2.8 Ga Meteoric Water Alteration of the Isua Supracrustal Belt

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Subaerial weathering of continents is critical to several elemental feedback cycles that stabilize climate and control ocean salinity and bio-availability of key nutrients. However, the age at which large stable continents first emerged above the ocean surface is poorly constrained. One indicator of large continental landmasses is the presence or mineralogical record of meteoric water with low δD or $\delta^{18}O$ values. Hydrogen and oxygen isotope values of silicate minerals from the 3.8 Ga Isua supracrustal belt in West Greenland indicate localized partial resetting due to infiltration of meteoric waters, with δD values of mineral separates as low as -129 ± 3‰, and $\delta^{18}O$ as low as 0.0 ± 0.2‰, relative to VSMOW [1].

We measured the Pb isotopic composition of serpentinites with published H and O isotopes, to constrain the timing of meteoric alteration. Samples with higher δD and $\delta^{18}O$ values align with a model 3.7 Ga Pb-Pb isochron, consistent with the interpreted end of supracrustal belt assembly, whereas samples with lower δD and $\delta^{18}O$ align with a 2.8 Ga model isochron. This latter age is contemporaneous with amalgamation of the North Atlantic Craton. Further, minerals exhibiting δD < −100‰ occur along discrete linear trends that are sub-parallel to crustal-scale faults associated with craton formation.

We modeled serpentine-water and anthophyllite-water isotope exchange at varying water/rock ratios, also varying fractionation temperature and δD and $\delta^{18}O$ of the meteoric fluid. The isotopic alteration pattern observed in the Isua samples are best explained when δD of the infiltrating meteoritic fluid is below -90‰. Today, meteoric waters with δD < -90‰ are present only in mid-continental or high-latitude regions with mean temperatures ≤ 7 º C. Paleolatitudes for the western North Atlantic Craton are < 46º at 2.8 Ga. Thus, the presence of deuterium-poor meteoric waters precludes global temperatures significantly above modern conditions, and requires either much colder temperatures globally, and/or vertically or laterally extensive emergent land at this time.

[1] Pope, Bird, Rosing (2012) *PNAS* 109, 4371-4376.