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Genesis of the Lijiahe banded carbonatite intrusions and associated iron mineralization, northwestern Yangtze Block, South China

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Banded carbonatites commonly show a rhythmic alternation between calcite and magnetite layers, the latter often containing significant iron oxide (magnetite) mineralization. However, the petrogenesis of banded carbonatites and the mechanism responsible for iron mineralization remain poorly understood. In this study, we present detailed petrographic observations as well as mineralogical and geochemical data for the Lijiahe banded carbonatites in the northwestern Yangzte Block, central China. The banded carbonatites outcrop as small-scale stocks and dykes in the field, and they can be subdivided into three distinct types of layers: a calcite-rich layer, a mixed layer, and a magnetite-rich layer. Each layer consists of varying proportions of magnetite, calcite, and apatite, with minor amounts of olivine, phlogopite, and Nb-rich minerals. Apatite U-Pb dating results reveal that the Lijiahe banded carbonatites were formed at ca. 778 Ma. Three layers in the Lijiahe carbonatites all have identical Sr and Nd isotopic compositions ($(^{87}Sr/^{86}Sr)_i$ = 0.7039–0.7048; εNd(t) = +1.5 to +3.4), similar to the regional arc-related mafic rocks and indicative of a lithospheric mantle enriched by slab-derived materials. Both calcite and whole rock samples for the Lijiahe carbonatites are characterized by flat REE patterns and low $(La/Yb)_N$ ratios (4.74–6.79 and 5.54–14.1, respectively), which is in stark contrast to global primary carbonatites and calcite. These distinctive flat LREE patterns may require magma generation from a garnet-poor, HREE-rich carbonated mantle source. The gradational contact and irregular boundaries between three types of layers, along with large variations in thickness and compositions, suggest that the banded structure from the Lijiahe carbonatites is the result of the slumping of immiscible Fe-rich melt into a calcite mush. The magnetite-rich layer has higher TFe_2O_3 (50.0–66.5 wt%), Co, HFSE (Nb = 193–741 ppm), Sn, and Zn contents but lower CaO, Sr, Ba, and REE contents than the mixed layer and the calcite-rich layer, which are characteristics of immiscible Fe-rich melts. Therefore, we propose that the Fe-HFSE-rich melts play a critical role in producing Fe oxide mineralization in the Lijiahe banded carbonatites.