Vivianite formation and its role in phosphorus retention in Lake Ørn, Denmark

Vivianite [(Fe₃(PO₄)₂·8H₂O)] may precipitate in anoxic lake sediments affecting the porewater orthophosphate concentration, and thereby the trophic status of lakes. We have investigated changes in lake diagenesis of Fe and P (1969-2009), with particular attention focused on vivianite formation with sediment depth (0-20cm) in an iron-silica-carbon rich lake sediment (Ørnsø, Denmark). Porewaters were supersaturated for vivianite by two to five orders of magnitude (upper 10cm) with porewater phosphate concentrations ranging between 0.69 and 10μmol⁻¹, in winter, and summer concentrations ranging between 9.8 and 40μmol⁻¹. Significant formation of vivianite was confirmed by X-ray diffraction while scanning electron microscopy and electron dispersive X-ray spectroscopy indicated an increase in vivianite crystal size with depth (~20 to ~70μm across). Variations in elemental composition of vivianite crystals in relation to at.% P and Fe were especially seen going from 9.5cm to 24.5cm. The total sediment Fe pool was very large ~3000μmolg⁻¹ and total P increased from 200μmolg⁻¹ to 400μmolg⁻¹ descending down the sediment profile. Differential extraction experiments of P release at pH3 estimated that vivianite amounts to between 3 and 5% of the total Fe pool. The total P burial fluxes estimate that ~38μmolcm⁻²yr⁻¹ or ~26% of sedimentary P in the lower sediments is sequestered as vivianite. There are seasonal variations in the porewater composition with lower Fe, orthophosphate and higher sulfate concentrations during winter (5°C), than during summer (15°C). This suggests that temperature modulates the rate of organic matter degradation which in turns affects the rate of Fe(III) phase reduction, release of phosphate, and thereby the porewater Fe²⁺ and orthophosphate concentrations and hence vivianite formation. This work highlights the role vivianite can play for P retention in a Si-Fe-C rich lake sediment.

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