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ULTRAMAFIC ROCKS AND Ni – Cu MINERALIZATION IN THE FLORENCE LAKE – UGJOKTOK BAY AREA, LABRADOR[1]

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Mineral Deposits Section

ABSTRACT

The Archean Florence Lake greenstone belt consists of a series of sub-belts defined by structural and intrusive contacts. Some of these sub-belts, including the Baikie, Knee Lake, Schist Lakes, Ugjoktok and Adlatok, contain significant quantities of ultramafic rocks. Ultramafic units commonly include talc, talc – magnesite, and talc – serpentine ± chlorite rocks. These units exhibit many features of komatiitic flows, such as polyhedral jointing, stratabound and strataform nature, and a thin (1- to 25-m) elongate (up to 8 km) shape. These rocks may represent massive, immature, undifferentiated flows characteristic of distal sheet flows or overbank spill-over. Similar flows occur in the Kambalda region, Australia.

Nickel – copper mineralization, occurring in ultramafic units in the Baikie sub-belt, displays several features of the Kambalda model including nearby sulphidic sediments and a komatiitic flow host. When using the Kambalda model, several other parts of the Florence Lake greenstone belt have potential for Ni – Cu mineralization.

INTRODUCTION

The Florence Lake greenstone belt (Figure 1) consists of Archean volcanic and sedimentary supracrustal units, which occur in a terrane of both older and younger, mainly felsic to intermediate, intrusive rocks (Ermanovics 1993; James *et al.*, 1995, *this volume*). Structural and intrusive contacts subdivide the greenstone belt into a number of spatially constrained sub-belts (Figure 2). The sub-belts in the study area, which include the Baikie (Figure 3), Knee Lake (Figure 4), Schist Lakes, Ugjoktok (Figure 5) and Adlatok sub-belts, range from less than 1- to 25-km long and from less than 0.5- to 5-km wide.

Ermanovics (1993) and Ermanovics and Raudsepp (1979) divided the supracrustal rocks of the Florence Lake greenstone belt into three stratigraphic formations: Schist Lakes, Adlatok and Lise Lake formations. More detailed mapping (e.g., McLean, 1992; James *et al.*, 1995, *this volume*; Miller, 1995) indicates that these formations are difficult to distinguish and facing directions are ambiguous at best. Thus, these formation names have been abandoned in favour of lithological map units (e.g., Figure 3; James *et al.*, 1995, *this volume*; Miller, 1995).

Recent mapping and sampling, at a scale of 1:10 000 and 1:25 000, in the Florence Lake greenstone belt revealed numerous occurrences of ultramafic rocks (James *et al.*, 1995, *this volume*; Miller, 1995). These ultramafic rocks host several known Ni – Cu and asbestos showings (Ermanovics, 1993) and occur with Fe – Cu sulphide showings in graphitic – siliceous – sulphidic sediments. Results of this summer's mapping located several new occurrences of Ni – Cu and Fe – Cu mineralization. These results also indicate the nature and origin of the ultramafic rocks and associated Ni – Cu mineralization.

Mineral exploration in the Florence Lake greenstone belt mainly focused on Ni – Cu and asbestos mineralization in the ultramafic rocks, and Au and Cu – Zn mineralization in felsic volcanic rocks and volcanogenic sediments (Table 1). Brace (1990) and McLean and Butler (1993) provide detailed summaries of exploration activities in the study area. Recent extensive exploration, including diamond drilling, lithogeo-

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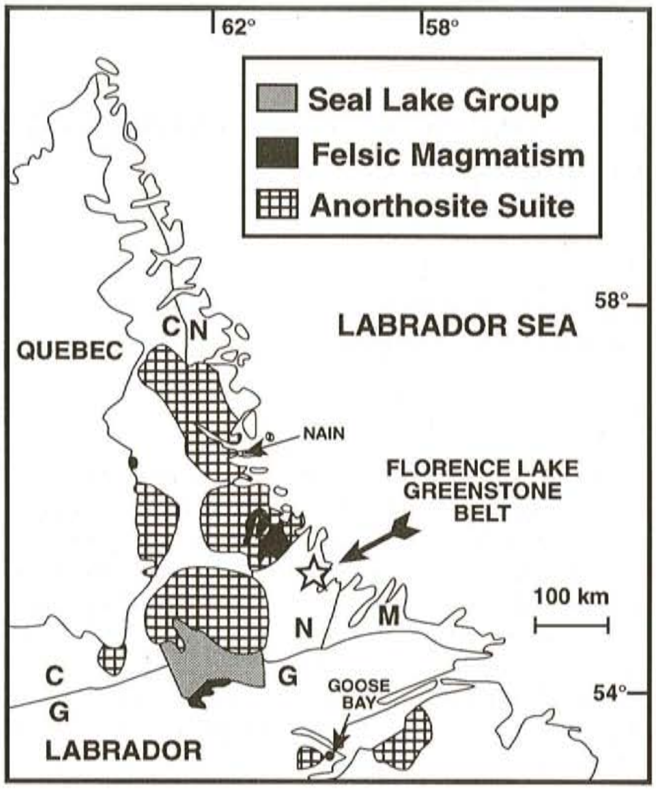

Figure 1. *Location of the Florence Lake greenstone belt, Labrador. Structural provinces: C = Churchill, N = Nain, G = Grenville, M = Makkovik.*

chemistry and ground geophysics, concentrated on Ni – Cu mineralization in the Baikie sub-belt (Table 1; McLean, 1991, 1992; McLean *et al.*, 1992).

This report describes the preliminary results of the portion of a multidisciplinary program (James *et al.*, 1995; Miller, 1995) that focused on detailed mapping and sampling of ultramafic rocks, felsic sulphide-bearing rocks and the associated mineralization in the Baikie, Knee Lake and Ugjoktok sub-belts. Preliminary interpretation of these data helps to develop an exploration model for mineralization in the Florence Lake greenstone belt.

MINERALIZATION

Ni – Cu MINERALIZATION

Ultramafic rocks host pyrrhotite – pyrite – pentlandite ± chalcopyrite semi-massive to disseminated mineralization in stratabound zones. The Baikie and associated prospects (Figure 3) contain 10 to 40 percent sulphides and grab samples assay 0.84 to 2.65 percent Ni and 0.01 to 0.07 percent Cu (Sutton, 1970; Brace and Wilton, 1990). Recent diamond-drill core included assays of 2.19 percent Ni, 0.22 percent Cu and 0.16 percent Co over 11.32 m and 1.86 percent Ni, 0.32 percent Cu and 0.05 percent Co over 1.21 m (McLean *et al.*, 1992) at the Baikie showing in the Baikie sub-belt. Mineralization at the DCP showing, north of the Baikie showing (Figure 3), assayed 0.68 percent Ni over 2.23 m. This mineralization occurs in greenschist- to amphibolite-grade talc – magnesite schists, which are probably meta-peridotites (Brace 1990; McLean *et al.*, 1992). Similar, but less abundant, disseminated mineralization (< 3 percent total sulphides), occurs in several other localities throughout the Florence Lake greenstone belt (Figure 4 and 5). Significant Ni – Cu mineralization also occurs in graphitic sediment associated with talc-bearing ultramafic rocks (e.g., Boomerang showing, 4.5 km southwest of Baikie showing; McLean *et al.*, 1992; Figure 3), which assay up to 2.1 percent Ni and 0.14 percent Cu in grab samples.

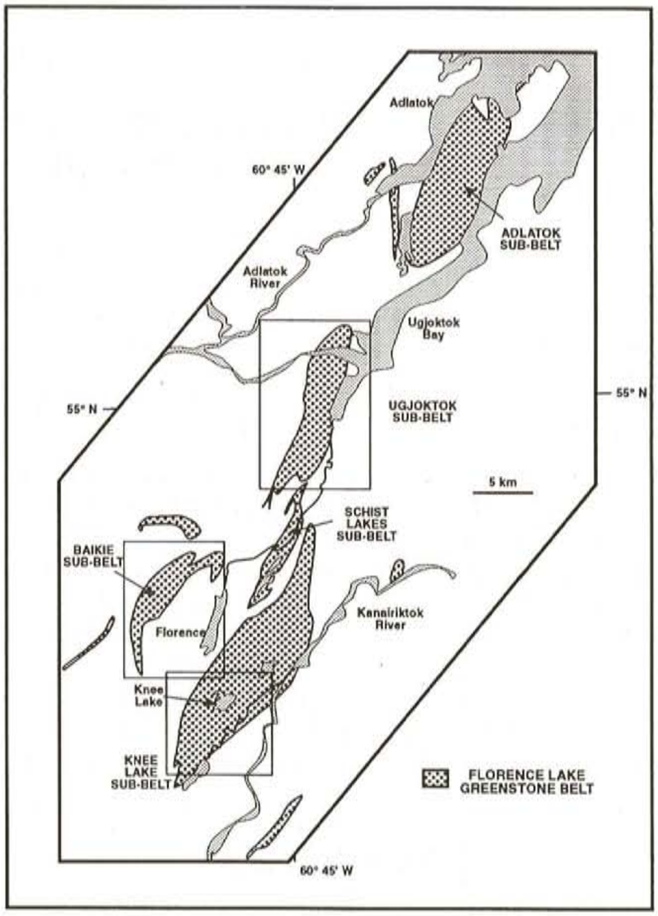

Figure 2. *Sketch illustrating the main sub-belts in the Florence Lake greenstone belt. Felsic intrusions, gneisses and structural breaks separate the sub-belts. Rectangles outline areas contained in Figures 3, 4 and 5.*

Fe – Cu MINERALIZATION

Felsic volcanic rocks and volcanogenic sediments host disseminated to rarely massive pyrite ± chalcopyrite mineral-

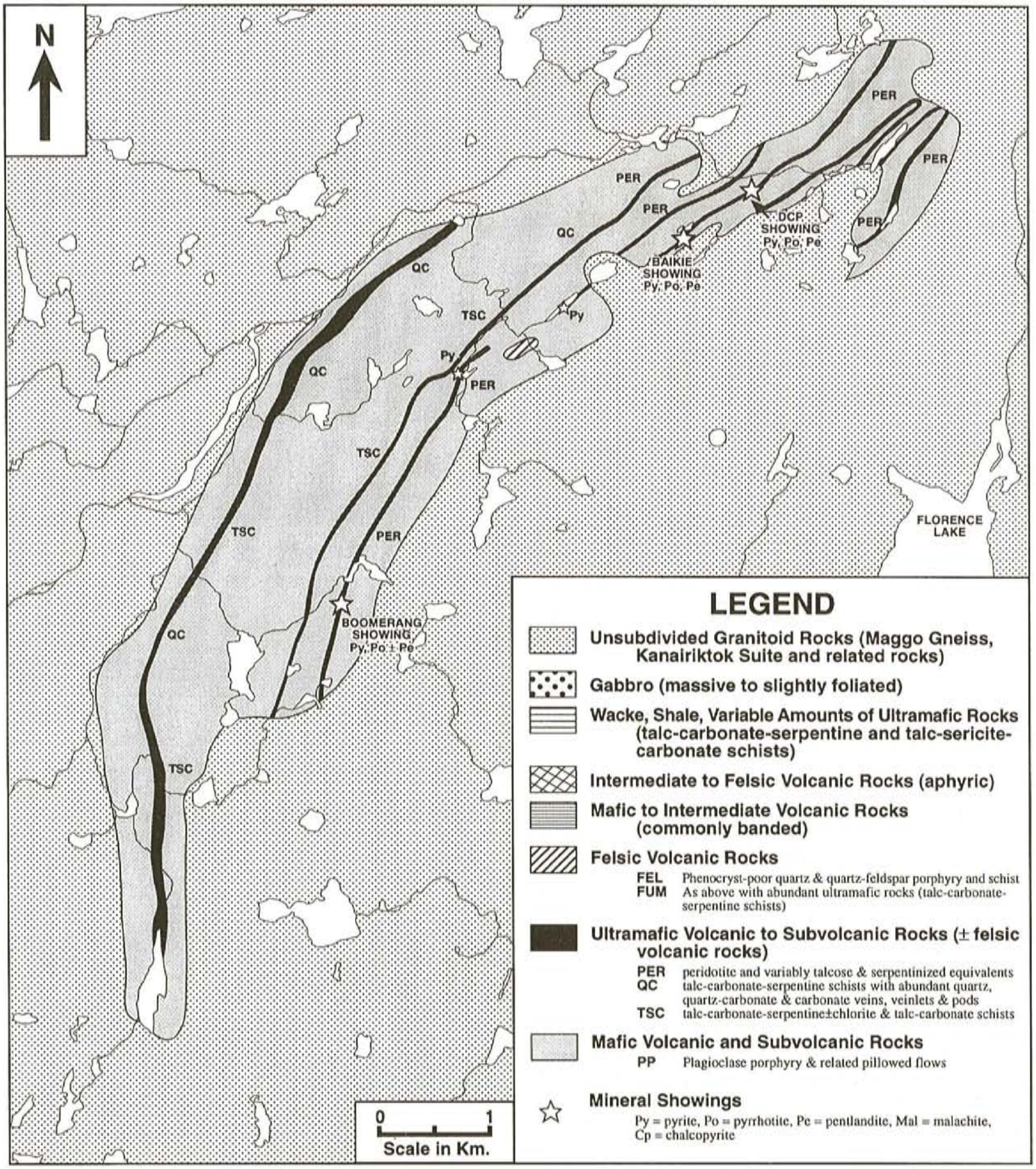

Figure 3. *Generalized geology of the Baikie sub-belt, focusing on ultramafic units and related mineral showings. This sketch summarizes 1:10 000-scale mapping of the sub-belt.*

ization at numerous localities. In greenschist-facies rocks, the sediments are graphitic, sericitic and cherty layered schists that range from 1 to 5 m thick. In amphibolite-facies rocks, these sediments occur as garnet-bearing pelitic schists that range from 1 to 3 m thick. The sulphides dominantly consist of pyrite that commonly occurs as disseminated grains and stringers ranging from <1 to 10 percent. Massive-sulphide units are less common; however, one occurrence consists of 1 m of mostly massive pyrite associated with garnet-bearing pelitic sediments. Sulphidic and related sediments most commonly occur in association with either ultramafic units, carbonate-bearing mafic units or mafic units of the Florence

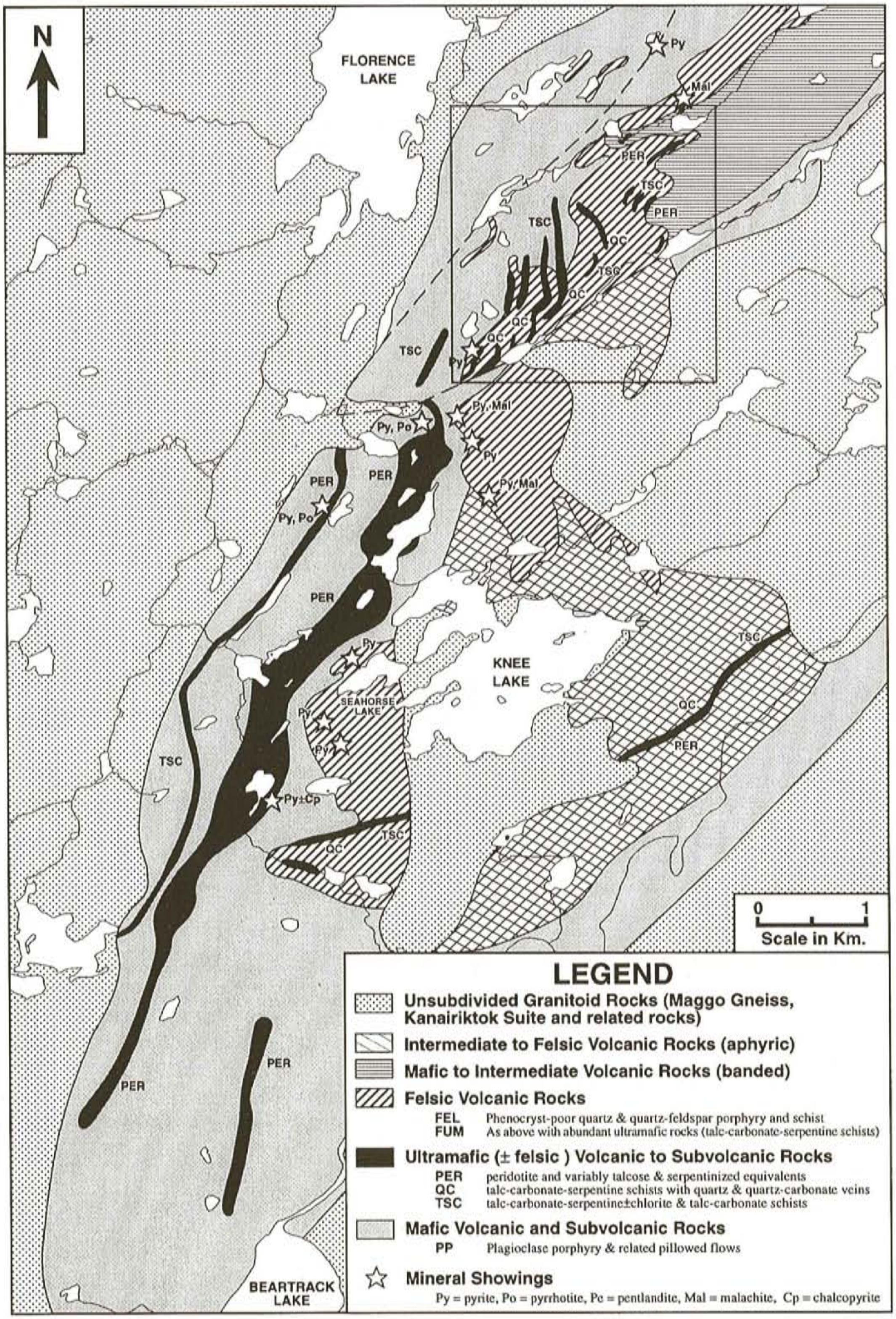

Figure 4. *Generalized geology of the southern part of the Knee Lake sub-belt, focusing on ultramafic units and related mineral showings. This sketch summarizes 1:10 000-scale mapping of the sub-belt (James* et al., this volume). *The rectangle outlines the area contained in Figure 6.*

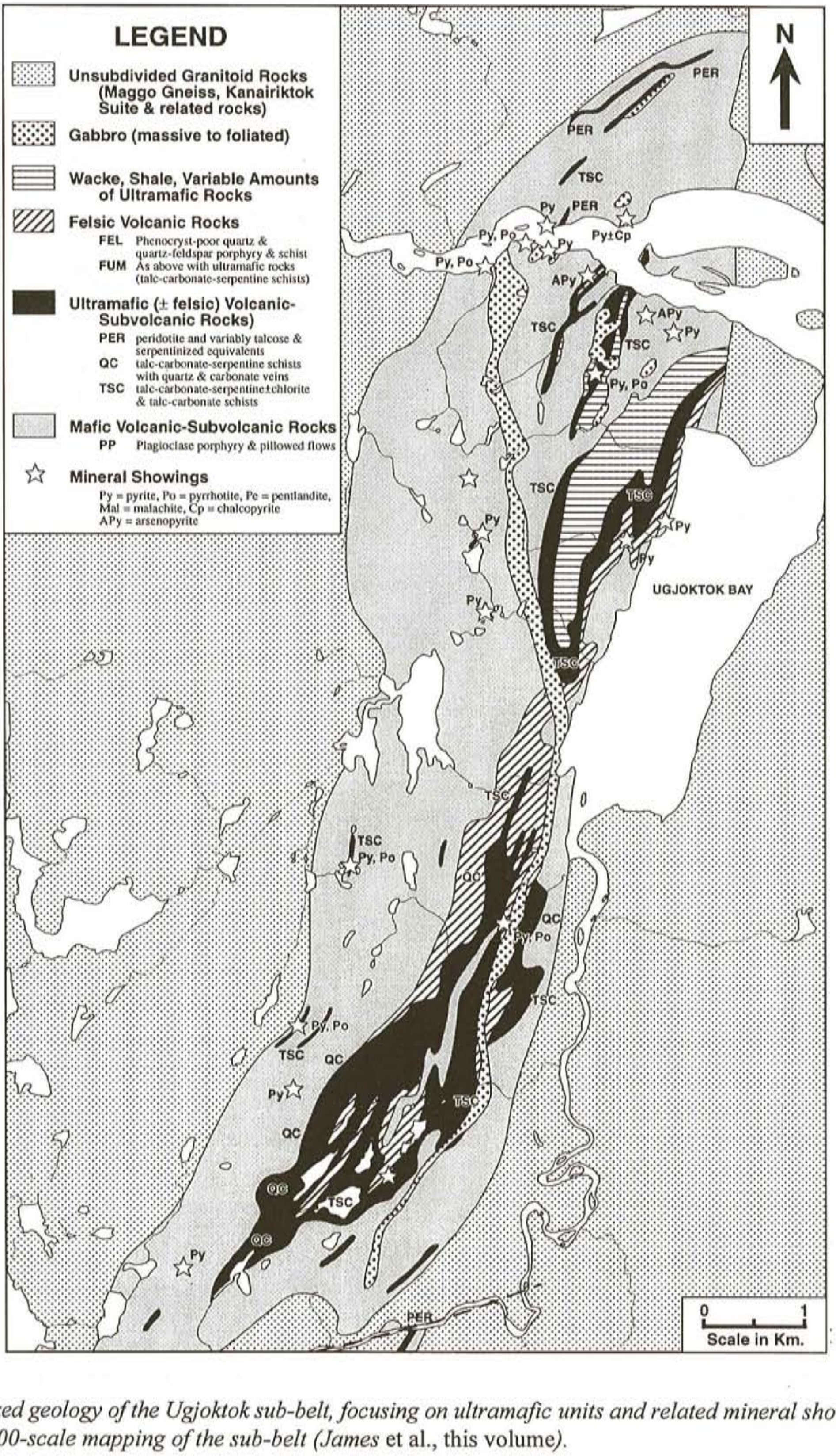

Figure 5. *Generalized geology of the Ugjoktok sub-belt, focusing on ultramafic units and related mineral showings. This sketch summarizes 1:25 000-scale mapping of the sub-belt (James* et al., this volume*).*

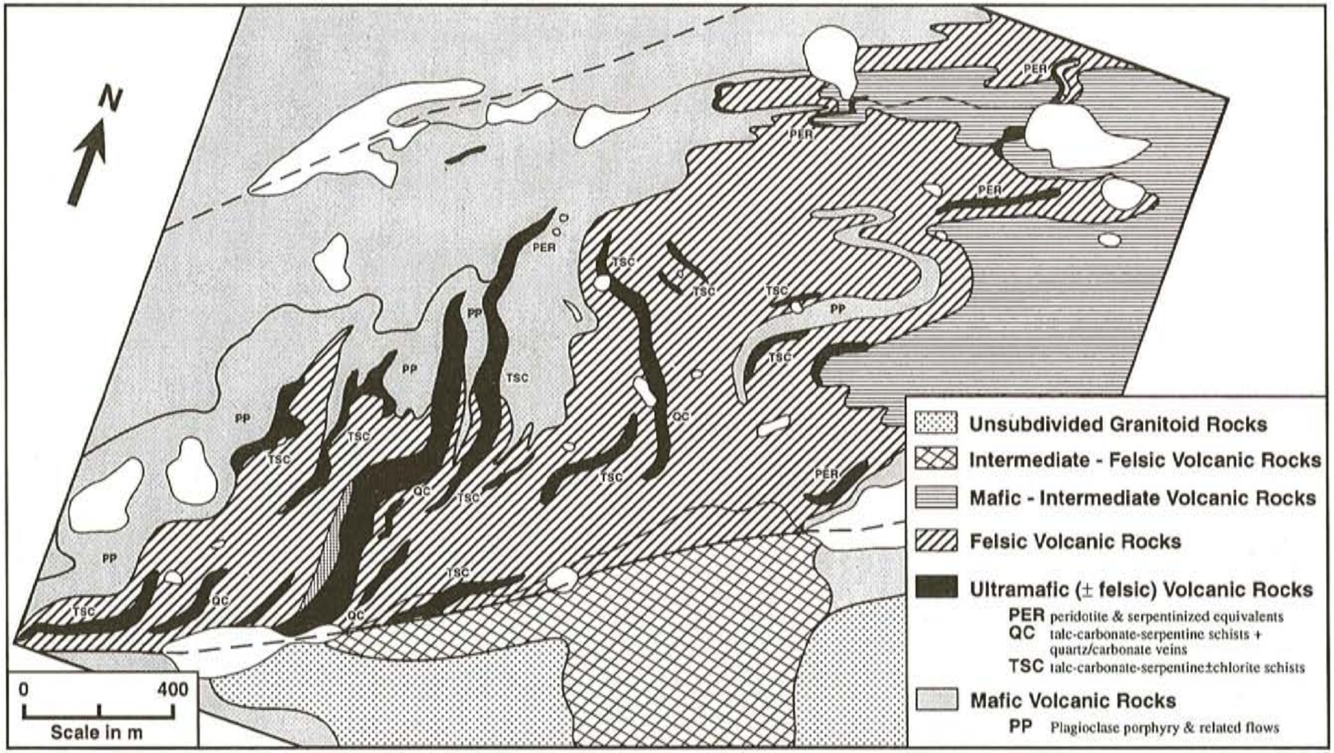

Figure 6. *Detailed geology of a portion of the Knee Lake sub-belt, focusing on the intimate relationships among ultramafic, felsic and mafic units in the study area. See Figure 4 for the location of this area. This sketch summarizes 1:10 000-scale and outcrop-scale mapping of this portion of the sub-belt (James* et al., this volume*).*

Lake greenstone belt. Locally, these sediments occur within felsic volcanic schists.

This type of mineralization normally displays very low Cu and Zn values. However, recent work in the Knee Lake area reveals mineralization with grab-sample values up to 6.7 percent Zn over a strike length of approximately 150 m (Tapestry Ventures Limited, press release, September 21, 1995). This mineralization occurs in chert – sulphide-bearing exhalative sediments associated with felsic volcanic rocks. Several other poorly explored showings of this type also occur in a similar stratigraphic position in the Knee Lake (Figure 4) and Ugjoktok (Figure 5) sub-belts.

ULTRAMAFIC VOLCANIC ROCKS

Ultramafic and related mafic rocks in the Florence Lake greenstone belt consist of a large number of stratabound rock types. Ultramafic rocks include: a) white to beige talc schist, b) blue-grey to light-green talc – serpentine ± chlorite schist, and, c) rusty-weathering brown to grey talc – magnesite schist. Related mafic (Mg-rich mafic? or komatiitic mafic?) rocks include: a) dark-green to grey plagioclase-phyric chlorite schist, b) dark-green to grey, very fine-grained chlorite – carbonate (calcite ± magnesite) schist, and, c) dark-green to grey chlorite ± serpentine schist. Units are commonly schistose, however, fine- to medium-grained massive units (metaperidotite?) are also found. In some localities, particularly where magnesite-rich units dominate, these rocks contain veins and pods of quartz or quartz and magnesite. These veins and pods range from less than 0.1 to 2 m thick.

Sericite and quartz-porphyritic sericite schists commonly occur with ultramafic rocks in the study area. In some sub-belts (e.g., Baikie; Figure 3), mappable felsic units are absent or exhibit limited distribution, however, thin, unmappable, felsic units or small lenses (less than 5 m thick) are commonly present. Felsic units host or occur with ultramafic units in the Ugjoktok (Figure 5) and Knee Lake (Figure 6) sub-belts.

Ultramafic – mafic bands, containing one or more of the units described above, range from 1 to 1300 m thick, but most are less than 25 m thick. The Baikie sub-belt contains at least five ultramafic – mafic belts that range from 1 to 25 m thick, with rare thicker zones (structurally thickened(?); see James *et al., this volume*). The main ultramafic band in the eastern portion of the Knee Lake sub-belt ranges from 50 to 350 m thick and mainly consists of fine- to medium-grained metaperidotite, with thin (<10 m) flanking talc – serpentine ultramafic and plagioclase-phyric mafic schists. Ultramafic units in the Ugjoktok sub-belt form a large podiform zone up to 1.3 km wide and 6 km long. Contrast these with the small

Table 1. Summary of previous assessment and metallogenic studies in the Florence Lake area

Year	Company/Agency	Author	Report No.	Type of Work	Comments
1959	Brinex	Wilson, 1959	LAB (219)	Airborne mag. and EM survey	777 sq. km by Lundberg Exp. Ltd. on parts of belt
1960	Brinex and Asbestos Corp.	Piloski *et al.*, 1960	LAB (333)	Prospecting, trenching and geological mapping	Baikie prospect; Ni, Cu and asbestos showings
1961-1963	Brinex and Asbestos Corp.	Piloski, 1962, 1963	13K/15(063) 13K/15 (082)	Ground mag. mapping and 6 packsack DDH	Ni – Cu showing at Baikie prospect
1963	Cliffs of Canada, and Brinex	Sutton, 1963 Bondar, 1963 Earthrowl, 1964	13K/15(062) 13K/15 (067) 13K(061)	Stream sediment geochem. and prospecting Geochemistry and prospecting	Ni, Cu, Mo, and Zn analyzed Final report
1970-1971	Brinex	Sutton, 1970, 1971	13K/15 (84)	Geological mapping	1:24 000 maps of Baikie area and south of Ugjoktok Bay; Ni, Cu
			13N/2 (21)	Geological mapping	1:24 000 maps of Baikie area and south of Ugjoktok Bay; Ni, Cu
1978-1982	GSC	Ermanovics, 1993	—	Geological mapping	1:100 000 and 1:50 000 maps of Florence Lake belt
1982-1983	BP Minerals-Billiton Canada	Stewart *et al.*, 1983	LAB (704)	Airborne mag. and VLF-EM Follow-up mapping and Prospecting	2000 line-km airborne survey; Baikie, Knee Lake, Schist Lakes, Ugjoktok and Adlatok sub-belts; lithogeochemistry; Cu, Ag
1987	Platinum Exploration Canada Inc.	Wilton, 1987	13K/15(174)	Lithogeochemistry	Significant platinum group element values: 497 ppb Pt and 1020 ppb Pd.
1990	Memorial University	Brace, 1990	—	Lithogeochemistry and petrography	Study of mineralization in the Florence Lake Group; M.Sc. Thesis
1991	Noranda	Dessureault, 1991	13K/15 (179)	Lithogeochemistry and prospecting	56 rocks sample: Cu, Ag
1990-1991	Falconbridge	McLean, 1991	13K/15 (182)	Lithogeochemistry, mapping and ground magnetic surveys	Knee Lake and Florence Lake areas; 1:10 000, 1:5000 mapping; Ni exploration
1992	Falconbridge	McLean *et al.*, 1992	13K/15(189)	Lithogeochemistry, mapping, geophysical surveys and DDH	1:5 000 mapping; 12 DDH (1634 m); airborne VLF; ground VLF, Mag IP, maxmin and TEM surveys; Baikie sub-belt; Ni, Cu
1992	Falconbridge	McLean, 1992	13N/2(45)	Lithogeochemistry, mapping and prospecting	Ugjoktok and Adlatok sub-belts; Ni, Cu
1993	Falconbridge	McLean, 1993	13N/2(48)	Lithogeochemistry, mapping and prospecting	Ugjoktok and Adlatok sub-belts; Ni, Cu
1993	Falconbridge	McLean and Butler, 1993	13K/15(200)	Lithogeochemistry, mapping, DDH and ground geophysics	23 DDH (3145 m); Mag/VLF, HLEM and TEM ground geophysics; 1:5 000 mapping; Baikie (DDH) and Schist Lakes sub-belts; Ni, Cu
1995	Tapestry Ventures Limited	News release	—	mapping, prospecting, trenching and lithogeochemistry	Knee Lake sub-belt (Seahorse Lake); Ni, Cu, Zn
1996	NDNR	Miller, *this report*	—	mapping and lithogeochemistry	1:10 000 and 1:25 000 mapping; Baikie, Knee Lake, Schist Lakes, Ugjoktok and Adlatok sub-belts
		James *et al.*, *this volume*	—	mapping and lithogeochemistry	

NDNR – Newfoundland Department of Natural Resources GSC – Geological Survey of Canada DDH – Diamond-drill hole ultramafic units, hosted by felsic volcanic rocks, north of Knee Lake (Figure 6) that range from 1 to 30 m wide and less than 100 to 1300 m long. Structurally controlled thickening and disaggregation of ultramafic bands may account for the variable lengths and widths of these bands (James *et al., this volume*).

ORIGIN OF ULTRAMAFIC ROCKS AND RELATED MINERALIZATION

Reviews of stratabound Ni – Cu mineralization hosted in ultramafic rocks (e.g., Lesher, 1989) indicate that most known deposits occur in ultramafic sills and ultramafic volcanic rocks. Brace and Wilton (1990) suggest that most of the ultramafic rocks in the Florence Lake greenstone belt are intrusive sill-like bodies. Thus, they conclude that the Ni – Cu mineralization is syngenetic and related to intrusion of ultramafic bodies (i.e., intrusive dunite model of Marston *et al.,* 1981). However, recent studies (e.g., Hill *et al.,* 1995) reinterpret the intrusive dunite model as volcanic-hosted cumulate-rocks formed in lava channels and lava lakes.

The following characteristics observed in the Florence Lake greenstone belt suggest a volcanic origin (see Arndt *et al.,* 1977; Lesher, 1989): a) occurrences commonly contain two or more ultramafic and related mafic rock types, and commonly more than one unit of each; b) occurrences are usually less than 100 m thick, with most being less than 25 m thick; c) graphitic – sulphidic – cherty, siliceous or sulphidic – pelitic sediments are interbedded with ultramafic rocks at most occurrences; d) individual ultramafic packages are up to 8 km long; e) at one locality, massive carbonate – talc fragments occur in sericite – magnesite schist; f) unpublished geochemical data (R.R. Miller) indicate that precursor units were peridotitic rather than dunitic (McLean, 1992); g) both small- and large-scale crosscutting features are absent (i.e., units are stratabound and strataform); h) many talc-rich schists exhibit blocky weathering patterns identified as polyhedral jointing, indicative of quick cooling of ultramafic flow tops and bottoms (Arndt *et al.,* 1977); and, i) rare spinifex texture, characteristic of ultramafic flows (Arndt *et al.,* 1977), occurs in some ultramafic rocks (McLean and Butler, 1993). In addition, some sediments (e.g., magnesite – sericite – quartz schists) that are interbedded with ultramafic schists contain high magnesium concentrations suggesting local derivation, in part, from adjacent ultramafic volcanic units.

Some problematic ultramafic units in the Florence Lake greenstone belt, having few or none of the characteristics listed above, were thought to be intrusive sills and dykes (Miller, 1995) similar to those postulated in the Kambalda region (Marston *et al.,* 1981). However, careful studies of textural, volcanological and geochemical relationships indicate that the Kambalda-type sills are really volcanic flows (e.g., Donaldson *et al.,* 1995; Lesher and Arndt, 1995; Hill *et al.,* 1995). These new studies indicate that thick units (> 300 m) of medium- to coarse-grained massive peridotite and dunite, associated with komatiitic flows, represent the lava channel or lava lake portions of a volcanic lava field. Similarly, thick ultramafic units in the Florence Lake greenstone belt (e.g., the large unit east of Knee Lake; Figure 4) probably represent lava channels or lakes. Thin lava flows, peripheral to these thick units, probably represent channel overflow units.

Most ultramafic units and composite bands in the Florence Lake greenstone belt probably represent lava channel overflow units or sheet-flow units (i.e., lava flows with few or no channels; Thompson, 1989; Lesher and Arndt, 1995). Units of this type are commonly thin, massive flows that rarely exhibit narrow spinifex-textured zones (Thompson, 1989). They represent units crystallized from moving, relatively undifferentiated or immature, lava flows (Thompson, 1989; Hill *et al.,* 1995). In the Kambalda region, this flow type occurs in both distal and proximal locations, relative to the volcanic centre, on the banks of feeder channels or in areas of sheet flow (Lesher and Arndt, 1995). In the Florence Lake greenstone belt, most of these units represent distal sheet-flow facies lavas because thicker channel flow facies units are sparse (Baikie sub-belt, Figure 3; northern part of the Knee Lake sub-belt, Figures 4 and 6). The presence of interbedded ultramafic flows and argillaceous – arenaceous sediments in the Ugjoktok sub-belt further suggest a distal environment.

The ultramafic volcanic rocks and associated Ni – Cu mineralization in the Florence Lake greenstone belt exhibit many of the characteristics of the Kambalda-type or peridotite-hosted model (Lesher, 1989; Lesher and Arndt, 1995). A major component of the Kambalda model is the occurrence of sulphidic – cherty and graphitic sediments that supply sulphur to the ultramafic Ni- and Cu-enriched magma to form the metal sulphides at the base of flows. Thermal erosion of underlying sulphidic sediments provides most of the sulphur for mineralization in the Kambalda region (Lesher and Campbell, 1993; Lesher and Arndt, 1995). Sulphide-bearing sediments, up to 5 m thick but commonly near 1 m thick, are widespread and closely associated with ultramafic rocks throughout the belt (Figures 3 to 6). However, these units commonly contain less than 10 percent sulphides and therefore commonly lack the substantial resources of sulphur necessary to produce large Ni – Cu deposits. The occurrence of the three most significant Ni – Cu showings in the Florence Lake greenstone belt in the Baikie sub-belt suggests that stratigraphically lower sulphidic sediment units contained more sulphur than in other areas. The sulphidic sediments are commonly cherty exhalative units associated with felsic volcanic rocks. The association of underlying sulphidic sediments, underlying or interbedded felsic volcanic rocks and ultramafic rocks is widespread in the Kambalda region (e.g., Barnes *et al.,* 1995); a similar association is common in the Florence Lake area. Hannington (1996) suggests that this association occurs in areas where hot ultramafic lava partially melts host mafic volcanic rocks to produce contemporaneous felsic and ultramafic flows.

Perring *et al.* (1995) suggest that flow thickness may be controlled by the amount of thermal erosion and the refractory nature of the underlying unit. Thus, basaltic flows, being more refractory, resist thermal erosion resulting in thin ultramafic lavas, and rhyolites, being less refractory, more easily erode resulting in thicker ultramafic units. However, the structural complexity observed may make it difficult to correlate the Florence Lake ultramafic units with models developed elsewhere.

CONCLUSIONS

Abundant field observations and mapping data indicate that ultramafic units in the Florence Lake greenstone belt represent ultramafic flows that are similar to those in the Kambalda region.

Following the Kambalda model, the best places to explore for komatiitic-hosted Ni – Cu mineralization are at the base of flow channels that eroded underlying units bearing substantial quantities of sulphidic sediments (e.g., Lesher, 1989). In the Florence Lake greenstone belt, the best Ni – Cu showings occur in relatively thin, distal, sheet flow units with associated thin sulphidic sediments. Thus, flow thickness and location may have some bearing on the quantity of mineralization but not on its presence. The thick ultramafic unit in the southern part of the Knee Lake sub-belt (Figure 4) and perhaps the thick band of composite units in the Ugjoktok sub-belt are better targets for larger Ni – Cu showings.

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