The role of multi-stage processes on REE enrichment in Kangankunde carbonatites, Malawi

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Carbonatites, igneous rocks associated with intracontinental rifting zones, are focused on as critical resources due to their enrichment in Rare earth elements (REEs) and other critical elements. Carbonatites are usually formed from magmatic processes followed by subsequent alteration, however, the role of the respective processes to REE enrichment remains a crucial topic. Petrographic, geochemical and isotopic analyses were therefore carried out to clarify the enrichment processes of REEs in carbonatites of Kangankunde carbonatite complex, the largest deposit of the Chilwa Alkaline province in Malawi.

Field observations of the complex indicate that earlier carbonatites were notably cut by later (carbothermal) fluids suggesting an occurrence of complex post magmatic processes. Monazite is the most abundant rare earth hosting mineral commonly occurring with strontianite, barite and occasional apatite in a dolomite matrix. Two distinct occurrences of monazite were observed, a primary poly-crystalline phase with minor enrichment of REEs and a later, well-developed crystalline phase that occurs along dolomite edges, and may have been disseminated by a later fluid that was highly enriched in REEs. A bulk geochemical analysis showed that REE patterns of Kangankunde carbonatites display a strong LREE enrichment in all carbonatites except those rich in apatite suggesting a mineral control for the REE uptake. Bulk $\delta^{13}C$ and $\delta^{18}O$ isotopic compositions ranged from –4.79 ‰ to –0.13 ‰ and 14.21 ‰ to 29.48 ‰ respectively, which revealed that minor magmatic signatures may have been preserved in the C isotopes, while the wide variation in isotopic O points towards low temperature post magmatic alteration.

A combination of the analyses shows that the Kangankunde carbonatites evolved from magmatic processes, which led to the occurrence of the REEs in the carbonatites, however, a subsequent low temperature fluid played a significant role in the enrichment of the REEs in the carbonatites.