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Water-Induced Mantle Overturns Leading to the Oxidation of Archean Upper Mantle

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As a consequence of the evolution of the water-bearing basal magma ocean (MO), water-induced mantle overturn can well account for many puzzling observations in the early Earth, such as the formation of the Archean continents and the boundary of the Archean and Proterozoic (Wu et al., 2023). The early Earth may have experienced a deep-water cycle totally different from the current. High pressure studies suggest that the whole-mantle MO evolved into an outer MO and a basal MO. With the solidification, water in the basal MO moved toward the core-mantle boundary and the basal MO eventually became gravitationally unstable because of the enrichment of water(Fig. 1). The instability triggered massive mantle overturns and resulted in the major pulses of the thick SCLM and continental crust generations in the Neoarchean. The mantle overturns eventually got rid of the whole basal MO and the mechanism which generated the Archean-type SCLM and continents likely no more worked after the overturns. Thus, water-induced mantle overturns can account for why Archean-type SCLM and continents basically occurred in the Archean (Wu et al., 2023).

The basal MO was also enriched with ferric iron. The ascent of ferric-rich basal MO and its mixing with the upper mantle could account for the observed shift in the redox state of the upper mantle during the Archean. Both the redox state shift and the generation of Archean continents result from these mantle overturns. Therefore, it is expected that the shift in mantle fO_2 aligns with the timing of continental generation. The mantle overturns are rare with age > ~ 3.6 Ga, but their frequency increases with age < ~3.6 Ga and reaches the maximum in the Neoarchean. The combined effects of the ascent of the deep oxidized material, the emergence of continents, and oxygenic photosynthesis generated the broader First Redox Revolution of the Earth system, ultimately initiating the GOE shortly after the end of the Archean.

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