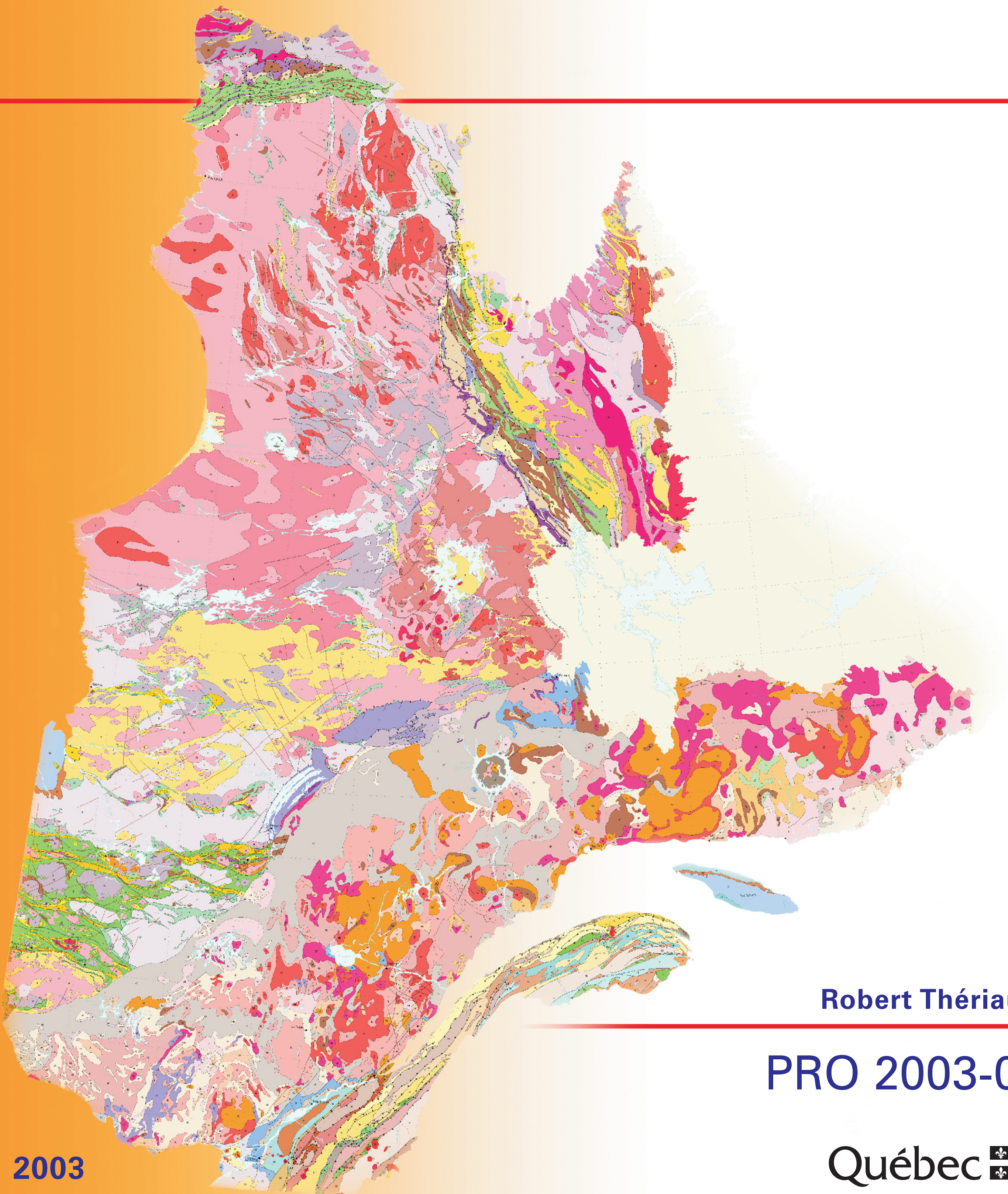
Ultramafic rocks in the Rivière Arnaud area, Ungava Peninsula : A new target for diamond exploration ?



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INTRODUCTION

The discovery of two diamond-bearing kimberlites in the Monts Otish area by the SOQUEM-Ashton Mining joint venture in December 2001, triggered a veritable frenzy for diamond exploration in Northern Québec. Thus, many other areas of interest are currently being investigated for diamonds in Québec, such as the Mistassini, Wemindji, Nottaway, Matagami, Témiscamingue, Caniapiscau, Bienville, Aigneau and Monts Torngat areas.

Geological mapping at 1:250,000 scale, conducted by the Ministère des Ressources naturelles in the summer of 2000 in the Lac du Pélican area (NTS 34P; Cadieux ***et al.***, 2002), identified ultramafic rocks possibly related to alkaline, even kimberlitic, rocks. In order to test this hypothesis, electron microprobe analyses were carried out over the past few months, in order to identify minerals with interesting chemical compositions.

The purpose of this document is to describe the ultramafic rocks observed in the Rivière Arnaud area, and to outline the promising potential of this area for diamond exploration.

REGIONAL SETTING

The study area is located in the northeastern corner of NTS sheet 34P (map sheet 34P/16), nearly 300 km from Povungnituk and Kuujjuaq (site #1 in figure 1). The area shows a relatively flat landscape cut by the Rivière Arnaud, which is located about 6 km north of the main discovery site.

The geology of the Lac du Pélican area (NTS 34P) consists of felsic intrusive suites, mainly tonalites, granites, granodiorites and orthopyroxene-bearing granitoids, with scattered remnants of volcano-sedimentary supracrustal rocks and minor amounts of mafic to ultramafic intrusive rocks (Cadieux ***et al.***, 2002). These Archean rocks are cut by two Paleoproterozoic diabase dyke swarms, namely the Klotz dyke swarm (Madore ***et al.***, 1999), with a U-Pb age of 2209±1 Ma (Buchan ***et al.***, 1998), and the Payne River dyke swarm (Madore ***et al.***, 1999), with an estimated age of emplacement slightly older than 2000 Ma (Fahrig ***et al.***, 1985). In the Lac du Pélican area, Klotz dykes and Payne River dykes are respectively oriented NW-SE and WNW-ESE.

As shown on the lithotectonic map of the northeastern Superior Province (figure 1A), as well as on the shaded total residual magnetic field map next to it (figure 1B), ultramafic rocks of the Rivière Arnaud area occur along the junction of two major lithotectonic domains, the Lepelle and Douglas Harbour domains. This boundary appears to correspond to a major lineament that can be traced for a minimum of 400 km (see Hocq, 1994; figure 1A), on both aeromagnetic (Dion and Lefebvre, 2000) and gravity (Geological Survey of Canada, 1994) maps. Relatively sharp contrasts are also observed on either side of this lineament, with regards to U-Pb ages and Sm-Nd isotopic compositions of lithological units, as well as the chemical composition of lake sediments (A. Leclair, personal communication). Furthermore, the boundary between the two domains is characterized by the very common presence of rocks exhibiting well-developed mylonitic textures. All these observations suggest that the Lepelle and Douglas Harbour domains represent terranes with quite distinct origins and geological histories. The lineament that separates the two domains has been named the Lestage-Messin lineament (Labbé, 2001; figure 1). Labbé (2001) interprets the extension of the lineament southward for more than 700 km, based on aeromagnetic maps. One of the interesting features of this lineament is the presence of numerous alkaline intrusions in the northern segment, namely the Briscot and Des Ombles nepheline syenites (see sites #2 and #3 respectively in figure 1) (Madore ***et al.***, 2000), as well as a carbonate unit strongly enriched in rare earth elements within the Kimber belt (see site #4 in figure 1) (Madore ***et al.***, 2001), which may very likely turn out to be a carbonatite (Labbé and Lacoste, 2002). Furthermore, along the inferred southern extension of this lineament (see Labbé, 2001; figure 1), abundant lamprophyre and carbonatite dykes are reported in the Lac Aigneau area (Berclaz ***et al.***, 2001; Lemieux ***et al.***, 2001), within the Utsalik Domain, whereas nepheline syenite intrusions of the Niaux Suite were mapped in the vicinity of the Réservoir Caniapiscau, bordering the Ashuanipi Complex (Thériault and Chevé, 2001). In fact, diamond exploration is

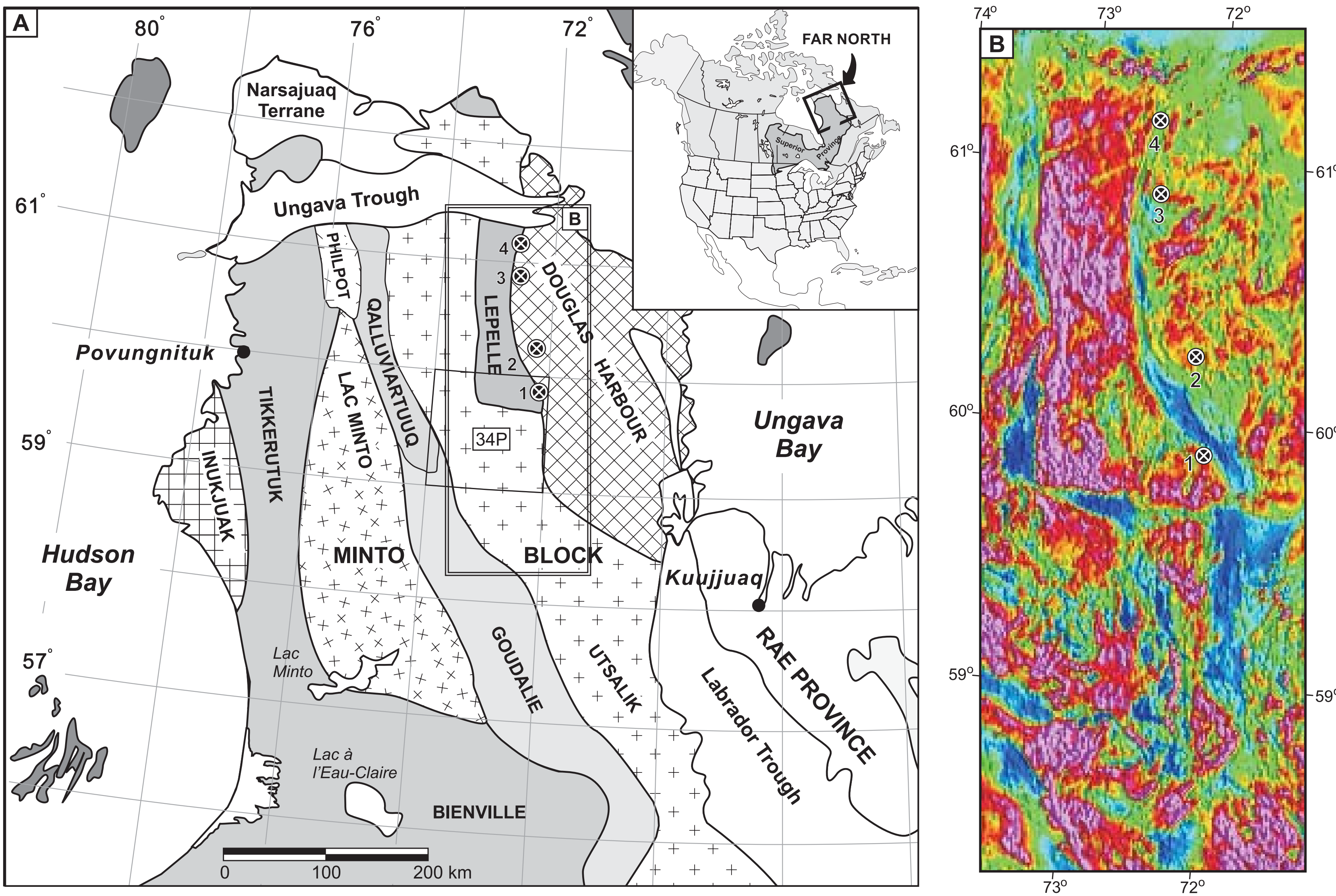

FIGURE 1 - A) Lithotectonic subdivision of the northeastern Superior Province (Québec's Far North) (modified from Percival ***et al.,*** 1997) and location of potentially diamond-bearing intrusive rocks near the contact between the Lepelle and Douglas Harbour domains; 1 = this study (see figures 2 and 3), 2 = Briscot syenite (Madore ***et al.***, 2000), 3 = Des Ombles syenite (Madore ***et al.,*** 2000), 4 = carbonatite (?) of the Kimber belt (Madore ***et al.,*** 2001); **B)** Shaded total residual magnetic field map showing the location of the four areas of interest listed above (aeromagnetic data derived from Dion and Lefebvre, 2000).

currently underway in the last two sectors. Note that the southern limit of the Lestage-Messin lineament, in addition to being associated with the Niaux syenites, crosses the eastern part of the Wemindji-Caniapiscau corridor, one of the main target areas identified by Moorhead ***et al.*** (1999) for diamond exploration in Québec. The presence of numerous alkaline intrusions distributed along this major regional lineament indicates it could very well correspond to a deep crustal structure; this type of structure may have facilitated the rapid transfer of mantle-derived magma into the Earth's crust.

Janse (1993) suggested that the average distance separating major kimberlite fields worldwide is on the order of 400 km. As for kimberlite fields in the Canadian Shield, this distance is roughly estimated at 470 km (Moorhead ***et al.***, 1999; Moorhead ***et al.***, 2000). It is interesting to note that ultramafic rocks in the Lac Arnaud area are located about 420 km NNE of the Lac Bienville target area proposed by Moorhead ***et al.*** (1999), the same location where chrome-rich picroilmenite was discovered in esker sediments (Parent ***et al.***, 2002).

LOCAL CIRCULAR STRUCTURES AND LINEAMENTS

Ultramafic rocks in the study area are not deformed, and mainly consist of phlogopite-calcite-unite, with minor amounts of lherzolite and harzburgite. These rocks scarcely outcrop, and apart from a thin (15 cm) dunite dyke observed in outcrop, they generally occur as sub-angular blocks up to one metre in size. The apparent distribution of these blocks along a brittle structure over a minimal distance of 2 km suggests the blocks underwent a very short glacial transport, and are probably derived from one or several dykes emplaced along this structure. In this sector, the country rocks consist of strongly mylonitized tonalite, accompanied by thin bands of amphibolitized mafic to ultramafic rocks. The intense deformation observed in the country rocks sharply contrasts with the massive texture typically observed in the ultramafic blocks.

Three high-potential zones were delineated in the study area (see insets A-1, A-2 and A-3 in figure 2). These zones correspond to areas where circular to elliptical shapes were interpreted from aerial photographs. These morphologies appear to be related to the distribution of units in the bedrock, and are not typical of landforms inherited from the passage of the last continental ice sheet (G. Martineau, personal communication). Sample location #1 (inset A-1, figure 2; table 1), which is the discovery site, is marked by the presence of many (10 to 15) sub-angular dunite blocks located along the north shore of a small elliptical lake roughly 150 x 250 m in size (figure 3A). The blocks are m-scale, and broadly appear to be aligned along a N-S orientation, over a distance of about 30-40 metres. The small lake itself is located along the eastern margin of a larger circular shape, measuring about 600 x 600 m. The latter is quite obvious on aerial photo-graphs, and is characterized by a raised border similar to a crater, mainly along the eastern margin. It is also cut by a major brittle structure oriented N-S, which may represent the site of emplacement of an ultramafic dyke. Very little work has been conducted in this area, such that it is currently impossible to confirm this hypothesis at this time. It is also possible that the dunite blocks are derived from an elliptical intrusion located directly beneath the small lake. Note that the lake appears to be relatively deep compared to surrounding lakes, given its very dark shade on aerial photographs. A larger (1000 x 1300 m), somewhat diffuse, elliptical structure surrounds the two previously described elements. Its northwestern shoreline appears to overlap with a circular positive magnetic anomaly (figure 2B).

The elliptical structure shown in inset A-2 (figure 2A) measures 300 x 500 m, and is delineated by a series of small elliptical to irregularly-shaped lakes. Its centre is also

TABLE 1 - Location and description of sample sites.

Site no.	NTS	Easting[1]	Northing	Outcrop no.	Comments
1	34 P/16	660830	6642000	RT-00-7118	Main discovery site; numerous dunite blocks located along the north shore of a small sub-circular lake (figures 2, 3A-C, 4 and 5; tables 2 and 3)
2	34 P/16	660980	6640040	RT-00-7283	Outcrop (and several blocks) of dunite located on the eastern shore of a small lake oriented along a lineament trending NNW-SSE (figures 2, 3D-E and 4; table 2)
3	34 P/16	661150	6639750	RT-00-7284	Block of tonalitic intrusive breccia (± blocks of dunite) located on the eastern shore of a lake oriented E-W (figures 2, 3F and 4)
4	34 P/16	663870	6641650	1997054856[2]	Sample derived from the lake sediment survey conducted by the MRN in 1997 (figure 2)
5[3]	34 P/16	655000	6632900	GM-00-4178	Blocks of serpentinite located near the southeastern shore of a lake oriented E-W (figure 4; table 2)

[1] UTM coordinates are in NAD 27

[2] SGDAC analysis number (MRN, 1998)

[3] This site is located roughly 9 km SW of site #3 (Berclaz *et al*., 2000)

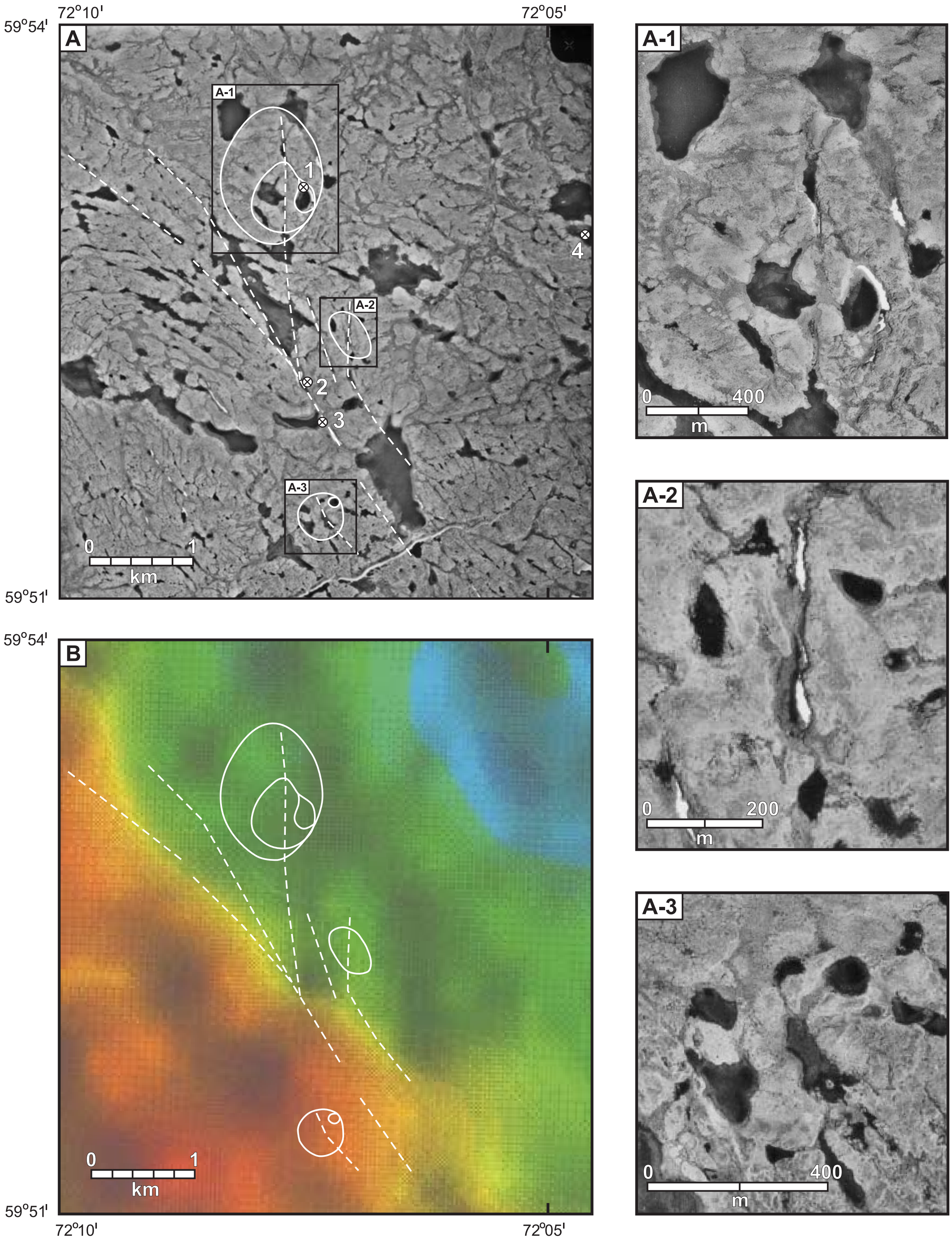

FIGURE 2 - A) Aerial photograph of the study area, showing the location of circular structures (insets A-1, A-2 and A-3), and lineaments (white dashed lines); sample locations #1, #2, #3 and #4 are described in table 2; **B)** Shaded total residual magnetic field map, with the location of circular structures and lineaments (aeromagnetic data derived from Dion and Lefebvre, 2000).

FIGURE 3 - A) Small sub-circular lake, where phlogopite-bearing dunite blocks were found along the shoreline (site #1; figure 2A), looking south; **B)** Dunite sample (weathered surface) site #1, note the presence of numerous irregular serpentine+magnetite veins; **C)** Dunite sample (fresh surface), site #1; **D)** Small (15 cm) dunite dyke intruding a mylonitic tonalite (site #2; figure 2A), the hammer points roughly east; **E)** Dunite block containing numerous calcite veins (site #2); **F)** Block of tonalitic intrusive breccia hosting numerous xenoliths of mylonitic tonalite (identical to country rock) and mafic to ultramafic rock (site #3; figure 2A).

transected by a N-S trending lineament. As described above, the small lakes surrounding this elliptical structure are characterized by a relatively dark shade on aerial photographs. Inset A-3 (figure 2A), located in the southern part of the study area, shows the location of a circular structure that measures 450 x 450 m. A lineament oriented NW-SE, more or less developed, runs across the centre of the circular shape. A small round lake about 75 to 100 m in diameter is located along the northeastern margin of the circular structure. The centre of this lake is black on the aerial photograph, which suggests it is also probably deep.

DESCRIPTION OF SAMPLE LOCATIONS

Massive dunite blocks from sample location #1 (figure 2A; table 1) show orange weathered surfaces, and contain 1 to 2 % phlogopite phenocrysts locally reaching up to 3 cm in size. The dunite is composed of olivine microphenocrysts (1 to 5 mm), partially altered to serpentine ± iddingsite, with minor amounts of chrome magnetite, chrome spinel, phlogopite (partially altered to vermiculite), calcite and chrome hornblende. Spinel exclusively appears as small inclusions or exsolutions in the magnetite. The rock is cut by numerous whitish veins (3 to 10 mm) of serpentine-magnetite, randomly oriented and mutually cross-cutting (figures 3B and 3C). The orange-coloured groundmass as well as the whitish veins are both cross-cut by thin (1 to 2 mm) calcite veinlets. The latter mineral also occurs as interstitial pods in the dunite groundmass.

Sample location #2 (figure 2A; table 1), located about 2 km south of site #1, is located along the eastern shore of a small lake characterized by a shape elongated towards the northwest, which coincides with a major lineament. At this location, a thin (15 cm) dunite dyke directed roughly towards the northeast cross-cuts the tonalitic country rocks (figure 3D). This dyke possibly represents an apophysis from a larger dyke, which could be associated with the dominant NW-SE lineament in the area (figure 2). About thirty blocks of massive dunite (± lherzolite and harzburgite) were also identified; they represent an important proportion of the block population in this area. The blocks are essentially composed of 85 to 95 % strongly serpentinized olivine crystals (1 to 3 mm), with minor amounts of clinopyroxene, orthopyroxene and/or hornblende. Very fine-grained disseminated green spinel (hercynite?) crystals are ubiquitous, and form 1 to 2 % of the rock. Vermiculite is also observed locally; it probably represents an alteration product of phlogopite. In certain blocks, numerous calcite veins cross-cut the ultramafic rock (figure 3E).

Sample location #3 (figure 2A; table 1) is located about 400 metres southeast of site #2, along the eastern shore of an E-W trending elongate lake. In this location, a sub-angular block (1 x 1 m) of tonalitic intrusive breccia was found, along with a few blocks of dunite. The breccia is composed of about 25 % sub-rounded enclaves of massive mafic gabbro, massive peridotite and mylonitic tonalite, set in a matrix of recrystallized tonalite (figure 3F). Thin calcite veinlets cut the tonalitic breccia. This rock is interpreted as the result of the brecciation of mylonitic tonalitic country rock, following the injection of and mixing with a fluid-rich ultramafic magma. Note that mylonitic tonalite enclaves are identical to the tonalitic country rock that outcrops about 10 metres east of the location where the block was found.

Site #4 (figure 2A; table 1), located approximately 3 km east of the main discovery site (site #1), is a lake sediment sample site visited by the MRN in 1997, within the scope of a vast sampling program covering the entire Far North region of Québec (MRN, 1998). Analytical results from this sample yielded very high values in Ce (225 ppm), Ba (196 ppm), Cr (63 ppm), Ni (318 ppm), Co (18 ppm) and Mg (1.41%), and represents one of the most important Ce-Ba-Cr anomalies detected by this geochemical survey (Moorhead ***et al.***, 2000). Note that this type of anomaly is typically observed near Lac de Gras kimberlites in the Northwest Territories (Kjarsgaard ***et al.***, 1992). A regional interpretation of ice flow trajectories in the Ungava Peninsula demonstrates that the eastern part of the peninsula was affected by at least three successive glacial movements, with respective flow directions estimated to be ESE, NNE and NE (Parent and Paradis, 1999). This indicates that the source of this geochemical anomaly could be derived from the ultramafic rocks under investigation, although the latter are relatively depleted in incompatible elements (see section entitled “Lithogeochemistry”).

Finally, sample location #5 (table 1), located about 9 km southwest of site #3, represents serpentinized dunite blocks containing thin calcite veinlets. Thin sections reveal that the olivine is completely transformed into serpentine. Thin oxide laminations are oriented parallel to calcite veinlets. It also appears to contain minor vermiculite and chlorite. These blocks are located in an area where the bedrock consists of mylonitic tonalite, with a few paragneiss and amphibolite bands.

LITHOGEOCHEMISTRY

A total of five ultramafic rock samples were analyzed for major and trace elements, and the results are shown in table 2. Samples 7118-B1 and 7118-B2, which correspond to the discovery site where phlogopite-bearing dunite blocks were found, are systematically enriched in MgO and depleted in TiO_2 and Al_2O_3 compared to the other samples. All the samples are depleted in incompatible elements, which contrasts with typical kimberlite compositions, which are generally strongly enriched in these elements. However, it is interesting to note that the composition of a few kimberlites from the Yakutian

TABLE 2 - Major and trace element composition of ultramafic rocks.

Sample no.	7118-B1	7118-B2	7283-B1	7283-B3	4178-D3
SGDAC no.	2000030226	2000030227	2000030277	2000030278	2000030261
SiO_2 (%)	39.80	38.20	38.30	37.80	39.60
TiO_2	0.07	0.07	0.17	0.16	0.18
Al_2O_3	1.12	1.07	2.81	2.69	4.60
Cr_2O_3	0.76	0.72	0.67	0.64	0.38
MgO	36.50	36.60	30.90	32.90	30.30
Fe_2O_3(tot)	10.90	12.70	14.60	10.90	13.80
CaO	0.12	0.04	1.58	1.72	2.80
MnO	0.13	0.14	0.18	0.15	0.14
Na_2O	<0.10	<0.10	<0,10	<0.10	0.12
K_2O	<0.01	0.02	0.01	<0.01	0.03
P_2O_5	<0.01	<0.01	<0.01	<0,01	<0.01
L.O.I.	10.70	10.40	11.20	13.20	8.57
Total	100.10	99.96	100.42	100.16	100.52
Ni (ppm)	1600	1600	1600	1800	930
Co	120	170	130	110	100
Ba	-----	63	5.7	-----	13.9
Rb	-----	1.72	1.71	-----	0.45
Th	-----	0.05	0.14	-----	0.06
Nb	-----	0.49	0.68	-----	0.41
Sr	-----	5.1	10.6	-----	14.4
Zr	-----	<6	10.0	-----	10.3
Hf	-----	0.16	0.32	-----	0.31
Y	-----	1.65	3.04	-----	4.63
La	-----	2.60	0.82	-----	0.80
Ce	-----	4.04	2.22	-----	1.70
Nd	-----	2.10	1.52	-----	1.12
Sm	-----	0.40	0.41	-----	0.38
Eu	-----	0.06	0.14	-----	0.10
Gd	-----	0.36	0.52	-----	0.55
Tb	-----	0.05	0.08	-----	0.11
Ho	-----	0.05	0.12	-----	0.17
Tm	-----	0.02	0.05	-----	0.08
Yb	-----	0.18	0.34	-----	0.55
Lu	-----	0.03	0.05	-----	0.08
Mg# [1]	0.84	0.82	0.77	0.83	0.78

[1] Mg# = MgO/(MgO+FeO(tot)) (mole %)

kimberlitic Province in Russia (Vasilenko ***et al.***, 2002) is very similar to that of ultramafic rocks from our study area, in terms of major elements, and more specifically concerning very low TiO_2, Al_2O_3, Na_2O, K_2O and P_2O_5 concentrations. Analyzed dunite samples are interpreted as being the product of partial melting of a mantle depleted in incompatible elements. Moreover, the origin of dunite xenoliths commonly encountered in kimberlites is attributed to partial melting of a harzburgitic source which is inferred to have undergone a previous episode of complete extraction of basaltic magma (Wilson, 1989).

The geochemical composition of ultramafic rocks in the Rivière Arnaud area and of the indicator minerals they contain (see section entitled "Microprobe Results") was compared with the composition of kimberlites, orangeites, lamproites and lamprophyres, on several discrimination diagrams shown below.

On an MgO-K_2O-Al_2O_3 ternary discrimination diagram (figure 4A), the five ultramafic rock samples plot in the kimberlite field, which at the very least suggests that they do not represent lamprophyre dykes.

The incompatible-element-depleted nature of ultramafic rocks relative to kimberlites is outlined on two chondrite-normalized diagrams (figures 4B and 4C). figure 4B shows that the pattern defined by three ultramafic rock samples forms a profile similar to that defined by kimberlites and orangeites, particularly sample 7118-B2. The latter exhibits negative Sr and K anomalies, and positive Ba, La, Ce and Nd anomalies, which are also present on kimberlite and orangeite patterns. On the rare earth discrimination diagram (figure 4C), samples 7283-B1 and 4178-D3 display a flat pattern and chondrite-normalized values ranging from 1 to 3, fairly typical of ultramafic rocks in general. However, the phlogopite-bearing dunite sample (7118-B2) is slightly

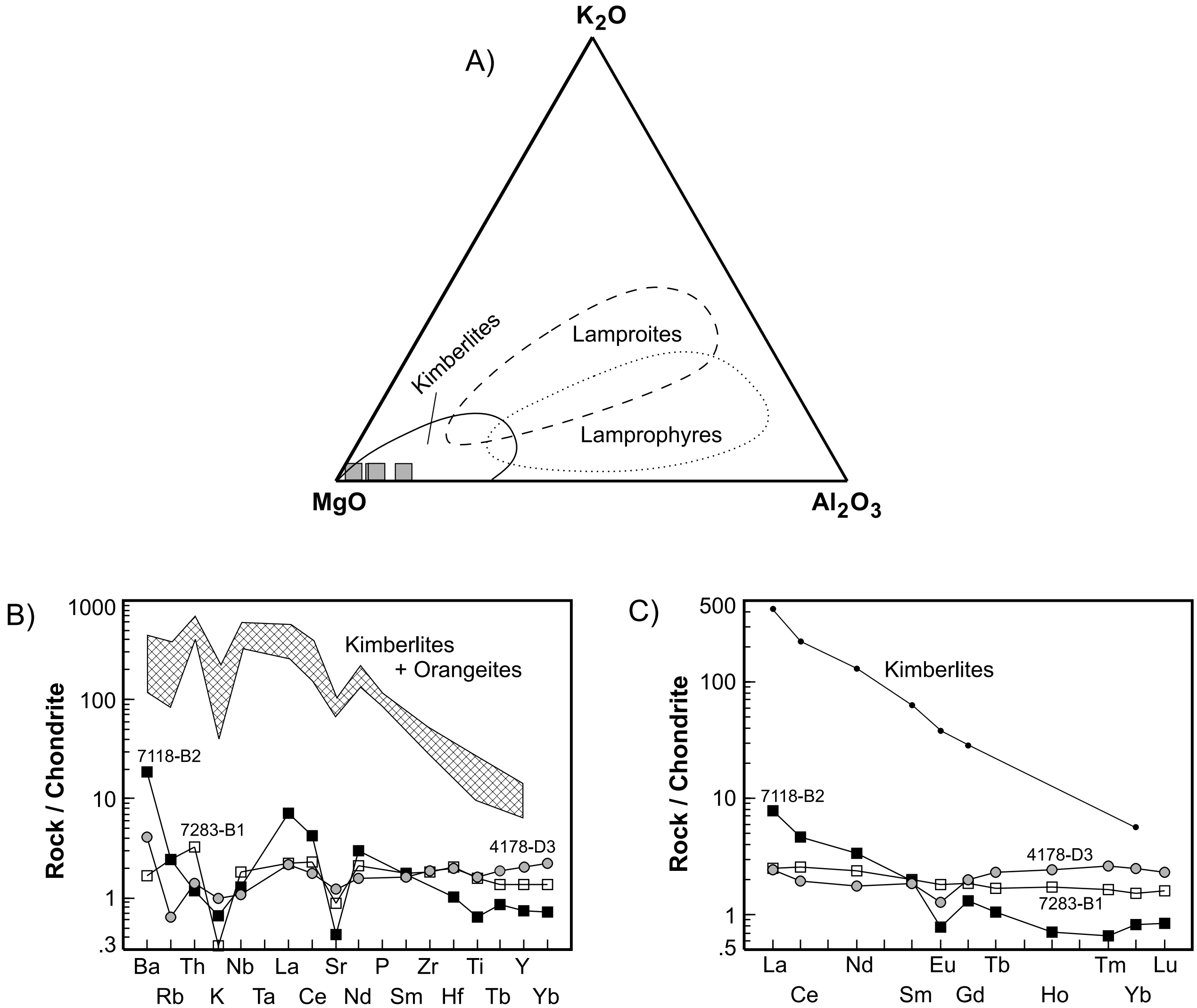

FIGURE 4 - A) Ternary MgO - K_2O - Al_2O_3 discrimination diagram showing the composition of ultramafic rocks analyzed in this study (grey squares) compared to kimberlites, lamproites and lamprophyres (fields taken from Bergman, 1987); **B)** Chondrite-normalized spiderdiagram (Thompson, 1982) for three dunite samples, with the average composition of kimberlites and orangeites (data taken from Smith ***et al.,*** 1985); **C)** Chondrite-normalized rare earth diagram (Nakamura, 1974) for three dunite samples, with the average composition of kimberlites (data taken from Bergman, 1987).

enriched in light rare earth elements, with chondrite-normalized values ranging from 0.7 to 8.0.

MICROPROBE RESULTS

A total of seven minerals were analyzed by electron microprobe, in a single thin section derived from sample 7118-B (table 3; figure 5). This sample was collected at sample location #1 (figure 2A), and represents a weakly altered phlogopite-bearing dunite cut by numerous randomly oriented serpentine-magnetite (±olivine) veins (see figures 3B and 3C).

Analyzed phlogopite crystals exhibit a strongly magnesian composition (Mg# = 0.93), and plot in the field of eastonitic phlogopites (figure 5A). This composition is identical to one of the two phlogopite varieties identified in the Lac Beaver kimberlite, in the Monts Otish area, and is also typical of kimberlitic phlogopites (Mitchell, 1995). Vermiculite analyses were plotted on the same Al-Mg-Fe (tot) ternary diagram; these show a gradual evolution towards more magnesian compositions (Mg# = 0.96) as a result of phlogopite alteration. The co-depletion in alumina and potassium of vermiculite relative to phlogopite is a common characteristic of kimberlites (Girard, 2001). On the binary diagram of Cr_2O_3 versus TiO_2 (figure 5B), analyzed phlogopites plot at the junction between primary phlogopites in lherzolites (or kimberlite-hosted xenoliths) and phlogopite megacrysts in kimberlites. Note that, although phlogopite megacrysts reaching 3 cm in size were identified in certain samples (ex. 7118-B2), crystals observed in the analyzed thin section were all relatively small, ranging

TABLE 3 - Average mineral compositions from electron microprobe analyses (sample 7118-B).

Mineral	Phlogopite	Olivine	Chrome spinel	Chrome magnetite	Serpentine	Vermiculite	Hornblende
n [1]	4	9	6	11	4	7	4
SiO_2 (%)	40.25	40.73	0.03	0.02	41.46	32.08	46.80
TiO_2	0.39	-----	0.14	0.96	-----	-----	0.39
Al_2O_3	15.63	0.01	29.49	2.13	0.68	10.20	10.23
Cr_2O_3	0.57	0.01	30.70	15.19	0.03	0.94	0.88
MgO	25.73	48.96	8.97	1.29	40.82	34.15	19.07
FeO	3.32	11.24	21.45	29.15	3.10	2.42	5.35
Fe_2O_3	-----	-----	7.95	51.01	-----	-----	-----
CaO	0.01	0.003	0.004	0.002	0.02	0.01	12.26
MnO	0.004	0.23	0.42	0.44	0.09	0.01	0.08
NiO	-----	0.29	-----	-----	0.14	0.11	-----
ZnO	-----	0.02	1.18	0.15	-----	-----	-----
Na_2O	0.04	-----	0.02	0.02	-----	-----	2.11
K_2O	8.00	-----	-----	-----	-----	-----	-----
H_2O	4.21	-----	-----	-----	12.66	20.00	2.00
Total	98.25	101.49	100.33	100.37	99.01	99.91	99.17
Mg# [2]	0.93	0.88	0.35	-----	0.96	0.96	0.80

[1] n = number of analyses

[2] Mg# = MgO/(MgO+FeO(tot)) (mole %)

from 0.5 to 1.5 mm. Compared to Lac Beaver phlogopites, those found in the Rivière Arnaud dunite are generally enriched in chrome (figure 5B). According to Girard (2001), the most reliable discrimination diagram to determine the composition of the parent magma from phlogopite compositions is the binary diagram Al_2O_3 versus TiO_2 (figure 5C). It shows distinct differentiation vectors for phlogopites associated with kimberlites, orangeites, lamproites and lamprophyres (alnoites and minettes), from a common primitive composition. Phlogopite analyses from the dunite are clustered near the vector that characterizes kimberlites, with relatively high Al_2O_3 values ranging from 14.8 to 16.5 %, and a low TiO_2 content from 0.34 to 0.43 %.

Analytical results from olivine microphenocrysts in the dunite are plotted on a binary diagram showing NiO (%) versus the forsterite content (molecular weight) (figure 5D). Olivine compositions show a wide range of NiO concentrations (from 0.24 to 0.33 %) for a relatively constant forsterite content (Fo = 88-90 mole %). This type of distribution is typical of olivine microphenocrysts found in the groundmass of the Peuyuk kimberlite in the Northwest Territories (Mitchell and Fritz, 1973) and of macrocryst boundaries in the Fayette County kimberlite in Pennsylvania (Hunter and Taylor, 1984). The latter analyses are interpreted as being the result of late overgrowths from the kimberlitic magma. The compositional range of olivine macrocryst cores from the Peuyuk and Fayette County kimberlites are also shown on figure 5D. These macrocryst analyses show a much greater variation in the forsterite content; this is interpreted as an indication that they represent xenoliths or phenocrysts derived from various regions of the mantle (Mitchell, 1986). The forsterite content of olivine microphenocrysts in the dunite is comparable to the composition of olivine macro- and microphenocrysts present in kimberlites throughout the world (figure 5E; Mitchell, 1995). The resemblance is even more striking when compared only with groundmass microphenocrysts in kimberlites, which show a forsterite content generally in the 87 to 89 mole % range (Mitchell, 1995).

Two types of oxides were analyzed in the dunite sample, namely chrome spinel and chrome magnetite. Compositions for these minerals are listed in table 3, and shown on the binary diagram $Cr_2O_3/(Cr_2O_3+Al_2O_3)$ versus FeO/(FeO+MgO) in figure 5F. This diagram is frequently used to identify kimberlitic spinels. Kimberlitic spinels typically plot along three distinct vectors, identified by Mitchell (1986); 1) the "AMC trend" (aluminous and magnesian chromites), 2) "trend 1" (magnesian ulvöspinel trend), and 3) "trend 2" (pleonaste reaction trend). Chrome spinel analyses from the dunite sample cluster about midway between trends 1 and 2, whereas chrome magnetite analyses plot outside of the three vectors. Although the chrome spinels do not appear to be typical of those found in kimberlites, their compositional range does however

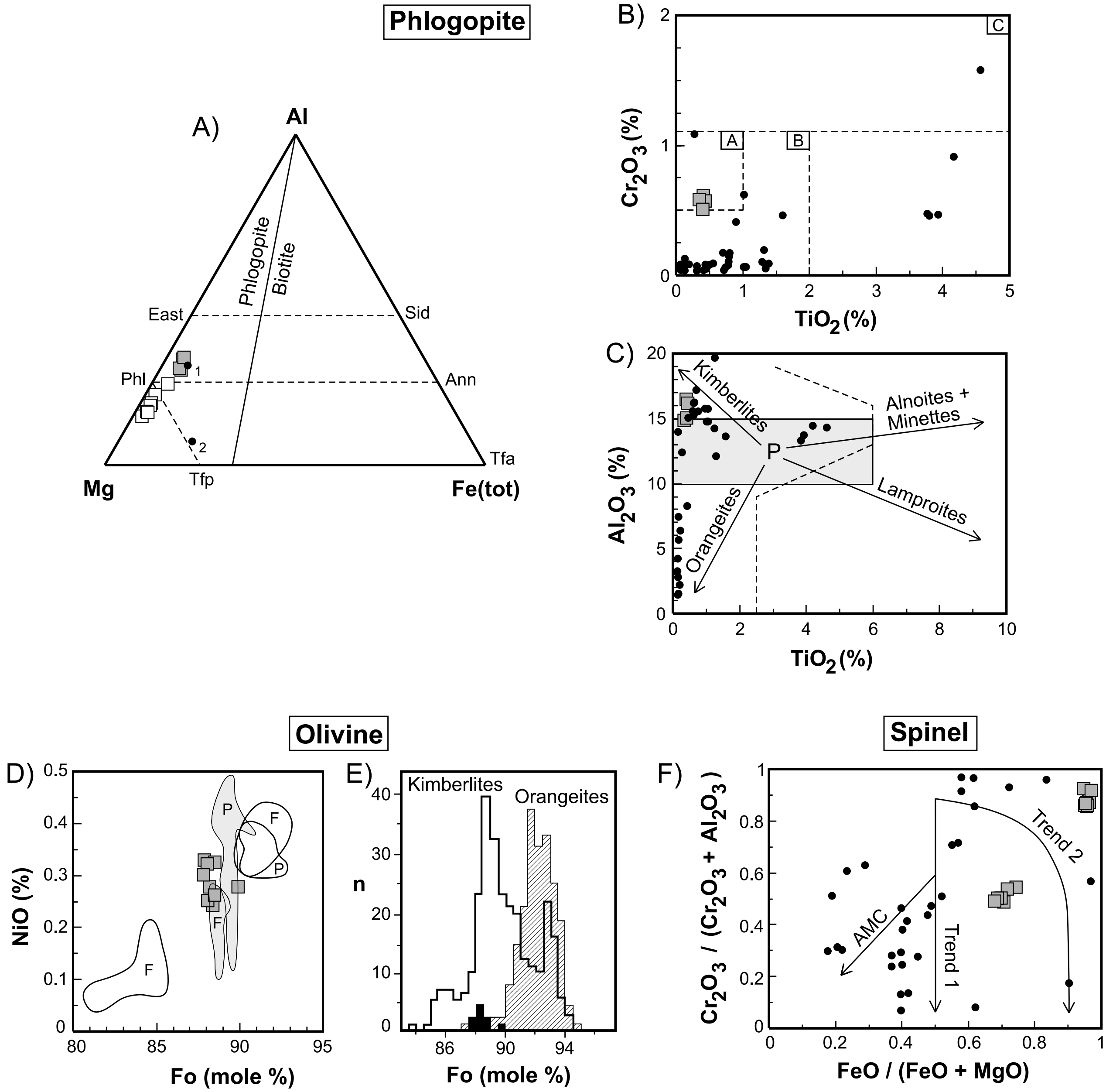

FIGURE 5 - A) Classification diagram for micas by Mitchell (1995) in the Al - Mg - Fe (tot) ternary system; grey and white squares respectively represent phlogopites and vermiculites analyzed in this study; the two black dots (1 and 2) respectively represent the average composition of phlogopites and tetraferriphlogopites at Lac Beaver, Monts Otish (Girard, 2001); note that in all diagrams in this figure, grey squares and black dots respectively represent analyses derived from this study and the Lac Beaver study; East = eastonite, Sid = siderophyllite, Phl = phlogopite, Ann = annite, Tfp = tetraferriphlogopite, Tfa = tetraferriannite; **B)** Cr_2O_3 versus TiO_2 discrimination diagram, A = primary phlogopite in lherzolites (or kimberlite xenoliths), B = phlogopite megacrysts in kimberlites, C = secondary phlogopite in lherzolites (or kimberlite xenoliths), (fields taken from Jago and Mitchell, 1985); **C)** Al_2O_3 versus TiO_2 discrimination diagram; the different magmatic trends evolve from the same field of primitive phlogopite compositions (P), the dashed line shows the boundary of the kimberlite and orangeite compositional field (Mitchell and Bergman, 1991) (modified from Mitchell, 1986; Girard, 2001); **D)** NiO versus Fo (molecular proportion of forsterite) binary diagram; F = Fayette County kimberlite (taken from Hunter and Taylor, 1984), P = Peuyuk kimberlite (taken from Mitchell and Fritz, 1973), grey fields represent analyses of olivine phenocrysts in the matrix (P) or of macrocryst borders (F), whereas white fields represent analyses of macrocryst cores; **E)** Histogram comparing the Fo content of olivine phenocrysts in kimberlites and orangeites throughout the world (modified from Mitchell, 1995); the black population represents the composition of olivines analyzed in this study; **F)** Projection of spinel analyses based on reduced and oxidized spinel prisms, with different compositional trends observed in kimberlites; AMC = trend of aluminous and magnesian chromites (modified from Girard, 2001).

form a vector parallel to that of aluminous and magnesian chromites. It is also interesting to note that spinels from the Lac Beaver kimberlite do not form very sharply defined vectors on this diagram either (Girard, 2001).

Chrome hornblende grains were also analysed in the dunite sample (see table 3). The hornblende contains between 0.85 and 0.91 % Cr_2O_3, and is relatively magnesian (Mg# = 0.80). The origin of this hornblende is uncertain: is it magmatic, or is it the result of the transformation of clinopyroxene? Although clinopyroxene was not observed in this thin section, it has been observed in a few other dunite samples (samples 7283-B1 and 7283-B3; table 2). More detailed work is therefore warranted in order to determine if these clinopyroxene grains represent chrome diopside.

CONCLUSIONS

Preliminary work carried out on ultramafic rock samples collected south of the Rivière Arnaud outlined several features indicative of the diamond potential of these rocks, namely:

1) The ultramafic rocks are associated with an important lineament that corresponds to the boundary between the Lepelle and Douglas Harbour lithotectonic domains, and along which several alkaline intrusions occur;

2) The ultramafic rocks are located about 420 km NNE of the Lac Bienville diamond potential target proposed by Moorhead ***et al.*** (1999); this distance corresponds to the average distance separating kimberlite fields throughout the world;

3) Several circular to elliptical structures and lakes were identified in the study area, as well as numerous lineaments, which overall show sub-parallel trends to the Lestage-Messin lineament;

4) The ultramafic rocks mainly consist of phlogopite-bearing dunite, cut by irregular serpentine-magnetite veins and calcite veinlets, suggesting a relatively explosive emplacement mechanism involving hydrothermal fluids; the discovery of a block of tonalitic intrusive breccia with numerous enclaves of mafic to ultramafic rocks, cut by calcite veinlets also suggests a similar process;

5) A sample of lake sediment, collected 3 km east of the main discovery site during a geochemistry survey conducted by the MRN in 1997, exhibits one of the strongest Ce-Ba-Cr anomalies in all of Québec's Far North;

6) Despite geochemical compositions relatively different from kimberlites in general, certain samples show similar trends on a few discrimination diagrams;

7) Microprobe analyses indicate that the ultramafic rocks contain minerals which, in certain cases, are compositionally very similar to those observed in kimberlites, particularly phlogopite and olivine.

Given their marked depletion in incompatible elements, and the fact that they are only very weakly alkaline, ultramafic rocks of the Rivière Arnaud area are not considered as members of the kimberlite family. However, the recent discovery of diamond-bearing lamprophyre dykes near Abloviak Fjord in the Monts Torngat area (Digonnet, 1997; Digonnet ***et al.***, 2000), in Campeau Township in the Témiscamingue region (Brack, 1996), at Lac de l'Astrée in the James Bay area (Dianor Resources, press release, May 2001), and in the Wawa area in Ontario (Sage, 2000), clearly demonstrates that other types of ultramafic rocks besides kimberlites, orangeites or lamproites can host diamonds (J. Moorhead, personal communication). Furthermore, considering the presence of phlogopite megacrysts, as well as the presence of certain minerals compositionally similar to kimberlitic minerals, additional work is recommended in this area, in order to fully assess the diamond potential of these ultramafic rocks. For example, sampling and caustic fusion analysis of phlogopite-bearing dunite blocks found at the main discovery site is strongly suggested, in order to determine their diamond content.

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