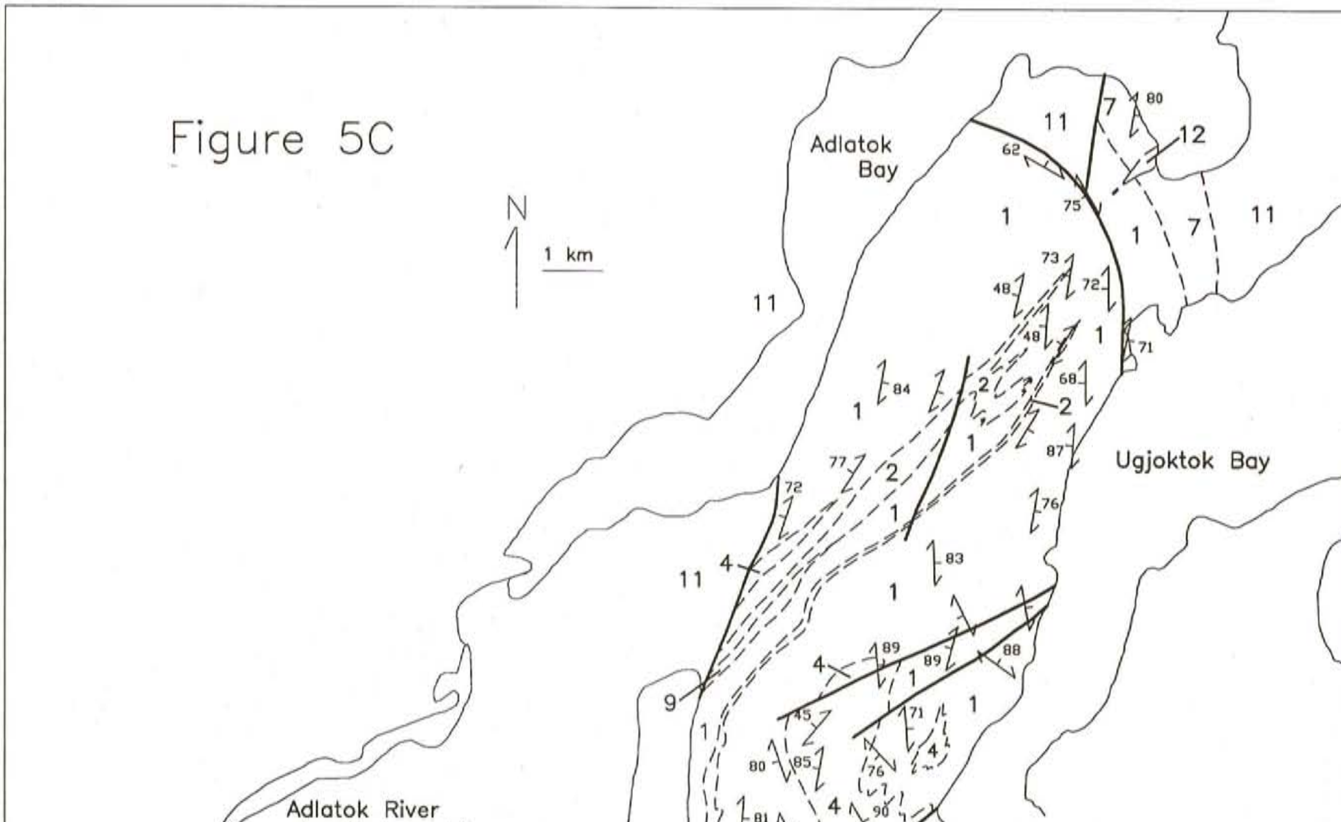

Figure 5. *General geology of the Florence Lake greenstone belt.* **5c,** *Adlatok sub-belt. (See Figure 4 for locations.)*

Unit 2 ultramafic rocks do not contain any pre-metamorphic textures that determine their origin. Being commonly interlayered with felsic volcanic rocks, plagioclase-phyric mafic flows and local, minor amounts of metasedimentary rocks to form composite units, suggests that they are probably extrusive rather than intrusive. Furthermore, unequivocal crosscutting relations with rocks that surround Unit 2 schists, which would demonstrate that they are derived from intrusive units, have not been found.

Some occurrences of dark-green- to black-weathering ultramafic schist in Unit 2 occur as layers in the mafic

Plate 1. *Typical field aspects of pillowed mafic flow of Unit 1.*

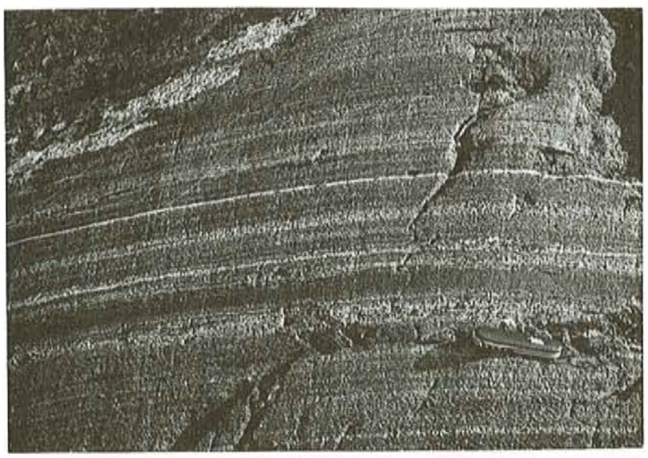

Plate 2. *Layered, amphibolite-facies mafic volcanic flow.*

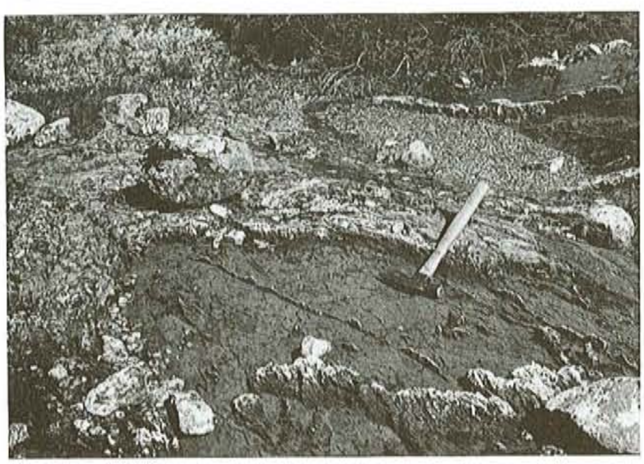

Plate 3. *Composite outcrop of Unit 2 schists consisting of talc schist (light-grey areas) and magnesite-rich layer (darker layer).*

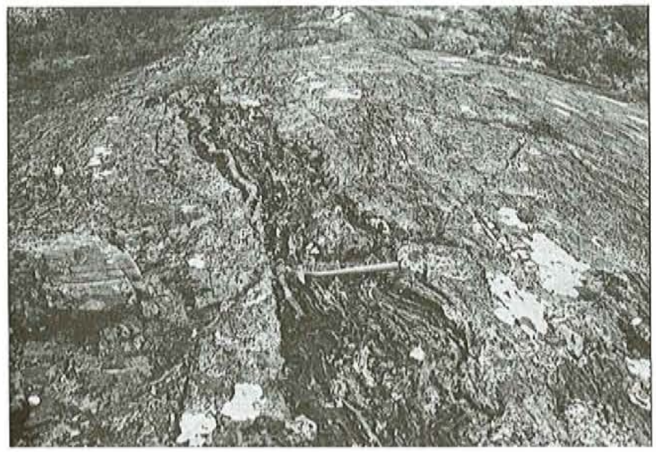

Plate 4. *Mafic volcanic rocks (Unit 2) having a layer of dark-green- to black-weathering ultramafic schist (centre of photograph) that may represent a metamorphosed dyke. These schists are recessive and typically have an uneven or hackled weathered surface.*

Plate 5. *Outcrop of magnesite-rich rocks of Unit 2 containing abundant quartz veins.*

volcanic unit (Unit 1) and are not associated with either felsic volcanic or metasedimentary rocks (i.e., they differ from the aforementioned composite ultramafic units). These ultramafic schists could represent ultramafic dykes or sills.

Unit 3 consists mainly of brown- to black- to green- to grey-weathering rocks inferred to be metamorphosed peridotites (Plates 7 and 8). The most prominent occurrence of these rocks is in the southwestern part of the Knee Lake sub-belt where they form a unit that is locally 350 m thick and can be traced for 8 km. The unit is poorly exposed in the area south of Knee Lake and its extent is interpreted mainly from magnetic anomalies as it is marked by a pronounced magnetic high. Unit 3 rocks also occur as minor layers with Unit 2 ultramafic schists.

Plate 6. *Plagioclase-phyric mafic flow that is interlayered with Unit 2 ultramafic rocks.*

Plate 7. *Prominent outcrop and talus slope of serpentinized peridotite (Unit 3) in the Knee Lake sub-belt, southwest of Knee Lake.*

Unit 3 rocks are mainly isotropic to weakly foliated and fine grained, although they locally contain relics of coarse-grained pyroxene. Poorly preserved vestiges of igneous layering defined by colour variations occur locally. The rocks are variably serpentinized and locally contain an anastomosing structure outlined by thin, green layers of serpentine that surround ovoid blocks of black peridotite. The rocks commonly contain several percent magnetite, disseminated pyrite, and rare occurrences of thin (1 to 2 cm) magnetite-sulphide veins.

The origin of Unit 3 rocks is uncertain; they could be extrusive or intrusive. Rare occurrences of metasedimentary schist along the eastern contact of the metaperidotite west of Knee Lake may suggest an extrusive origin. The sporadic occurrence of metasedimentary rocks along the eastern contact of the Unit 3 rocks near Knee Lake may suggest the metasedimentary rocks have been thermally eroded in the footwall of an ultramafic flow.

Plate 8. *Typical field aspects of Unit 3 peridotite. The rocks are brown weathering, black on the fresh surface, fine grained and isotropic.*

Felsic Volcanic Rocks (Units 4, 5 and 6)

Felsic volcanic rocks are abundant and form mappable units in the Knee Lake and Adlatok sub-belts. However, felsic volcanic rocks occur throughout the Florence Lake greenstone belt, commonly forming thin (less than 10 m) units that are interlayered with mafic volcanic rocks (Unit 1), and can be traced for several hundred metres. The narrow felsic units are not shown on Figure 5 because of their size. Felsic volcanic rocks are subdivided in the field into three units on the basis of texture, colour, and on the abundance of layers of ultramafic schist.

Unit 4 is defined to consist of white- to grey-weathering, strongly foliated felsic volcanic schist, and isotropic to weakly foliated felsic volcanic rocks. Rocks are aphanitic or have a very fine-grained granoblastic texture. They commonly contain less than 5 percent, fine-grained white or mauve quartz phenocrysts, and local feldspar phenocrysts. Locally, they contain up to 10 percent of a rusty-brown-weathering, fine-grained mineral thought to be magnesite. The origin of the magnesite is uncertain. Unit 4 felsic rocks are inferred to be extrusive volcanic (rhyolitic) rocks (flows and/or tuffaceous rocks), although primary textures are obliterated.

Unit 5 consists of grey-weathering, felsic to intermediate (dacitic?), aphyric volcanic rocks. The rocks are aphanitic, variably foliated, and are inferred to be extrusive. Unit 5 rocks occur around the eastern margins of Knee Lake.

Unit 6 is a composite unit consisting of a mixture of felsic volcanic rocks that are identical to those in Unit 4 and abundant layers of ultramafic schists. On the basis of lithological appearance, the ultramafic schists in Unit 6 are identical to those in Unit 2. Unit 6 rocks occur 1.5 km east of Florence Lake and in the area south of Ugjoktok Bay.

The close spatial association between felsic and ultramafic rocks, in areas underlain by Unit 6 and throughout the Florence Lake greenstone belt, suggests a genetic relationship between felsic and ultramafic volcanism. The felsic volcanic rocks may have been derived from melting of mafic volcanic rocks when very hot ultramafic magma passed through the dominantly mafic volcanic sequence during ultramafic eruptions (J.M. Franklin, personal communication, 1995).

Mafic to Intermediate Rocks (Unit 7)

Unit 7 is a heterogeneous division that could not be subdivided at the present scale of mapping. It mainly includes intermediate and mafic volcanic rocks, although the unit also contains, in variable proportions, volcanic and sedimentary rocks similar to those in all of the other units in the Florence Lake greenstone belt.

East of Florence Lake, the unit is characterized by a layered structure defined by 10- to 30-cm-thick layers of alternating intermediate, mafic or felsic volcanic rocks. The unit also includes minor amounts of ultramafic and pelitic metasedimentary schists. The intermediate rocks are grey-weathering, fine grained, and consist of variable amounts of quartz, feldspar, biotite and hornblende. Field relations suggest that Unit 7 rocks, east of Florence Lake, have a transitional, lateral facies relationship with felsic volcanic rocks (Unit 6). This implies that these rocks in this area represent intermediate and mafic composition volcaniclastic sediments derived from mixed felsic and mafic sources. Interlayered with the inferred volcaniclastic sediments are thin mafic and ultramafic volcanic flows, and layers of felsic tuff.

In the Adlatok sub-belt, Unit 7 consists mainly of grey-weathering, fine- to medium-grained intermediate rocks and lesser amounts of mafic rocks. The intermediate rocks consist of variable amounts of quartz, feldspar, biotite, hornblende and rare garnet. In places they are layered, defined by alternating intermediate and mafic layers up to several metres thick. They may also show fragmental textures (Plate 9) defined by highly flattened intermediate fragments up to 30 cm long. The Unit 7 rocks in this area are inferred to represent intermediate flows and pyroclastic deposits that are inter-layered with minor amounts of mafic volcanic flows.

Sedimentary Rocks (Units 8 and 9)

Greenschist- and amphibolite-facies metasedimentary schists form mappable units in the Ugjoktok and Adlatok sub-belts, although thin (less than 5 m) layers of schist occur throughout the Florence Lake greenstone belt. The greenstone belt also contains rare occurrences of white- or grey-weathering marble that are not shown on the map because of their small size.

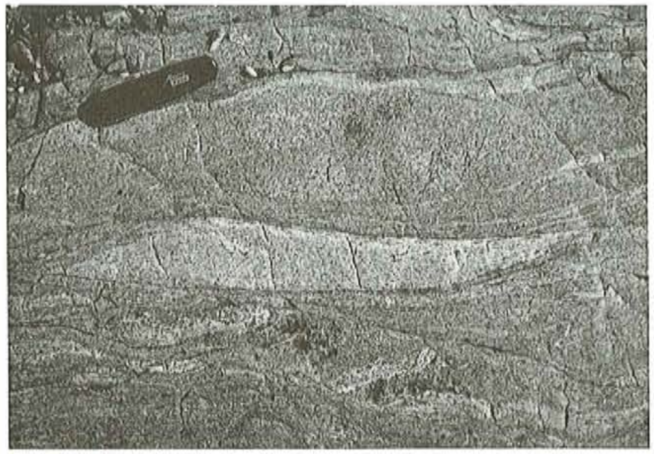

Plate 9. *Intermediate (dacitic?) composition fragmental volcanic rock (Unit 7) in the Adlatok sub-belt.*

Unit 8 consists of grey-, black-, or brown-weathering pelite and wacke. At greenschist facies, the rocks consist mainly of quartz, feldspar and chlorite. At higher metamorphic grades, rocks contain biotite, muscovite and local garnet (Plate 10). The Unit 8 schists south of Ugjoktok Bay contain abundant, thin layers of ultramafic schists that are identical to Unit 2 schists based on lithological appearance. On the basis of mineralogy, Unit 8 sediments are inferred to be derived primarily from mafic volcanic sources.

Unit 9 is a composite unit consisting of quartz wacke, local conglomerate, and semipelitic and pelitic schist. The quartz wacke is white- to rusty-weathering, and consists of a fine-grained schistose matrix containing abundant (15 percent) medium-grained relic quartz clasts; relic bedding was not observed. Locally, the quartz wacke is conglomeratic and contains elongate (10 cm), quartzitic lithic clasts inferred to be derived from felsic volcanic rocks (Plate 11). The clasts are matrix supported and completely unsorted. Interbedded with the quartzitic sediments are light-grey-weathering semipelitic schists containing quartz, feldspar, muscovite, minor amounts of biotite, and rare garnet. On the basis of composition, Unit 9 sediments are inferred to be derived primarily from felsic volcanic sources.

Intrusive Rocks (Units 10 and 11)

Granitoid rocks that intrude and envelop the Florence Lake greenstone belt were not studied in detail, although intrusive and structural relations between volcanic and

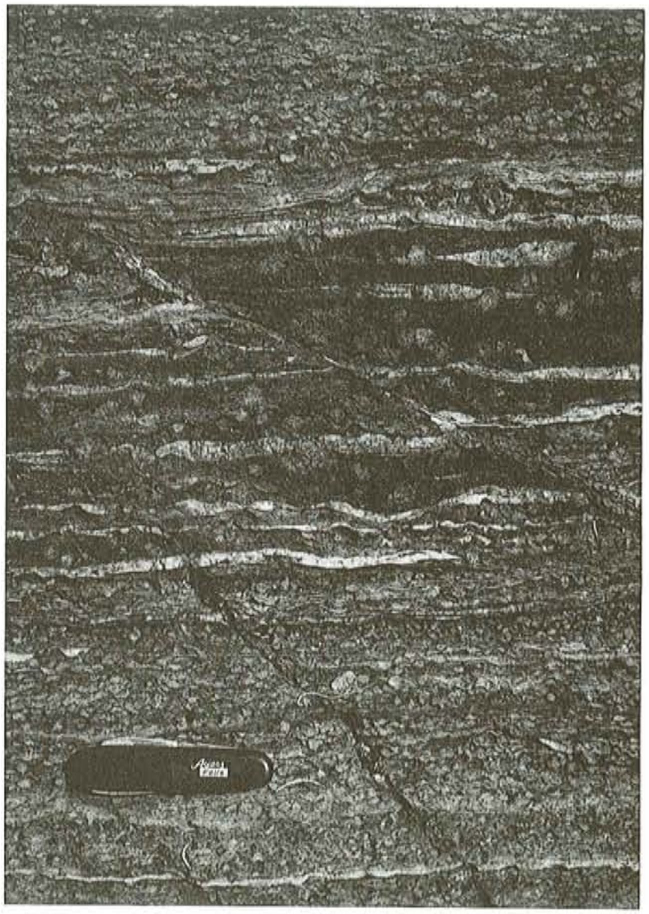

Plate 10. *Amphibolite-facies metasedimentary schist (Unit 8) containing biotite and abundant garnet. The rocks preserve primary sedimentary bedding defined by black (shale) and grey (wacke) layers.*

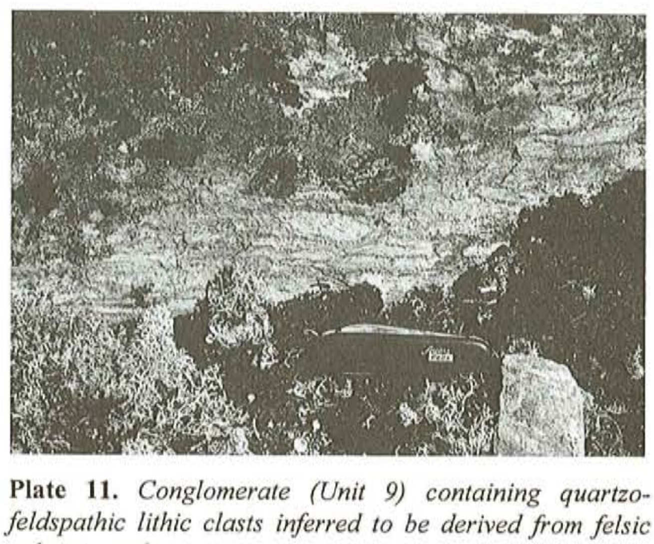

Plate 11. *Conglomerate (Unit 9) containing quartzo-feldspathic lithic clasts inferred to be derived from felsic volcanic rocks.*

granitoid rocks were recorded, and granitoid rocks in the area of the contact were given a cursory examination. The granitoid rocks are subdivided here into two units. Unit 10 forms a body that intrudes the volcanic rocks at Knee Lake. Unit 11 is an undivided granitoid unit that includes all other granitoid rocks in the study area. (Unit 11 is defined only for the purposes of making Figure 5; it should not be considered as containing rocks of one age or lithology, and has no regional significance.)

Unit 10 consists mainly of white- to grey- and local pink-weathering granodiorite, granite and quartz syenite rocks that are massive to weakly foliated and contain biotite. They are mainly fine to medium grained, although there are local examples of porphyritic textures defined by medium-grained, pink K-feldspar phenocrysts in a fine-grained grey matrix containing abundant biotite. The granitoid rocks commonly contain xenoliths of the volcanic rocks. The fact that Unit 10 rocks occupy the antiformal core of a major structure in the volcanic belt, and that the intrusion is rimmed by felsic volcanic rocks may suggest that this body represents a subvolcanic intrusion. Uranium–lead dating of this unit is necessary to corroborate this model. Subvolcanic granitoid intrusions have not been identified in the Florence Lake greenstone belt.

Unit 11 includes orthogneisses and variably deformed granitoid intrusions of several presumed ages. South of Ugjoktok Bay, the unit consists of a pink and grey orthogneiss (Plate 12) that is in tectonic contact with the greenstone belt. Ermanovics (1993) has correlated this orthogneiss with the pre-volcanic Maggo gneiss on the basis of lithological appearance. As the contact between the gneiss and the volcanic rocks is approached, the gneiss is progressively strained, recrystallized and converted to a fine-grained, white-weathering granitoid rock that contains no evidence of the pre-existing gneissosity. The zone of recrystallized gneiss, which contains local areas having relic gneissosity and mylonitic rocks, is approximately 300 m wide. The contact between the recrystallized zone and the greenstone belt is a 2-m-thick mylonitic pegmatite. Mafic and ultramafic rocks adjacent to the contact are also highly strained; the mafic rocks are very fine grained, straight layered and surround pods of ultramafic schists that are the highly dismembered relics of ultramafic layers.

West of Ugjoktok Bay, near the outlet of the south branch of the Adlatok River, and in the Adlatok Bay area, the greenstone belt is in contact with orthogneiss that has a similar composition and structure as the Maggo gneiss. Contacts between this gneiss and the volcanic rocks are unexposed, although amphibolite-facies mafic and ultramafic volcanic rocks that are inferred to be equivalent to the

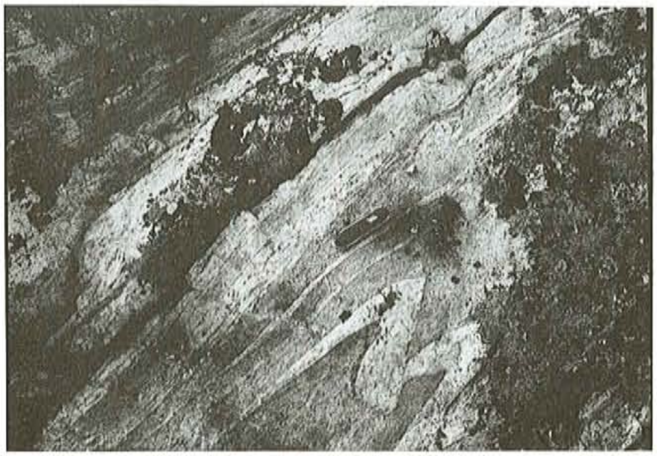

Plate 12. *Granitoid orthogeniss that is located along the western margin of the Ugjoktok sub-belt. These rocks are correlated with the pre-volcanic Maggo gneiss on the basis of lithology. In the study area, these rocks are in tectonic contact with the greenstone belt.*

Florence Lake greenstone belt volcanic rocks are unequivocally intruded by the gneiss (Plate 13). (Contact relations are visible on an island near the southwest end of the bay; 652290E, 6115450N UTM coordinates). On this basis, this orthogneiss is interpreted to be younger than volcanic rocks in the Florence Lake greenstone belt and is not correlated with the Maggo gneiss.

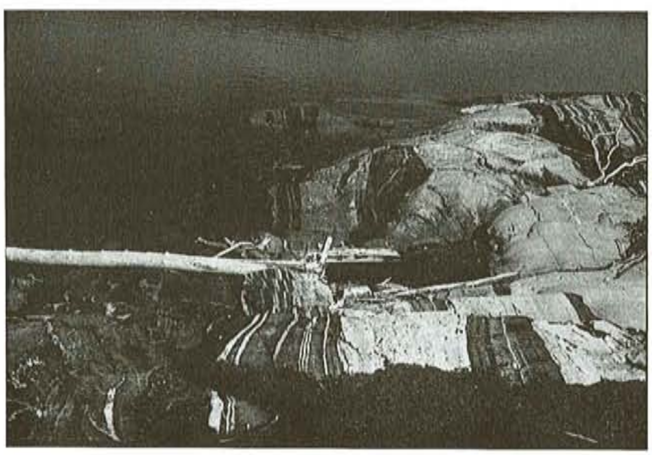

Plate 13. *Granitoid orthogneiss (right side of the photograph) at Adlatok Bay that is in intrusive contact with amphibolite-facies mafic volcanic rocks (left side of the photograph). The contact is transitional and marked by a narrow zone (10 m) consisting of orthogneiss containing mafic volcanic xenoliths.*

In other parts of the study area, Unit 11 consists of variably foliated granitoid rocks. They mainly include pink- and white-weathering biotite granite and granodiorite, and lesser tonalite. Some granitoid rocks contain xenoliths of deformed volcanic rocks but are themselves foliated and somewhat recrystallized, demonstrating that they must be late syntectonic with respect to deformation in the volcanic rocks, assuming that there was a continuum of deformation. In contrast, other granitoid rocks are undeformed and have pristine phaneritic textures suggesting they postdate deformation in the volcanic rocks. Uranium – lead geochronological studies are necessary to determine the range in ages of the granitoid intrusions and to bracket timing of deformation.

In the field, contacts between the granitoid intrusions and volcanic rocks are sharp (i.e., they are not defined by a wide, mixed zone consisting of volcanic rocks having granitoid intrusions and granitoid intrusions containing abundant volcanic xenoliths). Contacts are commonly sheared and mylonite is developed in the granitic rocks, locally. In some places (e.g., around the margins of the elongate intrusion centred 4 km east of Florence Lake), the intrusions have imposed a narrow (less than 50 m), amphibolite-facies contact aureole on greenschist-facies volcanic rocks.

STRUCTURE AND METAMORPHISM

The oldest structures in the volcanic rocks are primary compositional layering, pillows, and local fragments inferred to be pyroclastic in origin. These are overprinted and transposed by a variably developed northeast- to north-northeast-striking foliation (Figure 6) designated as S_1 and defined by alignment of the metamorphic minerals. Isoclinal closures (F_1) of pre-S_1 layering are observed locally. The S_1 foliation is deformed and folded into open to tight, northeast-trending F_2 folds that are the main, map-scale folds in the belt. The superposition of F_2 folds on F_1 isoclinal closures, of pre-S_1 layering, produced outcrop-scale Type III folds of the compositional layering. There does not appear to be a foliation associated with the F_2 folds. The ages of F_1 and F_2 folds are unknown, although field relations suggest that both are approximately synchronous with the peak of metamorphism. The fact that foliated granitoid plutons (that make up part of Unit 11) contain volcanic xenoliths having inferred S_1 foliation demonstrates that intrusion of these plutons was late syntectonic with respect to the main phase of compressional deformation and the peak of metamorphism. This is consistent with the observation that deformed granitic plutons have imposed local, amphibolite-facies aureoles on greenschist-facies volcanic rocks. Local mylonitization of granitic rocks along granite – greenstone contacts indicates that contractional deformation outlasted the peak of regional metamorphism.

The greenstone belt may contain pre- to syn-S_1, layer-parallel contractional faults that could duplicate or excise volcanic stratigraphy. These structures have not been mapped, although the possibility that they occur should not be

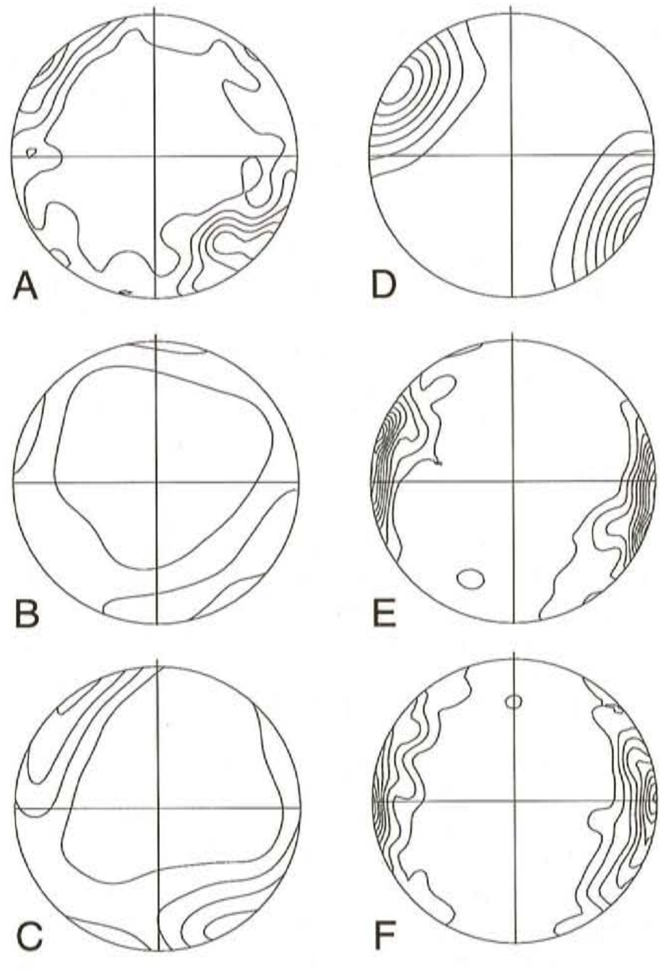

Figure 6. *Contoured lower-hemisphere equal area projection of poles to S_1. Contours are in increments of 2σ. A–Knee Lake sub-belt (all areas). n=265, σ=1.45. B–Southern part of the Knee Lake sub-belt. n=32, σ=1.17. C–Northern part of the Knee Lake sub-belt. n=62, σ=1.32. The dispersion of the S_1 data in B and C are the result of folding of S_1 by northeast-trending F_2 folds. D–Schist Lakes sub-belt. n=51, σ=1.27. E–Ugjoktok sub-belt. n=151, σ=1.42. F–Adlatok sub-belt. n=211, σ=1.44.*

discounted. Some of the thin and strike-continuous ultramafic units, which are highly schistose and incompetent relative to bounding mafic volcanic rocks, could be the locus for such faults. Detailed mapping and chemostratigraphic tests might assist in determining if these structures exist.

The greenstone belt is variably overprinted by a northwest- to west-northwest-striking foliation designated as S_3 (Figure 7). On the outcrop scale, S_3 is axial planar to minor, steeply plunging F_3 folds. The significance of S_3 folds on the map-scale structural pattern of the greenstone belt is equivocal, although the elongate, doubly-plunging antiformal structure defined by the Knee Lake sub-belt could be the result of superposition of F_3 on F_2.

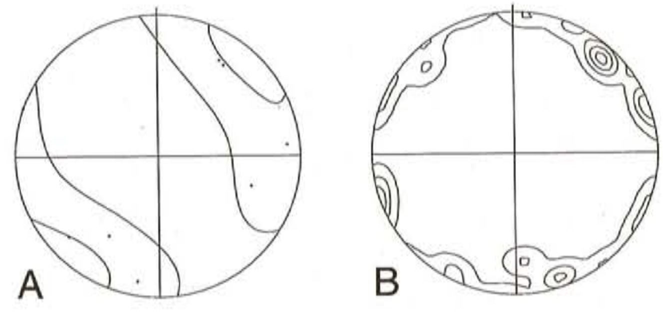

Figure 7. *Contoured lower-hemisphere equal area projection of poles to S_3. Contours are in increments of 2σ. A–Knee Lake sub-belt. n=8, σ=0.71. B–Adlatok sub-belt. n=22, σ=1.06.*

Several northeast- to east-northeast-striking and west-northwest-striking faults deform the greenstone belt and younger granitic plutons. Because the faults are mainly unexposed, they are inferred from offsets of the granite–greenstone contacts and topographic lineaments. They are commonly marked by prominent VLF anomalies. Some of the northeast-striking structures are marked by mylonitic granitoid rocks.

The metamorphic grade in the greenstone belt is variable from greenschist to amphibolite facies. In general, the metamorphic grade increases from southwest to northeast, although the northeastern part of the belt, which is mainly at amphibolite facies, contains a patchy distribution of greenschist-facies rocks. In greenschist-facies areas, mafic rocks contain the assemblage: chlorite + actinolite + plagioclase ± epidote, whereas at amphibolite facies they contain: hornblende + plagioclase ± garnet ± biotite. Pelitic schists contain chlorite + biotite + muscovite, and in higher grade areas, biotite + garnet ± muscovite. Aluminosilicate minerals were not observed.

EXPLORATION TARGETS

The Baikie nickel showing (see Miller, *this volume*) is hosted by komatiitic rocks (Brace, 1990) and is interpreted to be an example of komatiite-associated or Kambalda-type nickel sulphide mineralization. This class of mineralization occurs in the Archean greenstone belts of western Australia (Marston *et al.,* 1981; Gresham and Loftus-Hills, 1981; Groves and Lesher, 1982; Lesher *et al.,* 1984; Lesher and Groves, 1986; Marston, 1984), from where it derives its name, in the Abitibi greenstone belt in Canada (Naldrett and Gasparrini, 1971; Coad, 1979; Naldrett, 1981; Jensen, 1986), and in Zimbabwe (Williams, 1979; Hammerbeck, 1984). Komatiite-associated nickel sulphide deposits contain about 25 percent of the world total identified nickel resource (Lesher, 1989).

Lesher (1989) lists exploration guidelines for finding komatiite-associated nickel deposits. A partial list of these guidelines, as they apply to the Florence Lake greenstone belt, are shown in Table 2. The guidelines suggest that the Florence Lake greenstone belt is a favourable target for komatiite-associated nickel deposits, although detailed geochemical tests of Lesher's guidelines are lacking.

Table 2. Exploration guidelines for komatiite-associated nickel sulphide deposits (summarized from Lesher, 1989)

METALLOGENIC PROVINCE SELECTION

1. Archean greenstone belts in the range 2.7 to 3.0 Ga
2. Rift-phase greenstones including abundant komatiites (komatiitic peridotites and komatiitic dunites), and sulphidic sediments

LOCAL AREA SELECTION

1. Komatiitic sequences containing komatiitic peridotites and komatiitic dunites; typically not interlayered with komatiitic basalts
2. Komatiites containing Zn-rich ferrochromites
3. Komatiites exhibiting chalcophile element depletion
4. Structural highs

SELECTION OF TARGETS AS POTENTIAL ORE HORIZONS

1. Thickened areas of komatiitic sequences
2. Areas of stratigraphic discontinuities (poor lateral continuity of units)
3. Locally better textural and compositional differentiation in overlying komatiities (i.e., overlying potential ore horizon)
4. Locally absent sulphidic sedimentary rocks stratigraphically below target horizon
5. Anomalously thick, highly magnesian basal host units
6. Footwall embayments

The Florence Lake greenstone belt also has the potential to host volcanogenic massive sulphide (VMS) deposits. Relatively thick sequences of felsic volcanic rocks in the Knee Lake and Adlatok sub-belts make these areas the most prospective. Felsic volcanic rocks at Knee Lake are intruded by a pluton (Unit 10) thought to be a ca. 3.0-Ga sub-volcanic intrusion. If the interpretation of this intrusion is correct, it might enhance the VMS potential of this area as sub-volcanic intrusions provide a heat source necessary to produce VMS deposits.

MINERALIZATION

There are four types of known mineralization in the Florence Lake greenstone belt. These include:

1. *Disseminated Ni–Cu sulphide mineralization in ultramafic rocks (Miller, 1995, this volume).* Mineralization mainly includes several percent pyrite and local, minor amounts of pyrrhotite, pentlandite and chalcopyrite. Small occurrences of massive sulphide mineralization associated with the ultramafic rocks are rare. The Baikie and associated prospects in the Baikie sub-belt (Miller, *this volume*; and see Brace, 1990 and references therein), located 3 km northwest of Florence Lake, contain local occurrences of massive sulphides.

   Ultramafic rocks west of Knee Lake and in the Adlatok sub-belt are locally associated with coincident magnetic, VLF and EM anomalies (Figures 8 to 11). The geophysical data suggest that these are prospective areas for mineralization.

2. *Sulphide mineralization associated with felsic volcanic centres.* There are extensive areas of felsic volcanic rocks in the Knee Lake and Adlatok sub-belts. Disseminated and rarely massive sulphide mineralization occurs near the contact between felsic and mafic volcanic rocks southwest of Knee Lake.

   Disseminated to rarely massive Fe–Cu sulphide mineralization also occurs in thin (1 to 5 m) zones of felsic volcanic rocks and metasedimentary rocks (pelitic and cherty schists) that are interlayered with ultramafic and mafic rocks. Mineralization mainly includes pyrite (up to 10 percent).

3. *Disseminated pyrite and chalcopyrite in quartz veins hosted by mafic volcanic rocks.* The veins are locally malachite stained and some contain several percent arsenopyrite. The sulphide-bearing quartz veins are generally thin (less than 1 m) and there are no known occurrences of extensive vein systems.

4. *Rare occurrences of fibrous serpentine in the ultramafic rocks.* Veins of fibrous serpentine are thin (1 cm) and vein systems are not pervasively developed.

Assay samples were collected from prominent zones of gossanous rocks in the Florence Lake greenstone belt. The assay results are listed in Table 3.

In addition to the potential for sulphide mineralization, the ultramafic rocks in Unit 2 have potential for use by artisans in the soapstone carving industry. A 4-m-thick serpentinized ultramafic unit that occurs near the southwest end of Adlatok Bay (652290E, 6115450N UTM coordinates) has been quarried by local carvers.

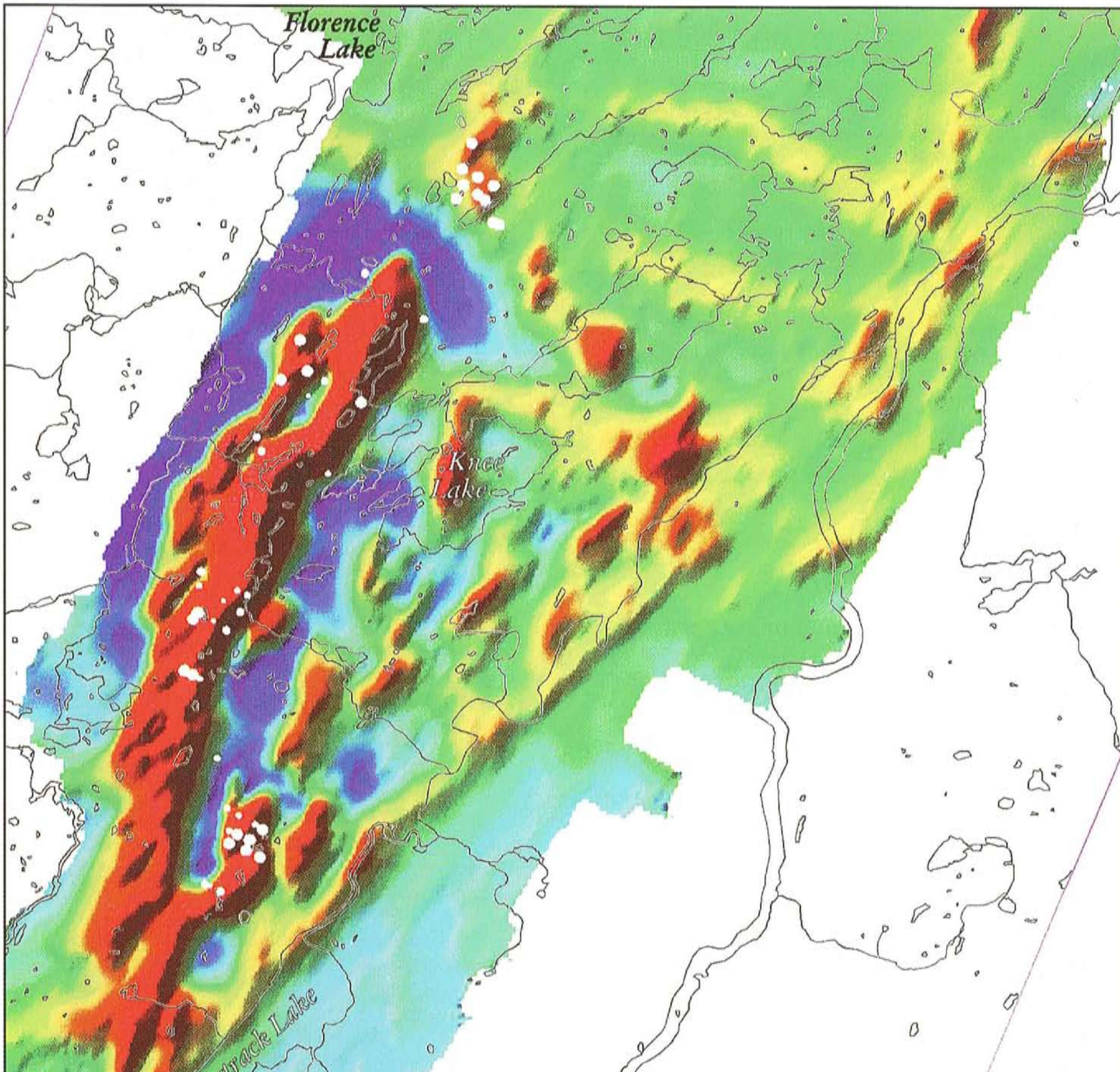

Figure 8. *Shaded-relief magnetic map for parts of the Knee Lake sub-belt. The data are from a 1993 survey by BP Minerals (see Stewart* et al., *1983).*

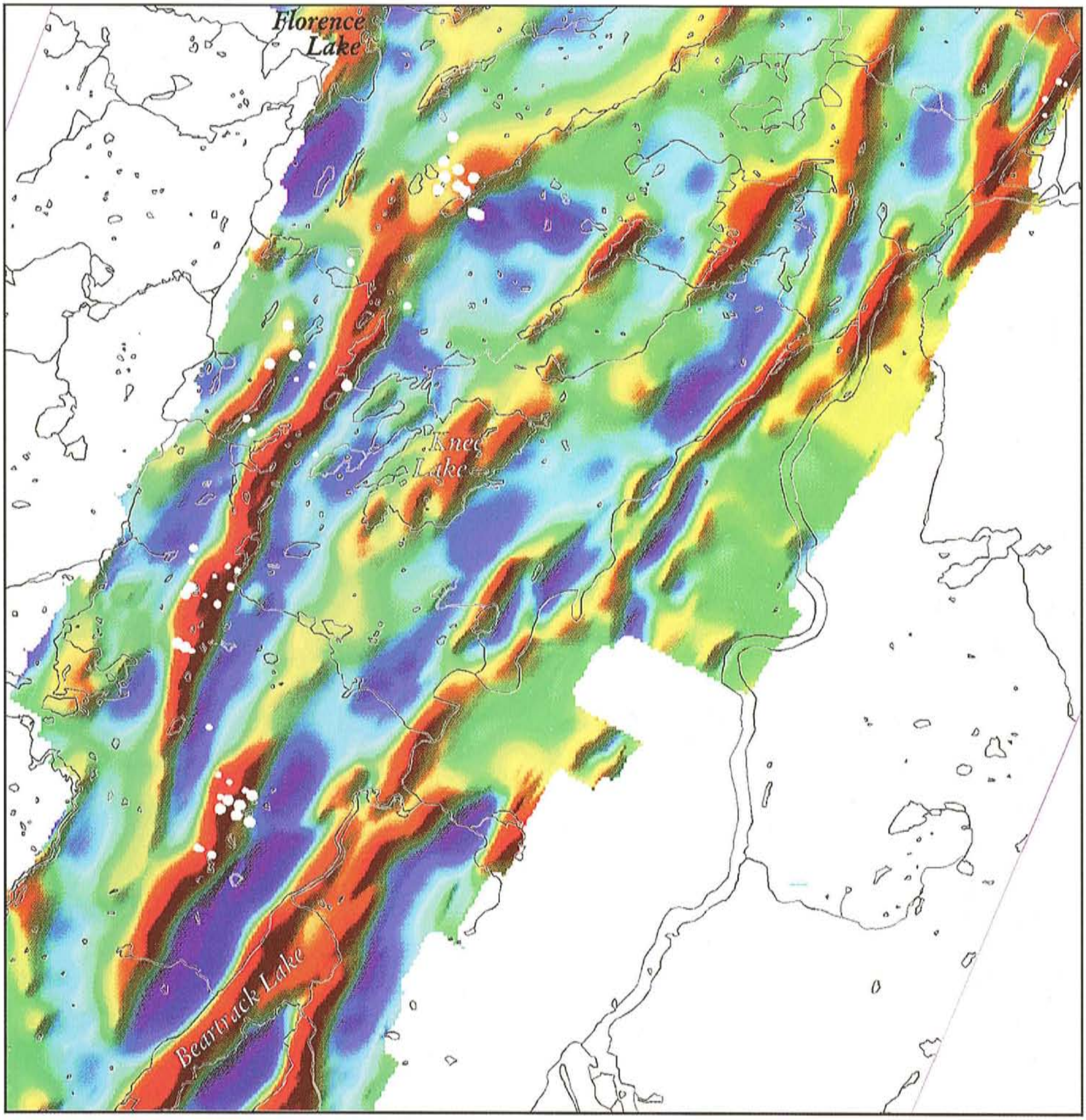

Figure 9. *VLF geophysical anomaly map for parts of the Knee Lake sub-belt. Displayed on the VLF-anomaly maps are locations of active EM anomalies (shown as white circles). The data are from a 1993 survey by BP Minerals (see Stewart* et al., *1983).*

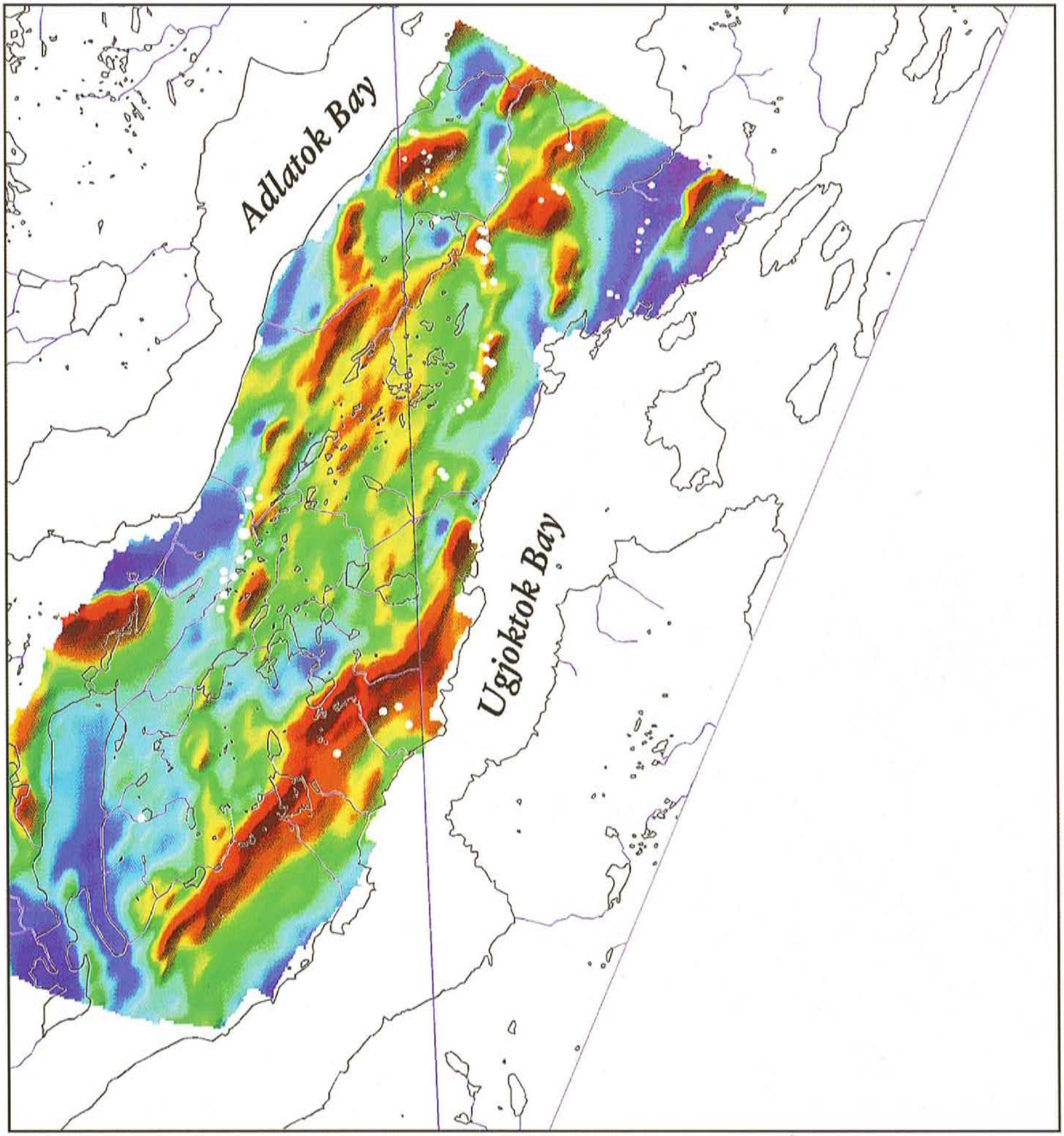

Figure 10. *Shaded-relief magnetic map for parts of the Adlatok sub-belt. The data are from a 1993 survey by BP Minerals (see Stewart* et al., *1983).*

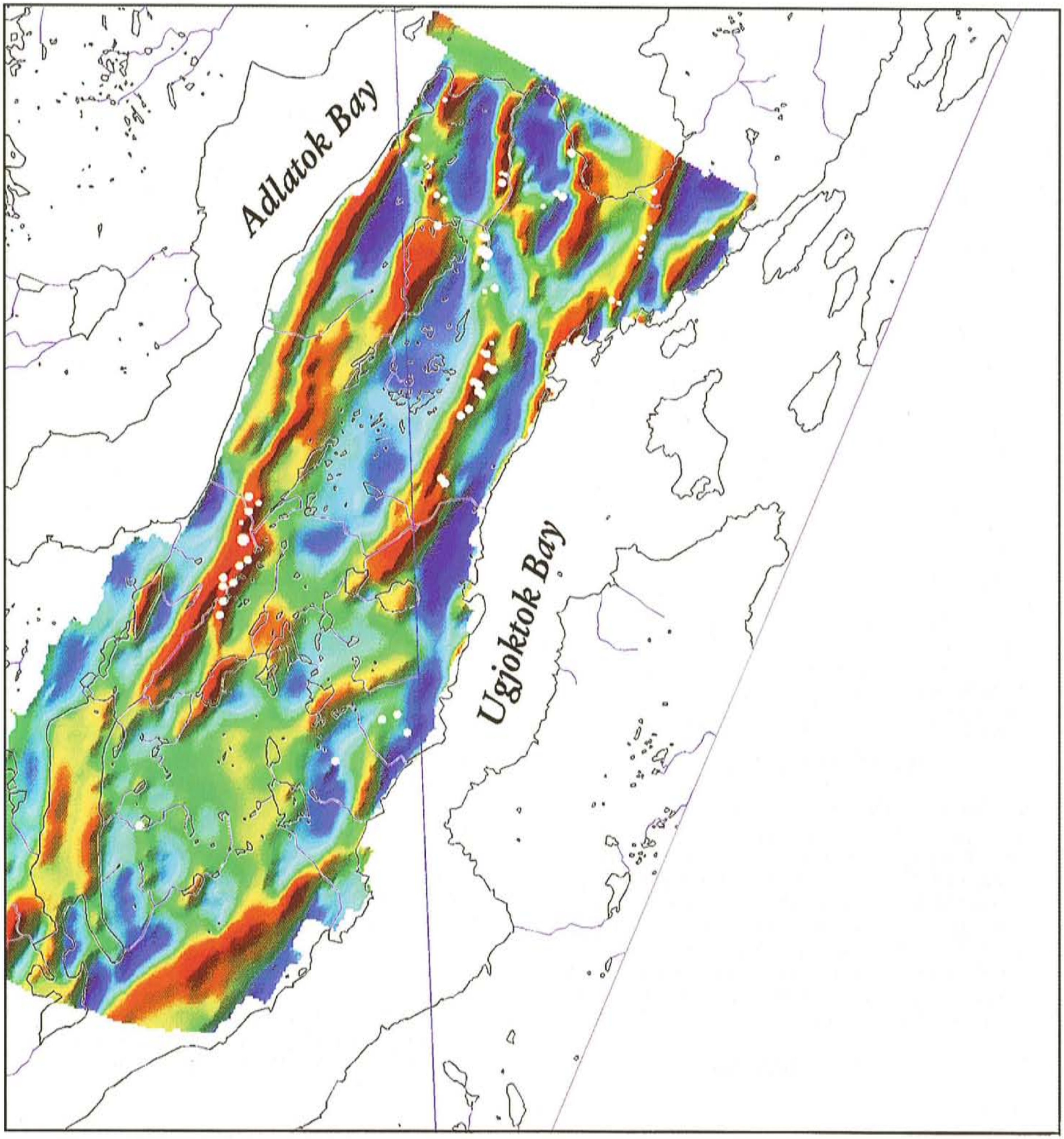

Figure 11. *VLF geophysical anomaly map for parts of the Adlatok sub-belt. Displayed on the VLF-anomaly maps are locations of active EM anomalies (shown as white circles). The data are from a 1993 survey by BP Minerals (see Stewart* et al.*, 1983).*

Table 3. Assay results of samples collected from gossanous rocks (grab samples) in the Florence Lake greenstone belt; all results are in ppm; negative values indicate results are less than the detectable limit

Sample	East	North	Au	Sb	As	Ba	Cr	Co	Ni	Zn
DJ-95-1152	637724	6074999	-2	0.2	1.6	640	-20	36	39	200
DJ-95-1183	639882	6073231	4	1.4	1.6	-50	-20	10	22	-100
DJ-95-1208A	636951	6071387	17	0.3	6.4	53	-20	80	140	-100
DJ-95-1208B	636951	6071387	10	0.3	6.5	-50	-20	54	110	-100
DJ-95-1218	635811	6071071	-2	0.6	1.6	89	54	37	-10	130
DJ-95-1222	637020	6071270	21	1.4	208	-50	-20	110	71	-100
DJ-95-1227A	639423	6070076	91	0.3	1.5	92	140	44	69	-100
DJ-95-1310	647255	6101133	10	0.4	22	170	83	71	170	1500
DJ-95-1311	647182	6101172	-2	0.5	2.5	860	150	230	320	280
DJ-95-1312	646978	6101202	-2	0.2	4.4	440	290	75	240	170
DJ-95-1320	646330	6093141	26	0.8	239	57	45	30	66	700
DJ-95-1369	635701	6086382	-2	0.2	-0.5	-50	250	30	70	340
DJ-95-1413	645469	6099471	7	0.2	0.8	69	62	5	-10	220
DJ-95-1474	660282	6114767	27	0.5	129	-50	-20	73	50	-100
DJ-95-1499	661346	6118027	8	0.3	2.3	89	58	19	41	170
DJ-95-1565	647651	6101721	2	1.5	37	480	86	32	130	-100
DJ-95-1571	647318	6102217	12	1	5	170	130	77	170	500
DJ-95-9069B	644257	6087444	10	0.5	3.1	130	56	19	36	-100
DJ-95-9069C	644257	6087444	2	0.2	1.5	-50	-20	-5	-10	-100
DJ-95-9104	642390	6079071	3	0.3	1.6	490	27	-5	-10	-100
DJ-95-9113D	644634	6093434	8	0.1	-0.5	240	220	52	74	-100
DJ-95-9174	639262	6075456	3	0.3	1.7	59	-20	12	27	-100
DJ-95-9219	635509	6070025	-2	1.4	8.8	-50	62	230	8980	-100
DJ-95-9222	636356	6070538	10	303	38	180	96	110	240	-100
DJ-95-9389C	652290	6115450	8	0.2	0.8	180	190	55	170	-100
DJ-95-9396	661845	6121816	35	0.1	0.8	-50	-20	16	29	-100

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