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The source nature, magma evolution of I-type granites revealed by zircon morphology and grain-scale Hf-O isotopes

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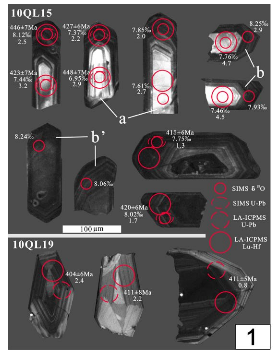
The definition of I-type granite was originally proposed for the intrusive rocks derived from igneous components of crust[2]. However, the mixing characteristics in isotope compositions, e.g., whole-rock Sr-Nd[3,5] and zircon in-situ Lu-Hf and Oxygen isotopes[1,6,9] have fed into the growing view that I-type granites are resulted from multi-components mixing, especially with mantle materials involved. Nevertheless, the mafic end-member referenced in the mixing model is usually inferred[10] while the felsic end-member could be well-constrained.

The North Qinling orogen, central China is an ocean-continent subduction zone with widespread early-Paleozoic I-type granites therein. Previous studies have shown the mantle wedge of the North Qinling was significantly metasomatized[8] and isotopically enriched relative to the lower basaltic crust in the early Paleozoic[7]. Therefore, the material contributions from mantle wedge and lower continental crust in North Qinling can be easily distinguished. Here, the source nature, magma evolution of Zaoyuan pluton have been thoroughly studied and the origin of isotope mixing characteristics in I-type granites has been detected. The CL images of magmatic zircons show two growth stages**(Fig.1)** and their Hf-O isotopes can be imparted through mixing of upper- and lower-crust. Mixing of the two crust components must have occurred before melting since the zircon cores crystallizing in the early stage are isotopically uniform($\delta^{18}O$:7.36~7.96‰) and have consistent morphology. The grain-scale record of elevated Th and U contents outward, as well as the negative correlation between $\delta^{18}O_{zir}$ and $\varepsilon_{Hf}(t)$ values from the early to the late stage**(Fig.2)** are preferred to be explained by crustal contamination rather than magma replenishment, which would cause resorption[4]. This means zircons bear great potential as a tool to monitor the distinct evolution of granitic magmas. Furthermore, the granite sample with more depleted Hf compositions also has higher MgO、Cr、Ni contents, implying more juvenile crustal materials in its source and thus indicating source heterogeneity. There is no evidence for addition of the mantle material during magma evolution. In conclusion, our results suggest partial melting of a heterogeneous crust source and subsequent magma assembly as well as assimilation of country rocks might be an important mechanism for the I-type granite to acquire isotope mixing characteristics.



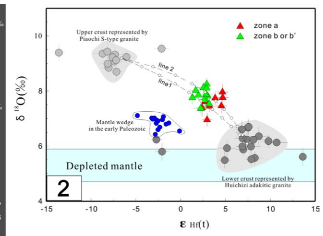


Fig. 1 The representative zircon CL images for two Zaoyuan granite samples

Fig. 2 $\varepsilon_{Hf}(t)$ vs. $\delta^{18}O$ for the two-stage magmatic zircons from the Zaoyuan granites

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