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Records of Archean mantle oxygen fugacity

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Mantle oxygen fugacity (f_{O2}) has great potential to alter the course of planetary evolution. The relative size of a planet's core, the formation of continental crust, the depth of melt initiation, and the composition of volcanic gases are all strongly influenced by mantle f_{O2}. For this reason, the evolution, or lack thereof, of Earth's mantle f_{O2} since the Archean has been studied and debated for decades.

Here we present new observations of mid-ocean ridge peridotites and mid-ocean ridge basalts that bear on the nature of the Archean mantle. Globally, the f_{O2} recorded by mid-ocean ridge peridotites is orders of magnitude more variable than the f_{O2} recorded by basalts, though on average they both record conditions near the QFM buffer [1]. The causes and implications of peridotite f_{O2} heterogeneity have been unknown. Here we present new spinel oxybarometry measurements of highly refractory peridotites from multiple ridges that reveal rare excursions to ultra-low f_{O2} (<QFM-2). Using thermodynamic modeling, we find that such excursions can be generated at high extents of melting in the garnet field when potential temperatures are high and melting continues to low pressure (Birner et al., this meeting).

These ultra-reduced mantle rafts must have been generated in the Archean because the conditions for their formation are not present at ridges or plumes today. But does this imply that the Archean mantle was more reduced than the modern mantle? We refined a vanadium-based trace element oxybarometer to revisit the f_{O2} recorded by Archean basalts. We show that Archean basalts record f_{O2} values consistent with modern MORB mantle, as previously shown by [2]. The ultra-reduced peridotites we observe may be reconciled with the Archean basalt record if melting conditions, but not the mantle's bulk redox chemistry (its Fe^{3+}/FeT ratio), have changed since the Archean. In this way, high Archean potential temperatures may have generated low f_{O2} komatiites [3] without any secular evolution of mantle composition nor causal link to the Great Oxidation Event.

[1] Birner et al., EPSL, 2018 [2] Li and Lee, EPSL, 2004 [3] Nicklas et al., GCA, 2019