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Trace element signatures of magmatic zircon

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Trace elements measured in magmatic zircon are used as proxies for geochemical composition, temperature, pressure and oxygen fugacity of the host magma during crystallisation. These proxies variably rely on a combination of empirical calibration, experimental data, estimated partition coefficients and correlation of natural data. As with many geochemical discriminators, small datasets are often extrapolated beyond their useful limits, and statistics can be used and abused. Here, we take a 'Big Data' approach to address both: 1) previous interpretations of trace element-based proxies, and 2) global secular trends.

Using a literature compilation of >35000 magmatic zircon analyses, including ~12000 zircon-whole-rock pairs that comprise ~600 individual whole-rock compositions, we are able to cross-correlate host geochemistry and zircon composition on a large-scale. To assist the interpretation of these coupled datasets we have modelled both the melt compositions and the theoretical zircon composition that would be in equilibrium with these melts for each whole-rock sample using PerpleX phase equilibrium modelling coupled with zircon saturation and trace element partitioning calculations. This approach allows us to compare both natural and theoretical zircon compositions in igneous rocks across a wide range of P-T-H_2O conditions.

Results show inconsistencies with the prevailing interpretations of several proxies. For example, P in zircon is not a reliable indicator of S-type granite affinity. Instead, U/Ce seems to more reliably correlate with S-type geochemistry; however, S-type granites have strong overlap with metamorphic zircon (including low Th/U <0.1). Several proxies have been postulated to be controlled largely by the fractionation of garnet vs. plagioclase during magma formation, and thus have been extrapolated to depth or pressure of crystallisation (e.g. Eu*/Eu, HREE/MREE [Yb/Gd], Lu/Hf). However, we demonstrate contrasting behaviour between these elemental ratios, and positive correlations with host geochemistry that complicate their use as proxies for crystallisation depth or crustal thickness.

Combining some of our revised interpretations of trace element proxies and signatures, with an updated detrital zircon trace element compilation comprising >70000 records, we are able to re-evaluate global secular trends in crustal evolution recorded by zircon.