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Multi-stage magma evolution recorded by apatite and zircon of adakite-like rocks: A case study from the Shatanjiao intrusion, Tongling region, Eastern China

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Abstract

The Shatanjiao pluton, located in the eastern Tongling region (Eastern China), is of great research significance for the study of magma evolutionary processes because this pluton is related to the regional Cu-Au mineralization. Zircon U-Pb dating on two granodiorite samples from this pluton yields ages of 141.9 ± 3.1 Ma (MSWD = 0.07) and 141.9 ± 3.3 Ma (MSWD = 0.03), respectively, which overlap the range of intense Late Jurassic to Early Cretaceous magmatism in the Tongling region. Based on the Sr content of apatite from the Shatanjiao granodiorites, they are subdivided into high-Sr apatite (apatite-I: 754–1242 ppm, mean = 1107 ppm) and low-Sr apatite (apatite-II: 415–613 ppm, mean = 507 ppm). Both apatite-I and apatite-II are characterized by high-Sr and -Sr/Y ratios and inconspicuous negative-Eu anomalies, indicating that these granodiorites have a likely adakite affinity. Considering their low-Rb contents (<0.05 ppm), in situ Sr isotopes of these apatite grains show $^{87}Sr/^{86}Sr$ ratios of 0.70848–0.71494 and 0.70767–0.71585 for apatite-I and apatite-II, respectively, indicating that the $^{87}Sr/^{86}Sr$ ratios of both apatite groups can represent the Sr isotopic compositions of their host rocks. Moreover, the La/Sm and Sr/Th ratios of both apatite groups suggest that the studied granodiorites might be sourced from the partial melting of subducted ocean slabs and overlying sediments. Based on their zircon trace element compositions, the calculated temperature and oxygen fugacity for the magma are characterized by high temperatures (mean T = 646 °C) and high oxygen fugacity (mean Ce^{4+}/Ce^{3+} ratios = 341). On the basis of MgO, FeO, SiO_2, and ΣREE contents of apatite, we further suggest that apatite-I and apatite-II might have crystallized at the early and late stages of magma evolution, respectively. Because apatite-I has much higher Eu/Eu* ratios (0.56–0.76) but lower $(La/Yb)_N$ ratios (7.85–28.6) than apatite-II of 0.39–0.58 and 95.9–132, respectively, it is indicated that plagioclase, garnet, hornblende, and zircon might control the trace element composition of melt during the magma evolutionary history, which were recorded by the apatite. Therefore, apatite can be an ideal tracer to reflect the sequence of multi-stage magma evolution.

Keywords: Apatite, U-Pb dating, adakite-like rocks, magma evolution, Shatanjiao; Experimental Halogens in Honor of Jim Webster