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Interrogating the Hf-Nd isotope compositions of Paleoarchean rocks in the Pilbara Craton by integrating whole rock and in situ datasets

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Hf and Nd isotopes are powerful tracers for understanding the geochemical evolution of the crust-mantle system over Earth's history. These systems, however, are often "decoupled" in Earth's oldest rocks, making it difficult to ascertain the age of the depleted mantle reservoir and the proportions of juvenile and reworked material in Earth's ancient crust. For example, the zircon Hf isotope record is chondritic-to-subchondritic prior to ~3.8 Ga, providing little evidence for a depleted mantle in the Hadean or early Archean. In contrast, whole rock Nd isotope compositions of most Eo-and-Paleoarchean cratons are highly variable, and this signal is taken to reflect very early differentiation of felsic crust. Recently, in situ analyses of LREE-rich minerals–the major Nd reservoir in rocks–have been used to dissect the Archean whole rock Nd isotope record and attribute the scatter of these data to open system behavior, where the primary Sm/Nd of these minerals are reequilibrated by later thermotectonic events[1]. We investigate the Archean Hf-Nd isotope dichotomy further using an approach integrating U-Pb geochronology with whole rock and in situ Hf-Nd isotope data inside several well-preserved Paleoarchean granitic rocks from the Pilbara Craton, Western Australia. We show these rocks have crystallization ages from 3466 to 3250 Ma. Unlike most Paleoarchean rocks, these rocks have well-correlated whole rock Hf-Nd isotopes ($\varepsilon_{Hf(i)}$=+1.5 to -1.8, $\varepsilon_{Nd(i)}$=+2.5 to -1.1), and zircon Hf isotopes ($\varepsilon_{Hf(i)}$=+0.9 to -0.8). Most samples have apatite-titanite-whole rock Sm-Nd isochron ages from 3494 to 3245 Ma. Titanite and apatite $\varepsilon_{Nd(i)}$ values agree with the whole rock data illustrating a closed system since igneous crystallization. Other samples have younger Sm-Nd ages and less radiogenic individual titanite and apatite $\varepsilon_{Nd(i)}$ values, but whole rock $\varepsilon_{Hf(i)} \approx \varepsilon_{Nd(i)}$. These are examples of localized reequilibration of Sm-Nd, without disruption of the whole rock Sm-Nd isotope system. The implications are three-fold: in situ Sm-Nd isotope data provide important context for interpreting the Hf-Nd isotope record of early Earth; demonstrably undisturbed Paleoarchean rocks show no evidence for early (>4.0 Ga) significant crust-mantle differentiation; and these granitic rocks are juvenile, indicating significant crustal growth in the Pilbara craton during the Paleoarchean.

[1]Hammerli et al., (2019), *Chem.Geol.* 524