Reconciling zircon and monazite thermometry constrains H2O content in granitic melts

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In this contribution, we compare and test the reliability of zircon and monazite thermometers and suggest a new and independent method to constrain the H2O content in granitic magmas from coeval zircon and monazite minerals. We combine multi-method single-mineral thermometry (bulk-rock zirconium saturation temperature ($T_{zr}$), Ti-in-zircon ($T_{(Ti-zr)}$) and monazite saturation temperature ($T_{mz}$)) with thermodynamic modelling to estimate water content and P–T conditions for strongly-peraluminous (S-type) granitoids in the Georgetown Inlier, NE Queensland. These granites were generated within ~30 km thick Proterozoic crust, and emplaced during regional extension associated with low-pressure high-temperature (LP–HT) metamorphism.

SHRIMP U–Pb monazite and zircon geochronology indicates synchronous crystallization ages of c. 1550 Ma for granitic rocks emplaced at different crustal levels—from the eastern deep crustal domain ($P = 6–9$ kbar), through the middle crustal domain ($P = 4–6$ kbar), to the western upper crustal domain ($P = 0–3$ kbar).

Bulk-rock $T_{zr}$ and $T_{(Ti-zr)}$ yielded magma temperature estimates for the eastern domain of ~800°C and ~910–720°C, respectively. Magma temperatures in the central and western domains were ~730°C ($T_{zr}$) and ~870–720°C ($T_{(Ti-zr)}$) in the central domain, and ~810°C ($T_{zr}$) and ~890–720°C ($T_{(Ti-zr)}$) in the western domain, respectively. These temperature estimates were compared with P–T conditions recorded in the host rocks to determine if the magmas had equilibrated thermally with the crust. Similar temperatures were obtained for the middle and lower crust suggesting that the associated magmas thermally equilibrated at their respective depths, whereas the sub-volcanic rocks were, as expected, significantly hotter than the adjacent crust.

By plotting the results on a P–T–X$_{H2O}$ petrogenetic grid, and assuming adiabatic ascent through the crust, the sub-volcanic magmas appear to be drier (~3 wt% H$_2$O) than the granitic magmas (~7 wt% H$_2$O) which formed at greater depth. Monazite saturation temperatures (which depends on the water content, light–REE content and composition of the granitic melt), are in agreement with the zircon thermometers only if water values of ~3 wt% H$_2$O and ~7 wt% H$_2$O are assumed for the
upper crustal magmas and deeper magmas, respectively. Moreover, melt compositions extracted from a modelled pseudosection of a sillimanite-bearing metapelite, which was interpreted to be the typical source rock for the surrounding granites (P=5 kbar and T=690°C–850°C), show comparable water content values.

The $T_{mz}$ results provide independent evidence for the $H_2O$ content in magmas, and we suggest that reconciling $T_{zr}$ with $T_{mz}$ is a new and independent way of constraining $H_2O$ content in granitic magmas.