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KIMBERLITES AND DIAMOND IN NORTHERN QUEBEC

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Kimberlites and Diamonds in Northern Quebec

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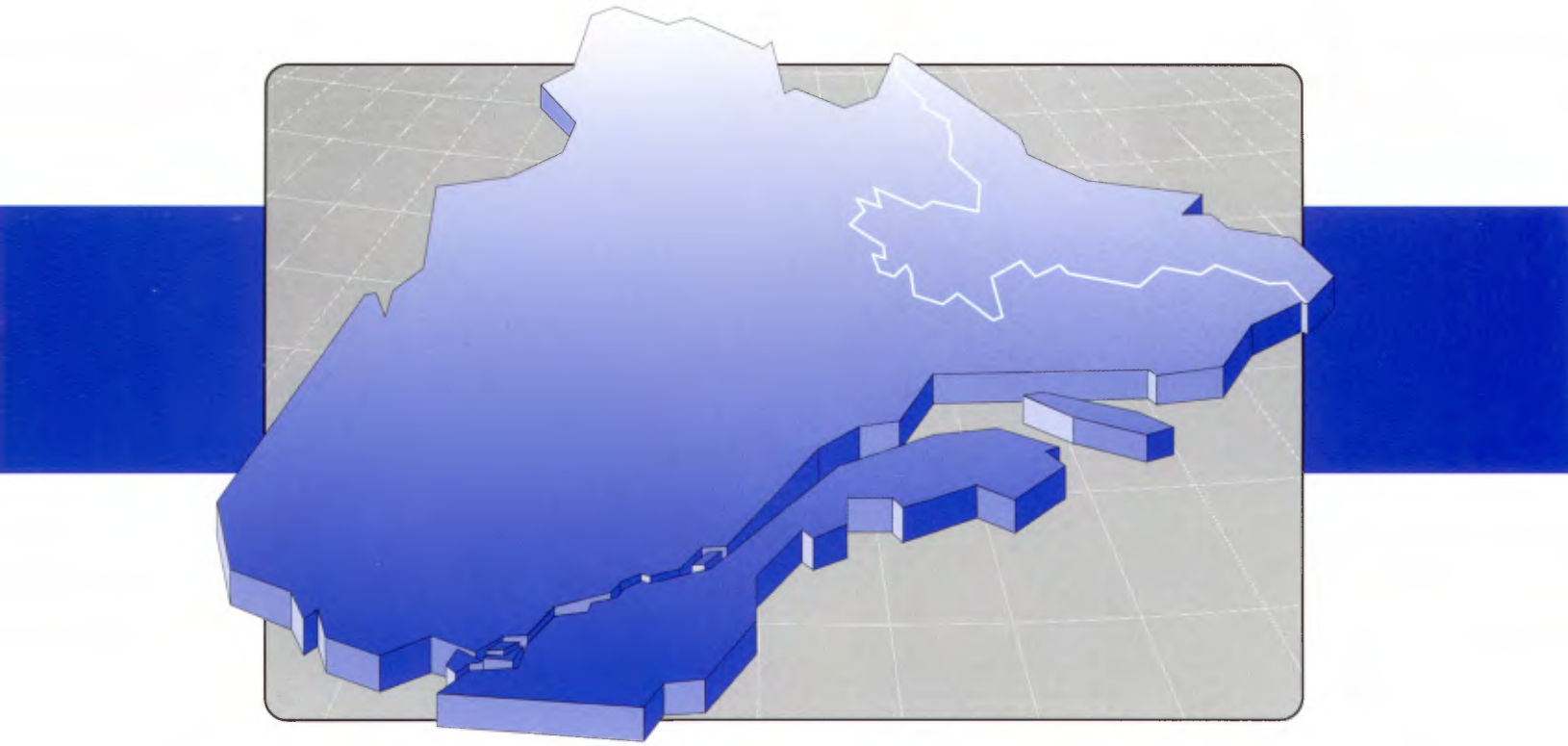
PRO 99-09



2000

Québec

Introduction

The Superior Province is one of the largest Archean cratons in the world, half of which is located in Quebec. It has long been established that economic diamondiferous kimberlites are concentrated on these cratons (Clifford, 1966). So far, 48 pipes and numerous dykes, distributed in 5 distinct fields (Missisa, Attawapiskat, Temiscamingue, Desmaraisville and Otish), have been discovered. This is quite small when compared to the 250 pipes identified so far in the much smaller Slave Province (Roger Clement, quoted in Macqueen, 1998) or the 2000 occurrences identified in South Africa (Gurney, 1989).

Four kimberlite fields are located in Quebec; they include the Temiscamingue, Desmaraisville, Otish and Torngat fields (Fig. 1). The Temiscamingue field is located in the Pontiac and Abitibi Sub-Provinces near the Quebec/Ontario border. The portion of the field located in Quebec contains 3 weakly diamondiferous diatreme and hypabyssal facies kimberlite pipes. Two of them have been dated at 125 and 142 Ma (Sage, 1996). The Desmaraisville field is located in the north-central portion of the Abitibi Sub-Province. It contains 5 very weakly diamondiferous hypabyssal facies kimberlite pipes and numerous dykes (Sharma and Lauzière, 1984), dated at 1100 Ma (Watson, 1967). The Otish field is located in the NE portion of the Opatica Sub-Province near the northern margin of the early Proterozoic Otish basin. It contains one weakly diamondiferous hypabyssal facies pipe and an adjacent dyke swarm (Gehrisch et al., 1979; DITEM, 1997). Diamondiferous kimberlite dykes have recently been identified in the Abloviak Fjord area of the Torngat mountains, to the west of the Nain craton (Digonnet, 1997; Twin Gold, 1999). These dykes have been dated at 544 Ma (Digonnet et al., 1996).

Superior Province Kimberlites

In Quebec, the 3 kimberlite fields of the Superior Province (Temiscamingue, Desmaraisville and Otish) are located south of the 52nd parallel. This portion of the Superior represents only 25% of the total area in Quebec. Although no kimberlites have yet been discovered north of the 52nd parallel, it is not unreasonable to suggest that remaining ¾ of the Superior Province in Quebec is likely to host more kimberlites.

During summer 1999, a 1 / 250 000-scale mapping project (Aigneau Project; Berclaz et al., 1999) which is part of the Far North Mapping Program of Géologie Québec (Leclair et al. 1998a, b), was undertaken over a 15 500 km^2 area in the Northeastern Superior Province. The area is located 140 km west of Kuujjuaq between 70°00'-71°30'W and 57°00'-59°00'N and corresponds to parts of NTS map sheets 24 L, 24E and 24F/04.

In this mapped area, 4 sets of unmetamorphosed dykes of post-Archean age were recognized: (i) gabbro dykes (<150 m-thick), (ii) diabase dykes (5 to 50 cm-thick), (iii) ultramafic lamprophyre dykes and (iv) ultramafic to mafic carbonate-bearing dykes (figure 4). These dykes are parallel to faults which strike (i) mainly NW to NNW, (ii) N-S, et (iii) locally E-W to WSW (fig. 5a et 5b).

Lamprophyre dykes are on average 1 m-thick and have sharp contacts with their host-rocks (fig. 6a and 6b). They display a fine- to medium-grained texture which ranges from homogeneous, microporphyritic, globular to microbrecciated. Mineral assemblages commonly include olivine-phlogopite-carbonate-spinel-magnetite-clinopyroxene-brown hornblende.

Ultramafic to mafic carbonate-bearing dykes are up to 35 m-thick. They were channeled by fault corridors which are easily traceable over a few kilometres in the field. The carbonate is typically dolomitic and forms an orange-colored, medium-grained, homogeneous matrix wherein are preserved microphenocrists of olivine, pyroxene, plagioclase, as well as fragments of enclosing host-rocks. This leads to typical brecciated, trachytoidal and amygdaloidal textures (fig. 6c).

Preliminary whole-rock geochemistry results indicate that both dyke types originate from mantle-derived alkaline magmatism, and may be related to kimberlites, lamprophyres or lamproites. Further studies are in progress to better define the whole compositional spectra, their eventual petrogenetic relationships, as well as their diamond potential.

Exploration targets in the northern Superior Province

In many cases, kimberlites found in Archean cratons are located along large lineaments or fault zones and are, in some instances, located near other types of alkaline intrusions, such as carbonatites, alnoites, ultramafic lamprophyres and nepheline syenites. Some kimberlite fields are situated at the intersection of cross-structures with the main lineament or fault zone (White et al., 1995). We have compiled syenites, generally nepheline bearing, carbonatites, kimberlites and other alkaline intrusions in Quebec (Fig.1; Moorhead et al., 1999). The main large linear brittle structural zones, locally defined by late faults, aeromagnetic and remote sensing lineaments and graben type sedimentary basins, have also been compiled (Fig. 1; Moorhead et al., 1999). In Quebec, in some cases, these brittle structural zones host alkaline intrusions. They probably have a relatively deep expression in the crust and are, at least in some areas, permeable to alkaline magmatism.

Globally, the distances between many of the large kimberlite fields are in the order of 400 km, although in some cases they may be much less (Janse, 1993). The average distance between kimberlite fields of the Canadian Shield is approximately 470 km (Fig. 2; Moorhead et al., 1999). The distances between some fields is significantly higher or lower, nevertheless the value of 470 km maybe useful as a general approximation for the location of yet undiscovered kimberlite fields. By extrapolating a distance of 470 km from known kimberlite fields and using the position of large brittle linear structural zones and their cross- faults, 4 areas of interest for diamond exploration have been defined (Fig.3):

1) The area between the village of Wemindji and the LG2 hydroelectric reservoir dam is located at the western end of the Wemindji-Caniapiscau structural zone, which extends from Wemindji, on the eastern shore of James Bay, ENE at 70^0 to the Labrador Trough in the vicinity of Schefferville. This area is located at roughly the same distance of 470 km from the three adjacent kimberlite fields; Attawapiskat, Desmaraisville and Otish. It also lies on the NE projection of the Kapuskasing tectonic zone of Ontario, which hosts numerous alkaline intrusions. This area encompasses an exploration permit of Monopros, which contains a 32 km long dispersion train of kimberlite indicator minerals. A total of 715 m were drilled on 9 aeromagnetic anomalies, no kimberlite was intersected (Pomares, 1998).
2) The area adjacent to the Caniapiscau reservoir in the eastern part of the Wemindji-Caniapiscau structural zone is cross-cut by numerous NNE trending faults and is located roughly 470 km from the Otish kimberlite field.
3) The area to the N of Bienville lake, near the western end of the Saindon-Cambrian structural zone, which extends from Cambrian lake in the south-central portion of the Labrador Trough WSW at 250^0 to the middle of the Superior craton. This area also lies on the NE projection of the Kapuskasing tectonic zone and is located approximately 470 km from the Otish kimberlite field and the Wemindji indicator mineral train of area 1.
4) The area adjacent to Tasiat lake in the Allemand-Tasiat structural zone, which extends from Allemand lake in the south-central portion of the Ungava Trough SSE to the center of Ungava peninsula. This area would be 470 km north of area 3.

The Far North Craton (east side of Ungava Bay) and the Torngat Mountains

During the fall of 1999, Twin Gold Corporation announced in press releases the discovery of more than 250 diamonds from 3 kimberlite dykes referred to as the Torngat-1,2 and 3 dykes. These dykes, located in Abloviak Fjord on the eastern margin of Ungava Bay (figure 8), were originally discovered in 1991 during a regional mapping project (Normand Goulet, personal communication, 1999). Digonnet (1997) identified the dykes as kimberlites and recovered one 0,5 mm diamond from a 30 kg sample.

In 1997, Fjordland Minerals, acquired 2 exploration permits centered on these dykes and conducted limited field work in the region. In 1999, Twin Gold took over the permits and in late September, the company announced the discovery of diamonds (figure 7).

Three dykes, oriented NE-SW, are diamondiferous. Torngat-1 dyke has a thickness of 2.5 m and can be traced over 1.5 km. Torngat-2 dyke has a thickness of 1 metre and Torngat-3 a thickness of 60 centimetres. They are separated by a metre of gneissic host rocks. Both dykes project into a 300 m high

cliff. Initially, 26 diamonds were extracted from a grab sample of 10.8 kg taken from kimberlite rubble of Torngat 2/3 dykes at the base of a cliff. Later, Twin Gold announced the recovery of 112 diamonds from 212 kg of kimberlite taken from the Torngat 1 dyke. Thirteen were macrodiamonds, defined as one dimension exceeding 0.5mm, the largest macro was 1.65 mm.

Twin Gold also collected a total of 366 kg of kimberlite material from 5 sample locations of Torngat-1. Extraction by caustic fusion yielded a total of 326 diamonds, including 57 macrodiamonds. On one sample site, Twin Gold collected 244 kg from the thin fine-grained margins of the dyke, it yielded 17 microdiamonds. However, 109 kg was extracted from the coarse-grained center of the kimberlite dyke, it contained 214 stones, of which, 44 are macrodiamonds. Eight diamonds are larger than 1mm in length. From this sample, 183 of the stones are classified as white, 23 as off-white, 7 are grey and one is brown. Of the 214 stones, 176 are transparent, 37 are translucent and one is opaque. The company reported a ratio of 2 stones per kilogram of kimberlite. In October, Twin Gold announced the discovery of an another set of dykes 10 km southwest of the Torngat dykes. Seven microdiamonds were found in a 27.5 kg sample from one of those dykes, located at the mouth of the Beaufremont river (figure 8).

Further south, a team of Géologie Québec (Ministère des Ressources naturelles du Québec), under the supervision of Pierre Verpaelst and Daniel Brisebois, mapped the western margin of the Abloviak shear zone during the summer of 1998. Several major brittle structures were identified. These structures are superimposed on a major Early Proterozoic ductile deformation event. The age of the brittle structures has not been precisely determined, and may vary from 1.5 Ga to 100 Ma. At least 3 crustal extension events are known in the area occurring in Middle Proterozoic, in lower Paleozoic and in Mesozoic. This last extension event corresponds to the opening of the rift that now separates Greenland from the North American continent.

During the mapping program carried out in 1998, one ultramafic (peridotite) dyke was recognised in the Torngat Mountains in the southern extension of the Abloviak deformation zone. An ultramafic lamprophyre dyke was also observed in the Lake Harbour Group paragneisses (figure 8). It is composed of olivine micro-phenocrysts with olivine and phlogopite phenocrysts in a fine grained groudmass with quartz and carbonate filled amygdules. It would seem that the kimberlite dykes (Torngat 1, 2 and 3) and the lamprophyre dykes located further south took advantage of similar brittle crustal weaknesses associated with the Abloviak deformation zone.

Discussion

The northern portion of the Superior Province in Quebec represents an attractive area for diamond exploration. Noteworthy features would include the presence of large-scale brittle fault zones, locally hosting alkaline intrusions, and the NE projection of the Kapuskasing structural zone into northern Quebec. This projection corresponds to a zone where orientations of the main lineaments change from a WSW direction, in the central part of the craton (i.e. the Saindon-Cambrian Zone), to a NW direction on its western margin (i.e. the Richmond Gulf Zone)(Portella, 1980). It also encompasses a kimberlite indicator dispersion train near the village of Wemindji on the eastern shore of James Bay (Pomares, 1998) and a recently discovered alkaline dyke field further to the NE, adjacent to the Labrador Trough (Berclaz et al., 1999). Curiously, the NE projection of the Kapuskasing tectonic zone also intersects the diamondiferous kimberlite dykes located in Abloviak Fjord, adjacent to the Torngat Mountains.

The location of a kimberlite indicator dispersion train in area 1 could indicate that identifying large brittle fault zones, permeable to alkaline magmatism, and extrapolating a 470 km distance from known kimberlite fields may be useful in predicting the general location of yet undiscovered kimberlite fields. By using these two features, 4 areas have been identified which may represent target regions for kimberlite exploration in the northern Superior Province.

The possibility of discovering other kimberlite dykes along strike of the Abloviak Fjord dykes seems quite good. Similar dykes and late structures have been discovered along strike 10 km to the SW and several km to the NE (Twin Gold, 1999). Post-tectonic ultramafic lamprophyres, some of which are kimberlites, have been identified in the northernmost portion of Labrador, approximately 75 km NE of the

Abloviak Fjord dykes (Wardle et al., 1994; Copper Hill Corporation, 1999). Furthermore, there may be other similar sub-parallel dyke fields further to the SE, in other portions of the Abloviak deformation zone, that were emplaced into late faults and fractures.

Reanalysis of lake sediments in the vicinity of the Lac de Gras kimberlites of the North West Territories (Kjarsgaard et al., 1992) indicates that they contain anomalous Ba, Ce and Cr values (Figure 9). This would suggest that kimberlitic material found in the till of this region was remobilized and deposited as lake-bottom sediments. In 1998, the whole northern third of Quebec was covered by a lake sediments geochemical survey with a grid size of 13 km^2 (figure 10a,b,c,d). This data base was filtered to highlight samples containing high Ba, Cr and Ce, which may indicate areas where mafic to ultramafic alkaline, possibly kimberlitic, intrusions occur.

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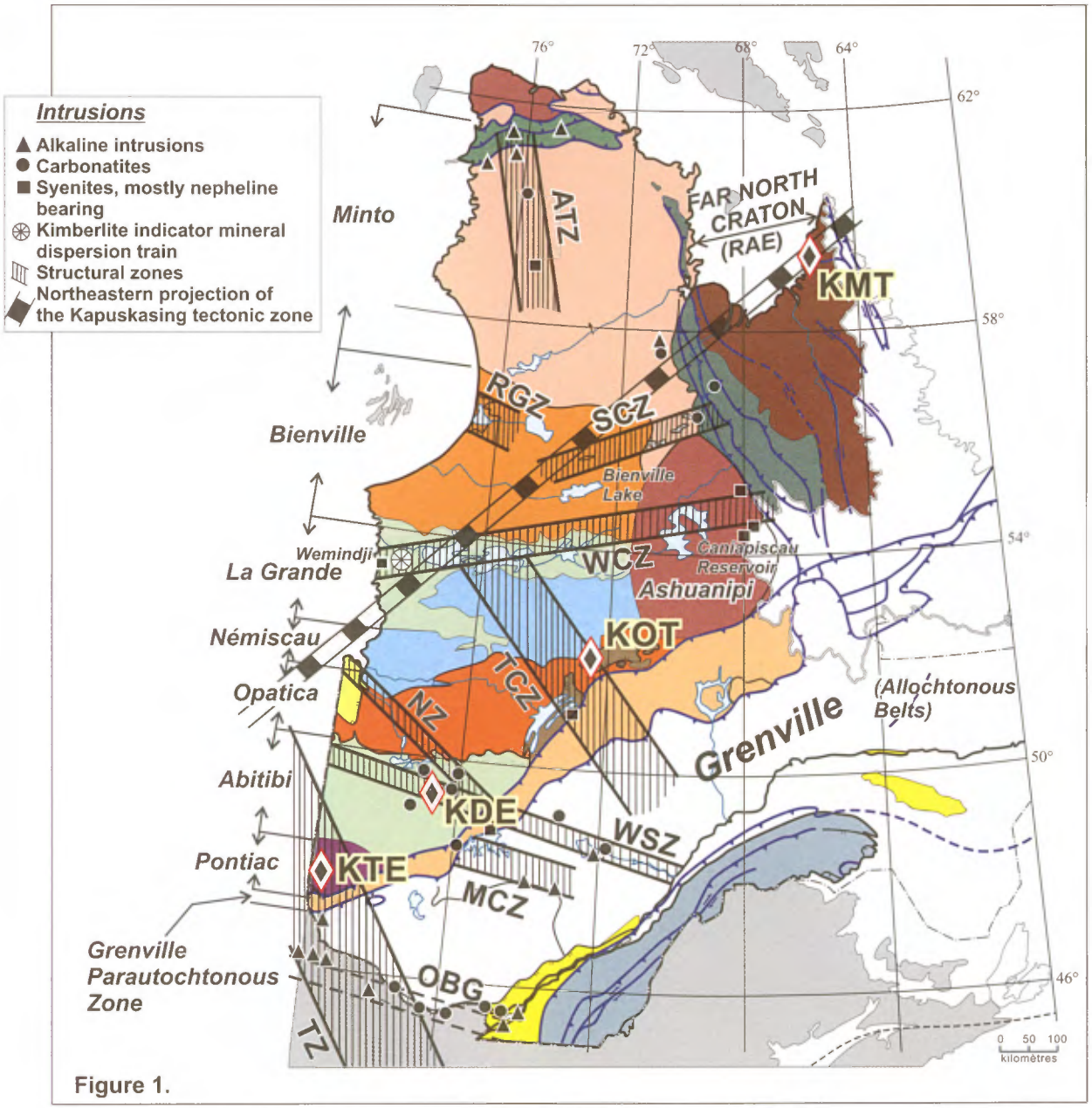


Figure 1.

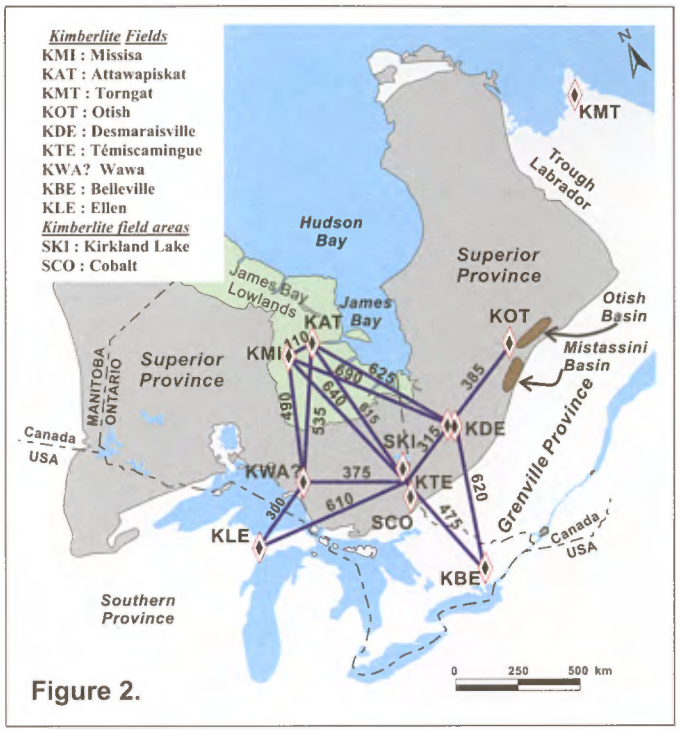


Figure 2.

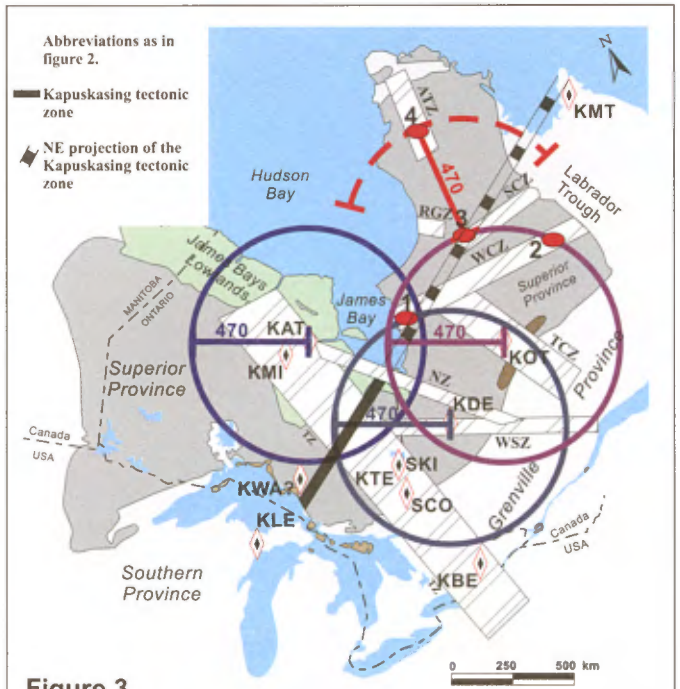


Figure 3.

Figure 1. Tectonic sub-divisions of Quebec (Hocq, 1994) with the location of large-scale brittle fault zones and alkaline intrusions. Structural zones: ATZ: Allemand-Tasiat Zone, RGZ: Richmond Gulf Zone, SCZ: Saindon-Cambrian Zone, WCZ: Wemindji-Caniapiscau Zone, TCZ: Témiscamie-Corvette Zone, NZ: Nottaway Zone, WSZ: Waswanipi-Saguenay Zone, MCZ: Mégiscane-Chasseur Zone, TZ: Temiscamingue Zone, OBG: Ottawa-Bonnechere Graben. Kimberlite Fields: Torngat (KMT); Otish (KOT); Desmaraisville (KDE); Témiscamingue (KTE).

Figure 2: Kimberlite fields of the Canadian Shield, with distances in kilometers. **Figure 3**: Kimberlite fields, structural zones, the Kapuskasing tectonic zone with its NE projection and circles with a 470 km radius centered on the three most northerly kimberlite fields of the Superior Province. Intersection areas (1-4) between the circles and the brittle structural zones may represent exploration areas for diamond exploration.

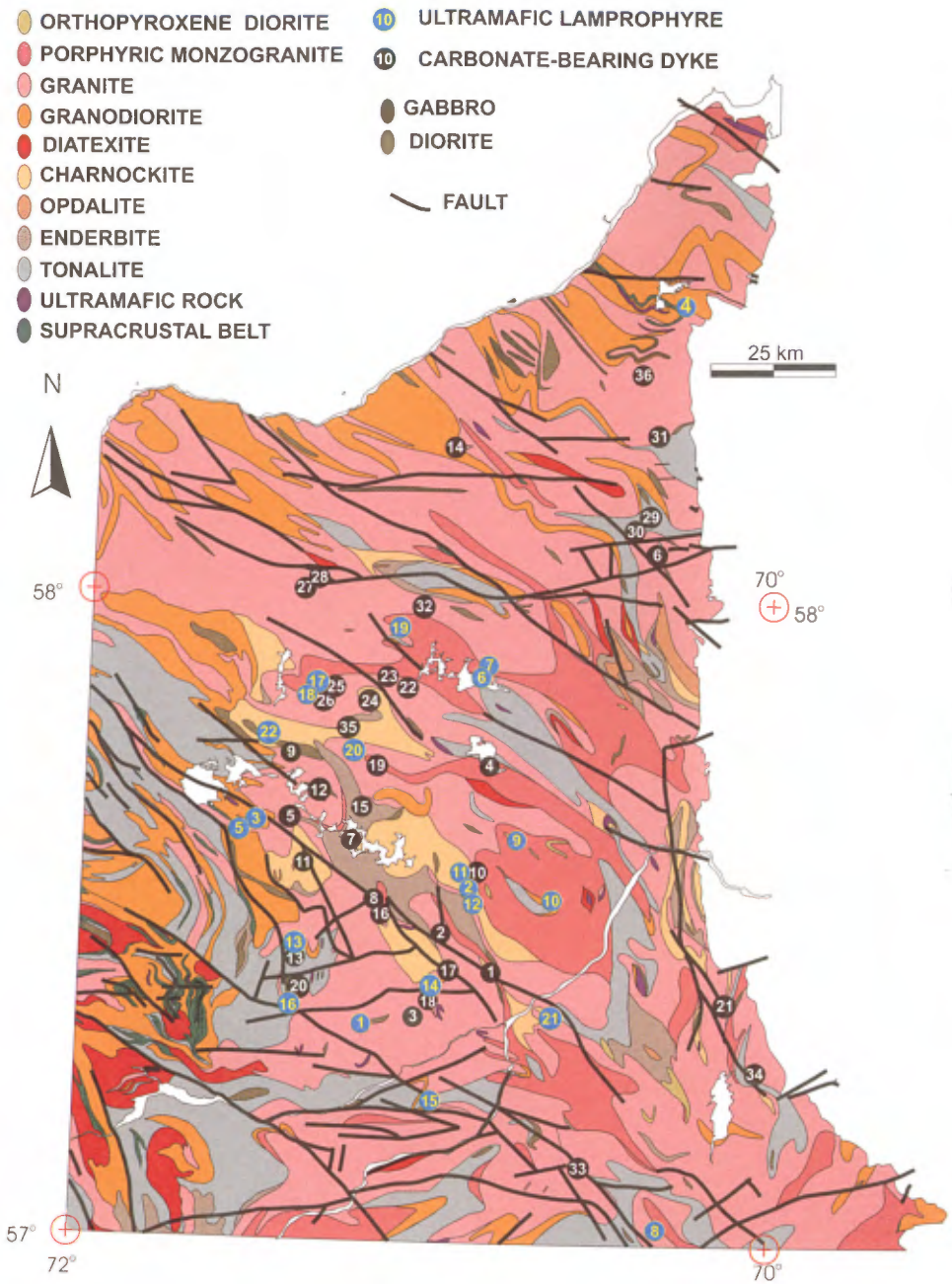
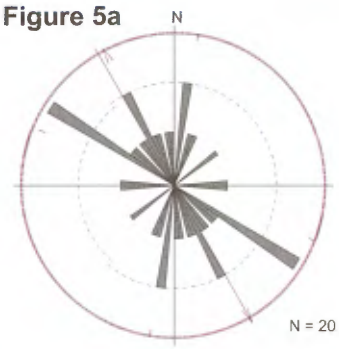
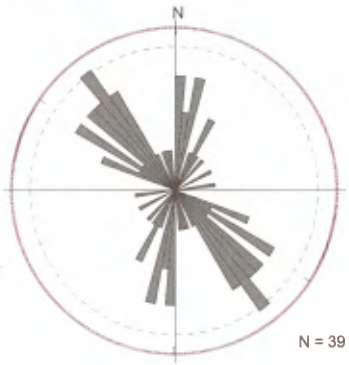


Figure 5a



ULTRAMAFIC LAMPROPHYRES

Figure 5b



CARBONATE-BEARING DYKES

Figure 6a

Figure 6b

Figure 6c

Figure 4. Geological map showing the location of ultramafic lamprophyre dykes (in blue) and ultramafic to mafic carbonate-bearing dykes (in black) on NTS 24 L, 24E and 24F04 map sheets. The area is underlain mainly by various Archean-age granitoid plutonic suites wherein are preserved belts of volcano-sedimentary supracrustal rocks and intrusive ultramafic rocks. **Figures 5a and b**. Orientation of ultramafic lamprophyre dykes (5a) and ultramafic to mafic carbonate-bearing dykes(5b), on stereonets. **Figures 6**. 6a) Photo of a typical 1,5 m-thick ultramafic lamprophyre dyke (sample #3 : 1150-K2). 6b) Note its sharp contacts and chilled margins agaist the enclosing rock. 6c) Photo of typical orange-colored ultramafic to mafic carbonate dyke. Note the sheared contact and fragments of host granitoid rock in the matrix (sample #2 : 1106-B).

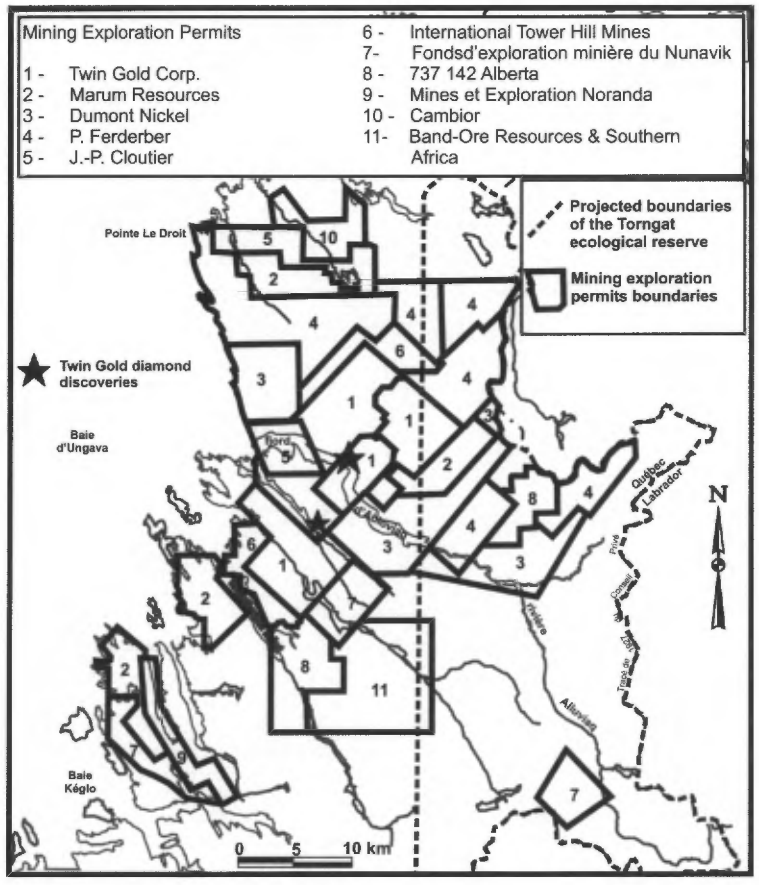


Figure 7

Figure 7. Map of the mining exploration permits given to companies, by the Ministère des Ressources naturelles du Québec, since July 1999 in the Abloviak Fjord area.

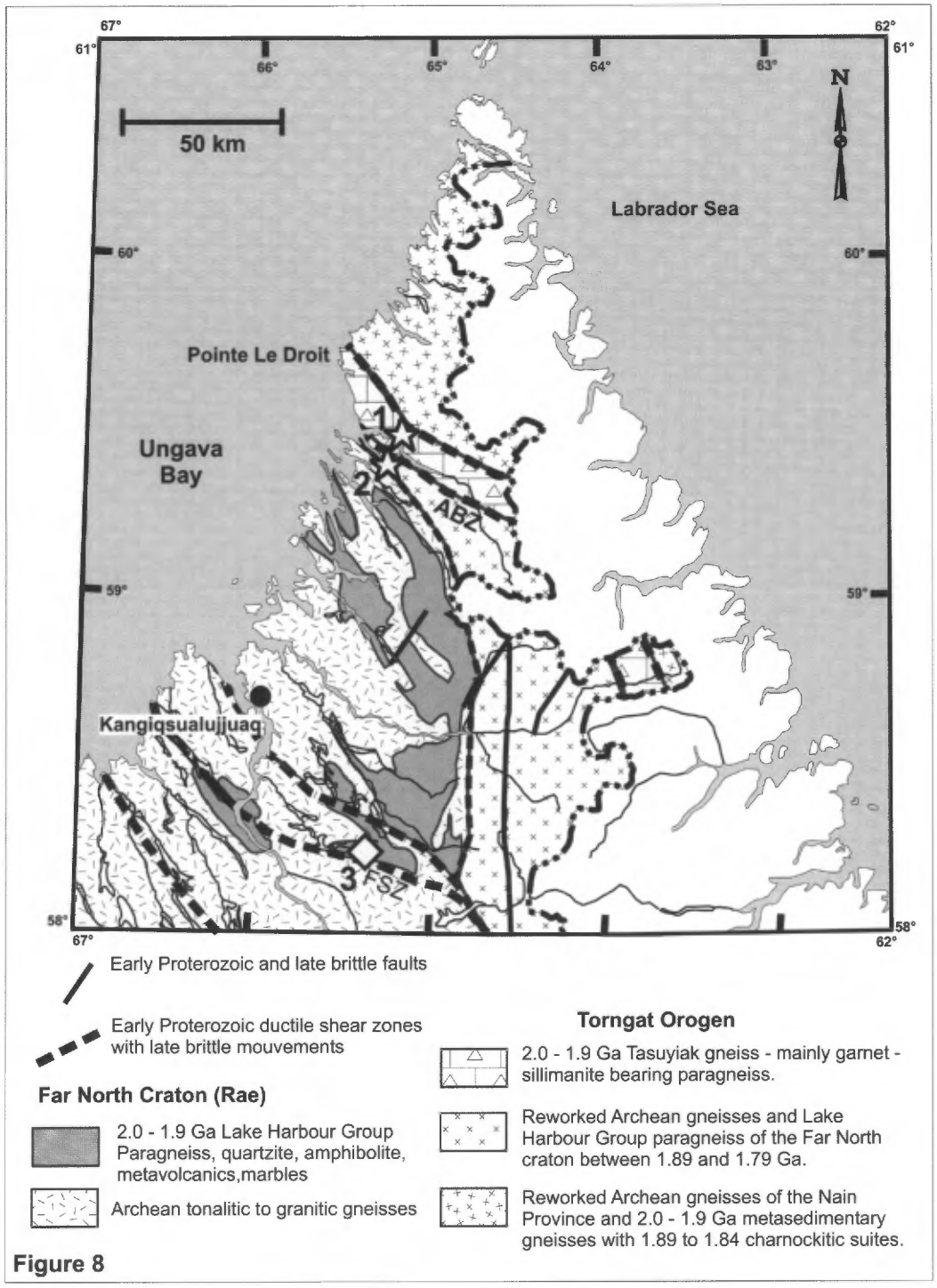


Figure 8

Figure 8. Simplified geological map of NTS 24I, 24P and 25I of the east coast of Ungava Bay. Star symbols represent Digonnet (1997) and Twin Gold diamond discoveries. 1. Torngat 1, 2 and 3 diamond-bearing kimberlite dykes. 2. Beaufremont river kimberlite dykes. Diamond shape symbol (3) represent an ultramafic lamprophyre dyke discovered in 1998 in the Falcoz shear zone.

ABZ = Abloviak shear zone ; FSZ = Falcoz shear zone

Figure 9

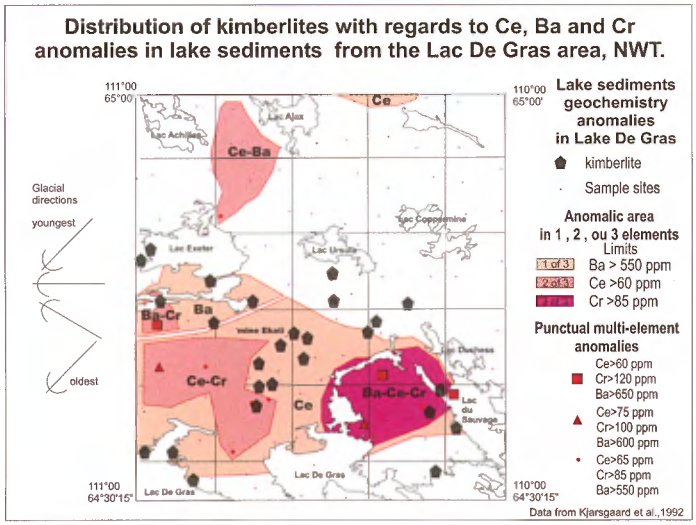
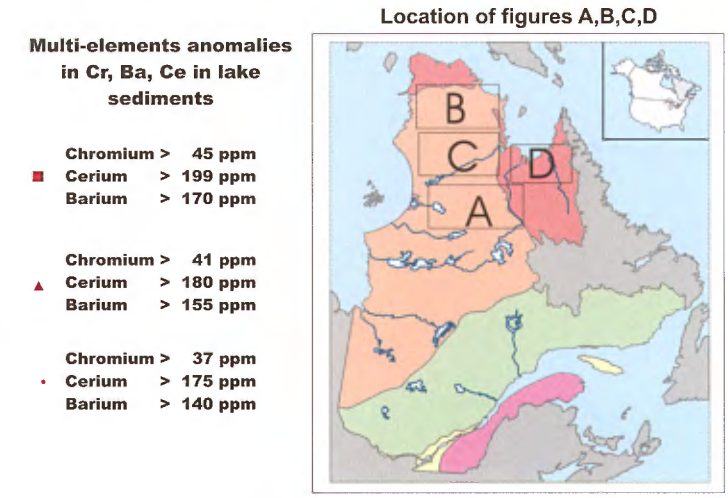


Figure 10



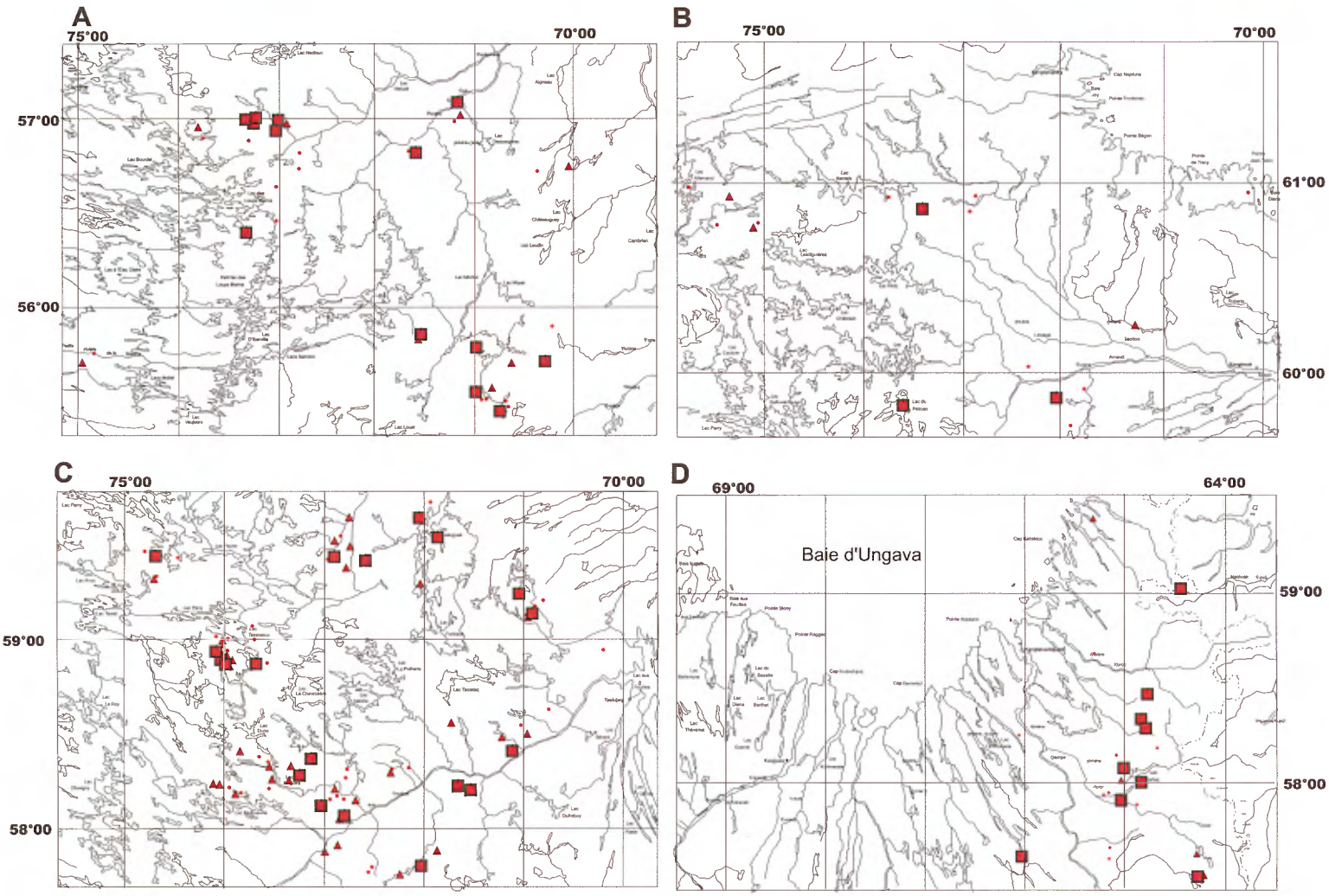


Figure 9 . Barium, cerium and chromium anomalies in lake sediments resulting from the remobilisation of kimberlitic till dispersions in the Lac De Gras area , Northwest Territories.

Figures 10 a,b,c,d. Location of anomalous sites from lake sediments geochemistry for Cr, Ba, Ce for 2700 sites of the Far North geochemical survey.