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Isotopic modelling of Archean crustal evolution from comagmatic zircon--apatite pairs

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The composition of Earth's early crust is challenging to assess as only fragmentary material remains from ancient Earth. Deciphering the composition of early crust as a means to understand early processes on our planet often relies on the isotopic composition of resistive minerals. Here we present a new tool for investigating igneous petrogenesis and crustal evolution by combining $^{87}Sr/^{86}Sr$ measurements of apatite inclusions with U–Pb and Hf isotope analysis of their host zircon crystal. We access the Sr isotope information contained in the apatite by applying a novel SIMS technique developed specifically for this purpose. This technique takes advantage of the high spatial resolution of the instrument to allow for the analysis of the small (< 20 µm) apatite inclusions that are common in many suites of magmatic zircons.

By combining information from the U-Pb, Lu-Hf, and Rb-Sr isotope systems, we develop triple isotope system models for the evolution of precursor crust. This approach exploits the complementary inverse fractionation behaviour of Rb/Sr and Lu/Hf during crustal differentiation processes to provide greater sensitivity to the input of both evolved and juvenile source material to melts, and links the isotope systems using the cogenetic host/inclusion relationship. This modelling allows us to reconstruct the bulk SiO_2 composition of the source of crustal melts, and infer the average crustal residence time of this precursor crust. A further product of this approach is the ability to place more robust empirical constraints on the Lu/Hf of precursor crust by comparison of the modelling output to a global whole-rock geochemical dataset.

We demonstrate an application of this method by analysing zircons containing apatite inclusions from Mesoarchean igneous rocks in the Akia terrane of SW Greenland. Our modelling implicates intermediate–felsic Paleo-Eoarchean crust in the genesis of voluminous 3.0 Ga magmatic rocks of the Akia terrane, one of the largest components of the Archean North Atlantic Craton. This approach provides a template for further application to ancient rocks in order to better understand the evolution of ancient Earth.