In-Situ Geochronological Investigation of the Carbonatite Complex from the Miaoya REE Deposit, South Qinling Orogenic Belt, China

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The Miaoya carbonatite complex located in the South Qinling orogenic belt hosts one of the largest rare earth element (REE)-Nb deposits in China, which comprises both carbonatite and syenite. The emplacement age of the Miaoya carbonatite complex and the geochronological relationship between carbonatite and syenite have long been debated. We present new in-situ geochronological data determined from accessory zircon, monazite, and columbite from both the carbonatite and syenite at Miaoya, and this geochronology is combined with chemical and isotopic analyses.

Abundant zircon crystals have been identified within syenite in thin section, which are huge crystals with grain sizes ranging from 100 μm to 1300 μm and elongation ratios varying from 1.2 to 1.8. Only small amounts of zircon have been observed in carbonatite with a grain size range from 50 to 200 μm. Growth zonation and alteration can be identified in SEM-CL images for zircon from both carbonatite and syenite. These zircons are enriched in Th, depleted in U, and display a steep increasing chondrite normalized REE trend from LREEs to HREEs without an Eu anomaly. This is typical for magmatic zircon from carbonatite and alkaline rocks and confirms their magmatic origin. In-situ geochronological analysis by LA-ICP-MS for zircon from syenite and carbonatite yield Th-Pb ages of 442.6 ± 4 Ma and 426.5 ± 8 Ma, respectively. The associated Hf isotope compositions of these zircons are similar and range from 0 to 8, indicating formation from a common mantle source. These chemical and isotopic signatures of magmatic zircons are distinct compared to the older zircons identified at Miaoya, which are possibly captured during the ascent of the carbonatite and syenite melts.

Monazite is present as very small crystals (1 to 30 μm) within both carbonatite and syenite, and these are characterized by similar chemical compositions and they generate a consistent Th-Pb age (~240 Ma). Columbite from carbonatite can be identified as two groups based on petrographic and chemical compositions. Columbite dispersed within carbonatite is characterized by a slightly LREE enrichment pattern and yields a U-Pb age of 232.8 ± 4.5 Ma, whereas that associated with apatite displays LREE depleted trends.

Our new results suggest that there are two major episodes of magmatic/metasomatic activity in the formation history of the Miaoya carbonatite complex. The early alkaline magmatism occurred during the Silurian opening of the Mianlue Ocean, whereas the late metasomatism or hydrothermal overprint took place during the Triassic South Qinling orogeny. The latter serves as the major ore formation period for both REEs (e.g., monazite) and Nb (e.g., columbite).