Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12207

Accessory mineral micro-zircon inclusions uncover more complete magma compositional evolution records

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Trace elements in magmatic zircon exhibit characteristic trends during magma compositional evolution[1]. Zircon geochemistry presents the advantage over whole rock geochemistry of showing progressive 'snapshots' of melt chemistry during the course of magma crystallization. However, one limitation is that zircon is typically a late-crystallizing phase, leaving much of the magmatic history unrecorded. Using the CAMECA *ims*1290 ion microprobe with Hyperion-II ion source[2], we explore whether micro-zircon in relatively early-crystallizing magmatic accessory minerals can meaningfully enhance the interpretations of zircon trace element records of magmatic evolution. Two Cretaceous granites from Southern California have oxide and phosphate minerals with an unusually high proportion of zircon inclusions: the La Posta 2-mica granodiorite and the Butler Peak granite. We find contamination of the inclusion measurement by the host is a problem for most measurements: Ti by Fe-Ti oxides and P, Th/U, and LREE by apatite and monazite. However, species which are not structural components of the host phases follow typical magmatic zircon trace element evolution trends such as decreasing Th/U and Eu/Eu* accompanied by increasing Yb/Gd and U/Yb with increasing Hf. Compared to free grains from a mineral separate, ca. 10 μm zircon inclusions in ilmenite and apatite from the La Posta 2-mica granodiorite are on average lower in Hf, recording plausible extensions of these magmatic evolution trends to earlier periods in magma evolution. Free zircons from the Butler Peak granite form a more complex story, potentially recording mixing between a peraluminous, low-U/Yb liquid (based on presence of high-P zircon[3]) and a less obviously peraluminous (presence of low-P zircon) liquid of potentially deeper origin (high U/Yb[4]). The zircon inclusions in Butler Peak magnetite and ilmenite are chemically like high-P, low-U/Yb zircons in the free matrix, suggesting these oxides largely derive from the same liquid as the high-P zircons and the low-P zircons may be anomalous antecrysts or xenocrysts.

[1] Claiborne et al. (2010), *Contrib. Mineral. Petrol.* 60, 511-531.

[2] Liu et al. (2018), *Int. Journ. Mass. Spec.* 424, 1-9.

[3] Zhu et al. (2020), *Earth Planet. Sci. Lett.* 536, 116140.

[4] Reimink et al. (2020), *Earth Planet. Sci. Lett.* 531, 115975.