Plumes, Plates, and Protocontinents: A U-Pb Perspective

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One of the enduring geochemical paradoxes for Earth is the apparent contrast between the petrogenetic processes and bulk compositions that characterize modern arc systems and the composition and structure of modern continents. Here we relate this paradox to the "Pb-paradox", which refers to the fact that the uranogenic Pb isotopic compositions of the depleted mantle (DM) sampled by mid-ocean ridge basalts (MORB) require an integrated $^{238}U/^{204}Pb$ (μ) greater than its current value (<5) and greater than that of the bulk silicate earth (BSE, ~8.5) for the last ~4.5 Ga (i.e., plot to the right of the 4.53 Ga Geochron). This paradox requires formation of complementary high-μ and low-μ reservoirs in the Hadean-Archean in order to generate the elevated $^{207}Pb/^{204}Pb$ compositions needed to eliminate the paradox. Because the high-μ reservoir's enriched Pb-isotopic compositions exist within the DM today, it is not necessary that this reservoir exist today. In contrast, the low-μ reservoir must remain as a physical entity today.

We suggest the remnants of these ancient low- and high-μ reservoir(s) are preserved in sections of Archean continental crust, which reflect both similarities and differences in Hadean-Archean mantle melting compared to modern mantle magmatism. Today there is a strong contrast between the μ-values of melts that characterize MORB and plume systems (μ >BSE or average continental crust) and arc systems (μ <BSE). This difference would be exacerbated in Archean-Hadean systems because those surficial environments were not sufficiently oxidizing to convert insoluble U^{+4} to soluble U^{+6}, which led to very low μ-values in Hadean-Archean seawater and altered oceanic crust. Consequently, early formation of high-μ proto-continents over zones of mantle upwelling followed by subduction-driven (low-μ) crustal growth beneath these proto-continents can solve both paradoxes.