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Metamorphic resetting is the culprit! Microanalysis of accessory minerals solves the Hf and Nd isotope paradox in Eoarchean tonalites of Greenland

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In situ trace element and Sm-Nd isotope analysis of accessory minerals in an Eoarchean tonalitic gneiss from Greenland: Implications for Hf and Nd isotope decoupling in Earth's ancient rocks

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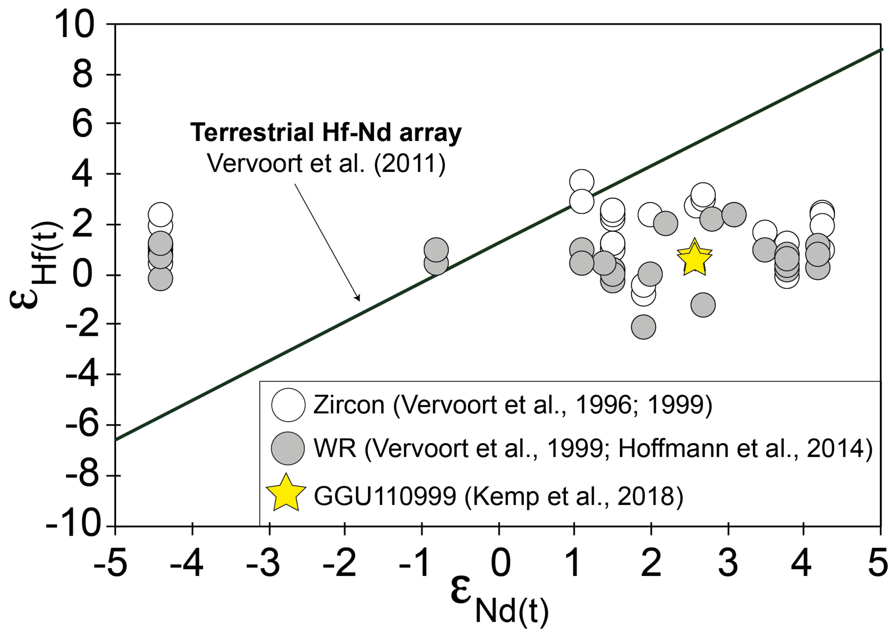
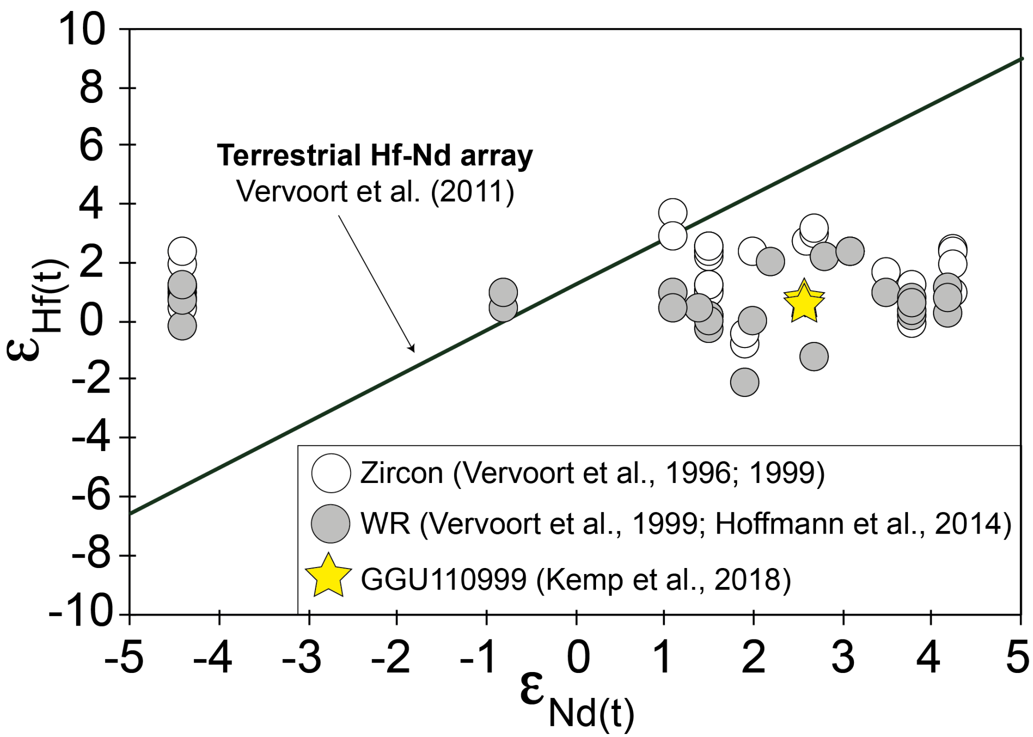
Background

During crust formation processes, Hf and Nd isotopes behave similarly, resulting in a terrestrial Hf-Nd array. ***However, some of the world's oldest preserved crust contains puzzling Nd and Hf isotope fingerprints***. Rocks from southern West Greenland contain chondritic Hf isotope signatures, but have superchondritic Nd isotope compositions.



Models to explain this discrepancy are divided with some using speculative processes, such as the presence of magma oceans and associated isotope fractionation to rationalise the "apparent" isotope decoupling. *Understanding the meaning of this discrepancy is essential to gain insights into processes that led to the formation of early continental crust and the geochemical differentiation of the mantle in the Eoarchean.*

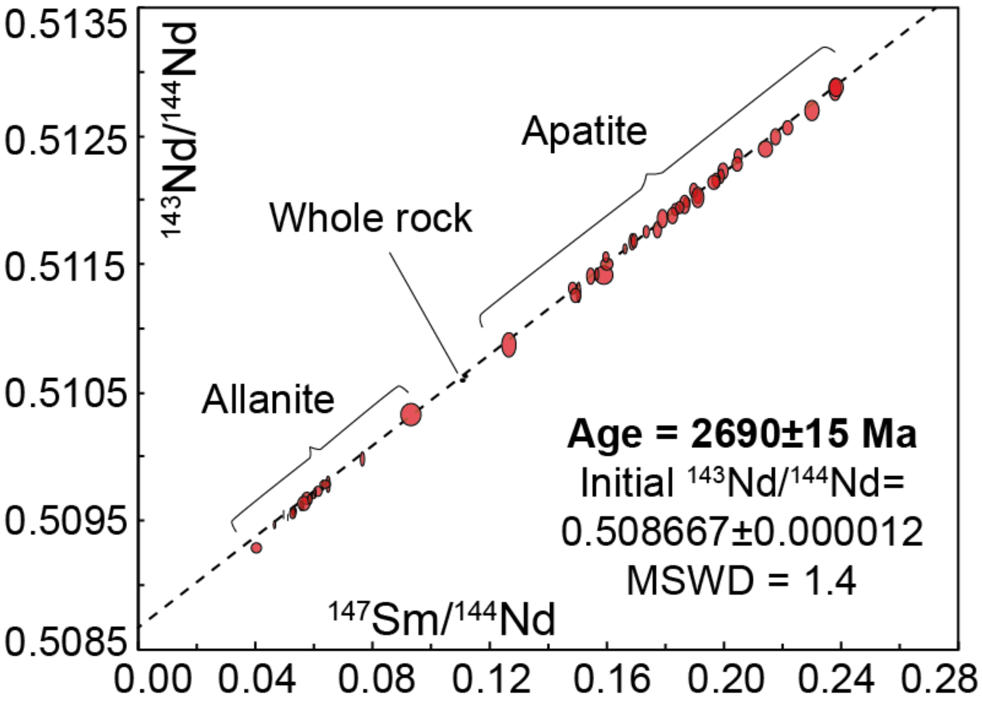
Metamorphic resetting at 2690 Ma



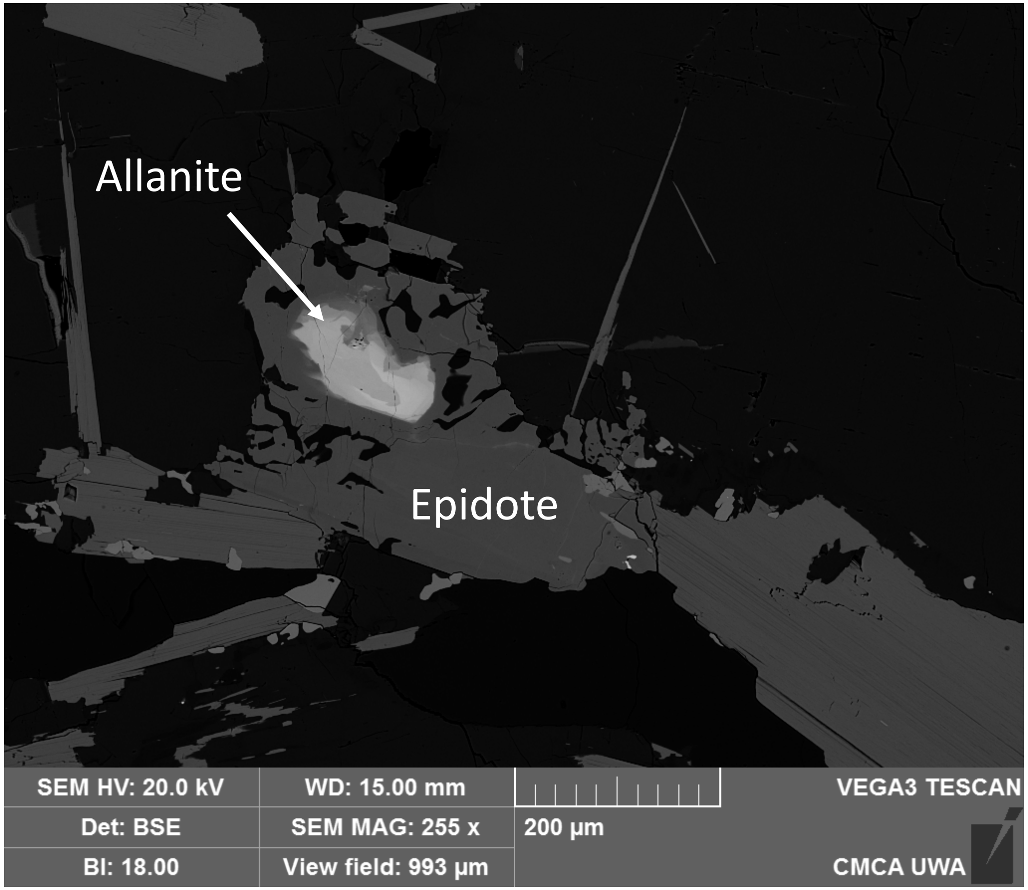
This study investigates an Eoarchean (3820 Ma) tonalitic gneiss from Greenland: ☆ which has a chondritic Hf signature, but a superchondritic Nd value.

Metamorphic resetting at 2690 Ma

The Sm-Nd isochron age of 2690 ± 15 Ma obtained from allanite and apatite is markedly younger than the inferred magmatic protolith age of the tonalitic gneiss (ca. 3820 Ma, Whitehouse et al., 1999). We interpret this to indicate that the Sm-Nd isotope system in this **gneiss was homogenized and reset in the Neoarchean**

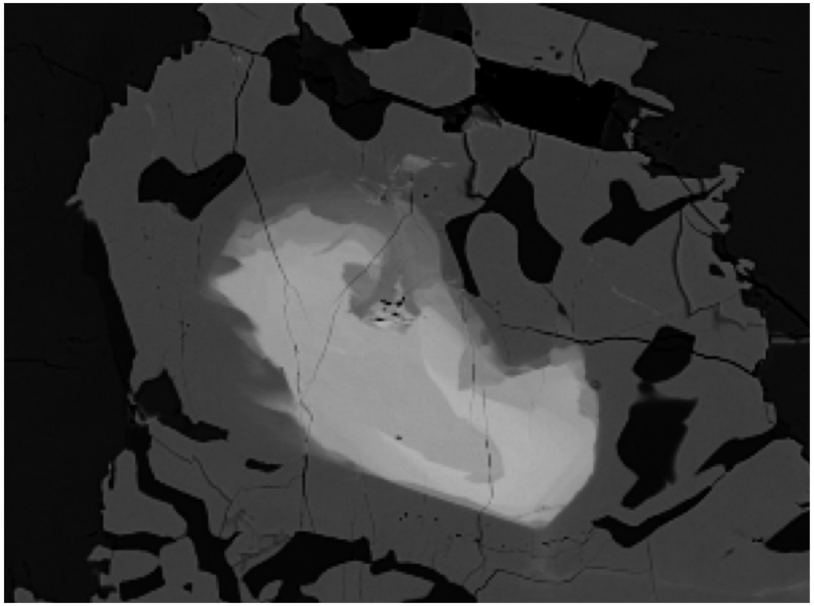


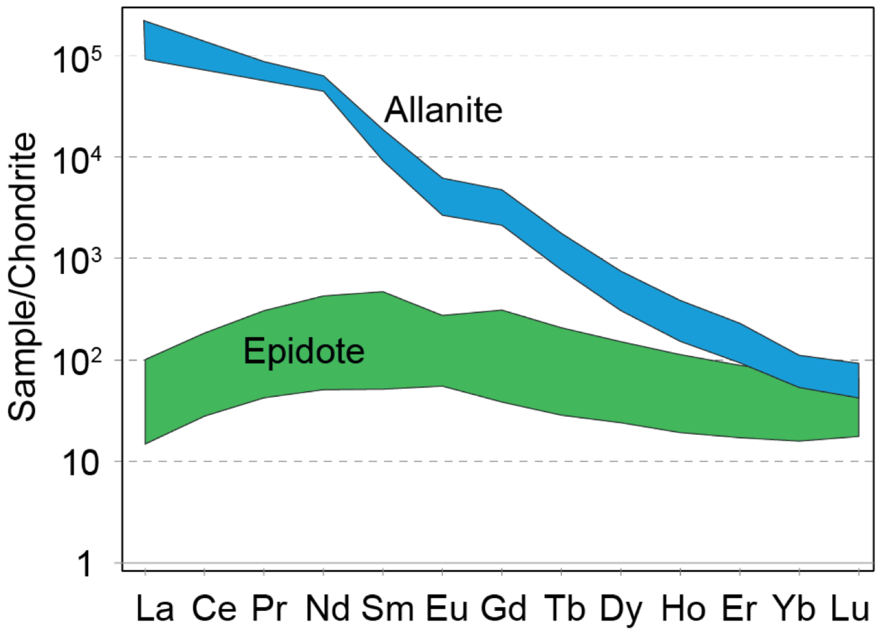
Key accessory minerals in GGU110999



Petrographic evidence suggests that epidote is a metamorphic product formed at the expense of allanite.

REE pattern of accessory minerals



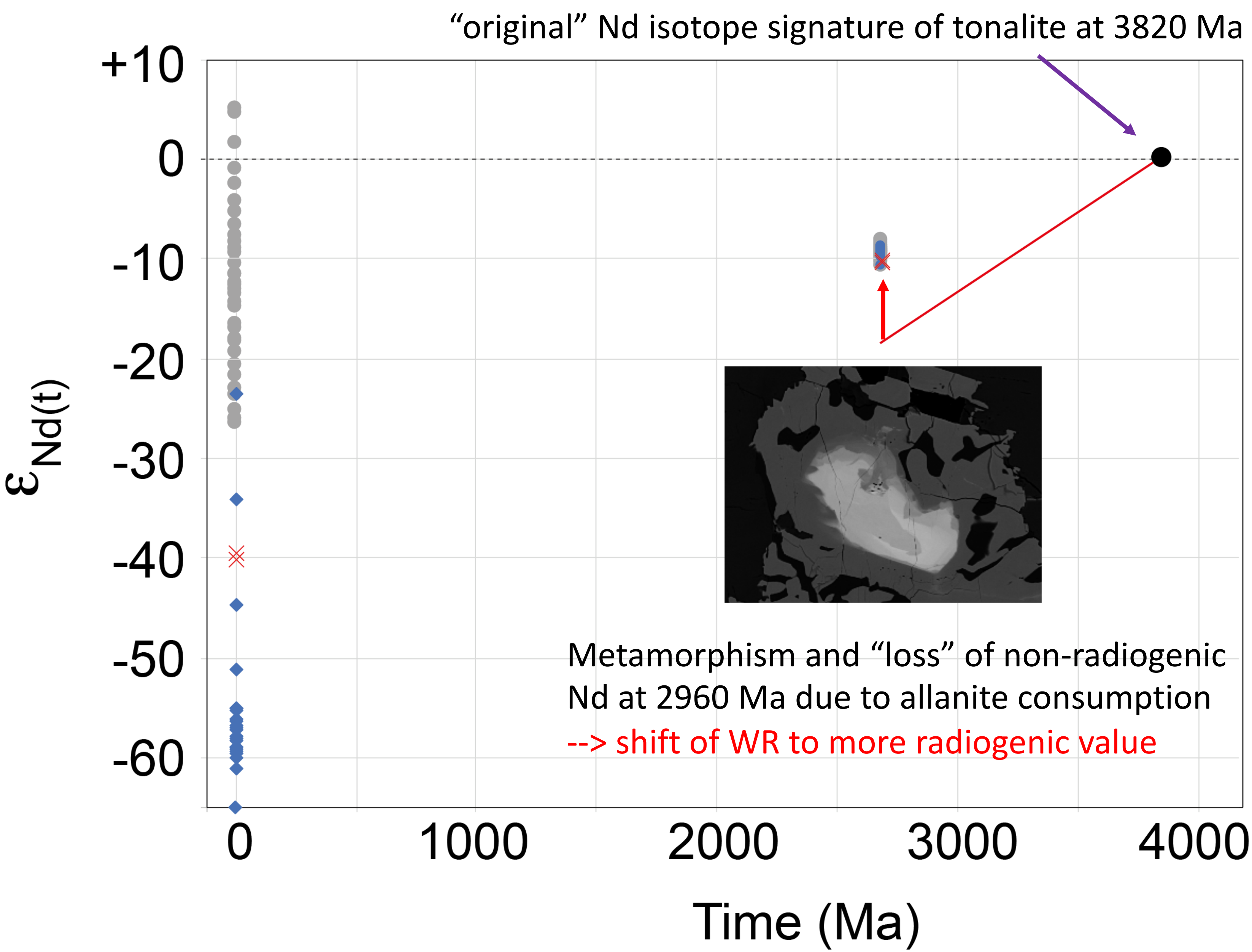


- **Allanite** has a low Sm/Nd ratio → **low ^{143}Nd production**

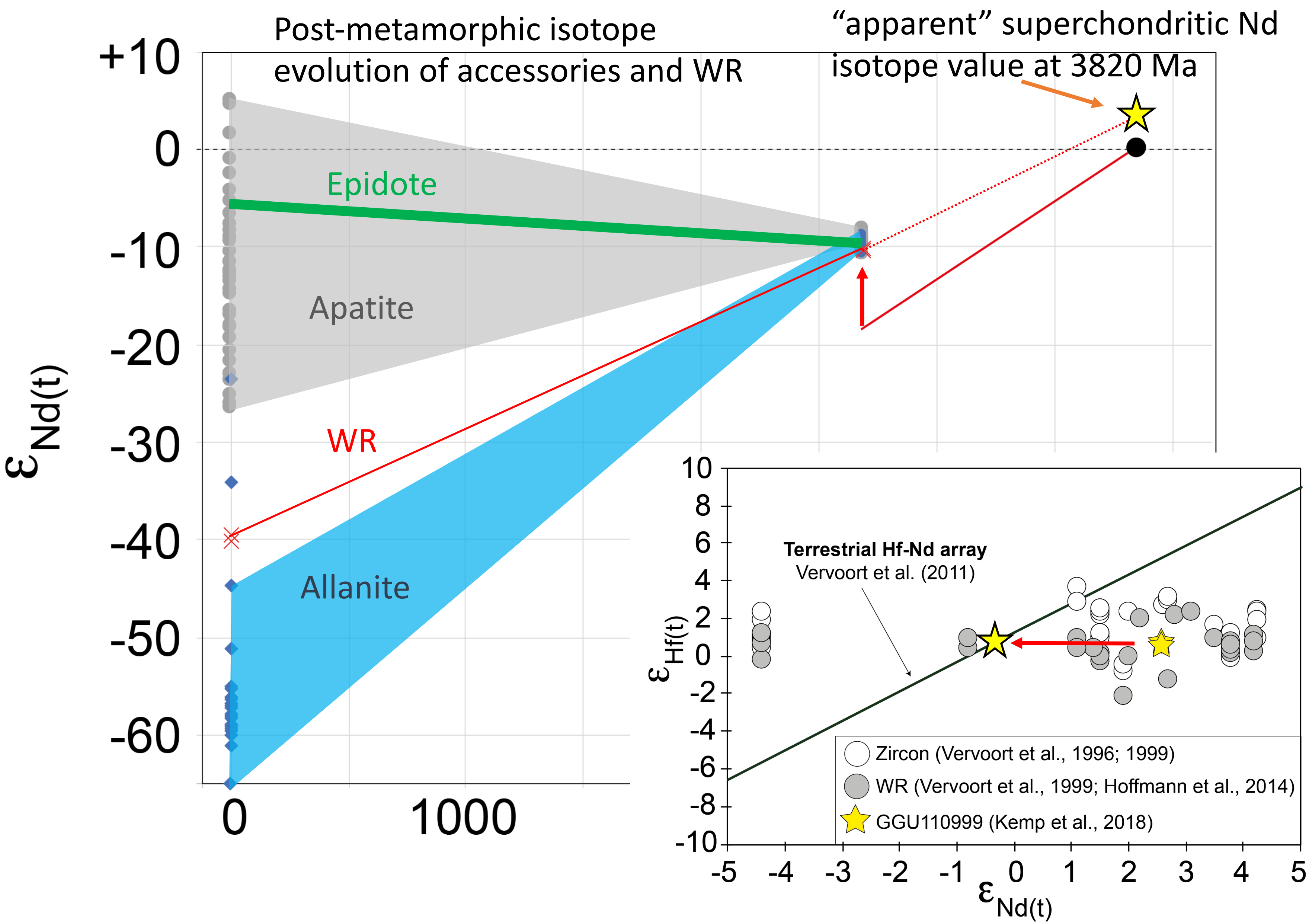
- **All other minerals** have higher Sm/Nd ratios → **high ^{143}Nd production** via ^{147}Sm to ^{143}Nd decay.

The consumption of allanite results in a "loss" of non-radiogenic Nd

Evolution of the Nd isotope signature



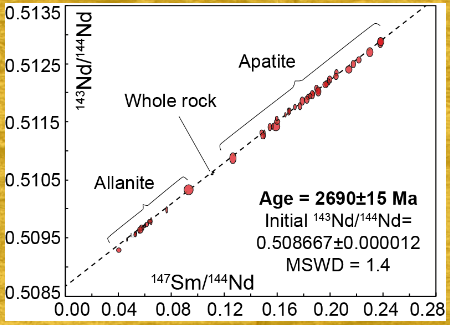
Evolution of the Nd isotope signature



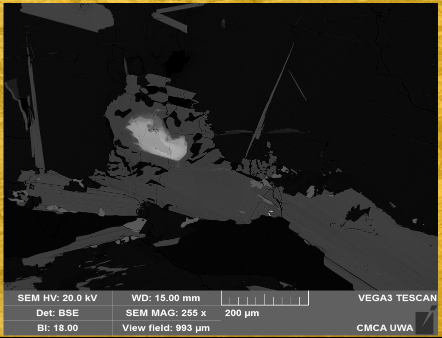
The Hf-Nd Paradox in Eoarchean Rocks

Accessory minerals give detailed insights into the evolution of ancient rocks:

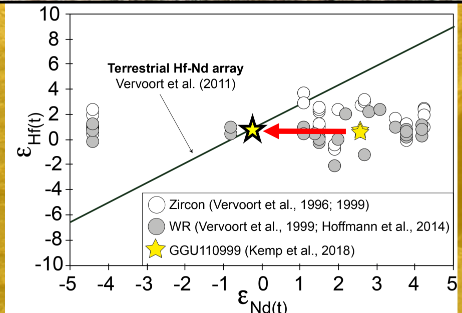
A metamorphic event at 2960 Ma reset the Sm-Nd isotope system in GGU110999.



The consumption of allanite in an **open-system environment** led to the **mobility of LREE** and loss of non-radiogenic Nd, which **shifted the WR Nd isotope value to a higher value.**



Calculating the initial Nd isotope signature at 3820 Ma leads to an ”apparent” superchrondritic Nd isotope signature.



Implications for current early Earth models

- No early decoupling of Hf and Nd isotopes in the Archean mantle.

- No requirement for unusual mantle melting processes in the early Earth.

- Models for crust extraction and volume calculation in the early Eoarchean have to be treated cautiously.

Recent study (Fisher et al., 2020) has found Sm-Nd isotope disturbance in Eoarchean Acasta Gneisses

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