

The petrology and geochemistry of kimberlite-like rocks from the Kontozero diatreme, Kola Peninsula, NW Russia

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Introduction

The Kontozero complex is located in the Baltic Shield, Kola Peninsula, Russia (Fig. 1). The complex consists of diverse plutonic and volcanic alkali-ultramafic and carbonatitic rocks filling a caldera-like depression some 8 km in diameter (Pyatenko and Saprykina, 1981). The volcanics are crosscut by a diatreme that comprises a suite of ultramafic alkaline and carbonate rocks, including kimberlite-like silicocarbonatites (KLS), hypabyssal carbonatites and carbonatite tuffs. The KLS have some petrologic similarities to Group-I kimberlites and were initially identified and logged as kimberlitic rocks, which prompted their detailed re-investigation. They were characterized and compared with bona fide kimberlites from several North American localities, including the Lac de Gras field in the Northwest Territories, Kirkland Lake field in Ontario and State Line region at the Wyoming-Colorado border.

Mineralogy of kimberlite-like rocks

The KLS have some textural similarities with kimberlites. They contain pseudomorphed macrocrysts and altered xenoliths in a fine-grained groundmass consisting of poikilitic phlogopite, spinel, perovskite, carbonate, apatite and serpentine (Fig. 2). The macrocrysts are commonly rimmed by “necklaces” of spinel and perovskite crystals. However, the KLS contain a higher proportion of phlogopite, carbonate and apatite in their groundmass and lack the diversity of macrocrysts typically observed in bona fide kimberlites (pyrope, pyroxenes and ilmenite). The macrocrysts in the KLS are consanguineous and consist of partial or complete pseudomorphs after monticellite (Fig. 2), although the presence of olivine in some varieties of these rocks cannot be ruled out. Microxenoliths in the KLS are represented by ultramafic rocks texturally and mineralogically distinct from mantle-derived peridotite nodules in kimberlites. We interpret these microxenoliths to originate from a cumulate unit fragmented and sampled by ascending melts.

Some of the principal constituents of the KLS (e.g., perovskite and phlogopite) show distinct compositional similarities to their counterparts in kimberlites. The phlogopite is indistinguishable in terms of its major-element chemistry from kimberlitic micas (24-28 wt.% MgO, 12-18 wt.% Al₂O₃, ≤ 0.5 wt.% TiO₂; Mitchell, 1995; Masun et al., 2004; Reguir et al., 2008). In common with kimberlitic phlogopite, that from the Kontozero rocks is commonly replaced by serpentine along the margin. Perovskite is low in Fe, Nb, Sr and rare-earth elements (≤ 2.3, 0.5, 0.7 and 2.7 wt.% respective oxides). In some samples, it is replaced by a cassite-type Ca-deficient oxide phase previously observed in both kimberlites and carbonatites (Chakhmouradian and Mitchell, 2000). Fresh monticellite from Kontozero is distinctly less magnesian and more calcic [$\text{Ca}/(\text{Ca}+\text{Mg}) > 0.52$; $\text{Mg}/(\text{Mg}+\text{Fe}) < 0.89$] than monticellite from hypabyssal kimberlites (< 0.51 and > 0.90,

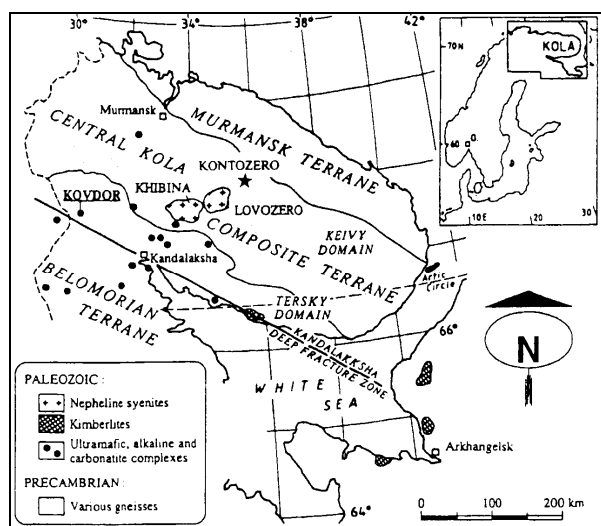


Fig. 1 Schematic structural map of the Kola Peninsula, Russia, showing the Precambrian terranes and Paleozoic alkaline and carbonatite intrusions. The location of the Kontozero complex is marked by a star (after Verhulst et al., 2000).

respectively). Spinel crystals commonly consist of aluminous (magnesian)chromite (up to 9.9 wt.% MgO, 7.2 wt.% Al₂O₃ and 43.6 wt.% Cr₂O₃) in the core and magnetite in the rim. Most crystals are relatively low in Ti and rich in Mn (≤ 5.2 and 1.7-3.7 wt.% respective oxides). Mg-Ti-rich compositions following magmatic trend 1 of Mitchell (1995) are characteristically absent.

Several minerals observed in the Kontozero rocks are inconsistent with their identification as kimberlites and indicate a carbonatitic affinity. These include groundmass Ca-Fe-Ti garnets containing up to 7.6 wt.% ZrO₂ and subsolidus sodic-calcic amphibole.

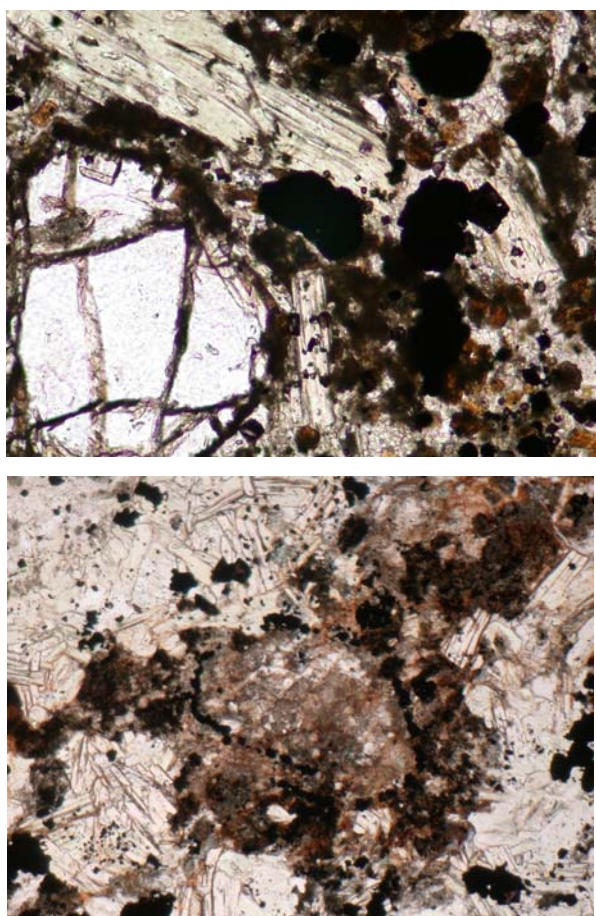


Fig. 2 Photomicrographs (in plane-polarized light) of KLS showing monticellite macrocrysts set in a fine-grained groundmass composed of phlogopite, spinel, perovskite, carbonate, apatite and serpentine. Width of the field of view is 2 mm for (a) and 5 mm for (b).

Geochemistry of kimberlite-like rocks

The KLS are characterized by lower SiO₂, MgO, Cr and Ni, but higher CaO, P₂O₅ and CO₂ contents relative to kimberlites, reflecting the higher modal abundances of calcite and apatite, and the scarcity of olivine and Cr-rich spinels in these rocks. The kimberlites are potassic [$(K_2O/Na_2O)_{\text{average}} = 4.9$] whereas the KLS from Kontozero are sodic [$(K_2O/Na_2O)_{\text{average}} = 0.7$].

The trace-element geochemistry of the KLS is compared to that of representative hypabyssal kimberlites from North America in Figure 3. The KLS can be distinguished from kimberlites by their strongly superchondritic Nb/Ta and Ga/Al values (28-39 and 0.0011-0.0016 respectively in the KLS; 17 and 0.0004 in the average hypabyssal kimberlite). The Zr/Hf ratio is variable, but its average value is higher than that in kimberlites (46 vs. 39) in accord with the enrichment of carbonatites in Zr relative to Hf worldwide (Chakhmouradian, 2006). The Kontozero samples lack a negative Sr anomaly typical of kimberlites (Fig. 3a). Both KLS and kimberlites are strongly enriched in light rare-earth elements (LREE) relative to heavy REE (Fig. 3b), but kimberlites show a much steeper REE profile (La/Yb = 28 for the KLS and 196 for the average hypabyssal kimberlite).

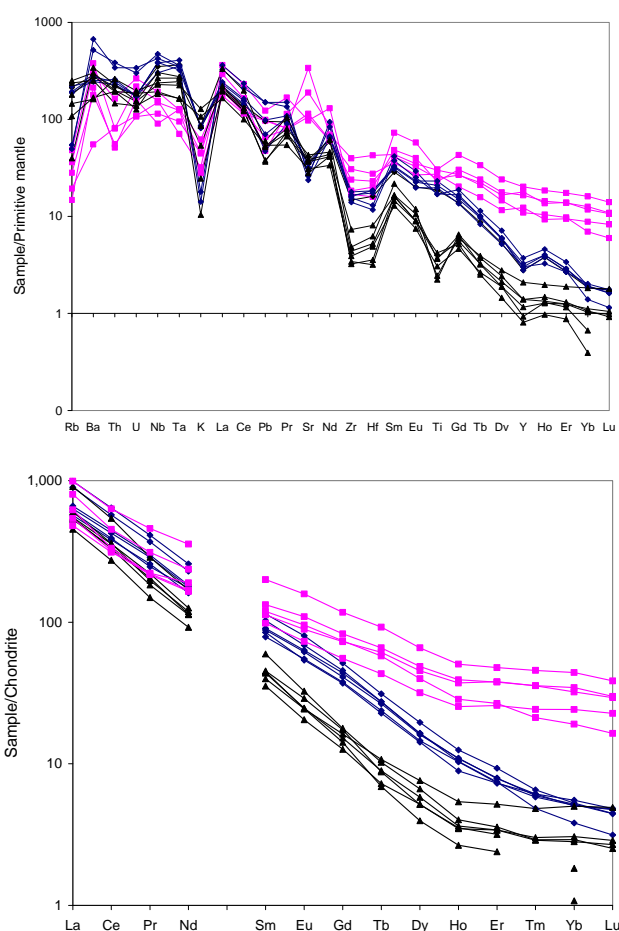


Fig. 3 (a) Primitive-mantle-normalized trace-element abundances and (b) chondrite-normalized REE abundances in the Kontozero KLS (purple squares) compared to North American kimberlites (blue diamonds and black triangles). Normalizing values are from McDonough and Sun (1995).

Discussion and conclusions

The kimberlite-like carbonate-rich rocks from the Kontozero diatreme are sufficiently different from kimberlites in terms of their mineralogy and geochemistry to preclude their identification as kimberlites. The observed differences in trace-element geochemistry indicate that the KLS originated from a mantle source significantly different from that producing kimberlitic magmas. The high Nb/Ta, Ga/Al and Zr/Hf values of the KLS imply that their source was a metasomatically modified lherzolite. Their enrichment in Sr and lower La/Yb values relative to kimberlites suggest a more shallow dolomitic source above the magnesite stability field.

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