Limited dissolution of organic carbon in slab melt causes the rise of atmospheric O_2 across GOE

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Dissolution reactions of carbon in silicate melt are key in controlling the mobility of carbon in the planetary interiors and therefore setting the planet-scale distribution of the volatile species. Solution of reduced, organic carbon in hydrous, silicic slab melt is critical in determining the efficiency of long-term sequestration of reduced carbon over the history of the planet and therefore for the build up of oxygen in the atmosphere. Here, we conducted high pressure-temperature experiments to determine the carbon carrying capacity of slab derived, rhyolitic melts under graphite-saturated conditions to constrain the subduction efficiency of organic carbon, the remnants of life, through time.

Experiments were performed at 1.5-3.0 GPa and 1100-1400 °C on a model hydrous rhyolitic melt in graphite capsules. Experimental glasses were measured for carbon and water by FTIR and SIMS and for major elements by EPMA. Based on our experimental data, we developed a thermodynamic model of CO_2 dissolution in slab melts [C (as graphite) = $CO_2^{mol.}$ (silicate melt); C (as graphite) = CO_3^{2-} (silicate melt)], with which we quantify the extent of organic carbon mobility as a function of slab parameters (pressure, temperature, and oxygen fugacity) during subduction.

Our data and model suggest that the subduction of graphitized organic (reduced) carbon, and the graphite/diamond formed by reduction of carbonates with depth, remained efficient even in ancient, hotter subduction zones where oxidized carbon subduction likely remained limited. We further combined the estimates of extent of subduction through time based on the crustal growth models and zircon age-frequency distribution with the estimates of initial organic carbon in the slab and extent of slab melting to constrain the mass of subducted organic carbon through time. Our model show deep sequestration of organic carbon in the mantle facilitated the rise (~10^{3-5} fold) and maintenance of atmospheric oxygen since the Paleoproterozoic and is causally linked to the Great Oxidation Event. Episodic recycling of organic carbon pre-GOE may also explain occasional whiffs of atmospheric oxygen observed in the Archean.