KIMBERLITES OF THE SUPERIOR PROVINCE, CANADIAN SHIELD

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Kimberlites occur in the following places in the Superior Structural Province of the Canadian Shield: Gauthier, Keith, and Michaud Townships in Ontario and Lesueur Township in Quebec. All are narrow post-orogenic dikes. They consist of olivine and altered olivine, phlogopite, calcite and/or dolomite, magnesian ilmenite, titaniferous magnetite, perovskite, clinopyroxene, apatite, and serpentine (Tables 1,2). Some contain xenoliths of igneous and metamorphic rock and rounded megacrysts of olivine, phlogopite, ilmenite, pyrope, and chromite (Table 3).

Carbonate minerals are abundant and in some samples exceed 50 percent. Although carbonate in kimberlite at some localities is considered to be a product of weathering, this cannot be so in the Superior Province occurrences. There, the bedrock is glacially scoured and the specimens are from a mine and drill holes far beneath the surface. Moreover, in Lesueur Township, it has been shown that no relationship exists between depth of intersection and amount of calcite present.

The alternative possibility that the calcite in the Lesueur kimberlite is a product of hydrothermal alteration derived from a source distinctly younger than the kimberlite may be ruled out since carbonates are either absent, or essentially so, from all the other rocks and ores of the area. Consequently, one may conclude that the carbonates in the kimberlite of Lesueur Township, and probably of Keith and Gauthier Townships as well, are a product of the kimberlite magma itself. Except for a little carbonate-facies iron formation, the Abitibi belt, unlike a large part of the adjacent Grenville Province, lacks carbonate sedimentary rocks. Hence, there is no sound reason for postulating that in the Abitibi belt, the kimberlite magma obtained its carbonate by reaction with limestone or dolomite.

The calcite in the kimberlite of Lesueur Township has an average Sr (87/86) ratio of 0.7040 $\pm$ 0.0001 and an average Sr content of approximately 4000 p.p.m. (Brookins and Watson, 1969, p. 370-371). These values match those of most carbonatites and differ from those of most sedimentary carbonates.

Some of the calcite and dolomite in the Superior Province kimberlites has formed by partial replacement of olivine and phlogopite. Most of the carbonate, however, shows no evidence whatever of a secondary origin. On the contrary, it occurs as medium- to fine-grained anhedral grains which are sharply molded against or completely enclosing euhedral crystals of olivine, phlogopite, magnetite, perovskite, clinopyroxene, and apatite in a manner indicating strongly that it is a late-crystallizing primary mineral.

One of the kimberlite dikes in Lesueur Township has narrow margins consisting mainly of calcite. Veinlets which are composed of calcite containing occasional crystals of

phlogopite and altered olivine, project from these dike margins. The rhyolitic country rock adjacent to the veinlets and dike margins has been replaced by fine-grained riebeckite. This alteration is comparable, albeit on a small scale, to the fenitization that commonly is associated with margins of carbonatites.

Chemically, these kimberlites are ultrabasic rocks, which compared to other ultrabasics, have unusually high contents of K_2O, CaO, CO_2, TiO_2, P_2O_5, Al_2O_3, and H_2O; low Mg/Fe ratios; and high K/Na and Fe^{3+}/Fe^{2+} ratios (Table 4). Their trace element content is similar to that of other kimberlites (Table 5).

The Abitibi orogenic belt consists of Archean volcanic and sedimentary rocks which were last deformed, metamorphosed and intruded by granite principally during the Kenoran orogeny, about 2500 million years ago (Goodwin and Ridler, 1970; McGlynn, 1970). Only two of the kimberlites in the Abitibi belt have been dated radiometrically. The one in Lesueur Township, based upon the K-Ar ratio in phlogopite, is 1100 m.y.(Neohelikian). This kimberlite is matched closely in age by several post-orogenic carbonatite and alkaline complexes of the Superior Province. The kimberlite of Gauthier Township has a K-Ar age obtained from phlogopite, of 151 $\pm$ 8 m.y. (Upper Jurassic) (Lee and Lawrence, 1968, p. 1).

The geological evidence, textural relationships, Sr content, Sr isotopic ratios, and local fenitization are consistent with a primary carbonatitic origin for the calcite and dolomite present in the kimberlites of the Superior Province. It seems likely that the kimberlite was intruded as an accumulation of rounded megacrysts and euhedral phenocrysts transported by highly fluid carbonatitic liquid from which calcite and/or dolomite, along with lesser amounts of other phases such as perovskite and apatite subsequently crystallized.

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Table 3. Megacrysts in Kimberlite from Superior Province
(Maximum size, mm)

	Gauthier	Keith	Lesueur	Michaud
Olivine	x (12)	x (18)	x (20)	x (5)
Phlogopite	x (2)	---	x (10)	x (2.5)
Ilmenite	---	x (1)	x (7)	---
Pyrope	x (2)	---	---	x (2.5)
Chromite	x (1)	---	---	---

Table 1. Mineralogical Composition of Kimberlite from Superior Province (Percentage by volume)

	1	2	3	4	5	6	7	8	9	10
Olivine & altered olivine	31	41	41	29	27	14	48	45	38	41
Phlogopite	25	25	27	24	20	28	9	21	20	26
Carbonate minerals*	--	20	20	39	39	38	18	13	20	17
Calcite & serpentine†	35	--	--	--	--	--	--	--	7	--
Ilmenite	--	2	2	1	7	10	7	4	--	3
Magnetite	5	4	4	6			12	6	5	4
Chromite		0.4	0.3	--	--	--	--	--	--	--
Perovskite	4	0.4	0.3	1	2	1	3	7	1	3
Clinopyroxene	tr	2	2	0.1	--	--	--	0.2	6	1
Apatite	tr	0.2	0.3	0.1	3	6	0.1	0.2	2	4
Serpentine & chlorite	--	3	2	--	2	3	3	4	1	1
Pyrite	--	2	1	--	--	--	--	--	--	--
Pyrrhotite	tr	--	--	--	--	--	--	--	--	--
Pyrope	tr	--	--	--	--	--	--	--	--	--

*Dolomite and minor magnesite in Nos.2 and 3; calcite in Nos.4-10.
†Includes some fine olivine and phlogopite in No.1; may be pseudomorphous after melilite in No.9

1. Gauthier Township, Ontario (Lee & Lawrence, 1968, p.4); 2. and 3. Keith Township, Ontario; 4-10. Lesueur Township, Quebec.

Table 2. Microprobe Analyses of Opaque Oxides in Kimberlite from Lesueur Township

	1	2	3	4	5	6	7	8	9
TiO_2	44.0	56.7	52.4	46.2	53.3	27.1	38.5	20.4	5.8
Al_2O_3	0.4	0.1	0.8	---	0.3	---	2.5	2.3	0.2
Cr_2O_3	0.5	0.3	1.1	0.7	0.8	0.2	5.4	2.5	0.1
FeO*	48.0	33.8	35.5	42.0	27.3	64.7	36.5	59.4	92.2
MnO	0.3	0.3	0.2	---	0.5	0.2	0.5	0.8	0.2
MgO	6.7	8.1	10.2	10.8	18.2	7.5	16.2	14.9	1.3
Total	99.9	99.3	100.2	99.7	100.4	99.7	99.6	100.3	99.8

*Total iron expressed as FeO
1,2,3,4, and 5. Magnesian ilmenite; 6. Magnesian ulvöspinel; exsolution lamella in magnesian ilmenite No.3; 7 and 8. Magnesian ulvöspinel; exsolution lamellae in magnesian ilmenite No.5; 9. Titaniferous magnetite. B. R. Berger, analyst

Table 4. Chemical Analyses of Kimberlite from Superior Province

	1	2	3	4	5	6
SiO_2	32.7	33.2	27.23	22.86	22.74	24.15
TiO_2	2.1	2.1	2.42	2.98	5.86	6.46
Al_2O_3	3.2	3.2	4.80	3.78	3.09	2.58
Fe_2O_3	3.9	4.1	2.57	4.79	8.47	7.67
FeO	5.8	5.8	7.05	5.32	7.54	8.36
MnO	0.2	0.2	0.21	0.17	0.21	0.16
MgO	31.5	31.6	15.63	14.58	23.83	24.03
CaO	8.1	8.3	16.02	22.24	11.82	10.27
Na_2O	0.5	0.4	0.45	0.33	0.27	0.25
K_2O	2.0	2.0	2.81	1.52	0.94	1.02
H_2O+	3.4	3.7	0.32	3.42	6.22	4.98
H_2O-	---	---	0.18	1.65	0.76	0.90
P_2O_5	0.4	0.4	1.03	1.32	0.68	0.23
CO_2	5.1	5.0	18.6	14.84	7.24	9.02
S	n.d.	n.d.	0.05	n.d.	n.d.	n.d.

1 & 2. Gauthier Township, Ontario (Lee & Lawrence, 1968, p.10).
3. Keith Township,Ontario;W.H.Herdsman,analyst; 4-6. Lesueur Township,Quebec;correspond to samples,4,7,and 8 in Table 1 (Watson,1967, p.318).

Table 5. Minor Element Content of Kimberlite (p.p.m.)

	1	2	3	4	5	6
Cr	1500	1600	600	1440	1000	2000
Ni	1100	1100	920	1140	1200	2000
Co	78	78	37	77	50	200
Rb	n.d.	n.d.	n.d.	21	250	2
Ba	1900	2000	1600	740	1000	1
Sr	710	760	960	445	600	1
Y	---	---	n.d.	46	40	---
Zr	250	250	450	445	190	30
Nb	220	210	100	240	200	1
La	150	150	80	370	n.d.	---

1 & 2. Gauthier Township,Ontario (Lee & Lawrence,1968,p.12);
3. Keith Township,Ontario; W.H.Herdsman,analyst;
4. Basutoland; average of 14 (Dawson,1967,p.273);
5. South West Africa; average of four, except Y which is average of two (Dawson,1967,p.273, after Janse,1964);
6. Ultrabasic rocks (Dawson,1967,p.273);
n.d. - not determined.