Vivianite formation and its role in phosphorus retention in Lake Ørn, Denmark - DTU Orbit (19/10/2019)

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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 l⁻¹, in winter, and summer concentrations ranging between 9.8 and 40μmol l⁻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 ~3000μmol g⁻¹ and total P increased from 200μmol g⁻¹ to 400μmol g⁻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 ~38μmol cm⁻² yr⁻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.

General information
Publication status: Published
Organisations: Department of Environmental Engineering, Urban Water Engineering, Center for Electron Nanoscopy, Geological Survey of Denmark and Greenland, University of Copenhagen, University of Southern Denmark
Number of pages: 12
Pages: 42-53
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Chemical Geology
Volume: 409
ISSN (Print): 0009-2541
Ratings:
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.99 SJR 2.925 SNIP 1.564
Web of Science (2015): Impact factor 3.482
Web of Science (2015): Indexed yes
Original language: English
Keywords: Burial flux, Eutrophication, Fe release, Fe-silicate, P release, P sequestration, Phosphate, Seasonal flux, Sulfate, Sulfide, Vivianite, Carbon, Lakes, Phosphates, Scanning electron microscopy, Sedimentology, Sediments, Silicates, Sulfur compounds, X ray diffraction, X ray spectroscopy, Burial fluxes, Seasonal fluxes, Phosphate minerals
DOIs:
10.1016/j.chemgeo.2015.05.002
Source: FindIt
Source ID: 275173291
Research output: Contribution to journal › Journal article – Annual report year: 2015 › Research › peer-review