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Low-$\delta^{18}O$ signatures in zircon – evidence for emergent land in the early Archean

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Evidence about surface environments in the Eoarchean (4–3.6 Ga) is limited. Based on numerical models of mantle convection and bathymetry, it was proposed that ocean islands and oceanic plateaus represented the only exposed landmasses [1]. As exposed land is a prerequisite for prebiotic chemical evolution leading to the emergence of life [2], the identification of potentially habitable environments in the Eoarchean is pivotal. Sub-mantle $\delta^{18}O$ magmas are examples of the manifestation of exposed land because their origin requires the interaction of rocks with meteoric water [3]. Zircon crystalizing from such magmas should preserve low-$\delta^{18}O$, even in rocks strongly affected by later processes.

Zircon from Eoarchean orthogneisses of the Tula Mountains, Napier Complex, East Antarctica [4] were analyzed for oxygen isotopes. A ca. 3.75 Ga granitic gneiss with a low Y-HREE-Nb-Ta signature, ascribed to melting of basaltic source rocks at pressures >1.5 GPa, contains zircon with $\delta^{18}O \sim +6$ ‰. In contrast, ca. 3.75 Ga trondhjemitic and ca. 3.55 Ga dioritic gneisses with higher Y-HREE-Nb-Ta, ascribed to the melting of sources at <1.0 GPa contain zircon with $\delta^{18}O \sim +2$ ‰. Such values are known in magmatic zircon associated with hot-spot or extensional environments, where meteoric water can interact with magmatic systems at shallow depths, e.g., Yellowstone, Iceland [3]. They are an indication that the magmas in which the zircon grew, or the source rocks from which the magmas were derived, had significant interaction with meteoric water.

This is the first report of significantly low $\delta^{18}O$ zircon from early Archean orthogneisses, and demonstrates the existence of shallow magmatic-hydrothermal systems involving meteoric water by 3.75 Ga. This provides new isotopic evidence for the presence of emergent land in the Eoarchean. The scarcity of such signatures in the early Earth zircon record may be an indicator of the limited extent of land formation; however, as such signatures are rare over all of Earth's history, this may also reflect a lack of preservation.

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