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Use of accessory minerals for accurate initial Nd isotope determinations in early Archean rocks: An example from the Minnesota River Valley terrane

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Two commonly used radiogenic isotope tracers, ^{176}Lu-^{176}Hf and ^{147}Sm-^{143}Nd, display different records in some of the oldest rocks on Earth (Fisher and Vervoort, 2019; Kemp et al., 2019). These rocks often have chondritic initial εHf(t) values in zircon but highly variable whole-rock εNd(t) values. Interpretations include uncoupled Lu/Hf and Sm/Nd fractionation during either deep magma ocean crystallization, subduction zone processes, or metamorphic disturbance to the whole rock Sm/Nd ratios. To clarify the cause of these early Archean Hf-Nd relationships, we have investigated the U-Pb and Sm-Nd isotope systematics of co-existing accessory minerals (titanite, apatite and allanite) in 3.5–3.4 Ga TTGs from the Minnesota River Valley (MRV) terrane. A previous study (Satkoski et al., 2013) showed closed-system crustal evolution in the zircon Hf record but apparently decoupled whole-rock Sm-Nd systematics.

The U-Pb age results show two populations. The major population of 2.6 Ga in all titanite and most apatite represents the Sacred Heart Orogeny, the accretion of the MRV terrane to the southern Superior craton. The younger population of 1.9 – 1.8 Ga in two apatite samples suggest the overprint of the ~ 1.85 Ga Penokean Orogeny in the MRV terrane interior. Sm-Nd isochrons provide 2.6 Ga ages in all apatite and titanite, suggesting terrane-wide Sm-Nd re-equilibration during the Sacred Heart Orogeny. Notably, one allanite sample survived the Sm-Nd resetting event, and yielded a Sm-Nd isochron age consistent with the crystallization age of the host rock (~3.4 Ga). This allanite has a chondritic initial εNd at 3.4 Ga. Based on these accessory minerals, we have reconstructed the Sm-Nd isotopic evolution of the MRV terrane, where the crust was repeatedly re-melted in a closed-system since the formation initially from a source with chondritic Sm/Nd. This is in good agreement with the previous zircon Hf isotopic record, suggesting a minimally differentiated or already rehomogenized mantle at 3.5 Ga. The MRV terrane appears to be formed from a source distinct from that of the Wyoming, Slave and Superior cratons in Laurentia. This study highlights the importance of using REE-rich accessory phases to obtain a clear Nd isotopic record of the early Earth.