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GEOCHEMISTRY AND GEOCHRONOLOGY OF TANZANIAN KIMBERLITES.

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The Tanzanian craton is host to numerous kimberlite intrusions, although few have been studied in any detail. Due to its proximity to the East African rift zone, this region provides a unique opportunity to investigate the effect of rifting on kimberlite volcanism. However, no geochemical studies have been conducted on Tanzanian kimberlites to date, largely due to their altered and weathered nature, and only four intrusions have published age constraints. The availability of modern high precision analytical techniques has provided an opportunity to study the kimberlites of this previously neglected region.

The study focused on 17 separate kimberlite intrusions located on the Tanzanian Craton. Due to their highly altered and weathered character, perovskite was used as a proxy to obtain geochemical and geochronological information on the host kimberlites. Perovskite is a common accessory mineral in kimberlites and contains substantial U, Sr and Nd and lesser amounts of Pb and Hf. Consequently, perovskite provides the means to determine both age constraints and initial isotopic signatures for the host kimberlites. This paper presents the first comprehensive geochemical and geochronological study of the Tanzanian Kimberlites.

Results

Perovskite extracted from the Tanzanian kimberlites was analysed for U-Pb geochronology as well as trace element and Sr-Nd-Hf isotopic compositions. Similar to kimberlites elsewhere, these samples show extreme enrichment in large ion lithophiles and LREE, whereas they are HREE depleted. Tanzanian kimberlitic perovskites are characterised by Lu/Yb_{cn} values ranging from 251 -1058. The REE distribution patterns display characteristics similar to those seen in perovskite from other worldwide occurrences (e.g. Mitchell and Reed, 1988, Melluso, *et al.*, 2008, Yang, *et al.*, 2009).

The isotopic compositions of Sr, Nd and Hf were determined via solution chemistry for 12 perovskite mineral separates. Perovskites analysed are characterised by moderately radiogenic Sr isotopic compositions, and plot within the range previously defined for Group I kimberlites (Figure 1). $^{87}Sr/^{86}Sr_i$ values range from 0.70341 to 0.70476 and εSr values range from -14.56 to +4.46‰. Initial Nd isotope compositions display a more restricted range and again lie within the range of previously reported for Group I kimberlites (Figure 1). $^{143}Nd/^{144}Nd_i$ values range from 0.51265 to 0.51277 and εNd_i values range from +1.8 to +3.8‰. Hf isotopic compositions were obtained in both perovskite and MUM spinel separates. Again, observed isotopic compositions are restricted and plot within the field previously defined for Group I kimberlites (Nowell, *et al.*, 2004; Figure 2). $^{176}Hf/^{177}Hf_i$ ranges from 0.282764 to 0.282966 and εHf values range from +0.8 to +8.2‰.

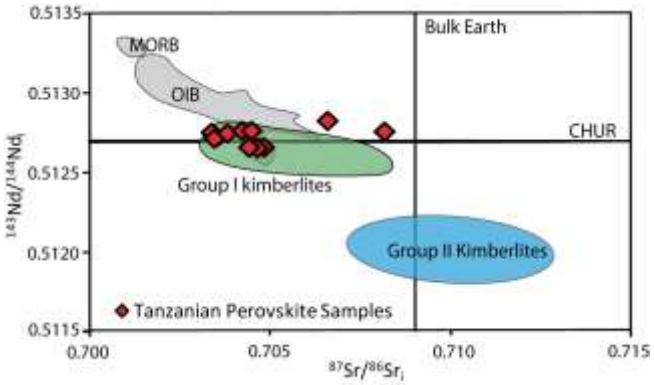

Figure 1 A plot showing $^{143}Nd/^{144}Nd_i$ vs. $^{87}Sr/^{86}Sr_i$ compositions of perovskite separates analysed during this study. Data for group I and II kimberlites are sourced from: Nowell, *et al.*, 2004, Le Roex, 2003 and Becker and Le Roex, 2006, Gaffney, *et al.*, 2007 and Smith, 1983. OIB and MORB data from Saunders, *et al.*, 1988 are shown for comparison.

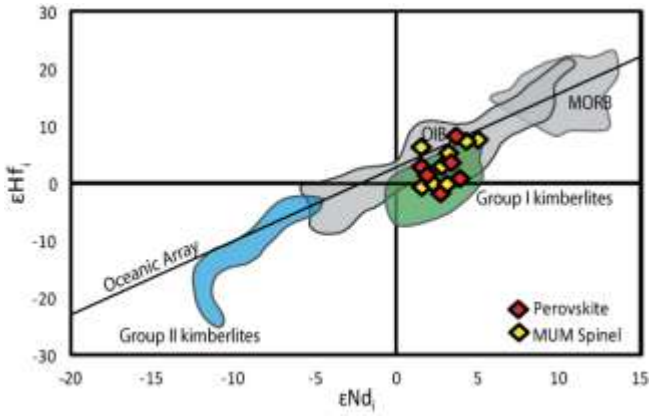

Figure 2 A plot showing εHf_i vs. εNd_i compositions of perovskite separates (red) and MUM spinels (yellow) analysed in this study. Regions for group I and II kimberlites (data from Nowell, *et al.*, 2004), MORB and OIB (data from Saunders, *et al.*, 1988) are shown for comparison.

In situ LA-MC-ICPMS determinations of perovskite Sr isotope compositions were also obtained from 24 samples representing seventeen kimberlites. $^{87}Sr/^{86}Sr_i$ values range from 0.70311 – 0.70489 and εSr_i values range from -19.04 to +6.35‰.As expected from previous studies (Woodhead, *et al.*, 2009), the results acquired via laser ablation sampling are similar to those obtained by solution chemistry methods.

Perovskite U-Pb dating was successfully applied to eight samples providing the most comprehensive geochronological study of these intrusions to date. This study has tripled the number of dated intrusions in this region. U-Pb dating of perovskite separates proved to be the most reliable method for obtaining age information from these samples. Sufficient perovskite to produce a pure separate was obtained for nine samples from eight intrusions.

The ages obtained for these samples define two periods of kimberlite volcanism for the Tanzanian Craton. Early Mesoproterozoic kimberlites include the Itanana kimberlite (1083 Ma) and the previously dated Bubiki kimberlite. All other kimberlites for which ages were obtained are significantly younger, with ages ranging from 44-80 Ma. The latter group includes some of the youngest reliably dated kimberlites known; the Kikhomango (44Ma) and X073 (47Ma) intrusions. Ages from both the older and younger Tanzanian kimberlites coincide with periods of known kimberlite activity worldwide.

Conclusions:

Previous studies (e.g. Griffin, *et al.*, 1991, Tainton, *et al.*, 1999) have observed a direct correlation between the temperatures recorded by garnet xenoliths entrained in the Tanzanian kimberlites and the proximity of the kimberlite body to the East African Rift. These authors both propose that rift related heating is likely to have affected the SCLM sampled by these intrusions. A similar correlation was expected between composition and proximity to the rift in the isotopic or trace element compositions of kimberlites sampled during this study. This is not observed, with no correlation between the geographic location of the kimberlite intrusion and its composition is observed. It is suggested that these results suggest a deeper source for the Tanzanian kimberlite magmas, below the influence of rifting in the region.

This contention is further supported by the homogeneity of the isotopic and trace element composition of kimberlite samples over the known age range. Tanzanian kimberlites with known ages range in age from ~40-~80Ma and ~1100Ma. During this time, multiple metasomatic events have affected Tanzanian SCLM resulting in significant changes to its mineralogical, chemical and isotopic composition. Again, no correlation between kimberlite age and composition are observed, further supporting a deep source for these intrusions.

A model which places the source of Tanzanian Group I kimberlite magmas within sub-lithospheric depths can also provide the best explanation for the unique Hf isotopic compositions observed in these rocks. Development of the negative $\Delta\varepsilon Hf$ values requires a source characterised by fractionated Lu/Hf relative to Sm/Nd to undergo long term isolation from the convecting mantle, allowing generation of their distinctive isotopic signature. Compositional modelling undertaken by Nowell, *et al.*, 2004 demonstrates that long term storage of MORB or NMORB type material at sub-lithospheric depths can produce these negative $\Delta\varepsilon Hf$ compositions. Again, a sub lithospheric source is indicated.

The results obtained during this study support the models proposed by previous authors (e.g. Ringwood, *et al.*, 1992, Nowell, *et al.*, 2004, Paton, *et al.*, 2009) which place the ultimate kimberlite source at sub-lithospheric depths, possibly as deep as the transition zone. Modelling undertaken by these authors has demonstrated that partial melting and long term storage of MORB-type material can explain both the trace element and isotopic compositions observed in kimberlite worldwide. Data obtained for the Tanzanian kimberlites further supports these models, providing additional evidence for a sub-lithospheric source for Group I kimberlites.

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