The conflicting Hf and Nd isotope records of early Earth crust-mantle evolution

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The Hf-Nd isotope record has long been used to understand the timing of crust extraction from the mantle and the corresponding development of the depleted mantle reservoir. Zircon from Eo- and Paleoarchean magmatic rocks have provided particular clarity to the Hf isotope record through the ability to confidently constrain the crystallization age of the zircons—even in complexly-zoned grains—and thus link the Hf isotope composition to a robust magmatic age. This latter requirement is essential for providing a meaningful isotopic record. For example, zircon from Eoarchean magmatic rocks of Greenland have well-constrained U-Pb ages ranging from ~3.82 to 3.64 Ga. All of these Greenland rocks have initial Hf isotope compositions that are broadly chondritic and provide no evidence for the existence of a depleted mantle reservoir through the Eoarchean. This signature of chondritic initial Hf isotope compositions appears to be a robust characteristic of all juvenile, nominally mantle-derived rocks through most of the Eoarchean and indicate growth of the depleted mantle reservoir starting no earlier than ~ 3.8 Ga. In contrast, the long-lived Sm-Nd isotope record shows considerably more variation in initial ^{143}Nd isotope compositions. Most notably, the same Paleo- and Eoarchean terranes that have chondritic Hf initial compositions seem to have significantly positive epsilon Nd values indicative of the early development of the depleted mantle reservoir—certainly by the start of the Paleoarchean. All of these Nd isotope data, however, come from whole-rock analyses and the Sm-Nd system may have been compromised because the Nd isotope budget in these rocks is contained in REE-rich accessory phases that can be easily mobilized during later metamorphic and magmatic events. We will discuss the Hf-Nd isotope record for the early Earth, provide examples of open-system Sm-Nd behavior in some of these rocks, and suggest a way forward to resolve the Hf-Nd isotope dichotomy.