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

JINGYA CAO1,2, HUAN LI2.*,†, XIAOYONG YANG1,*, LANDRY SOH TAMEHE3, and RASOUL ESMAEILI1‡

1Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou 511458, China
2Key Laboratory of Metallogenetic Prediction of Nonferrous Metals and Geological Environment Monitoring, Ministry of Education, Central South University, Changsha 410083, China

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 ±Sr/86Sr ratios of 0.70848–0.71494 and 0.70767–0.71585 for apatite-I and apatite-II, respectively, indicating that the ±Sr/86Sr 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 ZRE 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

INTRODUCTION

Adakites are intermediate to felsic rocks, which are assumed to be formed by partial melting of young (<25 Ma) oceanic slabs in hot subduction zones (Defant and Drummond 1990). Adakites are characterized by distinctive geochemical signatures such as high Sr but low Y contents as well as high Sr/Y and La/Yb ratios (Defant and Drummond 1990; Martin 1999; Martin et al. 2005). Further studies suggest that some intraplate magmatic rocks can also exhibit identical geochemical signatures to typical adakites (e.g., Defant and Drummond 1993; Erwan et al. 2002; Gao et al. 2007; Richards and Kerrich 2007; Wang et al. 2020). These magmatic rocks are commonly classified as adakite-like rocks and record geochemical evidence of melting, assimilation, storage, and homogenization (MASH) and/or assimilation and fractional crystallization (AFC) processes during their genesis and evolution (Chiaradia 2009). The AFC and MASH processes in the shallow and deep magma chambers are important for the formation of the adakite-like rocks because the geochemical signatures of these rocks are mainly controlled by the crystallization of specific minerals such as plagioclase, rutile, ilmenite, and clinopyroxene (+amphibole) at shallow depth, and/or garnet and amphibole in deep reservoirs (Rollinson 1993; Macpherson et al. 2006; Richards and Kerrich 2007). Both AFC and MASH processes can be detectable from the geochemical and isotopic characteristics of magmatic rocks. However, it should be emphasized that homogenization of magmas in shallow magma chambers has the potential to obscure the whole-rock geochemical compositions of magmatic rocks and thus make them useless for distinguishing the magmatic evolutionary processes. On the other hand, accessory minerals can record valuable information regarding the geochemical and isotopic characteristic of magma sources and/or magmatic conditions and evolutionary paths. Hence, these minerals are widely used

* E-mail: lihuan@csu.edu.cn (Orcid 0000-0001-5211-8324) and xxyang@ustc.edu.cn.
† Orcid 0000-0002-5080-5777
‡ Special collection papers can be found online at http://www.minsocam.org/MSA/AmMin/special-collections.html.