Empirical calibration of a Zr in rutile thermometer

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The studies available indicate that rutile is an important carrier of high field strength elements (HFSE; Zr, Nb, Mo, Sn, Sb, Hf, Ta, W). It was noted that Zr content in rutile is buffered in systems with quartz and zircon as coexisting phases. Therefore the effect of temperature (*T*) and pressure (*P*) on the Zr content in rutile was evaluated by analysing rutile-quartz-zircon assemblages of 31 metamorphic rocks spanning a *T* range from 430 to 1100°C (Zack et al., 2004). Electron microprobe measurements of Zr concentrations in rutile vary from 30 to 8400 ppm, being highly dependent on metamorphic grade. Using only rutile included in garnet and pyroxene, two similar sets of a rutile thermometer have been formulated. The favoured approach for metamorphic rocks results in the equation:

$$T(\text{in } ^{o}C) = 127.8 * \ln(\text{Zr in ppm}) - 10$$

where the maximum Zr content from several rutile grains included in garnet or pyroxene should be used. No pressure dependence was observed. An uncertainty of absolute *T* of ±50°C is inherited from *T* estimates of the natural samples used. A close approach to equilibrium of Zr distribution between zircon and rutile must be deduced as Zr content in rutile is highly reproducible when analysing different rock types from the same locality. Within a given locality, *T* range is mostly ±10°C, indicating the geological and analytical precision of the rutile thermometer.

Reference

Zack et al. (2004), **C.M.P.** *148*, 471-488

Magmatic zircon, titanite, and garnet: Oxygen isotope disequilibrium is good

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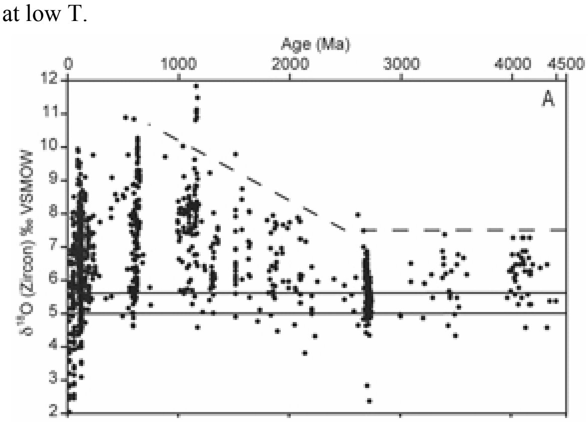
The oxygen isotope ratios of coexisting magmatic accessory minerals are commonly not equilibrated. Each mineral contains different information about evolving magma chemistry. In favorable situations with zoned minerals, in situ analysis by ion microprobe will reveal a continuous record.

Zircon is highly retentive of $\delta^{18}O$, which can be directly correlated to U-Pb age. Even inherited cores with magmatic overgrowths can preserve $\delta^{18}O$ from crystallization. With care, one can detect, image, and avoid post-magmatic, recrystallized, radiation damaged, or age-discordant domains that may be altered in $\delta^{18}O$. During closed system fractional crystallization, $\delta^{18}O(Zc)$ is insensitive to variable temperature or SiO_2 content. Thus $\delta^{18}O$ of zircon monitors supracrustal sources or contamination for a wide range of magmas.

Garnet or titanite commonly coexists with zircon. Magmatic garnet in peraluminous magmas is highly retentive of magmatic $\delta^{18}O$, while titanite has faster oxygen diffusion and, for slowly cooled plutons, a subsolidus closure T.

Analysis of $\delta^{18}O$ in zircons from over 1200 rocks of all ages from 4.4 Ga to recent reveals an oxygen isotope steady-state though the Archean and nonuniformitarian change to higher on average and more variable values in younger magmas due to increased recycling of rocks altered by water at low T.



In the central Sierra Nevada, zircon and coexisting garnet or titanite have been analyzed from ~250 granitoids of Cretaceous age. Garnet records $\delta^{18}O$(magma) over the period of crystallization, which is often later than zircon. Thus $\delta^{18}O(Zc) - \delta^{18}O(Gt)$ trajectories trace AFC, while $\Delta^{18}O(Zc\text{-}Tt)$ is sensitive to cooling rate and increases with depth of emplacement.