

## **Constraining the crust and mantle contributions to kimberlite – a multi-phase micro-sampling approach**

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The elemental and isotopic composition of ‘primary’ kimberlite magma has been the subject of considerable debate for decades. The frequent occurrence of variably sized crustal fragments within hypabyssal and volcanoclastic kimberlite sequences is a clear indication of the potential importance of crustal contamination in modifying the composition of the kimberlite magma. Recent systematic studies of kimberlite whole rock geochemistry have highlighted the impact of crustal interaction on kimberlite compositions (e.g., le Roex et al., 2003; Dowall, 2004). However, an accurate quantification of this process and a confident estimate of the pre-contamination composition of the kimberlite magma have proven elusive goals. In order to solve this problem an early-crystallising phase, such as perovskite, representing the pre-contaminated magma is required. The importance of perovskite for kimberlite geochronology and as a petrogenetic tracer was recognized some time ago (Heaman, 1989), but has not been routinely pursued. Perovskite is a relatively common groundmass phase that crystallises after the olivine and spinel (+/-phlogopite) phenocrysts. Within the groundmass, crystallization of perovskite is typically thought to be ‘early’ with respect to apatite, monticellite, Ba-phlogopite, spinel and calcite. Recently perovskites have been analysed for Sr isotopes using laser ablation

to try and address some of the above issues (Paton et al., 2007). In this study we pursue a multi-phase micro-sampling and hand-picking approach to examine the Sr, and in some cases Nd, isotope composition of kimberlite “magmas” at various stages in their crystallisation.

### **METHOD**

Perovskite crystals, ranging from 30 to 60µm in diameter, were hand-picked from coarse kimberlite crush produced from a hypabyssal phase of the C-14 kimberlite, part of the Kirkland Lake cluster, Canada. These were cleaned and leached before being dissolved and processed for isotope and trace element analysis.

The main reason for picking the perovskites rather than analysing them by laser ablation is that a greater amount of chemical information can be acquired for each sample. It is also possible to analyse smaller crystals than those typically required for laser ablation analysis therefore opening up a wider range of kimberlites and kimberlite-hosted phases for study

A number of individual crystals were analysed for Sr isotopes alone. Multi-crystal composites, of 3 to 9 grains, were analysed for both Sr and Nd as single grains did not

yield sufficient Nd for isotope analysis. All crystals were analysed for a range of trace elements, including REE.

## PRELIMINARY RESULTS

Sr isotope ratios for perovskites from C-14 show a wide range from 0.704703 ( $\pm 17$ , 2SE) to 0.705553 ( $\pm 18$ , 2SE) with significant inter-grain isotopic variation that is clearly resolvable outside of analytical uncertainty ( $\pm 16$ , 2SD). So far Nd isotopes have only been measured on multi-grain composites yielding very consistent ratios, averaging 0.512694 ( $\pm 45$ , 2SD  $n=4$ ). The REE patterns were also very consistent showing typical kimberlite REE patterns, i.e., high LREE and La/Yb ratios.

## DISCUSSION

Previous isotope studies of kimberlite hosted perovskites (Heaman 1989, Paton et al 2007) have found them to have considerably lower initial Sr isotope ratios than their host and to be isotopically homogeneous. The implication has therefore been that the perovskites crystallised before significant crustal contamination of the kimberlite took place. However, it is also possible that the lower initial Sr isotope ratios found by Paton et al (2007) could be in part due to the highly altered (i.e. non-fresh) state of the whole rock samples. Their application of the LA method may also potentially be biased towards the larger crystals which may have crystallised earlier, recording a more primary signature closer to values previously suggested for megacrysts (Nowell et al., 2004).

The  $^{87}\text{Sr}/^{86}\text{Sr}_i$  results for the perovskites from C-14, however, show significant heterogeneity which overlaps that from the closest available whole rock analysis (Upper Canadian Mine, Kirkland Lake). The  $^{143}\text{Nd}/^{144}\text{Nd}$  results, on the other hand, are homogeneous but more radiogenic than the whole rock from the Upper Canadian Mine. The trace element concentration suggest that perovskites in this sample crystallised late in the groundmass sequence, perhaps after

apatite, thus explaining lower Nd concentrations than expected.

The heterogeneity in  $^{87}\text{Sr}/^{86}\text{Sr}$  coupled with homogeneous  $^{143}\text{Nd}/^{144}\text{Nd}$  is consistent with variation observed in different whole rock analyses from some kimberlites, e.g. Jericho (Kopylova, this volume). Varying degrees of crustal contamination have been modeled to explain these observations. The initial data therefore suggest that the C-14 perovskites are probably recording the changing composition of the magma and not a primary mantle signature.

The variable effects of crustal and post-emplacement contamination recorded by perovskites from different locations warrants further investigation before this phase is used to better assess kimberlite primary melt isotopic compositions. Analyses of other kimberlite phases, such as apatite and calcite, is underway to better understand the timing of contamination effects during the crystallization of the kimberlite groundmass. This will hopefully identify a phase that has been least affected by crustal contamination of the kimberlite magma.

Estimation of the “uncontaminated” Sr isotope composition of kimberlite melt will assist the debate regarding the relationship between the low-Cr megacryst suite and their host kimberlites (e.g., Nowell et al., 2004; Davies et al., 2004) and some recent studies have argued that the commonly observed difference between kimberlites and their megacrysts, often used to deny a co-genetic relationship even though Nd and Hf isotope compositions overlap, can be explained via modest degrees of contamination of the bulk kimberlite (e.g., Kopylova et al, this volume). Further studies of other samples from a variety of locations, some of which have megacryst data, will help to resolve this issue.

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