THE SPINEL MINERALOGY OF THE C14 KIMBERLITE, KIRKLAND LAKE, ONTARIO, CANADA

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The C14 kimberlite is one of approximately 11 kimberlite occurrences located near Kirkland Lake, Ontario. A drillhole which intersects both diatreme and hypabyssal facies kimberlite within the pipe has formed the basis of a detailed investigation of the spinel mineralogy of the kimberlite. Over 350 new spinel analyses can be grouped into three distinct spinel populations within the diatreme:1) spinels associated with the kelyphitic rims on garnets, 2) spinel macrocrysts, and 3) groundmass spinel microphenocrysts.

The spinels associated with garnet kelyphite rims are of variable size (>50 μm to <5 μm), and occur as euhedral to subhedral, brown, translucent crystals occurring within the kelyphite proper or intergrown with associated mica and clinopyroxene. Generally these spinels are Al-rich with *CR#* < 0.3 (where *CR#* = Cr/(Cr + Al)) although some do range up to *CR#* = 0.7. The *MG#* (where *MG#* = Mg/(Mg + Fe^{2+}) of this group of spinels is restricted from 0.7 to 0.9. The majority of the kelyphitic spinels are homogeneous, however spinels with Cr-rich cores (*CR#* = 0.4 to 0.7) and Cr-poor rims (*CR#* = 0.1 to 0.25) do occur associated with a single garnet.

The second spinel population consists of relatively large (> 0.08 mm), well rounded, red transparent to opaque grains which have been identified in the nucleated autoliths and serpentine/calcite matrix of the diatreme facies as well as in the hypabyssal kimberlite. These spinels are considered macrocrysts and are characterized by high chromium contents (>50 wt% Cr_2O_3) with *CR#* = 0.7 to 0.9 and *MG#* = 0.5 to 0.65. In general the macrocryst spinels are chemically homogeneous, although some are mantled by a thin rim of titanium-rich magnetite. Traditional ratio plots are not particularly effective at distinguishing these spinels as a distinct population from early forming chromite microphenocrysts (figs. 1 and 2). However, a Cr vs. Fe^{2+} plot delineates these macrocryst grains as being compositionally distinct from the early forming groundmass spinels (fig. 3). Based on the different appearance and chemistry of the macrocryst spinels they are interpreted as being true xenocrysts, transported from depth within the kimberlite. The few points on figure 3 which overlap the groundmass spinel field represent rim analyses of grains in the hypabyssal kimberlite. These more evolved compositions are considered to be the result of the reinitiation of spinel growth at the edges of these grains within the kimberlite melt.

Microphenocrystal groundmass spinels are a ubiquitous phase in both facies of kimberlite. They are very small (generally <0.03 mm), euhedral to anhedral, opaque crystals and may occur as solitary grains or as inclusions in perovskite and, less commonly, in olivine. Chemically these spinels exhibit two zonation trends. The first trend, occurring in titaniferous magnesian aluminous chromites (TIMAC) (terminology of Mitchell, 1986), is one of increasing *CR#* (0.7 to 0.9) at restricted *MG#* (0.4 to 0.5) and constant Fe^{3+} and Ti (Figs. 4 and 5). This Cr-enrichment trend occurs in the earliest crystallizing chromites of both facies of kimberlite and includes those crystals which are included within silicates. The second chemical trend exhibited by the groundmass spinels occurs in complexly zoned grains ranging from TIMAC to titaniferous magnetite. This zonation trend, best displayed in the hypabyssal kimberlite, is one of decreasing Cr and Al, and increasing Ti, Fe^{3+}, and Fe^{3+}/Fe^{2+} (figs. 1-5). $Fe^{2+}/(Fe^{2+} + Mg)$ remains relatively constant over much of the trend, however, the latest forming titaniferous magnetites tend to be Mg-poor. In the diatreme facies, spinels showing this second trend have been identified only within nucleated autoliths and pelletal lapilli and never in the latest forming serpentine/calcite matrix. Where the Ti-magnetite does occur it may form as small (<0.01 mm) discrete, euhedral grains, as rims on continuously zoned TIMAC, or as atoll spinels with a TIMAC core and thin (1-10 µm) Ti-magnetite rim separated by a gap filled with a cryptocrystalline serpentine-like material similar in composition to the matrix. Occasionally, atoll spinels occur with euhedral Ti-magnetite cores and very thin (<1-2 µm) Ti-magnetite rims. There appears to be a continuum in crystal habit from continuously zoned spinels to the well formed atoll spinels. The textural and chemical relationships exhibited by atoll spinels suggest that this texture may represent a growth feature within the late stage kimberlite groundmass rather than being the result of a resorption event (Mitchell, 1986). The initial Cr-enrichment trend in the earliest formed groundmass chromites may be explained if Al was being removed from the melt at a faster rate than Cr. This may be accomplished by the co-precipitation of another Al-bearing phase such as phlogopite. However early phenocrystal phlogopite is not a modally important phase in the C14 kimberlite. The second chemical trend displayed by the groundmass spinels is similar to Mitchell's (1986) magnesian ulvöspinel trend and is interpreted as being the result of late-stage crystallization from an increasingly oxidized melt.

Mitchell, R.H. (1986) Kimberlites: Mineralogy, Geochemistry, and Petrology. Plenum Press, New York.

Figures 1-5 (next page): Cation ratio and cation-cation plots of C14 spinels. Plots are based on 3 cations per 4 oxygen. Crosses - microphenocrysts; open squares - macrocrysts; filled squares - kelyphitic spinels.

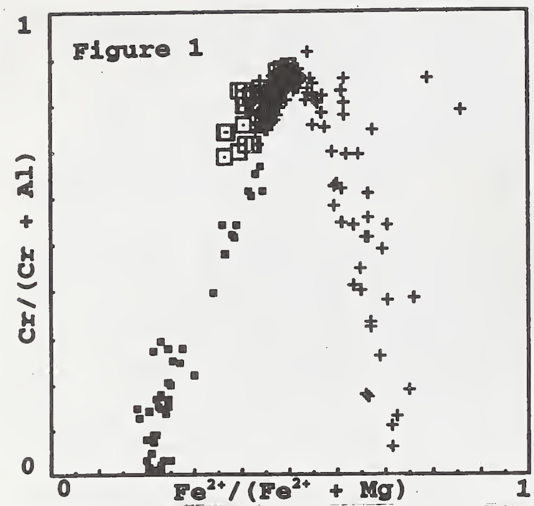

Figure 1
Cr/(Cr + Al)
1
0
0
$Fe^{2+}/(Fe^{2+} + Mg)$
1

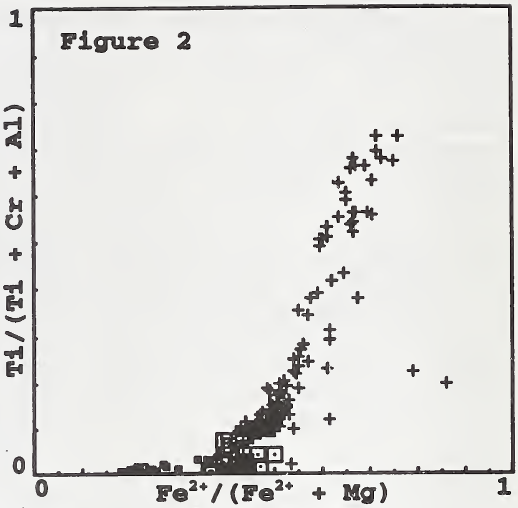

Figure 2
Ti/(Ti + Cr + Al)
1
0
0
$Fe^{2+}/(Fe^{2+} + Mg)$
1

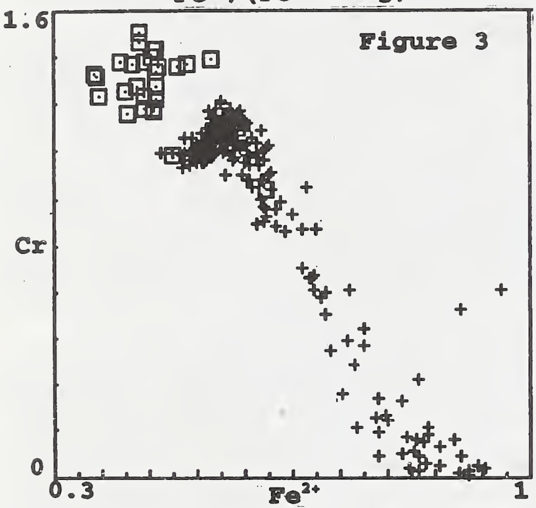

Figure 3
1.6
Cr
0
0.3
Fe^{2+}
1

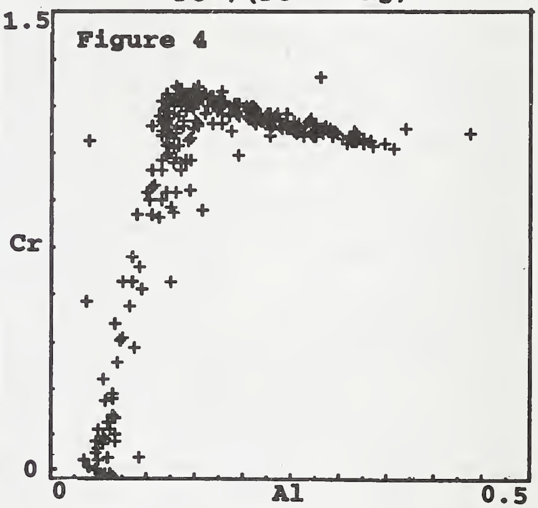

Figure 4
1.5
Cr
0
0
Al
0.5

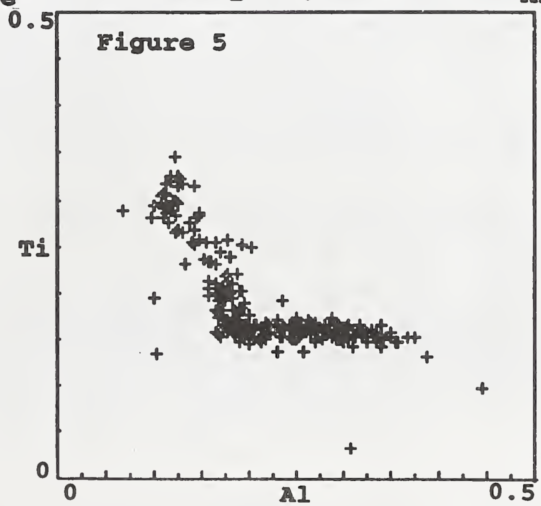

Figure 5
0.5
Ti
0
0
Al
0.5