Connecting the History of the Deep and Shallow Earth

WILLIAM M. WHITE[1]

[1]Dept. Earth & Atmos. Sci., Cornell Univ., Ithaca, NY 14853 USA wmw4@cornell.edu

The isotope geochemistry of oceanic basalts has taxonomy, 'the Mantle Zoo', such that groups of oceanic islands tend to fall into restricted regions of Sr-Nd-Hf-Pb isotopic space. This taxonomy reflects extant deep mantle reservoirs. The problem is to decipher their evolution. The first observation is that these reservoirs have evolved through the uppermost mantle or crust/hydrosphere processes: there is no evidence of lower mantle chemical fractionations. The depleted upper mantle reservoir has evolved primarily through melt extraction to form crust, although fluxes from mantle plumes and subducted oceanic crust undoubtedly help to maintain its fertility. A dilute near-primitive component may be nearly ubiquitously present (the FOZO or 'C' component), evidenced primarily in noble gas isotopic compositions (not quite primitive because Xe isotope ratios appear to record very early unique events in Earth's hisotry), but does not account for the more extreme compositions. Similarly, modern crustal recycling can account for typical, PREMA-like compositions, but not the extreme ones, whose origin is more enigmatic. The extremely radiogenic Sr isotope ratios in Samoan lavas and other evidence, such as O isotopes, demonstrate that the EM II reservoir originated through recycling of continental crust, but modern subducted material would evolve to neither these nor extreme EM I compositions. MIF sulfur, as well as O isotopes, confirms the HIMU reservoir has also evolved through recycling of surficial material, but fixes the timing of this as earliest Proterozoic or older, ruling out MOR hydrothermal processes as the cause of the U enrichment.

The rarity of extreme EM and HIMU compositions is also significant in two respects: they are unlikely the result of common, continous plate tectonic processes such as oceanic lithosphere and marine sediment subduction and they are unlikely to occupy large regions of the lower mantle such as the LLSVP's. Thus the uniformitarian approach fails and we need to look at them through the lens of historical geology. I suggest that these reservoirs are linked to unique processes/events in the chemical, climatic, and/or tectonic history of the Earth's surface. One example is the profound changes in tectonics, oxidation state, and climate that occurred around the Archean-Proterozoic Boundary. Conversely, the compositions of these unique reservoirs may provide insights into deep past evolution of the Earth's surface.