The case for crust-mantle interaction during silicic magma genesis: the zircon testimony

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The Sr-Nd-O-Pb isotope arrays exhibited by granitic batholiths and their volcanic associates implicate crust-mantle mixing, but this is commonly not corroborated by whole-rock geochemical evidence. The nature of the alleged mixing process, the stage of magmatic evolution at which it occurs, the composition of the end-member components, and the relevance of the process for the generation of Earth's continental crust all remain contentious. Zircon is a robust witness, since the O and Hf isotope compositions of its growth zones record the crystallisation history of the host magma, and potentially fingerprint the involvement of mantle-derived agents, or the reworking of pre-existing crust. Such evidence can now be readily summoned by precise in situ microanalysis using new generation ion microprobes and laser ablation systems. Here, we here examine and evaluate the zircon testimony with reference to the classic granitic/volcanic rocks of eastern Australia, where the case for large scale magma mixing has been keenly debated for three decades. We find that zircons in I-, S- and A-type granites and their enclaves indeed preserve the legacy of isotopically open-system behaviour, but that the zircon response has different guises depending on the intrinsic circumstances of each magmatic system. Large variations in O-Hf isotope and trace element compositions indicate that zircons of a single rock have sampled very different melt compositions, suggesting physical accumulation from an evolving magma body, and having implications for pluton construction in the upper crust. The similar zircon isotope systematics of rocks with markedly different silica contents suggests that the processes controlling isotope variations in minerals were decoupled from those that determine bulk rock geochemistry. Linking these observations, we conclude that the isotopic properties of the Lachlan granites are set by open-system differentiation of parental magmas in the deep crust, whereas within-suite compositional differences reflect shallow-level crystal-liquid sorting processes. The extent to which forensic zirconology can reinvigorate studies of granitic rocks, and help stitch the plutonic-volcanic connection, will be discussed.