Phosphorus scavenging and release during low temperature alteration of oceanic crust

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Phosphorus (P) is generally agreed upon to be the ultimate limiting nutrient on Earth. The mass transfer of P to and from seawater upon alteration of the oceanic crust plays a critical role in the modern global P cycle and in shaping the evolution of the marine P levels through Earth's history, and is likely to be one of the key factors controlling the scope of biospheres on terrestrial exoplanets. It is well known that the flux of P from the oceanic crust upon hydrothermal alteration in oxygenated modern Earth systems is limited, primarily because of P scavenging by adsoprtion onto iron-oxides. However, there is a dearth of experimental data that provide direct cause and effect relationships of P mobility at a range of conditions indicative of early and modern Earth and of exoplanets.

To examine and quantify the process of P release and scavenging during hydrothermal alteration of oceanic crust, we performed a set experiments at a range of conditions indicative of low temperature off-axis hydrothermal systems of early and modern Earth. Specifically, the experiments are performed at a range of low temperatures suggestive of the subseafloor aquifer, 15-75 °C, and a range of redox conditions, anoxic to present day atmospheric O_2 concentrations. The experiments also implement an anomalous isotope tracer, ^{29}Si, to quantify the kinetics of basalt and ultramafic crust alteration at far from and close to steady-state conditions, which provides constraints for the extent of alteration, secondary mineral formation, and the mass transfer of P between the crustal-seawater reservoirs.

The new data provide novel constraints regarding the rate of oceanic crust alteration and element specific mobility at a range of temperature and redox conditions. These data can be utilized to explore Earth states with greater extents of marine weathering and exoplanets thought to be dominated by marine weathering ('waterworlds').