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The Marathon Dikes: ultrabasic lamprophyres from the vicinity of McKellar Harbour, N.W. Ontario

R. GARTH PLATT AND ROGER H. MITCHELL

Department of Geology, Lakehead University
Thunder Bay, Ontario P7B 5E1, Canada

Abstract

Lamprophyre dikes from the vicinity of McKellar Harbour, Lake Superior, consist of phenocrysts of olivine (mg = 0.81–0.87) and titanian phlogopite set in a groundmass of titanian phlogopite, spinel, apatite, perovskite and carbonate. Spinels range in composition from titanian–aluminous–chromites to ulvöspinel–magnetites and a compositional trend that indicates affinities with alkaline rock–carbonatite magmatism. Rare groundmass ilmenites are MnO–rich (2–8 wt.%). Minerals of a lath-shaped habit, now composed of an intimate mixture of andraditic garnet and calcite, are thought to be melilite pseudomorphs. Rare small xenoliths consisting of granular intergrowths of picroilmenite (MgO = 7–10 wt.%) and carbonate–talc–quartz pseudomorphs after olivine(?) occur. The dikes are extremely silica-undersaturated, alkaline, ultrabasic CO_2–rich rocks of alnöitic affinity. They represent a previously-unrecognized period of alkaline magmatism (1653 m.y.) in the Lake Superior Basin.

Introduction

Platt and Mitchell (1979) introduced the name "Marathon Dikes" as a reference term of convenience for the numerous dikes, of diverse mineralogy and age, found in the vicinity of Marathon, N.W. Ontario (48°43′N, 86°22′W). This second contribution to the petrology of these dikes describes a previously unrecognized group of lamprophyres, with alnöitic affinities, from the McKellar Harbour shoreline of Lake Superior. Additional exposures occur in road and rail cuts in the same general area. Although the dikes described have a relatively restricted distribution, we believe that their true extent is camouflaged by the poor outcrop within the dense boreal forest cover of this region. Walker (1957) initially mentioned the occurrence of lamprophyres in the McKellar Harbour area but did not elaborate on their mineralogy.

The lamprophyres intrude the metavolcanic–metasedimentary sequence of the east-west trending Archean Schreiber-White River greenstone belt. The predominant strike of the thin (generally less than 1 m) vertical dikes is north-south. However, for short distances, they often follow the dominant east-west regional trend of the country rocks.

As a group, the lamprophyres are essentially fine- to medium-grained, and when fresh they are characteristically dark grey-green in color. In contrast, the weathered surfaces are typically dun-brown. In many dikes, small mica phenocrysts, and in some examples, large mica macrocrysts a centimeter or so in diameter are observed. Olivine phenocrysts, commonly pseudomorphed, are readily apparent. In general the dikes show no evidence of chilled margins, and only one composite dike has been observed. Recent whole rock Rb–Sr isotope studies (Platt and Mitchell, in preparation) indicate an age of 1653±122 (2σ) m.y. for the McKellar Harbour dike suite. Such an age is considerably older than the Keweenawan igneous activity associated with the Mid-continent rift system in the Lake Superior basin (*i.e.*, 950–1170 m.y.; Douglas, 1980).

We believed initially that the dikes were in some way related to the carbonatitic activity of the Prairie Lake complex (1023±74 m.y.; Bell and Blenkinsop, 1980) or the alkaline activity of the Coldwell complex (1044.5±6.2 (2σ) m.y.; Platt and Mitchell, 1982), both of which lie in close proximity to McKellar Harbour (30 km and 5 km respectively). These two complexes, together with that of Killala Lake (1098±48 m.y.; Bell and Blenkinsop, 1980) may have formed within an aulacogen of a plume-generated triple junction associated with the Superior Mid-continent rift (Mitchell and Platt, 1978). However, petrological studies (Currie, 1980 and

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Mitchell and Platt, 1982) of the Coldwell complex have shown that no dikes of the type described here occur within this complex.

These observations and the Rb–Sr age determination clearly demonstrate that the dikes are not connected with the Neohelikian (950–1170 m.y., Douglas, 1980) magmatism but are examples of a previously unreported Paleohelikian/Aphebian period (1653 m.y., Platt and Mitchell, in preparation) of alkaline magmatism in the Lake Superior Basin. Alkaline rocks and carbonatites of a similar age have been reported, however, from the Kapuskasing High 200 miles to the east of the Marathon area (Currie, 1976).

Petrography

Mineralogically, all the dikes studied consist of varying proportions of olivine, phlogopite, primary carbonate, spinel and apatite. Olivine is strictly a phenocrystic phase and shows varying degrees of alteration to either a talc–dolomite–quartz mixture or to serpentine-like minerals; complete pseudomorphing is common. Phlogopite occurs as phenocrysts and as a groundmass phase. Apatite and spinel form small acicular and subhedral grains. They are minor but significant phases. Small opaque to deep red perovskite crystals have developed in some of the dikes. The above minerals are set in a mesostasis of anhedral primary carbonate.

Many of the dikes are characterized by the occurrence of small lath-shaped crystals. These crystals are now completely pseudomorphed by an intimate mixture of andraditic garnet and carbonate. Similar pseudomorphs described by von Eckermann (1948), from rocks of the Alnö complex, were considered to be pseudomorphs after melilite. Accordingly, we believe that melilite was a common mineral in the lamprophyres. Pyroxene is absent in all the dikes studied. In one particular dike, we observed the rare assemblage calcite, phlogopite, tetraferriphlogopite, Zr–Ti–rich andradite, monticellite, perovskite, and spinel, together with pseudomorphs after melilite. This dike has in part been described by Platt and Mitchell (1979). The absence of pyroxene and the presence of perovskite, monticellite, and melilite (?) indicates the extremely silica-undersaturated nature of the magmas of these dikes.

Xenoliths are rare. They have been identified from a single dike (C10). These very small xenoliths (< 5 mm) consist of a mixture of olivine pseudomorphs (carbonate–talc–quartz mixtures) intergrown with picro–ilmenite. This dike also contains large corroded ilmenite macrocrysts.

Petrochemistry

Whole rock analyses of representative dikes are given in Table 1. The general characteristics of the dikes are their extreme ultrabasic nature, moderate to high total iron and CaO contents, high MgO, low Al_2O_3 and Na_2O contents, and high K_2O/Na_2O ratios. Contents of CO_2 are variable but essentially high.

The dikes contain abundant Rb and Ba; a strong positive correlation between K, Rb and Ba ($r_{Ba/K}$ = 0.94; $r_{Rb/K}$ = 0.87; $r_{Rb/Ba}$ = 0.81) indicates that Rb and Ba are hosted by phlogopite. The high Ni contents reflect the Ni–rich nature of olivines (Table 2). Significant negative correlations between Ni and Ba ($r_{Ni/Ba} = -0.76$) and Ni and K ($r_{Ni/K} = -0.70$) reflect varying modal proportions of phlogopite and olivine.

The Ni content of the dikes (247–644 ppm) falls in the upper range of values accepted for primary upper mantle liquids in equilibrium with lherzolite (Frey *et al.*, 1978). However, these Ni contents may have been enhanced by olivine accumulation. Scandium contents (16–33 ppm) also cover the range of primary upper mantle liquids (15–28 ppm; Frey *et al.*, 1978).

Chemically, the McKellar Harbour dikes are similar to alnöites (von Eckermann, 1948), kimberlites (Gurney and Ebrahim, 1973), and lamprophyres (Ferguson and Currie, 1972).

Mineral chemistry

Olivine

Representative analyses of olivine phenocrysts are given in Table 2 (Analyses 1–3). These olivines are moderately rich in NiO and contain minor amounts of CaO and MnO. Ratios of Mg/Mg + Fe^{2+}(mg) (0.81–0.87) correspond closely to those of olivines from a variety of mafic and ultramafic rocks (*e.g.*, peridotites, olivine nephelinites, xenoliths and megacrysts from alkali basalts; Meyer, 1977). They are, however, more evolved than those generally associated with kimberlites (mg = 0.86–0.94) (e.g., Mitchell, 1973; Boyd and Clement, 1977), or those in equilibrium with primitive upper mantle liquids (mg = 87–0.90) (*e.g.*, Frey *et al.*, 1978; Ringwood, 1975).

In general, the olivine phenocrysts are either partially or wholly serpentinized or completely

Table 1. Representative whole rock analyses

Sample No.	C10	C690	C693	C695	C696	C699	C800	C844	C847	C851	C853
SiO_2	28.10	30.90	27.80	33.10	25.80	25.20	30.20	29.20	29.80	27.20	31.13
TiO_2	3.26	4.28	3.93	3.96	3.12	3.37	3.33	3.12	3.78	4.97	4.16
Al_2O_3	3.37	3.66	3.42	4.53	3.07	3.46	3.35	3.66	5.86	4.36	4.28
Fe_2O_3	2.69	10.29	4.43	4.56	5.70	8.60	3.52	3.84	5.71	6.84	5.45
FeO	9.28	5.80	8.92	6.92	6.60	5.80	9.20	6.88	9.28	9.48	10.72
MnO	0.17	0.27	0.22	0.26	0.27	0.22	0.23	0.26	0.35	0.26	0.24
MgO	19.72	19.25	19.34	17.84	16.05	22.18	18.76	19.80	14.79	13.18	17.52
CaO	9.41	14.37	12.28	13.47	18.40	15.63	13.10	12.45	15.50	15.12	10.43
Na_2O	0.28	0.31	0.30	0.37	0.32	0.41	0.40	0.37	0.35	0.29	0.35
K_2O	1.73	0.95	1.09	1.44	1.60	1.63	1.18	2.10	1.90	2.36	2.21
P_2O_5	0.35	0.78	0.52	0.82	2.28	0.91	0.63	0.98	1.64	1.32	0.70
H_2O	2.25	5.04	4.32	4.41	4.32	3.78	3.42	2.07	3.60	1.98	9.90
CO_2	20.02	4.62	14.41	9.24	13.31	8.47	14.08	15.95	9.24	13.42	3.42
Total	100.63	100.52	100.98	100.92	100.84	99.66	101.39	100.68	101.80	100.78	100.51
Trace Elements (ppm)											
Ba	nd	738	662	872	903	828	740	1433	1262	1572	1259
Rb	nd	37	66	73	60	56	54	100	75	129	145
Sr	nd	1122	1130	876	1495	1266	742	1236	1156	1367	1100
Sc	nd	18	28	24	16	nd	18	27	27	33	28
Ni	nd	644	526	563	446	637	564	506	337	247	485

nd = not determined.

transformed into a fine-grained mixture of dolomite + talc + quartz. These alterations occur to the mutual exclusion of each other and have never been observed in the same dike.

No in-depth studies have been made on the nature of the serpentinization of the olivines; however, some chemical information is given in Table 2. Analyses 4–5 are of pale green to colorless serpentines immediately surrounding patches of remnant olivine. They commonly appear dusty due to myriads of minute globular opaque grains. Impossible to analyze directly, the presence of S and Ni in some of the serpentine analyses suggests that these opaques may be Fe–Ni sulphides of the type reported by Wicks and Plant (1979, p. 793). These serpentines are chemically similar to the pale green, high-relief 1T–lizardites with anomalously high SiO_2 associated with the Type 3 retrograde serpentinization of Wicks and Plant (1979, p. 797).

Analyses 6 and 7 (Table 2) are green serpentines again associated with patches of remnant olivine. They are chemically akin to lizardites but contain slightly anomalous Al_2O_3 (Wicks and Plant, 1979). Orange-brown serpentines, commonly occurring as islands within the greener varieties, are represented by analyses 8 and 9 (Table 2). These are SiO_2–poor and comparatively iron-rich. The occurrence of iron-rich serpentine is common in alpine peridotites, layered ultrabasic intrusions, and kimberlites (Mitchell, 1978; Smith *et al.*, 1978; Wicks and Plant, 1979), where it forms by metamorphic reactions.

In general, olivine serpentinization appears to conform to the Type 3-retrograde event of Wicks and Plant (1979, p. 796).

Olivine commonly alters to an intimate mixture of talc and dolomite. Minor quartz is frequently observed, and opaque grains (magnetite?) commonly outline the pseudomorphed olivines. These grains also form within the body of the pseudomorph. Alteration of the olivine is always complete. If intermediate products (*e.g.*, serpentine) were formed during the reactions, they have not been preserved, although the opaque grains may be remnants of a prior serpentinization (Coats and Buchan 1979, p. 853).

Carbonation by CO_2–charged aqueous fluids is the logical cause of the talc + dolomite (+ quartz) alteration. For the formation of these three phases, moderate to high CO_2 contents of the fluid phase were required at moderate temperatures. The actual

Table 2. Representative olivine and serpentine analyses

Sample No.	C3	$C690_C$	$C690_R$	C690	C698	C690	C846	C846	C846
Analyses No.	1	2	3	4	5	6	7	8	9
SiO_2	39.38	40.69	40.51	42.74	42.91	39.05	40.39	36.76	36.93
Al_2O_3	-	-	-	0.75	0.86	2.12	2.47	3.37	1.06
FeO*	18.05	11.59	13.97	1.95	3.61	5.37	6.45	8.89	11.84
MnO	0.55	0.15	0.23	-	-	-	-	-	-
MgO	42.12	46.74	45.38	39.12	38.44	38.64	36.50	36.86	36.26
CaO	0.29	0.19	0.25	0.09	-	-	-	0.12	-
NiO	-	0.38	0.45	-	-	-	-	-	-
Total	100.39	99.74	100.79	84.65	85.82	85.18	85.81	86.00	86.09
Cation Content (Olivine=4 oxygens; Serpentines=14 oxygens)									
Si	1.001	1.009	1.006	4.076	4.070	3.800	3.903	3.626	3.703
Al	-	-	-	0.084	0.096	0.243	0.281	0.391	0.125
Fe^{2+}	0.384	0.241	0.290	0.155	0.286	0.436	0.520	0.732	0.991
Mn	0.012	0.004	0.005	-	-	-	-	-	-
Mg	1.596	1.727	1.679	5.557	5.430	5.600	5.253	5.416	5.415
Ca	0.008	0.006	0.007	0.009	-	-	-	0.013	-
Ni	-	0.008	0.009	-	-	-	-	-	-

*total iron as FeO, C=core R=rim

Analyses 1-3 = olivine; Analyses 4-9 = serpentine (see text)

values depend on the fluid pressures operative during the reactions (Slaughter *et al.*, 1975). At 1 kbar P_f, and assuming the formation of tremolite (now completely destroyed) as an intermediate product in the carbonation process, maximum temperatures on the order of 420–440°C, and an aqueous fluid composition of 70–95 mole percent CO_2, could well have existed (Slaughter *et al.*, 1975).

Mica

Mica is a ubiquitous phase in all the dikes; it occurs both as a groundmass phase and as small phenocrysts. Large macrocrysts were observed in one dike (C10, Figure 1), and further mention of these is made below. Compositionally (Table 3) all the micas analysed are phlogopites with Al in excess of two atoms in the tetrahedral sites. TiO_2 contents are variable but significant. For the most part CaO, Na_2O, Cr_2O_3 and MnO are either undetectable or insignificant. Inter-dike variations seem no more significant than intra-dike variations.

The large megacrysts or macrocrysts in dike C10 (Fig. 1) reach a size of about a centimeter across and they are commonly bent and distorted. They are distinctively composite in nature with large cores and narrow rims. The cores have orange to

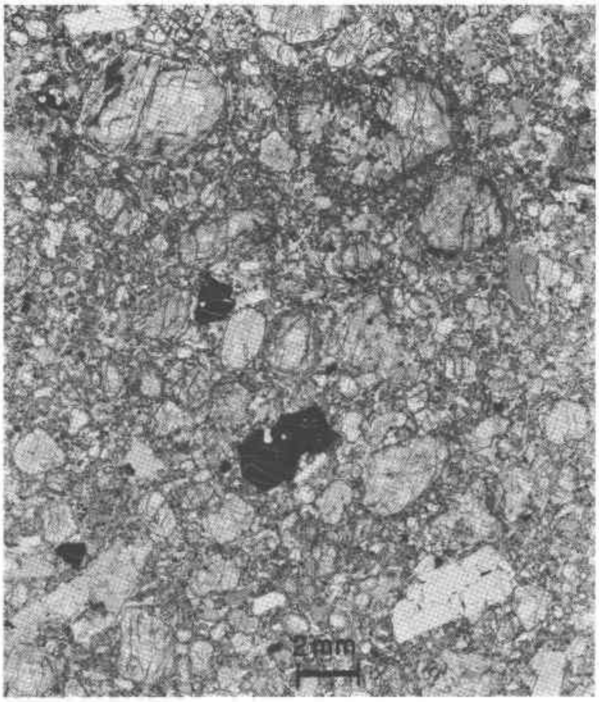

Fig. 1. Photomicrograph (plane polarized light) of McKellar Harbour dike C10 showing phenocrysts of ilmenite, phlogopite and olivine (pseudomorphed) in fine grained groundmass of spinel, carbonate and apatite.

Table 3. Representative phlogopite analyses

Sample No.	C689	C690	C691	C846	$C10_C$	$C10_R$
Analysis No.	1	2	3	4	5	6
SiO_2	36.89	37.52	39.26	38.79	39.29	37.05
TiO_2	5.77	2.64	3.06	1.51	2.34	5.26
Al_2O_3	14.87	14.10	11.98	13.92	12.20	14.86
Cr_2O_3	-	-	-	-	0.36	0.32
FeO*	9.98	7.16	8.46	6.40	7.62	7.80
MnO	-	0.21	-	0.10	-	-
MgO	17.46	22.31	21.81	23.90	22.37	19.82
K_2O	9.56	9.75	9.79	8.92	9.51	9.26
Total	94.62	93.93	94.36	93.54	93.69	94.66**
Cation Content (22 oxygens)						
Si	5.320	5.503	5.743	5.634	5.758	5.396
Ti	0.639	0.291	0.337	0.165	0.258	0.576
Al	2.581	2.457	2.067	2.384	2.108	2.552
Cr	-	-	-	-	0.042	0.037
Fe^{2+}	1.229	0.879	1.036	0.778	0.934	0.951
Mn	-	0.026	-	0.012	-	-
Mg	3.834	4.881	4.760	5.179	4.890	4.306
K	1.796	1.826	1.828	1.654	1.779	1.722

*total iron as FeO. **total contains 0.16% CaO.
C = core, R = rim

light orange pleochroism, whereas rims have red-brown to pale orange pleochroism. The core-rim boundary is invariably sharp, suggesting two distinct generations of mica. The rim mica optically resembles some smaller phenocrysts and the groundmass micas of the dike, a similarity confirmed by the chemical data. From Table 3, it is seen that the rim/groundmass micas are enriched in TiO_2, Al_2O_3 and Fe/Mg and depleted in SiO_2 and K_2O (Analysis 6). In comparison to the phlogopites from other dikes (Analyses 1 to 4, Table 3), the core phlogopites are generally richer in SiO_2 and Cr_2O_3 and have a lower Fe/Mg ratio. The rim phlogopites are also different in having lower K_2O, often lower SiO_2, and higher Cr_2O_3 values.

The phlogopite cores could either be xenocrysts or early-formed phenocrysts. The distorted nature of the crystals suggest some degree of stress, perhaps induced by transportation. The relatively high TiO_2 contents of the crystal cores precludes a primary upper mantle lherzolite origin (Carswell, 1975). However, they may indeed be high pressure phenocrysts. It is now generally accepted that the stability field of phlogopite extends well into the upper mantle. The crystal rims and smaller phenocryst/groundmass micas probably represent low pressure shallow level phases.

Reversely pleochroic mica (tetraferriphlogopite) was observed in a dike previously described by Platt and Mitchell (1979). No chemical data are available, but optically similar micas have been described from kimberlites, carbonatites, and ultramafic alkaline rocks (*e.g.*, Farmer and Boettcher, 1981).

Spinel

The main compositional variations found in the spinels are shown in Figure 2, and representative analyses are given in Table 4. The most primitive spinels, in terms of Ti–Fe–Cr content, are present as inclusions in olivines, as corroded crystals and as rare large euhedra. These early spinels (Table 4, analyses 1–2) are titaniferous–aluminous–magnesian chromites with Fe/(Fe + Mg) = 0.6–0.7, Cr/(Cr + Al) = 0.4–0.8 and Ti/(Ti + Cr + Al) = 0.1–0.4.

Intermediate groundmass type spinels (Table 4, analyses 3–4) are richer in Ti and Fe and are titaniferous aluminous chromites with Fe/(Fe + Mg) = 0.8–1.0; Cr/(Cr + Al) = 0.4–0.6 and Ti/(Ti + Cr + Al) = 0.3–0.8. The most evolved spinels are ulvöspinel magnetites (Table 4, analyses 5–6) with Fe/(Fe + Mg) = 0.8–1.0, Cr/(Cr + Al) = 0–0.1, and Ti/(Ti + Cr + Al) = 0.6–0.9. As the spinels become richer in total Fe, they become poorer in Cr and Mg, and richer in Mn. The spinel trend, established by the analysis of zoned crystals, is along the axis of the spinel prism rising from a point well above the Ti-free base towards the Fe-rich ternary face, and ultimately, with further increase in Ti and Fe, towards the Fe_2TiO_4 apex (Fig. 2).

This trend is markedly different to that observed in kimberlites (Mitchell, 1979), and the spinels in the McKellar dikes are characteristically poorer in the Mg_2TiO_4 molecule than are kimberlite spinels. The McKellar trend has some similarities with trends found in lamprophyres from the Fen complex and the W. Kentucky dikes (Mitchell 1979), but the McKellar spinels are markedly poorer in Al_2O_3.

A subsidiary trend to the main McKellar Harbour trend of spinel compositions has been documented from zoned spinels in a single dike, C10. This trend and representative chemical analyses of the spinels are shown in Figure 3 and Table 4 (Analyses 7–9) respectively. The most primitive (Cr-rich), and presumably earliest, spinels in this subsidiary trend are titaniferous aluminous magnesian chromites with Fe/(Fe + Mg) = 0.5–0.7, Cr/(Cr + Al) = 0.5–0.7, and Ti/(Ti + Cr + Al) = 0.05–0.15. These spinels are similar in composition to early spinels in the main trend, although they are distinctly poorer in TiO_2. The spinels appear to evolve parallel to the

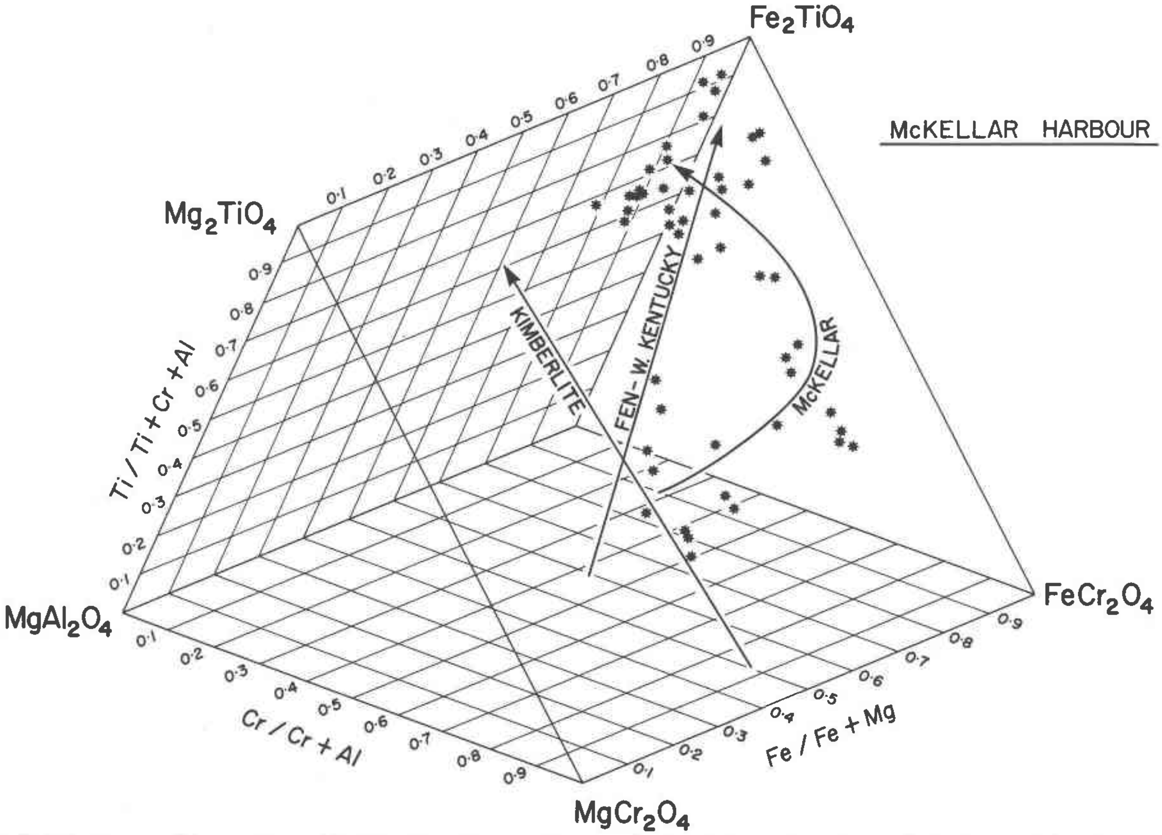

Fig. 2. Spinel compositions and trend from the McKellar Harbour dikes plotted in a reduced iron spinel prism. Kimberlite and Fen–West Kentucky lamprophyre trends plotted after Mitchell (1979).

Table 4. Representative spinel analyses

Sample No.	C690	C690	C694	C690	C691	C846	C10	C10	C10
Analyses No.	1	2	3	4	5	6	7	8	9
TiO_2	6.1	7.8	13.7	12.2	17.3	7.6	4.65	7.53	8.19
Al_2O_3	9.4	11.41	6.2	6.2	5.4	3.5	8.81	2.82	2.13
Cr_2O_3	35.9	28.7	12.5	13.0	0.0	0.0	40.12	32.65	30.79
FeO*	37.9	39.0	61.7	58.0	69.4	78.5	35.03	47.63	55.18
MnO	0.0	0.2	2.1	2.8	0.7	0.5	0.00	0.28	0.31
MgO	10.4	10.4	0.5	4.9	3.2	4.8	10.74	6.19	1.57
Total	99.7	97.5	96.7	97.1	96.0	94.6	99.35	96.89	98.17
Recalculated analyses**									
Fe_2O_3	16.3	16.3	24.6	27.5	30.3	52.9	15.27	20.58	20.38
FeO	23.2	24.3	39.5	33.3	42.2	30.9	21.27	28.90	36.84
Total	101.3	99.1	99.2	99.9	99.0	100.0	100.88	98.95	100.21
mol. % end member molecules									
$MgAl_2O_4$	15.5	18.6	2.3	9.6	8.1	5.1	14.9	4.8	3.7
$MgTiO_4$	19.2	18.1	-	7.1	2.9	9.4	15.0	16.4	2.4
$MnTiO_4$	-	0.4	3.8	4.5	1.0	0.8	-	0.5	0.6
Fe_2TiO_4	-	5.9	40.3	24.3	45.0	11.1	-	7.6	24.0
$MgCr_2O_4$	2.4	-	-	-	-	-	10.9	-	-
$MnCr_2O_4$	-	-	-	-	-	-	-	-	-
$FeCr_2O_4$	37.3	31.5	14.1	13.5	-	-	35.5	37.2	35.6
Fe_3O_4	25.7	25.5	39.6	40.7	43.0	79.8	24.7	33.5	33.7

*total iron as FeO **Recalculated by Carmichael's (1967) method.

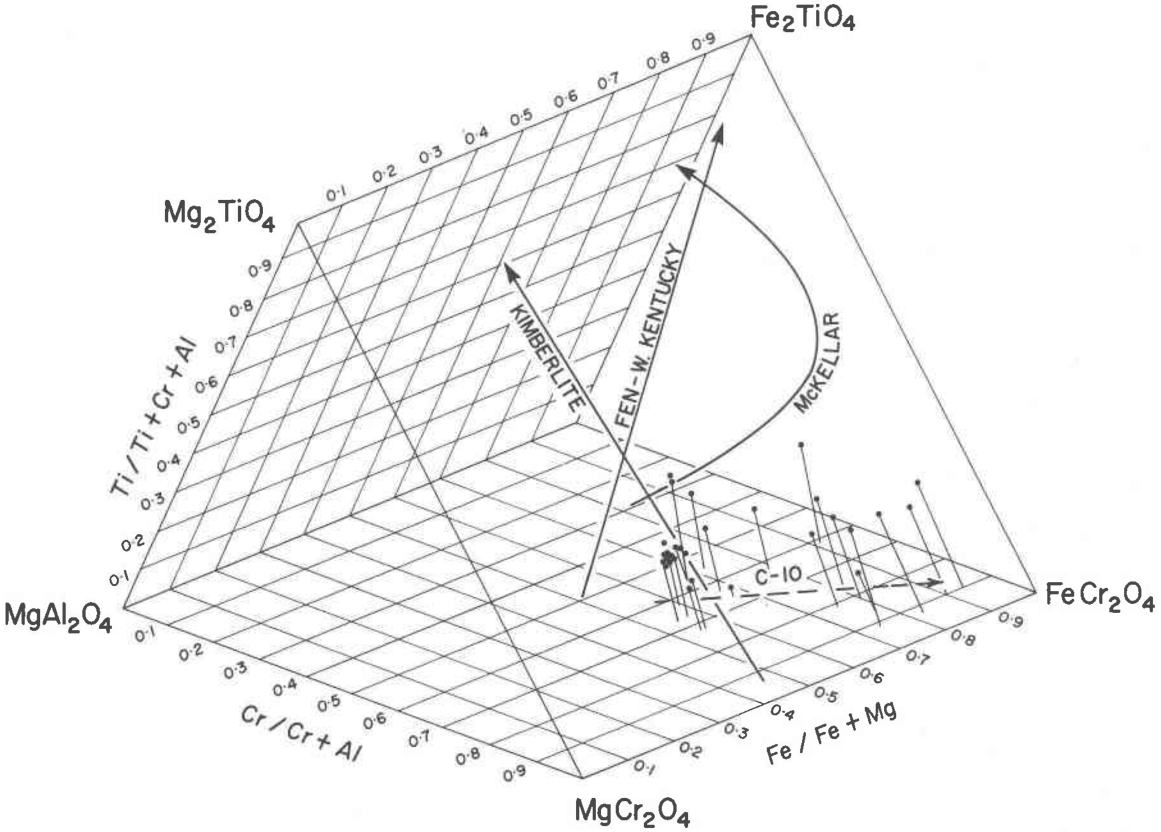

Fig. 3. Subsidiary spinel compositions and trend from McKellar Harbour dike C10 plotted in a reduced iron spinel prism.

base of the spinel prism (Fig. 3) towards $FeCr_2O_4$. This trend is one of increasing Fe and Cr at the expense of Mg and Al with approximately constant Ti. The most evolved spinels are titaniferous chromites with Fe/(Fe + Mg) = 0.9, Cr/Cr + Al) = 0.9 and Ti/(Ti + Cr + Al) = 0.2. As seen from Figures 1 and 2, this subsidiary trend is also different from that shown by kimberlites.

In general, the spinels from the McKellar Harbour lamprophyres have evolutionary trends that indicate affinities with alkaline rock-carbonatite magmatism (Mitchell, 1979).

Ilmenite

Ilmenite grains are found in three parageneses. They occur as small groundmass crystals, as large, corroded, phenocrysts, and as constituents of small ultramafic xenoliths. The latter paragenesis is discussed below. Representative analyses are given in Table 5.

The small groundmass crystals, which occur sporadically in the majority of dikes, are rich in MnO (2–8 wt.%). The chemical characters of these ilmenite show similarities to ilmenites associated with carbonatitic magmatism, particularly with respect to their Mn content (Mitchell, 1979).

Large (up to .5 cm) ilmenite phenocrysts have

Table 5. Representative ilmenite analyses

Sample No.	C4	C10	C10	C10	C10	C10
Analysis No.	1	2	3	4	5	6
Cr_2O_3	-	0.60	-	2.50	2.49	3.42
TiO_2	52.11	49.44	51.38	52.73	50.92	50.27
Fe_2O_3*	-	5.10	2.67	5.72	6.13	7.48
FeO	43.45	43.82	45.75	27.86	33.33	31.80
MnO	3.16	-	0.45	0.45	0.36	0.30
MgO	-	0.36	-	10.72	6.79	7.35
Total	98.72	99.32	100.25	99.98	100.01	100.62
Mol.% end member molecules						
$MnTiO_3$	6.85	-	0.96	0.90	0.74	0.62
$MgTiO_3$	-	1.37	-	37.78	24.64	26.55
$FeTiO_3$	93.15	93.45	96.50	55.1	67.86	64.46
Cr_2O_3	-	0.29	-	1.12	1.15	1.57
Fe_2O_3	-	4.90	2.53	5.09	5.61	6.82

*Fe_2O_3 calculated from total iron by Carmichael's (1967) method.
Analysis No. 1 = groundmass ilmenite; 2 & 3 = ragged ilmenite phenocrysts; 4, 5 & 6 = picroilmenites from ultramafic xenolith.

been observed in one dike (C10) (Fig. 1). Typical analyses are given in Table 5, and compositional variations are plotted in Figure 4. Figure 4 also serves to delineate the compositional range of the picroilmenites occurring in small ultramafic xenoliths within the same dike, C10.

Carbonate

The essential groundmass carbonate in most of the dikes studies is calcite, which commonly contains minor amounts of FeO, MnO, or MgO. The exception is dike C10, in which ankeritic dolomite or perankerite (Analysis 4, Table 6) occurs in close association with the Mg/Fe carbonate breunnerite (Analysis 5, Table 6) in the groundmass. Secondary dolomitic-carbonate (Analysis 6, Table 6) occurs with talc and quartz as a replacement of olivine. Calcite forms an intimate intergrowth with andraditic garnet as a probable replacement of melilite.

Table 6. Representative perovskite and carbonate analyses

Sample No.	C691	C698	C698	C10	C10	C698
Analysis No.	1	2	3	4	5	6
SiO_2	-	0.29	0.59	-	-	-
TiO_2	55.71	53.59	52.73	-	-	-
Al_2O_3	0.30	0.49	-	-	-	-
FeO*	1.61	2.17	8.03	6.94	23.70	4.28
MnO	-	-	1.77	0.28	0.62	0.75
MgO	-	-	-	17.63	29.06	18.37
CaO	39.14	38.11	28.24	28.65	0.33	28.29
Nb_2O_5	0.32	1.03	2.66	-	-	-
Total	97.08	95.68	94.02	-	-	-

*total iron as FeO

Analyses 1-3 perovskites; Analyses 4-6 carbonates

Perovskite

Perovskite is a minor phase in a number of dikes, where it occurs as small subhedral to euhedral deep brown to opaque grains. The majority of the perovskites analyzed contain moderate but significant amounts of Nb_2O_5 and small amounts of FeO, (Table 6, Analyses 1–2). Low totals suggest the presence of unanalysed elements (*e.g.*, REE or Sr). These perovskites are similar to those described from kimberlites (Mitchell, 1972; Boctor and Boyd, 1980).

Markedly different perovskites (Table 6, Analysis 3) have been analyzed from an olivine-free, phlogopite– calcite– zirconium–rich, titanian garnet–melilite (?)–spinel unit with the composite dike de-

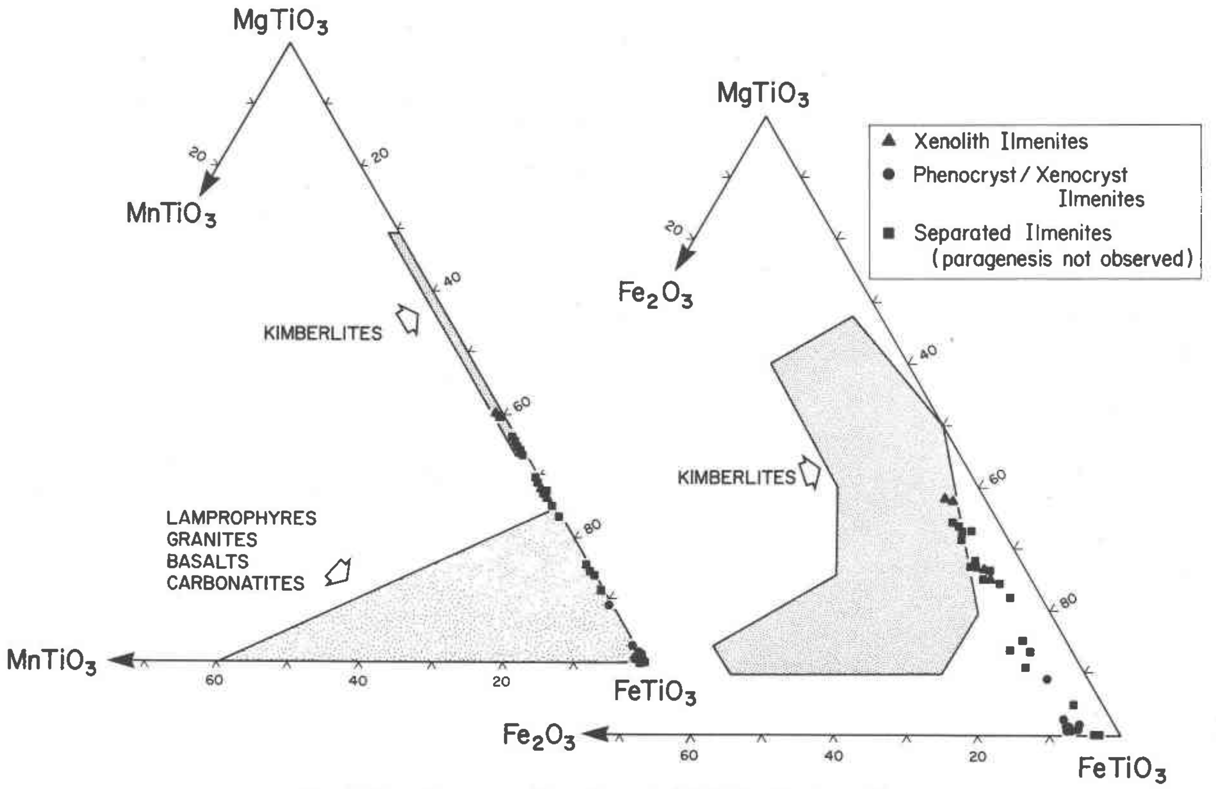

Fig. 4. Ilmenite compositions from the McKellar Harbour dikes.

scribed by Platt and Mitchell (1979). These perovskites are much richer in FeO, MnO and Nb_2O_5 than those generally observed in the present dike suite.

Xenoliths

Xenoliths have been found only in dike C10. They occur as small (2 mm or less) fragments sparsely scattered through the dike. They consist of carbonate–talc–quartz intergrowths (olivine pseudomorphs) and picroilmenite. Analyses of the ilmenite (Table 5) show significant MgO and Cr_2O_3 contents, and are quite different in composition from the ragged ilmenite phenocrysts found in the host dike (Table 5). The xenoliths, although small, display a distinctive granular texture.

The textural and mineralogical nature of these xenoliths suggests a high pressure origin. None of the low-temperature breakdown stages of Cr–ilmenite (Wyatt 1979, p. 261/2) has been observed, suggesting high temperature origin for the xenoliths. Figure 4 shows the close similarity between magnesian ilmenites from kimberlites and those reported here.

Conclusions

The McKellar Harbour dikes are characterized by the mineral assemblage phlogopite–olivine–spinel–perovskite–apatite–carbonate (calcite). Pseudomorphs considered to be after melilite are common. In North America, such calcite-rich ultrabasic dikes are commonly referred to as "kimberlitic dikes" (*e.g.*, Watson *et al.*, 1978). The mineralogy of the dikes, however, indicates no affinites with kimberlites; *i.e.*, they lack Cr–pyrope or picro–ilmenite megacrysts, they have a lamprophyric trend of spinel compositions, and they lack magnesian ulvospinels (Mitchell, 1979). Andradite–calcite replacements of melilite, rare occurrence of monticellite, and the presence of Zr–Ti–rich garnets indicates that the dikes have affinities with alnöites. No totally satisfactory petrographic term exists to define these lamprophyres (*e.g.*, Streckeisen 1978; Kresten 1979). We consider the McKellar Harbour dikes to be ultrabasic lamprophyres with alnöitic affinities.

The alkaline ultrabasic magmatism generating the lamprophyres has not been previously recorded in the Lake Superior Basin. They are not related to the late Neohelikian (1010–1050 m.y.) alkaline magmatism expressed as the Coldwell, Prairie Lake and Killala Lake complexes. Their characteristic mineralogy and chemistry suggest derivation from upper mantle liquids. We are unfortunately unable to speculate further on the petrogenesis of these dikes as we lack information regarding any contemporaneous or consanguineous magmatism.

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