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The Kuboos-Bremen Line in Namibia and South Africa: New Genetic Insights and its Potential as a Hub for REE Enrichment Research

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Carbonatites and associated alkaline igneous rocks are usually enriched in critical metals, such as the Rare Earth Elements (REEs), and they are a vital REE source in the current mineral and energy/technology industries, with 40% of REEs exploration projects targeting such rocks. However, there is still a gap in the understanding about which processes and mechanisms govern REE enrichment.

The Kuboos-Bremen Line (KBL; South Africa and Namibia) is defined by aligned alkaline igneous intrusions that contain carbonatites that have REE-rich occurrences. The KBL extends for about 250 km with both the varying intrusions level (increase in altitude by about 1.2 km) and a suggested younging of the intrusions, occurring from SW to NE. It hosts a large variety of rocks, including granite and syenite, foid-syenite, carbonatite, and a carbonate-bearing diatreme field in the west, central, and the eastern portions, respectively.

Zircon, titanite, and apatite U-Pb ages provide a range from 530 to 457 Ma for the KBL. The older zircon and titanite ages indicate the onset of magmatism with apatite ages being around 30 Ma younger in individual complexes. The total REE content in apatite from different complexes varies from ~0.02 to 0.68 apfu and correlates positively with Si, which varies from ~0.01 to 0.73 apfu (britholite substitution).

The obtained ages are scattered having no clear relationship with earlier interpretations of a systematic younging of the intrusions toward NE. Moreover, the apatite's lower closure temperature for U-Pb, compared to zircon and titanite, reveals a varying cooling history for the individual complexes.

Enrichment of REEs with increasing Si in apatite does not show apparent connection with compositional and age evolution or emplacement depth of the individual complexes, but rather is related to magma contamination and wall rock interaction, indicating that these processes are critical for REE enrichment to economic levels.