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"Kimberlite" from Wekusko Lake, Manitoba: a diamond-indicator-bearing beforsite and not a kimberlite, after all

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Introduction

Despite its long and successful history of mineral exploration, the Province of Manitoba has been somewhat of a backwater on the Canadian diamond-exploration scene. Although several prospective targets have been recognized in the central and north-eastern parts of the Province, only one of them has so far been provisionally identified as "kimberlite". It was first intersected in drillhole GBO-16 (80.2-85.4 m) by Falconbridge Nickel Mines Ltd. during their 1983 drilling program focused on the Copper Man massive-sulfide deposit in the south-western section of Wekusko Lake, central Manitoba. The intersected rock was described as fine- to medium-grained breccia containing "occasional pyrope garnets" (Assessment File 70569, Manitoba Science, Technology, Energy and Mines). Following up on the reported garnet-bearing breccia, European Ventures Inc. drilled a series of holes in the same area in the early 1990s, three of which (EPV-5-93, -12A-94 and -17-94) intersected what was described as "a kimberlitic rock" visually identical in all of the three holes. A five-kilogram sample of the rock, examined by Gurney and Zweistra (1993), was reported to contain G10, G9 and possible diamond-inclusion eclogitic garnets. Clearly, accurate identification of the rock in question is important for further diamond exploration in the region, and interpretation of relations between kimberlites and texturally similar rocks around the world. The lack of reliable petrographic, mineralogical and geochemical data on the Wekusko Lake "kimberlite" prompted us to re-examine the material extracted in the course of the initial exploration activities. We used polarized microscopy, back-scattered-electron imaging, electron microprobe analysis, laser-ablation inductively-coupled-plasma mass-spectrometry (ICP MS), whole-rock borate-fusion ICP-MS, and stable-isotope and radio-isotope analysis to ascertain the nature of these rocks. The present report is a summary of our findings.

Regional geology

The study area is located in the eastern part of the Flin Flon belt of the Trans-Hudson Orogen. The tectonic evolution of this part of the Orogen is believed to have involved diachronous collision of the Archean Hearne, Superior and Sask cratons, which was largely complete by 1.8 Ga (Hajnal et al., 2005). Convergence between the Sask and Superior cratons at depth probably continued to 1.77 Ga, as indicated by post-collisional shortening structures. The relative extent of the Archean (Sask) rocks underplating this part of the Flin Flon belt is largely unknown. Bedrock exposures in the Wekusko Lake area comprise dominantly metavolcanic and metasedimentary supracrustal rocks intruded by granitoids and unconformably overlain by Ordovician dolomite (Gilbert and Bailes, 2005). The youngest intrusive rocks in this area are represented by gabbros and "kimberlitic dikes", the latter being the focus of the present report.

Petrography and mineralogy

The examined samples (EPV-12A-94 and GBO-16) differ in macroscopic color (brownish grey and greyish green, respectively), but both are fresh fine-grained rocks of inequigranular uniform to segregation texture (Fig. 1). The texture is dominated by abundant macrocrysts (0.2-2.5 mm across) set in a carbonate groundmass making up 70-85% of the rock by volume. The macrocryst suite comprises predominantly phlogopite (or chlorite pseudomorphs after phlogopite) and subordinate spinel-group minerals and ilmenite. Garnets were not observed in the present work. In addition to the macrocrysts, sample EPV-12A-94 contains abundant ovoid segregations (0.5-2.5 mm in size) of coarser-grained dolomite and angular quartz xenocrysts (Fig. 1). Dolomite segregations are also present in GBO-16, but these invariably host crystals of (chloritized) phlogopite.

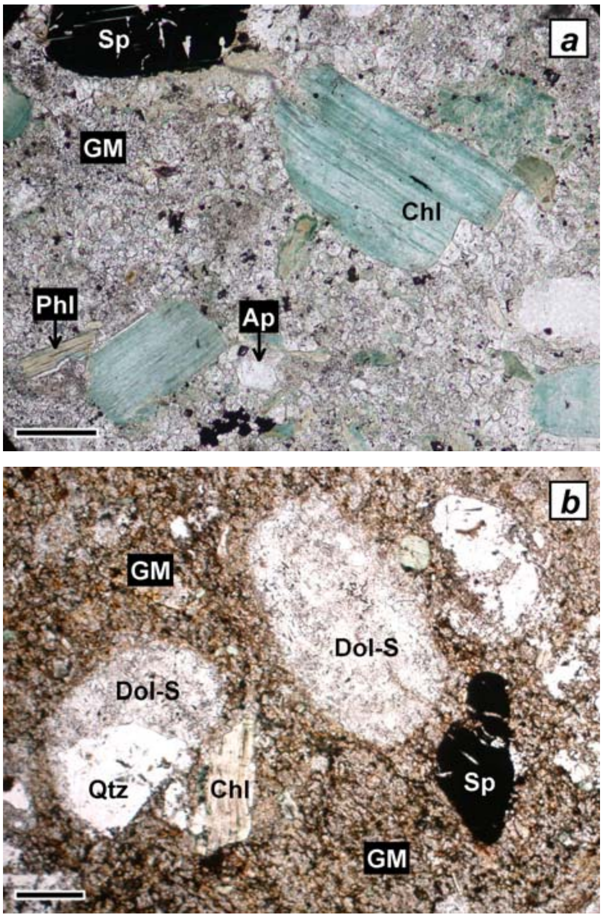

Fig. 1 Textural characteristics of samples GBO-16 (a) and EPV-12A-94 (b) as seen in thin section in plane-polarized light. Scale bars are 200 μm (a) and 500μm (b). Note chlorite (Chl), phlogopite (Phl) and spinel (Sp) macrocrysts and fluorapatite (Ap) phenocrysts in a dolomitic groundmass (GM). Sample EPV-12A-94 (b) also features ovoid segregations of coarser-grained dolomite (Dol-S) and quartz clasts (Qtz)

The bulk of the Wekusko Lake rocks is made up of dolomite with variable proportions of ankerite component in its composition. The highest Fe content (8.3 wt.% FeO) is observed in the core of large crystals from GBO-16, which also show elevated levels of Sr (0.3-0.6 wt.% SrO). Dolomite from both EPV-12 and GBO-16 (particularly, the latter) is also enriched in Ba (up to 320 ppm) and rare-earth elements (up to 950 ppm ΣREE). The Sr-Ba-REE enrichment is characteristic of carbonate minerals from carbonatites. The $\delta^{13}C_{PDB}$ values of dolomite (-7.6 to -5.3‰) are indicative of mantle origin, but its enrichment in heavy oxygen relative to unmodified mantle compositions ($\delta^{18}O_{SMOW}$ = 20-25‰) suggests isotopic re-equilibration with low-temperature CO_2-poor fluids. The Sr isotope composition of dolomite ($^{87}Sr/^{86}Sr$ = 0.70349±1) is distinct from that of sedimentary dolomite sampled south of Wekusko Lake (0.70853±1) and is indicative of a depleted mantle source.

Phlogopite macrocrysts and crystals from segregations have mg# = 0.64-0.85, 8.8-14.9 wt.% Al_2O_3 and 0.1-1.9 wt.% TiO_2. In terms of its mg#, Al and Ti contents, the Wekusko Lake chlorite covers the same range as the phlogopite, confirming that it as a product of phlogopite replacement. Notably, chloritization of phlogopite is much more typical of carbonatites than kimberlites. Given that micas from kimberlites and other carbonate-rich mantle-derived rocks cannot be reliably distinguished on the basis of their major-element composition, we analyzed the Wekusko Lake phlogopite by laser-ablation ICP MS and compared our data with the extensive dataset on micas from carbonatites and kimberlites (Reguir et al., 2008). The trace-element chemistry of the macrocrysts (< 100 ppm Cr and 200 ppm Ni, but 100-300 ppm Nb and > 400 ppm Mn) is inconsistent with a kimberlitic origin and is similar to that of Fe-Mg micas from carbonatites.

Spinel macrocrysts show zoning from a Mg-Al-Cr-rich core (10.0-13.4, 11.1-21.9 and 46.7-55.6 wt.% respective oxides) to a narrow Mg-Al-depleted, Fe-Ti-enriched reaction rim. Ilmenite macrocrysts are rich in Mg and Cr (9.3-10.0 and 1.6-2.6 wt.% respective oxides), but very low in Mn and Nb. Spinel macrocrysts of composition identical to the cores of the Wekusko Lake macrocrysts have been recovered from diamondiferous kimberlite around the world (Fig. 2a). The ilmenite compositions plot in the upper middle part of the well-defined kimberlitic trend and well away from the reference curve (blue, dashed) for non-kimberlitic ilmenite (Fig. 2b; Wyatt et al., 2004). It is noteworthy that, although ilmenite compositions from some melnoitic rocks straddle the reference curve, very few of them contain as much Mg and Cr as the ilmenite macrocrysts examined in this study.

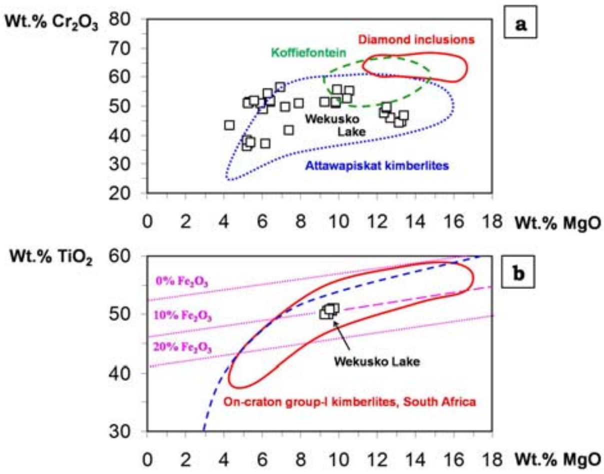

Fig. 2 Composition of spinel (a) and ilmenite (b) macrocrysts from Wekusko Lake rocks. Data for macrocrysts from bona fide kimberlites and diamond inclusions (Kong et al., 1999; Wyatt et al., 2004) are plotted for comparison

Whole-rock geochemistry

The Wekusko Lake rocks show the following major- and trace-element characteristics:

- high MgO, CaO and CO_2 (>20 wt.% each), moderate SiO_2 and $(Fe_2O_3)_T$ (3-8 wt.%), and low TiO_2, Na_2O, K_2O and MnO contents (<1 wt. %); relative enrichment of GBO-16 in K_2O, Al_2O_3, SiO_2 and P_2O_5 reflects much greater abundances of chloritized phlogopite and fluorapatite in that sample;
- elevated levels of compatible trace elements (30-110 ppm Co, 910-990 ppm Cr and 380-610 ppm Ni);
- enrichment in incompatible elements, particularly Sr (170-670 ppm), light REE (350-880 ppm), Nb (160-190 ppm), Zr (270-290 ppm), Th (60-100 ppm) and U (~20 ppm);
- high Nb/Ta, Zr/Hf and Ga/Al ratios (>21, 48 and 7×10^{-4}, respectively), but comparable Y/Ho ratio (25-28), relative to those in the primitive mantle (McDonough and Sun, 1995);
- strong enrichment in light REE relative to heavy REE, accompanied by negative Rb-Ba, K, Pb, Sr, Zr-Hf and Ti anomalies (Fig. 3).

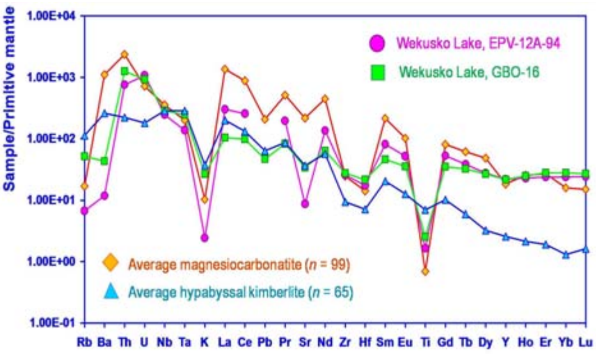

Fig. 3 Abundances of selected trace elements in Wekusko Lake rocks normalized to the primitive mantle (McDonough and Sun, 1995). Average compositions of magnesiocarbonatite and hypabyssal kimberlite are plotted for comparison (authors' unpublished data)

The most notable geochemical differences between the Wekusko Lake rocks and kimberlites are lower Th and U contents in the latter (≤ 40 and 12 ppm, respectively), as well as their mantle-like Nb/Ta, Zr/Hf and Ga/Al ratios (17, 39 and 4×10^{-4}, respectively, for the average hypabyssal kimberlite). In terms of their major- and trace-element geochemistry, the Wekusko Lake rocks are most similar to magnesiocarbonatites, but contain much higher levels of Cr, Co and Ni comparable to those observed in kimberlites. Note, however, that these elements are largely bound in spinel and ilmenite macrocrysts and, hence, do not necessarily reflect the Cr-Co-Ni budget of the Wekusko Lake parental magma.

Conclusions

With the exception of garnet, spinel and ilmenite macrocrysts, the modal and chemical makeup of the Wekusko Lake rocks is inconsistent with the identification of these rocks as kimberlite. On the basis of their modal, major- and trace-element composition, the samples studied should be classified as fine-grained magnesiocarbonatite (beforsite). The majority of phlogopite macrocrysts are cognate with their host rock and exhibit compositional variation typical of carbonatitic micas. The trace-element and isotope composition of dolomite also suggests carbonatitic affinity. The spinel and ilmenite macrocrysts are compositionally indistinguishable from their counterparts in kimberlites. This similarity, plus the essentially dolomitic composition of the samples studied, imply that their parental magmas were derived directly from a mantle source similar to those that produce kimberlites. Although mantle-derived spinels have been reported from several carbonatites worldwide (e.g., Ripp et al., 2006), the Wekusko Lake beforsite is the first example containing extremely Cr-Mg-rich macrocrysts equivalent to the indicator minerals routinely used in diamond exploration. This conclusion has important implications for indicator-based exploration in the Trans-Hudson Orogen and beyond. A detailed radio-isotope study of the Wekusko Lake rocks is being presently undertaken to elucidate the nature of their mantle source and geodynamic regime at the time of their emplacement.

References

Gilbert, H.P. and Bailes, A.H., 2005. Geoscientific Map MAP2005-2, scale 1:20,000.

Gurney, J.J. and Zweistra, P., 1993. Report on the diamond potential of kimberlite EPV-01 submitted by Orex Laboratories under Batch OR93/002, 6 p.

Hajnal, Z., Lewry, J., White, D., Ashton, K., Clowes, R., Stauffer, M., Gyorfi, I., Takacs, E., 2005. The Sask Craton and Hearne Province margin: seismic reflection studies in the western Trans-Hudson Orogen Canadian Journal of Earth Sciences 42, 403-419.

Kong, J.M., Boucher, D.R., Scott Smith, B.H., 1999. Exploration and geology of the Attawapiskat kimberlites, James Bay Lowlands, Northern Ontario, Canada. In: Proceedings of the 7th International Kimberlite Conference, Volume 1. Cape Town, 452-467.

McDonough, W.F. and Sun, S.-s., 1995. The composition of the Earth. Chemical Geology 120, 223-253.

Reguir, E.P., Chakhmouradian, A.R., Halden, N.M., Malkovets, V., Yang, P., 2008. Major- and trace-element compositional variation of phlogopite from kimberlites and carbonatites as a petrogenetic indicator. Extended Abstracts CD, 9th International Kimberlite Conference, Frankfurt, Abstract No. 9IKC-A-00049.pdf.

Ripp, G.S., Karmanov, N.S., Doroshkevich, A.G., Badmatsyrenov, M.V., Izbrodin, I.A., 2006. Chrome-bearing mineral phases in the carbonatites of Northern Transbaikalia. Geochemistry International 44, 395-402.

Wyatt, B.A., Baumgartner, M., Anckar, E., Grutter, H., 2004. Compositional classification of "kimberlitic" and "non-kimberlitic" ilmenite. Lithos 77, 819-840.