Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.16080

Low-$\delta^{18}O$ deep mantle reservoir reveals oceanic crust recycling before 3.3 billion years ago

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Composition variability in mantle-derived magmas is commonly ascribed to mantle heterogeneity, which can be caused by the subduction of recycled slabs. How early this process started on Earth remains highly debated due to the rarity of early Archean materials of pristine mantle compositional signatures. Mg-rich komatiites occurred almost exclusively in the Archean and were regarded as products of a high degree of partial melting of deep-seated mantle plumes, which are generally considered to originate at the lower mantle, even at the core-mantle boundary. They are unique archives of the compositional and thermal state of the early deep mantle and can help constrain the nature of mantle heterogeneity, which may not be recorded in the modern lavas due to the unidirectional evolution of the Earth. Numerous studies have demonstrated the potential of the oxygen isotope-element systematics of olivine for tracing source compositions and magma-evolving processes. However, the systematics of olivine from komatiites remains largely unexplored.

Here using the oxygen isotope-element compositions of fresh olivine grains in the 3.27-Ga komatiites of the Weltevreden Formation in the Barberton Greenstone Belt in Southern Africa, we discovered two groups of primitive olivine grains. Group I exhibits mantle-like $\delta^{18}O$ values and high Fo contents (Fo = 93-95); Group II is characterized by lower $\delta^{18}O$ values (as low as 3.6 ‰) with slightly lower Fo contents (Fo = 91-93). Both groups' $\delta^{18}O$ values correlate with multiple geochemical proxies (i.e., Ni*FeO/MgO, Ca/Fe, Zn/Fe, and Co/Fe) of olivine-poor iron-rich pyroxenite source, indicating that the Weltevreden komatiites were derived from two distinct mantle sources. The existence of the low-$\delta^{18}O$ magmas can be best explained by recycling altered oceanic crust into the deep mantle arguably by subduction, which started 3.3 billion years ago, and is responsible for the deep mantle heterogeneity in early Earth.