Facilitating atmosphere oxidation through mantle convection

KANANI K. M. LEE[1*], TINGTING GU[2], NEALA CREASY[1], MINGMING LI[3], CATHERINE MCCAMMON[4]

[1]Yale University, New Haven, CT 06511, USA (*correspondence: kanani.lee@yale.edu)
[2]now at the Gemological Institute of America, New York, NY 10036, USA
[3]University of Colorado, Boulder, CO 80309, USA
[4]Bayerisches Geoinstitut, Bayreuth 95440 GERMANY

Earth's mantle connects the surface with the deep interior through convection, and the evolution of its redox state will affect the distribution of siderophile elements, recycling of refractory isotopes, and the oxidation state of the atmosphere through volcanic outgassing. While the rise of oxygen in the atmosphere, i.e., the Great Oxidation Event (G.O.E.) occurred ~2.4 billion years ago (Ga), multiple lines of evidence point to oxygen production in the atmosphere well before 2.4 Ga. In contrast to the fluctuations of atmospheric oxygen, vanadium in Archean mantle lithosphere suggests that the mantle redox state has been constant for ~3.5 Ga. Indeed, the connection between the redox state of the deep Earth and the atmosphere is enigmatic as is the effect of redox state on mantle dynamics. Here we show a redox-induced density contrast affects mantle convection and may potentially cause the oxidation of the upper mantle. We compressed two synthetic enstatite chondritic samples with identical bulk compositions but formed under different oxygen fugacities (fO_2) to lower mantle pressures and temperatures and find Al_2O_3 forms its own phase separate from the dominant Mg-silicate perovskite phase (i.e., bridgmanite) in the more reduced composition, in contrast to a more Al-rich, bridgmanite-dominated assemblage for a more oxidized starting composition. As a result, the reduced material is ~1-1.5% denser than the oxidized material. Subsequent experiments on other plausible mantle compositions which differ only in redox state of the starting glass materials, show similar results: distinct mineral assemblages and density contrasts. Our geodynamic simulations suggest that such a density contrast can cause a rapid ascent and accumulation of oxidized material in the upper mantle, with descent of the denser reduced material to the core–mantle boundary [1]. The resulting heterogeneous redox conditions in Earth's interior may have contributed to the large low-shear velocity provinces in the lower mantle and the rise of oxygen in Earth's atmosphere.

[1] Gu et al., (2016) *Nature Geoscience* **9**, 723-727.