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An investigation of rare earth element enrichment processes in diatremes and related carbonatites in western South Africa

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Mantle-derived carbonatites (and their supergene alteration products) make up one of the most important types of rare earth element (REE) deposits on Earth. In many cases, carbonatites appear to have formed from a CO_2-rich, mafic or ultramafic alkaline parent magma from which a carbonatitic melt phase separated at relatively shallow depths. In western South Africa there occur hundreds of diatremes of Late Cretaceous to Early Tertiary age present mainly in two linear zones, a 400 km NNE-SSW oriented swarm in Namaqualand-Bushmanland and a swarm with far fewer diatremes extending 340 km south from the area around the town of Sutherland in the southern Karoo [e.g., 1]. These are composed of CO_2-rich igneous rock types such as olivine melilitite, kimberlite and, rarely, carbonatite. In some cases, these diatremes are capped with a layer of oxidatively altered material that is highly enriched in the rare earth elements. The best example of this is the carbonatite complex at Zandkopsdrift in Namaqualand, in which, due to supergene processes, the upper ≈70 m has been highly REE enriched, with total rare earth oxide (TREO) contents of up to 10 wt.% [2]. We have recently conducted geochemical studies of REE-enriched mineralised crusts from 27 volcani-clastic breccia-filled diatremes in southern Bushmanland as well as carbonatites, melilitites and fenitised/mineralized breccias and crusts from the Saltpeterkop carbonatite complex.

Supergene crusts partially cover many Bushmanland volcaniclastic breccia pipes and are typically thin (< 1 m). Their compositions are dominated by SiO_2 and Fe_2O_3, with K_2O and P_2O_5 also being relatively high (averaging 3 and 1.5 wt.%, respectively). XRD study of their mineralogy is under way. REE con-tents in the crusts are high with average TREO values of 0.7 wt.% and a maximum value of 2.2 wt.%. All crusts are moderately to strongly LREE-enriched and a few show distinct positive and negative Ce anomalies, suggesting that alteration occurred under variably oxidising and reducing conditions. The trace element compositions of most crusts show a strong resemblance to ferrocarbonatite, which may have formed as a late-stage magmatic liquid separating from evolved melilitite magmas.

The Saltpeterkop complex, located 18 km ESE of Sutherland in the Northern Cape, is unusual in both its size (a 1 km-diameter central tuff ring along with dykes, sills and diatremes occurring up to 6 km radial

distance) and the wide variety of igneous rocks present, including carbonatite (calcium and iron-rich varieties), K-rich trachyte and olivine melilitite [1]. Volcanic and hypabyssal rocks of the complex are dominated by silicified volcaniclastic breccias and bedded tuffs within the central ring structure, and dykes, sills and diatremes of carbonatite and fenitised volcaniclastic breccias and (rarely) olivine melilitite on the periphery [1]. REE contents are highest in patchy, Fe-rich oxidised crusts (containing up to nearly 1 wt.% TREO) that are most common within 1 km of the central ring. Next highest in REE are Ca- and Fe-rich carbonatite dykes and sills (mostly silicified) with typically less than 0.5 wt.% TREO. Lowest REE contents are in the olivine melilitites, which contain at most 0.1 wt% TREO. Preliminary evidence suggests a genetic relationship between the melilitites, carbonatites and Fe-rich crusts, with the change in REE enrichment being due to a combination of igneous processes (e.g., fractional crystallization and liquid immiscibility to generate the carbonatites) and both supergene and hydrothermal alteration processes to produce the crusts.

References:

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