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Resolution, the key to unlocking granite petrogenesis using zircon U-Pb – Lu-Hf studies

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Coarse-scale understanding of crustal evolution and source contributions to igneous systems has been drastically enhanced by coupled zircon U-Pb and Lu-Hf data sets. These are now common place and potentially offer advantages over whole-rock analyses by resolving heterogeneous source components in the complex crystal cargos of single hand-samples. However, the application of coupled zircon U-Pb and Lu-Hf studies to address detailed petrogenetic questions faces a crisis of resolution - On the one hand, micro-beam analytical techniques have high spatial resolution, capable of interrogating crystals with complex growth histories. Yet, the >1-2% temporal resolution of these techniques places a fundamental limitation on their utility for developing petrogenetic models. This limitation in data interpretation arises from timescales of crystal recycling or changes in source evolution that are often shorter than the U-Pb analytical precision. Conversely, high-precision CA-ID-TIMS U-Pb analysis of single whole zircons and solution MC-ICP-MS Lu-Hf isotopes of column washes (Hf masses equating to ca. 10-50 ng) have much greater temporal resolution (<0.1%), yet lack the spatial resolution to deal with complex crystal growth. Analyses homogenize any heterogeneity within the zircon and convolute the petrogenetic model.

A balance must be struck between spatial and temporal resolution to address petrogenetic issues. Here, we demonstrate that micro-sampling of complex xenocryst-rich zircon crystals (e.g. <40 μm zircon tips) from the granitic post-Variscan Cornubian Batholith (SW England), in tandem with low-common Pb blank CA-ID-TIMS U-Pb chemistry, permits the analysis of zircon volumes that approach those of LA-ICPMS analyses, whilst simultaneously retaining the majority of the temporal resolution associated with the CA-ID-TIMS U-Pb technique. The low volume of zircon within these analyses may only provide <5 ng Hf, and therefore gaining useful precision from Lu-Hf isotopes is beyond the scope of typical solution MC-ICP-MS techniques. However, we demonstrate that an uncertainty level of ca. 1 εHf can be achieved with as little as 0.4 ng Hf through the use of low-volume solution introduction methods – thus bridging the gap in resolving power between in-situ and isotope dilution coupled zircon U-Pb – Lu-Hf studies.

We demonstrate the potential of this approach to unravel intra- and inter-sample heterogeneity and address models for granite genesis using a new regional data set for 21 samples encompassing all major granite types within the Early Permian Cornubian Batholith (SW England). The data provide a refined chronological framework for magma source evolution over 20 Myrs of crust-mantle melt extraction and upper crustal batholith construction. The resulting petrogenetic model will also be evaluated through the lens of low- temporal resolution commonly employed in granitic zircon U-Pb – Lu-Hf studies in order to highlight the enhanced insights into geological processes gained though our approach. The current limitations to data interpretation and directions of future research will be discussed.