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Tracking source and crustal contamination by U-Th-Pb, Nd, Hf and O isotopes in zircon and monazite for the Laojunshan granite in the North Qinling orogen, central China

XING ZHANG, YUANBAO WU, WENXIANG ZHANG, GUANGYAN ZHOU AND YU HE

China University of Geosciences, Wuhan

Presenting Author: xingzhang@cug.edu.cn

In-situ analyses of zircon and monazite geochemical and isotopic compositions can provide compelling and detailed insights into the source and evolution process of granitic magmas. Here we investigate U-Th-Pb ages and Hf/Nd-O isotopes of zircon and monazite in two samples from the Laojunshan granite pluton in the North Qinling orogen, central China. Co-existing magmatic zircon and monazite in the two samples yield identical crystallization ages of ca.113 Ma. Magmatic and relict zircons are recognized in sample 17QL79, which have $\varepsilon_{Hf(t)}$ of -6.5 to -5.0, -17.4 to 5.1 and $\delta^{18}O$ of 5.25 to 5.78‰, 5.17 to 9.15‰, respectively; whereas only magmatic zircons can be identified in sample 17QL89 and have $\varepsilon_{Hf(t)}$ of -3.2 to 2.7, and $\delta^{18}O$ of 4.65 to 6.36‰. The trace element compositions and age distribution of the relict zircons are similar with those of detrital zircons from wall-rock meta-sedimentary rocks in the Kuanping unit. Relict and magmatic monazites are also observed in sample 17QL79. They are dominated by cheralite-type substitution and have $\varepsilon_{Nd(t)}$ of -10.4 to -9.57, -5.78 to -4.63 and $\delta^{18}O$ of 9.22 to 9.81‰, 3.79 to 5.66‰, respectively. While only magmatic monazites can be acquired in sample 17QL89 and are dominated by huttonite-type substitution and have $\varepsilon_{Nd(t)}$ of -5.70 to -4.42 and $\delta^{18}O$ of 4.65 to 6.36‰. Chemical and isotopic data confirm that the relict zircons and monazite are from wall rock contamination. The relict monazite has similar U-Pb but distinct Nd-O isotopes from the magmatic grains, indicating the detrital monazite might have experienced dissolution-precipitation process and completely lose Pb. Sample 17QL79 has lower whole-rock Hf-Nd isotopes than sample 17QL89, further suggesting significant crustal contamination. Furthermore, the Hf-Nd isotopes of zircons and monazites in sample 17QL89 are consistent with its whole-rock isotopes and no relict grains are observed, indicating they might record the source isotope compositions. The Laojunshan pluton was derived by partial melting of juvenile lower crustal materials and experienced different formation processes. Accordingly, we suggest that the combination of U-Pb and Hf-Nd-O isotopes in zircon and monazite can be used to better track source nature and evolution process than each mineral was used separately.