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The evolution of the Archean mantle from combined isotope systematics in Pilbara basalts and komatiites

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Combined Hf-Nd isotope systematics are used for reconstructing the depletion history of the Archean mantle. We performed Ce, Nd and Hf isotope systematics for a comprehensive sample selection of 45 basalts, komatiites, and felsic crustal rocks from the Pilbara Craton, NW Australia. These rocks erupted from 3525-2775 Ma and are one of the best preserved Archean mafic rock successions. This dataset is complemented by conventional trace element data and high-precision isotope dilution measurements of HFSE, U-Th, and several REE including La-Ce and Sm-Nd for a better petrogenetic understanding. Positive initial εHf and εNd of the Pilbara samples indicate the presence of depleted mantle domains since at least 3.6 Ga. Our dataset shows covariations between Hf and Nd isotope signatures with La/Yb_{CN} ratios, implying that the original melts from depleted mantle domains interacted with an isotopically enriched second component, likely reflecting contamination by felsic crust (see also [1]). Our whole rock data are broadly consistent with recently published Hf isotope data from zircons [2], although our dataset indicates an earlier onset of mantle depletion and mixing with older felsic crust. Early mantle differentiation processes in the Pilbara Craton are also corroborated by previously reported positive ^{182}W isotope excesses for mantle-derived rocks from the East Pilbara Terrane [3]. The key implication from the combined data is therefore, that mantle-crust differentiation in the Pilbara Craton as preserved in the rock record had most likely already begun in the early Eoarchean, and possibly as early as in late Hadean time.

[1] Arndt et al., (2001) Australia. Spec. Pap.-Geol. Soc. Am., 352, 359-387. [2] Gardiner et al., (2019) Precam. Res. 321, 64-84. [3] Tusch et al., (2021) PNAS 118, 1-6.