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Isotope (Nd and Sr) and Geochronology studies of Quebec Kimberlites and Lamprophyres

Par

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ABSTRACT

Nd and Sr isotope data for kimberlite and lamprophyre suites across Quebec define four post-Archean age groups based on Nd model ages **and published ages;** 1. Proterozoic (Lac Leclaire and Lac Aigneau); 2. Grenville (Desmaraisville, Bachelor Lake, Temiscamingue); 3. Cambrian (Torngat, Otish, Temiscamingue) and 4. Jurassic (Ayres Cliff, Isle Bizard-Oka, Temiscamingue-Guigue). The Nd and Sr isotope ratios suggest that the source of these alkaline magmas was influenced by MORB depleted mantle and OIB plume sources. A number of suites also reveal signs of crustal contamination in both Nd and Sr isotopes and that the Sr isotopes are frequently perturbed by later alteration. The degree of crustal contamination as measured by the isotopic compositions could influence the degree of diamond resorbtion due to oxidation of the magmas. The Cambrian and Jurassic groups tend to intrude older fault zones, however the more diamondiferous fields are found where these groups break new ground in cratonic continental crust.

1. INTRODUCTION

The discovery of diamond-bearing kimberlites at Lac-des-Gras in the Northwest Territories demonstrated the diamond-bearing potential and economic feasibility of diamond exploration in the Canadian Shield. This discovery and subsequent discoveries in Alberta, Saskatchewan and Ontario added impetus for companies to explore the Canadian Shield of Quebec for diamonds. Rocks of kimberlitic affinity have long been recognized in a number of locations in Quebec, most notably the Jurassic Isle Bizard and Temiscamingue pipes, and more recently the Torngat and Otish mountains regions. Identification of diamond in these latter two localities served to spur on diamond exploration in Quebec. This present study is part of a joint effort with colleagues at McGill University to characterize the age, isotopic and geochemical composition of kimberlite-related rocks in Quebec in order to provide a context for exploration in these rocks of diverse composition and possibly provide constraints for the exploration community. This present report will concentrate on the isotopic (Sm-Nd and Rb-Sr) compositions and ages of the sampled suites. The geochemical properties will be presented by the McGill group.

Mafic alkaline magmas of the kimberlitic and lamprophyre affinity are ultimately mantle-derived magmas. However, because these magmas have all traversed thick continental crust, the character of the mantle sources must be deciphered through a potential screen of crustal contamination. Fortunately, these magmas are normally highly enriched in large ion lithophile (LILE), Rare Earth (REE) and high field strength elements (HFSE) which include Sr, Nd and Hf, and thus contamination by continental crust with lesser amounts of these elements is relatively minor. The enrichments of these magmas in LILE and HFSE elements are thought to reflect the influence of a mantle plume source similar to those of ocean island basalts (OIB). Radiogenic isotope studies (Nd, Sr Hf) have also identified components of an OIB source mantle and a MORB source mantle in the generation of these magmas (Salters and White 1998, Tilton and Bell, 1994 Nelson et al, 1988). We present Nd and Sr isotope data for 25 samples of kimberlitic and carbonatitic affinity of diverse ages from across Quebec that indicate similar results.

2. METHODOLOGY

The year of 2002-2003 saw the start of an ambitious kimberlite-lamprophyre sampling campaign across Quebec followed by extensive major and trace element (McGill) and radiogenic isotope analytical (UQAM) program in 2003-2004. The samples are largely derived from the Canadian Shield and from known kimberlite fields such as the Temiscamingue, Otish Mountains, Torngat Mountains and newly discovered fields such as Lac Aigneau and Lac Leclaire in northern Quebec. Monteregian lamprophyres were also included to compare with those in the shield (Figure 1). The petrology and geochemistry of the samples is discussed by the McGill group.

Samples from the different kimberlite and lamprophyre fields were crushed to a fine gravel and inspected under a microscope in order to remove fragments of crustal origin that would otherwise contaminate the chemical analyses. The picked-fractions were then powdered and divided for geochemical and isotopic analyses. The geochemical fraction was analysed for major and trace elements by the McGill group, while the isotopic fraction was analysed for Sm-Nd and Rb-Sr isotopes by the UQAM group (Lu-Hf isotopes will be attempted if time permits). Major and some trace elements were analysed by x-ray florescence while the bulk of the trace elements were analysed by ICP-MS. The samples for isotopic analyses underwent chemical dissolution and elemental separation at UQAM and analysis by thermal ionization mass spectrometry.

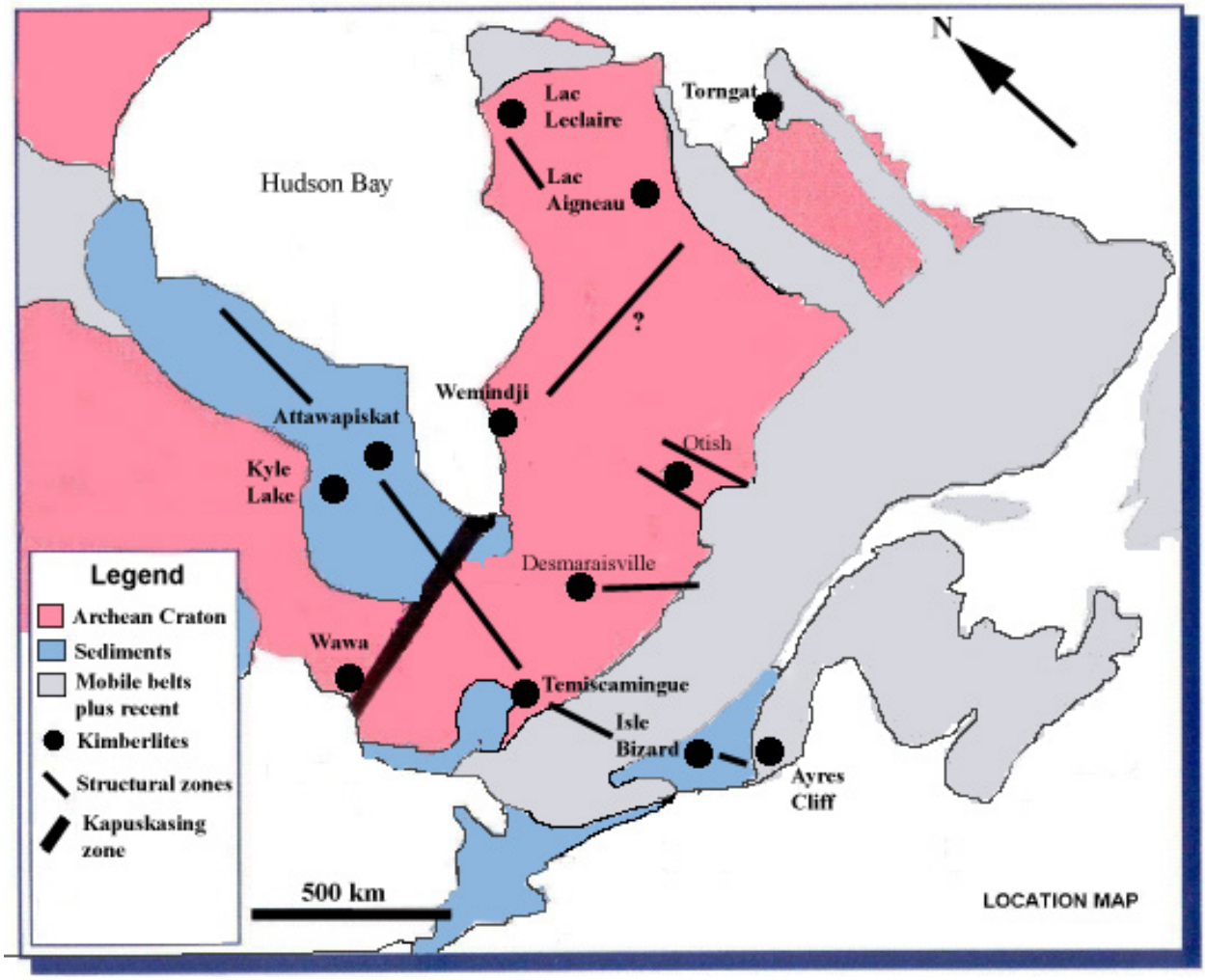

Figure 1. General geological map showing locations of kimberlites and lamprophyres discussed in this report as well as proposed structural zones. The map and structural zones are modified from Moorhead et al. (1999).

3. RESULTS

This section deals with the isotopic data obtained from kimberlite and lamprophyre intrusions in Quebec. Nd and Sr isotopic data have been obtained for kimberlite and lamprophyre suites from the Lac Aigneau, Lac Leclaire, Otish Mountains, Torngat Mountains, Temiscaming, and Monteregian regions of Quebec and these areas are compared with published data from other localities such as the alnoites of Isle Bizard and Cambrian kimberlites from southwestern Greenland.

The data are presented in Table 1. The ranges in Nd (10-167 ppm) and Sm (2-25 ppm) concentrations and resulting $^{147}Sm/^{144}Nd$ ratios (0.08-0.14) are similar for most of the suites and reflect the light REE enriched nature of these alkaline magmas. The concentrations of Rb (0-130 ppm) and Sr (30-2100 ppm) vary more greatly, reflecting the greater solubility of these elements in the melts and associated fluids, but also perhaps the potential remobilization of these fluids by post magmatic fluids. As a result, the $^{87}Rb/^{86}Sr$ ratios tend to vary over an order of magnitude from near zero to 0.5. The overall low $^{87}Rb/^{86}Sr$ ratios reflect the enrichment of Sr in these mafic melts.

An overview of the isotopic results is presented in figures 2 through 5, and individual cases are discussed in subsequent paragraphs. Figure 2 compares the Nd model age (TDM)of the samples against their assumed

Table 1. Nd and Sr isotope data for Quebec kimberlites and lamprophyres

Sample#	Locality	age Ga	Sm	Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	eNd(t)	TDM	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr(t)$
Cretaceous AC-05-05*	Ayres Cliff	0.1	9.75	56.1	0.1051	0.512874	6.0	0.27	44	1107	0.116	0.70519	0.70500
Isle Bizzard	Monteregian	0.1	16.3	105.0	0.0944	0.512707	2.9	0.45	51	763	0.195	0.70497	0.70497
Cambrian/Grenvillian													
T96-13-89*	Temiscamingue	0.6	16.7	88.2	0.1146	0.512547	4.5	0.77	38	555	0.199	0.70603	0.70433
T96-14*	Temiscamingue	0.6	9.3	55.4	0.1011	0.512502	4.7	0.74	68	964	0.206	0.70591	0.70415
T97-22-209*	Temiscamingue	0.6							59	303	0.560	0.71341	0.70862
DT-96-12-52*	Temiscamingue	0.6							58	385	0.433	0.71213	0.70842
T97-23-3*	Temiscamingue	0.6	2.3	9.7	0.1419	0.512059	-7.1	2.09	109	716.6	0.442	0.71204	0.70826
Cambrian OH97*	Otish-Beaver L.	0.6	11.3	82.3	0.0831	0.512447	5.0	0.71	104	714	0.420	0.70681	0.70322
OH98*	Otish-Beaver L.	0.6	9.3	69.4	0.0814	0.512467	5.5	0.67	119	701	0.491	0.70728	0.70308
BL-OH-98*	Otish-Beaver L.	0.6							134	778	0.500	0.70710	0.70282
BL-OH-61*	Otish-Beaver L.	0.6							91	449	0.584	0.70918	0.70419
BL-OH-61-15*	Otish-Beaver L.	0.6							127	456	0.803	0.70923	0.70236
PETER PIPE*	Torngat	0.6							110	2136	0.149	0.70608	0.70481
BELLA DYKE*	Torngat	0.6	13.48	88.53	0.0920	0.512116	-2.2	1.16	66	1017	0.189	0.70583	0.70422
Tongat	Torngat	0.6	7.7	41.0	0.1130	0.512307	0.0	1.12					
Tongat	Torngat	0.6	15.1	81.7	0.1117	0.512454	2.9	0.89					
Tongat	Torngat	0.6	19.2	108.0	0.1079	0.512448	3.1	0.86					
Tongat	Torngat	0.6	21.9	113.0	0.1170	0.512459	2.6	0.93					
Tongat	Torngat	0.6	18.5	103.0	0.1086	0.512425	2.6	0.90					
Grenvillian Bachelor L.	Bachelor lake	1.1	26.5	167.0	0.0962	0.512155	4.7	1.15	111	1685	0.191	0.70581	0.70581
A93-1-87*	Desmaraisville	1.1	18.6	100.1	0.1124	0.512226	3.8	1.23					
A94/828*	Desmaraisville	1.1	23.83	133.31	0.1081	0.512188	3.7	1.23	58	689	0.243	0.70815	0.70433
A94/866*	Desmaraisville	1.1							101	747	0.391	0.71319	0.70704
Proterozoic 30319*	Lac Aigneau	1.9	8.1	46.8	0.1046	0.511589	2.4	2.03					
30323*	Lac Aigneau	1.9	8.4	44.5	0.1139	0.511678	1.8	2.08					
30332*	Lac Aigneau	1.9	17.3	118.2	0.0885	0.511344	1.6	2.07					
30303*	Lac Aigneau	1.9	7.4	41.7	0.1065	0.511575	1.6	2.09					
LCR-1*	Lac Leclair	1.9	10.0	64.7	0.0936	0.511531	4.0	1.92	1	364	0.009	0.70427	0.70401
LCR-3*	Lac Leclair	1.9	10.0	63.9	0.0950	0.511534	3.7	1.94	0	30	0.036	0.70628	0.70527
Archean 30310*	Lac Aigneau	2.5	15.2	3.3	0.1328	0.511699	2.2	2.55					
Carbonatite 30321*	Lac Aigneau	1.9	1409.0	167.9	0.0720	0.511071	0.3	2.12					

* denotes samples analysed for this study, other data taken from the literature. Analytical error for isotope ratios are less than 0.000020 (2σ).

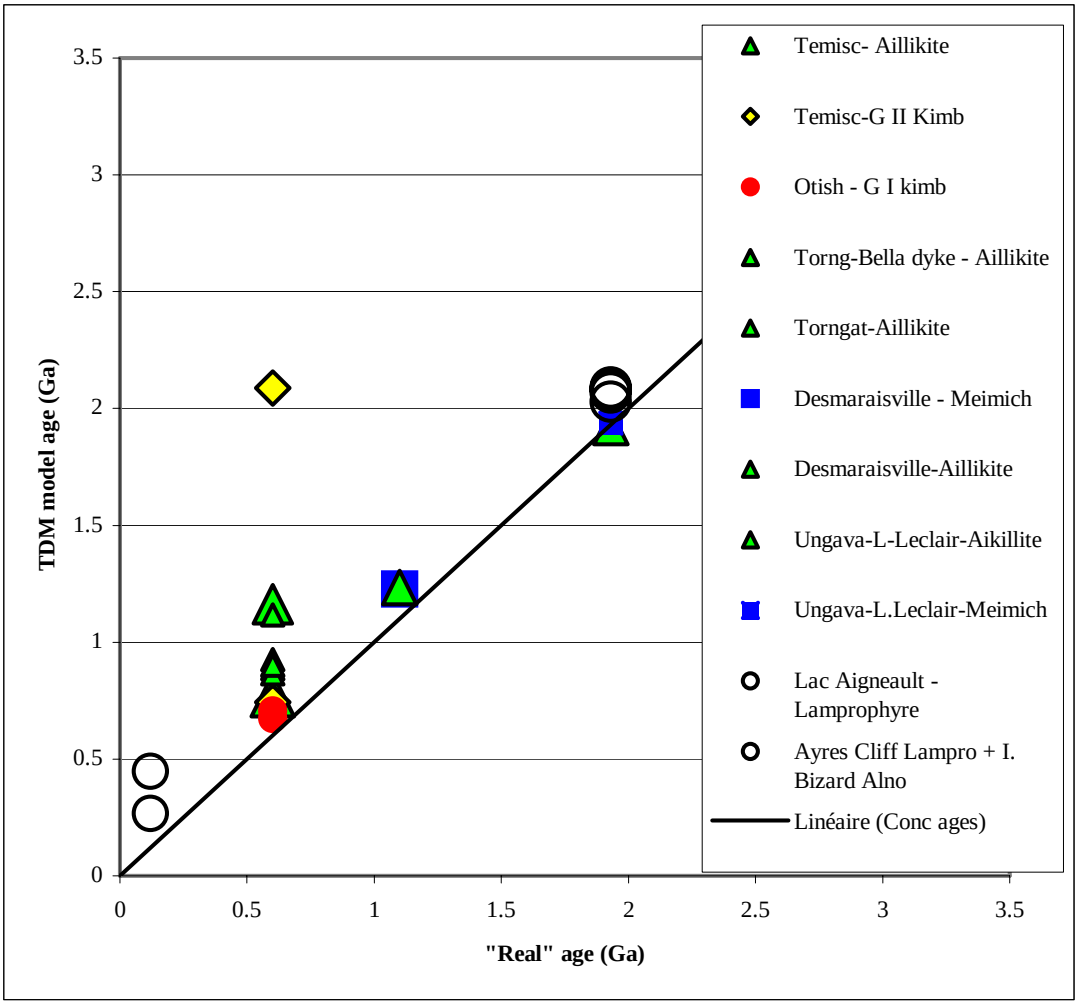

Figure2. Comparison of Nd Model ages (TDM) and dated or assumed real (emplacement ages).

or dated emplacement age. There is general good agreement between the model ages and emplacement ages for those suites that have been dated by geochronological methods. A lack of agreement likely reflects an incorrect assumption in the emplacement age or significant crustal contamination of the suite. Figure 3 illustrates the range in Nd isotopic compositions for Quebec kimberlites and lamprophyres through time with a comparison to published carbonatite data. There is a relatively large spread in the Nd isotope compositions from values of near Bulk Earth composition to depleted mantle values. There is good overlap between the carbonatite and kimberlite values. There is no correlation between rock type (kimberlite, lamprophyre, aillikite, etc) and isotopic composition.

Figure 4 shows the variation in Sr isotope compositions of the suites and they show greater variation in that they exceed Bulk Earth values suggesting alteration or remobilization of the Rb-Sr system during or subsequent to emplacement. Figure 5 is a combined Nd and Sr isotope plot on which is super-imposed the fields for Group I and Group II kimberlites. The majority of the Quebec suites plot near the Group I and OIB fields, reflecting input from MORB and OIB sources. Only one Temiscamingue sample plots towards the Group II field, but this may result from an erroneous age of emplacement (see below). In most case, the samples plot at higher Sr isotope compositions and this may reflect alteration/contamination.

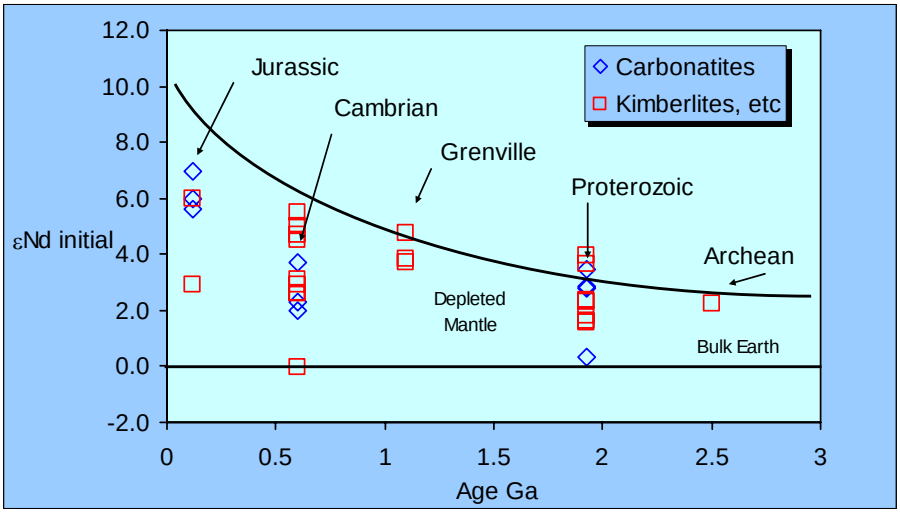

Figure 3. A comparison of Nd isotope compositions of Quebec kimberlites and lamprophyres with carbonatites from Quebec.

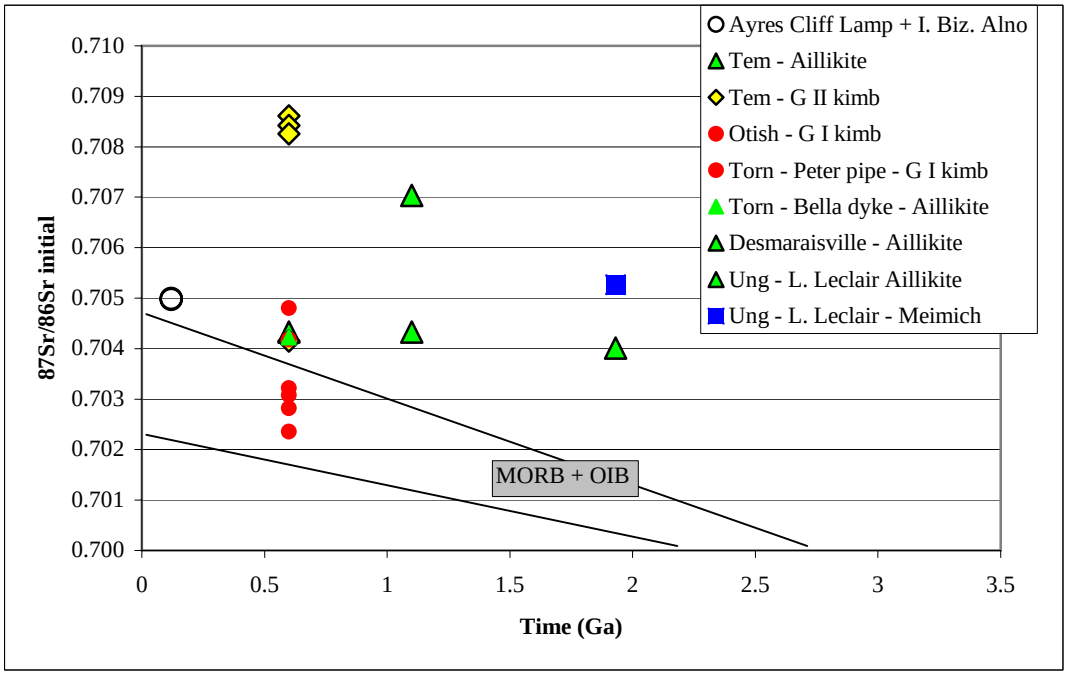

Figure 4. Initial Sr isotope compositions of Quebec kimberlites and lamprophyres with MORB and OIB-type reservoirs for comparison

3.1. Lac Aigneau, Lac Leclaire

The Lac Aigneau dykes are currently being studied at UQAM as part of a MSc thesis by G. Lemieux. The dykes range from ultramafic lamprophyres, to mafic lamprophyres, carbonatized lamprophyres and carbonatites. A subset of these dykes was obtained by the Divex group for isotopic analysis (by J. O'Neil). Two samples of lamprophyres from the Lac Leclaire region in northern Quebec were also obtained and

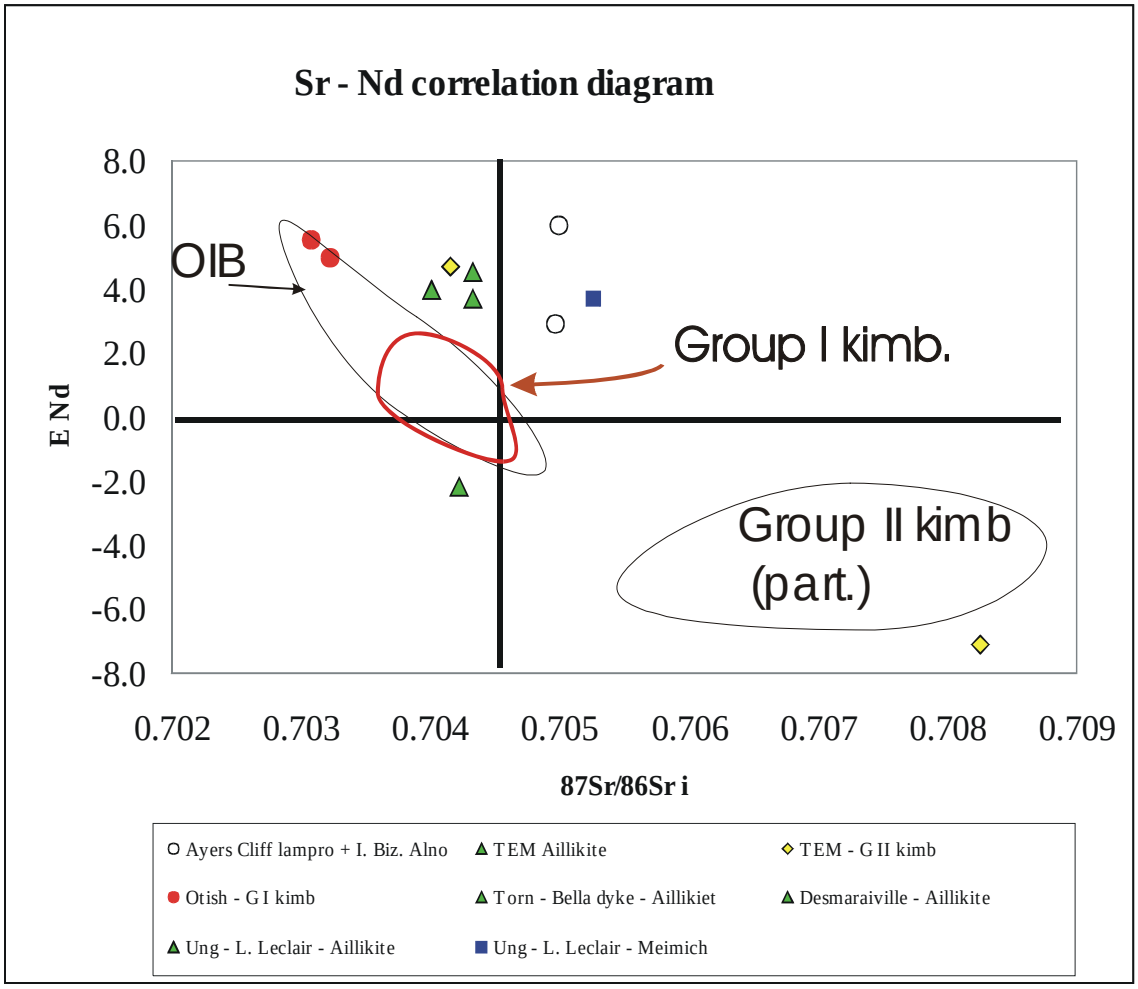

Figure 5. A Nd and Sr isotope plot of Quebec kimberlites and lamprophyres super-imposed with the fields of Group I and Group II kimberlites.

analysed. The results of these analyses are provided in Table 1. Both the Lac Leclaire and Lac Aigneau lamprophyres have similar REE and Nd contents (40-118 ppm) and $^{147}Sm/^{144}Nd$ ratios (0.0720 to 0.1328). Initially the dykes of both regions were thought to be of Paleozoic age, however, the Nd isotopic compositions were not consistent with Paleozoic mantle values. In fact, most of the Nd model ages (TDM) range from 2.0 to 2.2 Ga, suggesting that the majority of the dykes are Proterozoic in age, with one outlier at 2.6 Ga, suggesting that at least one of the dykes might be Archean in age. The isotopic compositions of the dykes were recalculated to an age of ca. 1.9 Ga and the resulting εNd values are broadly consistent with an origin from a Proterozoic mantle. The isotopic composition of the lamprophyre samples generally decreases with decreasing Nd concentration, a trend that likely reflects increasing crustal contamination in the samples with lower Nd concentrations (Figure 6). This suggests that the Lac Leclaire samples are the least contaminated. Initial Sr isotope ratios for the Lac Leclaire suite are high (0.704 to 0.705) compared to the rather low values of the Lac Aigneau suite (0.69 to 0.702). The rather low values of the Lac Aigneau suite could reflect remobilization of the Rb-Sr system by later events.

3.2. Desmaraisville

The Desmaraisville suite is also light REE enriched

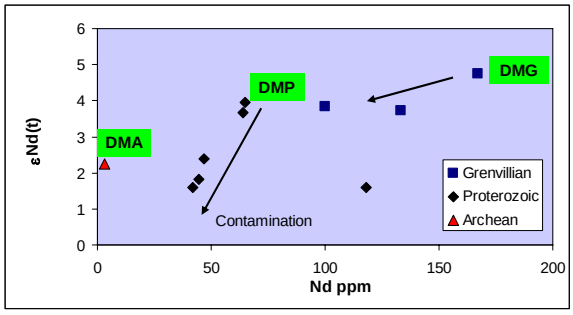

Figure 6. Initial Nd isotope compositions plotted against Nd concentration. Trends of decreasing εNd with decreasing Nd content could reflect increasing crustal contamination in some suites. Depleted Mantle Grenville (DMG), Proterozoic (DMP), Archean (DMA).

with Nd concentrations in the 100 ppm range. They yield model ages of ca 1.2 Ga and are thus either near Grenville in age or, if younger (Cambrian) then they are highly contaminated. Initial isotopic compositions calculated at 1.1 Ga yields εNd values of ca 3.8 and Sr isotope ratios of 0.704 to 0.707. The Nd isotopic compositions are close to depleted mantle values for the late Proterozoic, the Sr isotope ratios are decidedly higher than mantle values and suggest either contamination or remobilization of the Rb-Sr system. This may also be reflected in a comparison with the Bachelor Lake kimberlite (Alibert and Albarède 1988; Figure 6). There is a slight decrease in the εNd values of the samples with decreasing Nd content, possibly as a result of slight crustal contamination. The Sr isotopes may show this more strongly due to their greater mobility.

3.3. Torngat Mountains

Lamprophyre dykes from the Torngat region of northern Quebec were the first to yield diamonds in Quebec. Digonnet et al. (2000) classified these dykes as aillikites on the basis of geochemistry and mineral chemistry. We have added 4 new analyses from the Digonnet study as well as samples of two other Torngat dykes (Bella and Peter; Table 1). The whole rock samples range from 40 to 113 ppm Nd and 7 to 22 ppm Sm, resulting in 147Sm/144Nd ratios of 0.10 to 0.11. Digonnet et al. (2000) dated the dykes at 550 Ma and calculation of the Nd isotopic compositions at this age yield values of +2.5 to -0.5; well below the mantle isotopic composition of at least +6 at 550 Ma (Figure 7). Nd model ages (TDM) range from 864 to 1160 Ma, well in excess of the 550 Ma age of the dykes. The Bella dyke has a much lower εNd of -2 and also yields an older model age of 1.2 Ga. Initial $^{87}/^{86}$Sr isotope ratios for the Torngat samples (Peter and Bella dikes) hover around 0.7043 which is higher than Bulk Earth values. These low (enriched) isotopic compositions and old model ages could all indicate a strong component of crustal contamination in the dykes. However, given the high Nd concentration of these samples, the contamination would have to be in the order of 50%, but this level of contamination is not evident from the major element data (< 35% SiO2). Similarly, the initial Sr isotope ratios for the Peter and Bella dykes are greater than the Cambrian Bulk Earth value. This could also be construed as contamination; however, given the high Sr content of these dykes (1000-2000 ppm), this is unlikely. Thus, the old model ages and high initial Sr ratios could reflect either an enriched mantle source (an OIB source) or possibly the fact that there are dykes of two different ages in the Torngat region. One set would be Cambrian in age as shown by Digonnet and the other would be older, possibly ca 1.1 Ga in age. This possibility is being investigated through geochronology.

3.4. Otish Mountains (Beaver Lake)

Kimberlite pipes in the Otish Mountain region have become a prime focus of diamond exploration in Quebec following the initial discoveries by the Ashton/SOQEM consortium. Samples from this region are derived from the Beaver Lake pipe. Depleted mantle model ages for these pipes average about 700 Ma and initial Nd isotopic compositions are about +5. These values are more depleted than those found in the Torngat Mountains (Fig. 7). Initial Sr isotopic compositions range from 0.7023 to 0.7041 and thus overlap the Torngat values.

3.5. Temiscamingue

The Temiscamingue ultramafic lavas lavas are kimberlitic in composition but vary widely in isotopic composition. Of the three Nd isotope analyses, two yield ca 750 Ma model ages and near mantle εNd values (+4.6) when recalculated to with a Cambrian age (Fig. 7). The third sample (T97-23-3) gives a ca 2.1 Ga model age and an εNd value of -7 at 600 Ma. A pipe from the Temiscamingue kimberlite field (Guigue) in was dated at ca. 142 Ma (Heaman and Kjarsgaard 2000), however, these samples cannot be that young. Three of the four samples are likely Cambrian and

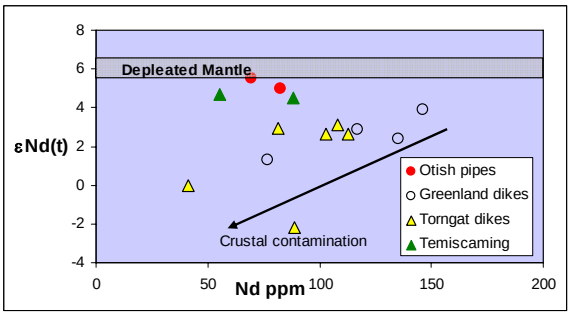

Figure 7. εNd vs Nd ppm as an index of crustal contamination. The Torngat suite either contains some significantly contaminated dykes or some are older than Cambrian age. The Otish and Temiscamingue suites contain greater MORB component whereas the Greenland and possibly Torngat contain more OIB component.

Iapetus-related Grenville dykes are known from Quebec Temiscamingue region (Kamo et al 1995). Sample T97-23-3 may be a dyke of Grenville origin. Thus the Quebec Temiscamingue field may include three generation of alkaline magmatism ranging from Proterozoic through Cambrian to Jurassic in age. Samples from this field will be dated by the U-Pb method to investigate this possibility.

3.6. Monteregian Suites

A sample of a lamprophyre dyke from the Ayres Cliff area in the Appalachian mountains of southern Quebec yields a Nd model age of 270 Ma and an εNd value of +4.6 at 120 Ma. The initial Sr isotope composition is 0.705.

4. Discussion

The kimberlite and lamprophyre suites of Quebec can be broadly divided into 4 different age groups: Proterozoic (ca 1.9 Ga), Grenville (ca 1.1 Ga), Cambrian (ca 600 Ma) and Jurassic (ca 120 Ma).

4.1. Proterozoic Group

The Proterozoic group includes the Lac Aigneau and Lac Leclaire suites. The available data suggests that they are derived from a depleted mantle, but have suffered variable amounts of crustal contamination. Distinction between MORB and OIB sources is difficult in Proterozoic suites because the potential isotopic differences between these reservoirs are small in suites older than 1.0 Ga. These dikes are likely related to the onset of rifting at the margins of the Superior Province associated with the formation of the Tran-Hudson/Cape Smith/New-Quebec Orogens and form part of the Proterozoic dyke swarms described by Buchan et al (1998).

4.2. Grenville Group

The Grenville group includes the Desmaraisville dykes and possibly the Bachelor Lake dyke. Both these suites yield similar model ages of ca 1.2 Ga and similar initial Sr isotope ratios of 0.7043 to 0.707. A more precise date is needed for the Desmaraisville suite to confirm the existence of this group. The group may also include at least one dyke from the Temiscamingue field. The Bachelor Lake, Desmaraisville and Temiscamingue suites may be related to ca 1.16 dyke magmatism described in the western Quebec Grenville Province (Coriveau and van Breeman 2000) The Bachelor Lake and Desmaraisville dykes lie along an east-west structural zone (Waswanipi-Saguenay Zone) which forms an extension of the Saguenay rift. The Saguenay rift also contains Cambrian alkaline intrusions (Doig and Barton 1968). This suggests that the Iapetus-related Saguenay rift zone likely exploited a Proterozoic zone of weakness. If the Temiscamingue dyke proves to be a member of the Grenville group, then the Temiscamingue field formed along a zone of weakness that has been exploited in the Proterozoic, Cambrian and Jurassic. A ca 1.1 Ga kimberlite in northern Ontario (Kyle Lake) may be related to this group and may be ultimately related to the ca 1.1 Ga Keewenawan rifting event.

4.3. Cambrian Group

The Cambrian group consists of the Otish Mountains, Torngat Mountains and possibly two samples from the Temiscamingue suite. All have model ages in the range of 670 to 1100 Ma. The Nd and Sr isotopes of the Torngat pipes appear to be lower and higher, respectively, than the Otish pipes. These differences may reflect a comparison of dykes of different ages (Cambrian vs Proterozoic?) or possibly crustal contamination (the isotopic compositions of the Torngat dykes vary with contamination indices such as MgO and SiO_2 (Fig. 8). However, the different mantle components involved become more evident when these suites are compared with similar Cambrian-aged dykes in southwestern Greenland. The Otish and Temiscamingue suites have a higher depleted mantle component than the Greenland dykes suggesting a greater MORB source in the Otish suite and a stronger

OIB input in the Torngat and Greenland suite. The Temiscamingue and Otish suites both lie along NW-SE trending structural zones that extend at near right angles to the Iapetus suture (graben) in southern Quebec. The Torngat suite has been proposed to lie along an extension of the Kapuskasing Structural zone (a long extension), but it is also possible that there is a yet un-recognized NW-SE zone related to the Torngat and Greenland suites.

4.4. Jurassic Group

This group includes Monteregian-related intrusions such as the Ayres Cliff Lamprophyre in the Appalachian Mountains of southern Quebec, the historic alnoite of Isle Bizard and other Juraasic-Cretaceous kimberlites in the Temiscamingue (Guigue pipe) area (Fig. 9). Data for the Isle Bizard suite was taken from Alibert and Albarède (1988). The alnoite and lamprophyre from Isle Bizard and Ayres Cliff have nearly identical initial Sr isotopic compositions of 0.7049, however the initial Nd isotopic composition of the alnoite is of +3 versus +6 for the lamprophyre (TDM = 450 vs 270 Ma). Carbonatites from the Oka Hills yield Nd values of up to +6 and initial Sr isotope ratios of 0.7033 (Wen et al. 1987, Bell and Blenkinsop 1987). This suggests that the alnoite has suffered some contamination with respect to Nd and both have suffered contamination with respect to Sr. It is likely that the above alnoite sample reflects some degree of crustal contamination. The emplacement of these suites is evidently related to the Jurassic-Cretaceous hot spot first described by Crough (1981) and subsequently by Foland et al. (1988) and Heaman et al. (2000).

5. Conclusions

Kimberlite and lamprophyres in Quebec fall into one of four post-Archean groups: Proterozoic, Grenville, Cambrian and Jurassic. This new data set reveals minor crustal contamination effects among samples with lower LILE and REE abundances, but plume (OIB) and MORB type mantle influences among non-contaminated samples. Although the isotopic composition of the different groups is independent of diamond content, the general preservation of diamonds in kimberlite magma will depend on a reduced (non-contaminated) oxidation state. Crustal contamination leads to oxidation of the magma and resorption of

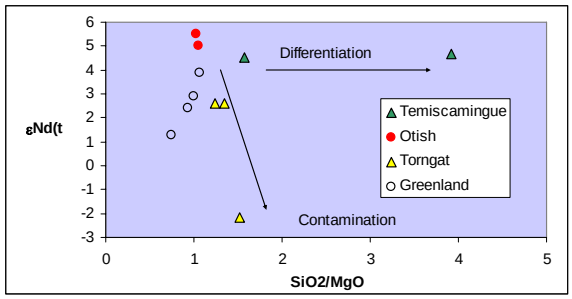

Figure 8. SiO_2/MgO vs εNd as an index of contamination. The Torngat suite is either contaminated by crust or contains dykes of variable ages (Canmbrian and older).

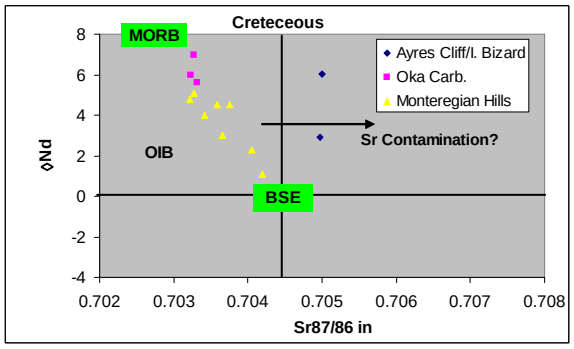

Figure 9. A comparison of Jurassic –Cretaceous intrusive of the Monteregian intrusive suite with Alnoites of Isle Bizard and the Ayres Cliff Lamprophyre. Monteregian data from Foland et al. (1988).

diamonds. Thus, the lack of diamonds in the Torngat suite could reflect, in-part, the greater degree of crustal contamination of these dykes. By comparison, less contamination in the Otish suite will mean less resorbtion and possibly better diamonds. This does not mean that diamond abundance will be controlled by contamination; simply that it plays a part in their preservation. For example, isotopic data indicate that the Isle Bizard alnoite is contaminated, where as the Ayres Cliff lamprophyre preserves a mantle signature. However, the lack of diamond in either of these lithologies may have more to do with lithosphere thickness than oxidation states or mantle sources.

The four age groups identified in this study may be related specific structural zones that were identified by Moorhead et al. (1999). Proterozoic lamprophyre dykes are largely confined to the Superior Craton in northern Quebec and trend NW-SE and may be related to the Minto dykes described by Buchan et al. (1998). The

Grenville Group is the most problematic. The Temiscamingue and Kyle Lake (Ontario) suites lie along a NW-SE trend. The possibility that the structure responsible for the Desmaraisville suite lies along a similar trend rather than an almost E-W trend with the Saguenay rift should be investigated. The Cambrian Group appears to be also related to NW-SE bearing structural zones that are at near right angles to the paleo-Iapetus suture in southern Quebec and the Jurrassic-Cretaceous Group is related to the Great Meteor Hotspot track as defined in Heaman and Kjarsgaard (2000). Both the Cambrian and Jurassic Groups tend to exploit pre-existing planes of weakness. The most exciting diamond plays appear to be related to zones that have traversed Archean crust that was not previously exploited, such as the Jurrasic Attawapiskat field in northwestern Ontario and the Cambrian suite in the Otish Mountains in Quebec. This suggests that the most interesting diamond potential in Quebec will be areas in which Cambrian-aged kimberlites have intruded Archean crust, but have not exploited faults that have already been intruded by older magmas.

REFERENCES

Alibert, A., Albarède, F., 1988. Relationships between mineralogical, chemical and isotopic properties of some North American Kimberlites. J. Geophys. Res. 93 (B7), 7643-7671.

Bell, K., Blenkinsop, J., 1987. Archean depleted mantle: evidence from Nd and Sr initial isotopic ratios of carbonatites. Geochimi. Cosmochim. Acta 51, 291-298.

Bell, K., Tilton, G.R., 2001. Nd, Pb and Sr isotopic compositions of East African carbonatites: Evidence for mantle mixing and plume inhomogeneity. Journal of Petrology, v. 42, p. 1927–1945.

Buchan, L., Mortensen, J.K., Card, K.D., Percival, J., 1998. Paleomagnetism and U–Pb geochronology of diabase dyke swarms of Minto block, Superior Province, Quebec, Canada. Can. J. Earth Sci. 35, 1054–1069

Coriveau, L, van Breeman, O., 2000. Docking of the Central Metasedimentary belt to Laurentia in Geon 12: Evidence from the 1.16-1.17 Ga Chevreuil intrusive suite and host gneisses, Quebec. Canadian Journal of Earth Sciences 37, 253-267.

Crough, S.T. 1981. Mesozoic hotspot epeirogeny in eastern North America. Geology 9, 342-343.

Digonnet, S., Goulet, N., Bourne, J., Stevenson, R.K. Archibald, D. 2000. Petrology of the Abloviak aillikite dykes, New Quebec: evidence for a Cambrian diamodiferous alkaline province in northeastern North America. CJES 37, 517-533.

Doig, R., Barton, J. M., 1968. Ages of carbonatites and other alkaline rocks in Quebec. Can. J. Earth Sci. 5, 1401–1406.

Foland, K.A., 1988. Nd and Sr isotopic signatures of Mesozoic plutons in northeastern North America. Geology 16, 684-687.

Heaman, L., Kjarsgaard, B.A., 2000. Timing of eastern North American kimberlite magmatism:
continental extension of the Great Meteor hotspot track? Earth and Planetary Science Letters 178, 253-268.

Kamo, S. L., Krogh, T. E., Kumarapeli, P. S., 1995. Age of the Grenville dike swarmOntario-Quebec: implications of Iapetan rifting. Can. J. Earth Sci. 32, 273–280.

Labbé, J-Y., 2001. Crustal lineaments and kimberlite discovery potential in western Nouveau-Québec. Ministère des Ressources Naturelles, Québec. PRO 2001-02, 8p.

Moorhead, J., Beaumier, M., Lefèbvre, D., Bernier, L., Martel, D. 1999, Kimberlites, lineaments et rifts crustaux au Québec. Ministére des Ressources naturelles, Québec. MB 99-35, 130 pages.

Nelson, D.R., Chivas, A.R., Chappell, B.W., McCulloch, M.T., 1988. Geochemical and isotopic systematics in carbonatites and implication for the evolution of ocean-island sources. Geochimica et Cosmochimica Acta, 52, p. 1–17.

Nelson, D.R., 1989. Isotopic characteristics and petrogenesis of the lamproites and kimberlites of central west Greenland. Lithos 22, 265-274.

Salters, V.J.M., White, W.M., 1998. Hf isotope constraints on mantle evolution. Chemical Geology, v. 145, p. 447–460.

Wen, X., Bell, K., Blenkinsop, J. 1987. Nd and Sr isotope systematics of the Oka complex, Quebec, and their bearing on the evolution of the sub-continental upper mantle. Contrib. Mineral. Petrol. 97, 433-437.