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Development in the early Archean of the modern-styled geochemical cycles of Fe & U through the crust-ocean-mantle system

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Modern oceans are U-rich but Fe-poor, because U is leached from, but Fe is retained in, rocks during weathering under an oxygenated atmosphere. The oceanic U is removed by three major processes: (1) co-precipitation with carbonates in shallow seas (~60%); (2) adsorption/reduction by carbonaceous matter in black shales, which deposited in euxinic basins (~20%); and (3) adsorption by Fe^{III}-(hydr)oxides that formed in submarine hydrothermal systems on mid-ocean ridges (MORs) (~20%). Many researchers have assumed that before ~2.4 Ga, the oceans were Fe-rich but U-poor, because the atmosphere was presumably reducing.

Here we report the results of our investigations on ~3.46 Ga jaspers (low-grade oxide-type BIFs) and associated submarine basalts from ABDP #1 drill hole at Marble Bar, Pilbara, Western Australia. These samples exhibit the mineralogical and geochemical characteristics that are essentially identical to those of jaspers and hydrothermally-altered basalts on modern ocean floors, including: (a) enrichments of Fe(III) as ferric (hydr)oxides; (b) enrichments of U, Mo and Li with Fe(III); (c) enrichments of Ba, Cu, Zn, Pb and Ag; (d) depletions of Ca and Sr; (e) anomalies (both positive and negative) in Ce concentrations; and (f) the $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and $^{238}U/^{232}Th$ ratios that significantly deviate from those of the bulk Earth. These data suggest that by ~3.5 Ga, the modern-styled geochemical cycles of the redox sensitive elements through the continental crust, oceans, oceanic crust and mantle had been established. This suggestion is further substantiated by the data on U/Th ratios and Ce anomalies in submarine volcanic rocks that are associated with volcanogenic massive sulfide deposits of 3.2-2.7 Ga in ages.

Subduction of oxidized and U-enriched oceanic crust has created the large-scale heterogeneity of the mantle since ~3.5 Gyr (or earlier), including the features known as 'the lead paradoxes' where Pb in the mantle is more radiogenic and has higher ratios of uranogenic Pb/thoriogenic Pb compared to Pb in the bulk Earth. Therefore, through the creation of the oxygenated atmosphere and oceans, aerobic microbes have influenced the geochemistry of the deep Earth since at least ~3.5 Ga ago.

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