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Facilitating oxidation of the atmosphere through mantle convection

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 occurred ~2.4 billion years ago, multiple lines of evidence point to oxygen production in the atmosphere well before then. 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. Using a laser-heated diamond-anvil cell, we
compressed synthetic plausible lower mantle samples (e.g., pyroxenite, enstatite chondrite) to lower mantle pressures and temperatures. We tested the behavior of samples of otherwise identical bulk compositions but formed under different oxygen fugacities (fO2) and find distinct mineralogies, densities and seismic velocities. Samples which are more reduced (low Fe3+/Fetotal) have more complex mineralogies and are denser by ~1-1.5%, as compared to their more oxidized (high Fe3+/Fetotal) counterparts. Our geodynamic simulations suggest that such a density contrast causes a rapid ascent and accumulation of oxidized material in the upper mantle, with descent of the denser reduced material to the core–mantle boundary. 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.