Stable Zr isotope insights into magmatic processes throughout Earths history

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Zirconium is a key element within the field of terrestrial geochemistry. It is a member of the high field strength group of elements (HFSEs), making it both incompatible during mantle melting and highly refactory in nature. Consequently, the elemental behaviour of Zr has been used to study historic mantle depletion events and the generation of new crustal material. More recently the development of Zr stable isotopes have been demonstrated to have the potential to be used as a powerful new tracer of terrestrial magmatic processes [1].

Variations of the $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ value are observed within magmatically evolved (i.e. >65wt% SiO_2) samples. Data from the Hekla volcano (Iceland) show that continued differentiation of basaltic melts by fractional crystallisation processes can drive whole rock Zr isotope compositions towards heavy values, up to 0.53 ‰. This variation was explained by the citing of isotopically light Zr within 8-fold coordinated sites of crystallising zircon relative to silicate melts with lower coordination chemistries [2]. Based on this finding Zr isotopes are suggested as a sensative tracer of magmatic differentation processes, which should be recorded within zircon grains crystallsing from parent melts. However, there had been no attempt to evaluate the composition of magmatic zircons to test this hypothesis.

Building on this we present new data for 20 magmatic zircon grains. These zircons are previously well characterised for trace elements and radiogenic isotope compositions. They span a range of ages from 4.4 Gyr (Jack Hills) to 12.4 Myr. It is demonstrated that the average $\delta^{94/90}Zr_{IPGP\text{-}Zr}$ of these 20 magmatic zircons is -0.05 +/- 0.096 ‰, which fits well with suggestions that magmatic zircons should preserve light isotopic comppositions relative to silicate melts. This data will be coupled with trace element compositions and radiogenic isotope data to comment on the effect of source vs. process during zircon growth throughout Earth's history.

[1] Inglis et al., 2018. Chemical Geology
[2] Inglis et al., 2019. GCA