The Third Lead Paradox

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Lead isotopes in terrestrial rocks have been known to pose two "paradoxes": (1) Pb isotopes are generally more radiogenic than required for a 4.50 – 4.57 Ga old Earth. (2) Pb isotopes in MORB source(s) are inconsistent with the mean age of continental crust formation. Here I identify a third Pb paradox: All Archean greenstones and "conformable" Pb deposits have $^{208}Pb^*/^{206}Pb^*$ ratios (≡ (($^{208}Pb/^{204}Pb$) – ($^{208}Pb/^{204}Pb$)init.)/(($^{206}Pb/^{204}Pb$)-($^{206}Pb/^{204}Pb$)init.)), which require a source prehistory possessing Th/U = 4.0 to 4.3, well in excess of the chondritic Th/U = 3.8. In younger rocks, this anomaly disappears, and the present-day silicate Earth has a chondritic Th/U ratio within narrow limits of uncertainty (Wipperfurth et al. 2018). This means that in Archean time, Earth must have harboured a hidden reservoir with subchondritic Th/U, and this reservoir must have later been homogenized with the accessible silicate mantle. Hofmann (2011) speculated that crystallization of an early magma ocean might have created a transient deep-mantle reservoir containing sub-chondritic Th/U and a complementary, high-(Th/U) upper mantle. Here I propose another alternative, based on recent experiments by Wohlers and Wood (2017): Uranium may have entered the core via sulfides during early, highly reducing phases of accretion. This would create an early mantle with high Th/U. Subsequently, the core would gradually release its initial uranium during its first billion or two years, perhaps as a result of gradual re-equilibration with a more oxidized mantle.

Wipperfurth, S.A. et al. EPSL 498, 198 (2017). Hofmann, A.W. EOS Trans. AGU 2011 Fall Meet. Suppl. V43E-05. Wohlers, A. & Wood, B.J. GCA 205, 226 (2017).