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Apatite in Ziyang-Zhuxi alkaline rocks (Central China): Implications for REE migration during magmatic-hydrothermal processes

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Apatite containing elevated rare-earth elements (REE) is a ubiquitous accessory mineral in alkaline rocks and often exerts important controls on the behavior of REE in these magmatic-hydrothermal systems. This study investigates the textural relationships and compositions of apatite from a series of alkaline volcanic-intrusive rocks in the Ziyang-Zhuxi region of the Southern Qinling Belt, China. The alkaline rocks include gabbroic rocks (pyroxenite, basalt, gabbro, and diabase), dioritic rocks (pyroxene diorite and amphibole monzonite), and syenitic rocks (biotite syenite and trachyte). Two main types of apatite, magmatic and metasomatic, have been identified in these rocks. The magmatic apatite (Ap-1) occurs as euhedral hexagonal inclusions in pyroxene, amphibole, and feldspar. The metasomatic apatite (Ap-2), found only in syenitic rocks, exhibits replacement textures, including the common occurrences of secondary monazite. The large ion lithophile elements (LILE; e.g., Sr, Ba) and compatible elements (e.g., V, Sc) in Ap-1 decrease from alkaline mafic rocks to felsic rocks, indicating that fractionation of feldspars and mafic minerals such as pyroxene and amphibole dominated the magmatic crystallization process. The total REE contents in Ap-1 increase from 4,060 to 37,100 ppm, suggesting a fractionation-controlled REE enrichment. On the other hand, Ap-2 has lower ΣREE contents (mean of 10,480 ppm) than Ap-1 (mean of 30,890 ppm), indicating ~60% REE leaching from primary apatite during metasomatism. The leached REE from apatite either precipitated to form monazite inclusions or were remobilized locally. Also, Ap-2 has higher Sr contents and $^{87}Sr/^{86}Sr$ ratios than Ap-1 (0.7090-0.7107 vs 0.7033-0.7046), indicating an external contribution of Sr from hydrothermal fluids. Therefore, we propose a two-stage model of magma fractional crystallization followed by hydrothermal metasomatism for REE enrichment in the alkaline rocks investigated in this study.