Fe isotope evidence for remnants of early silicate differentiation in the Earth's mantle

H.M. WILLIAMS[1], S. MATTHEWS[1], O. SHORTTLE[1], H. RIZO[2]

[1]Dept. Earth Sciences, The University of Cambridge, UK; hmw20@cam.ac.uk

[2] Dept. Earth Sciences, Carleton University, Ottawa, ON, Canada; HanikaRizo@cunet.carleton.ca

The differentiation of the Earth has defined the planet's chemical evolution and dynamic behaviour over the last ~4 Ga. The short-lived ^{146}Sm-^{142}Nd isotope system constrains silicate differentiation to have taken place by the early Hadean, where it may record the crystallisation of a magma ocean and the formation of refractory cumulate domains within the mantle. The geological record of these events has been largely erased, but geochemical evidence remains in the form of μ^{142}Nd variability Archean and modern mantle rocks. The presence of positive and negative μ^{182}W values, respectively, in ancient and modern mantle rocks can also inform on this debate. However, this μ^{182}W variability is difficult to interpret and may reflect multiple processes including the incomplete addition of late accreting chondritic material into the early Earth mantle, contributions from the outer core and magma ocean differentiation processes. Iron stable isotopes (δ^{57}Fe) offer a potential solution to this problem, as the incorporation of core metal or chondritic material should produce vastly different signatures to internal silicate differentiation processes. We present Fe isotope data for metabasalts from the Isua Supracrustal Belt (ISB), which display positive μ^{142}Nd and μ^{182}W anomalies and Sm-Nd-Lu-Hf isotope systematics that may be consistent with derivation from a deep-seated source region formed in the first 500 Myr of Earth history [1]. The δ^{57}Fe values of the ISB samples define striking correlations with fluid-immobile trace elements and μ^{182}W, with the samples showing the most pronounced excesses in μ^{182}W displaying elevated δ^{57}Fe signatures relative to most modern ocean-floor basalts. Phase equilibria modelling shows that the trace element, radiogenic isotope and δ^{57}Fe signatures of the ISB can be explained by the upper-mantle melting of an originally deep-seated cumulate source dominated by bridgmanite, which preferentially incorporates heavy δ^{57}Fe associated with lower mantle FeO disproportionation and removal of Fe metal to the core [2]. The δ^{57}Fe, μ^{182}W and radiogenic isotope signatures of the ISB samples may therefore provides a tantalizing glimpse of a cumulate residue from magma ocean crystallization that formed within the first 30 Myr of Earth history.

[1] Rizo et al., (2011) EPSL 312. [2] Williams et al., (2012) EPSL 321.