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The Hadean upper mantle conundrum: Evidence for source depletion and enrichment in 3.71 Gy boninite-like metabasalts (Isua, W Greenland)

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Here we present Sm-Nd and Re-Os isotopic data of carefully screened, least altered samples of boninite-like metabasalts from the Isua Supracrustal Belt (ISB, W Greenland), which characterize their mantle source at the time of their formation. The principal observations of this study are that by 3.7-3.8 Ga melt source regions existed in the upper mantle with complicated enrichment / depletion histories. Relying on a maximum formation age of 3.71 Gy defined by external age constraints, we calculate an average εNd [T=3.71 Ga] value of +2.2 +/- 0.9 (n=18, 1σ) for these samples, which is indicative of a strongly depleted mantle source. This is consistent with the high Os concentrations, falling in the range between 1.9-3.4 ppb, which is similar to the estimated Os concentration for the primitive upper mantle. Re-Os isotopic data yield an isochron defining an age of 3.76 +/- 0.09 Gy (with an initial γOs value of 3.9 +/- 1.2). the initial γOs value of is indicative of enrichment of their source region during, or prior to, its melting. Thus, this study provides the first observation of an early Archean upper mantle domain with a distinctly radiogenic Os isotopic signature. This requires a mixing component characterized by time-integrated suprachondritic Re/Os evolution and a Os concentration high enough to strongly affect the Os budget of the mantle source. At this point, the nature of the mantle or crustal component responsible for the radiogenic Os isotopic signature is not known.

Our results are broadly consistent with models favoring a time-integrated Hadean history of mantle depletion and with the existence of an early Hadean protocrust, the complement to the Hadean depleted mantle, which after establishment of subduction-like processes was, at least locally, recycled into the upper mantle prior to 3.7 Ga.

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Geochemistry of early Archean *Akilia association* supracrustal rocks on Innersuartuut, West Greenland

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The geology, age and origin of pre-3.8 Ga supracrustal sequences on Akilia (island), used to define the type locality of the *Akilia association* in West Greenland and suggested to be both the oldest marine sediments and containing the oldest signs of life [1,2], has been hotly debated. The invariably multiply metamorphosed units of this age have contributed to long-standing debates over protoliths and interpretation of complex zircon age spectra. Mapping of metasedimentary packages and host orthogneisses in the *Akilia association* at the appropriate scale (1:250), coupled with sampling guided by mapping, can properly address these contested issues [3]. Structurally crosscutting orthogneisses have been identified and whole-rock and mineral geochemistry coupled with ion microprobe depth profiling of individual zircon grains [4] confirms the > 3.8 Ga age of the enclosed supracrustal units. Trace element, $\delta^{18}O$ and mass independent sulfur isotopes ($\Delta^{33}S$) [5] corroborate a sedimentary origin for Akilia Fe-rich quartzitic enclaves. These studies provide mutually supportive means for establishing a sedimentary protolith even for highly metamorphosed supracrustal assemblages.

Considering the rarity of pre-3.8 Ga sediments and the importance of these rocks in understanding Earth evolution, it is pertinent to extend this approach to other supracrustal outcrops in the Godthåbsfjord/Ameralik region. Here we report data from early Archean supracrustal rocks on Innersuartuut, a small island ~10 km to the south of Akilia. Gabbros previously reported [6] from Innersuartuut give a whole-rock Sm-Nd isochron age of 3887±65 Ma (MSWD=0.7), providing a (statistically valid) hint that early Archean rocks are in the vicinity. Sample *GR97m27* is a garnetiferous quartzite (79 wt.% SiO_2); we report whole rock $\delta^{18}O_{SMOW}$ (+16.4‰) and $\Delta^{33}S$ values (>0.6‰) that confirm its sedimentary origin. It may be possible to directly establish the depositional age of this rock by searching for volcanogenic zircons from ash fall deposits and/or detrital zircons from emergent landmasses at time of formation. Determining the age of deposition in such multiply metamorphosed units has generally been problematic, however, the distinction between igneous and metamorphic zircons based on $[U/Th]_{zircon}$ could potentially be used to resolve this problem.

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