Microbial Ecosystem Evolution
Biogeochemical Nutrient Scavenging is a Prerequisite

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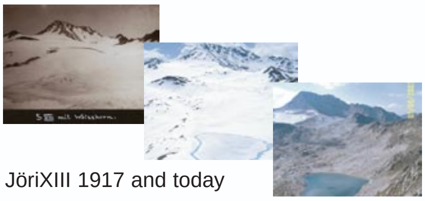
Naturally oligotrophic high-mountain lakes are excellent ecosystems for the study of early evolutionary processes

Objectives

- Which are the geochemical and microbiological processes that might have governed ecosystem evolution in the Precambrium ?
- Where did the phosphorous compounds come from ?
- How was P concentrated from dilute solutions to amounts needed to synthesise phosphate-containing biomolecules?
- Was self-trophication through iron cycling a nutrient scavenging process ?
- Do „Early Earth“ conditions still exist on earth today ?

Model systems in oligotrophic environments

Lakes in deglaciating areas are evolving ecosystems



JöriXIII 1917 and today

Where do nutrients come from ?

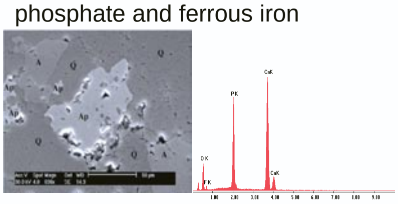
Nutrients of atmospheric origin

Inorganic substances in snow at a remote high-altitute site (Jungfraujoch 3450 m a.s.l.)

	w/o. Sahara dust [g/m³, ppm]	w. Sahara dust [g/m³, ppm]	maximal values [g/m³, ppm]
Cl^-	0.10	2.06 (x 21)	4.38
NO_3^-	0.65	0.99 (x 1.5)	2.09
SO_4^{2-}	0.65	4.09 (x 6.3)	6.00
NH_4^+	0.13	0.44 (x 3.4)	0.48
HPO_4^{2-}	?	?	?
Na^+	0.06	2.01 (x 33)	3.83
K^+	0.04	0.44 (x 11)	0.58
Ca^{2+}	0.24	7.10 (x 30)	11.1
Mg^{2+}	0.03	0.82 (x 27)	1.22

For Jungfraujoch March, 1-29,1990. Sahara dust event March 20 -23, 1990, p 657 mbar, T_{air} -11.2°C (PSI, Annual reports, Gäggeler, H., et al.)

Nutrients of lithosperic origin: Hydroxyapatite and Ankerite in carbonate veins are sources of phosphate and ferrous iron



$$Ca_{10}(PO_4)_6(OH)_2 + 10\ HCO_3^- \longrightarrow 10\ CaCO_3 + 2\ H^+\ 6\ HPO_4^{2-} + 2\ H_2O$$

$$Fe_xMg_yCa_z(CO_3)_{x+y+z} + (x+y+z)\ H^+ \longrightarrow xFe^{2+} + y\ Mg^{2+} + zCa^{2+} + (x+y+z)\ HCO_3^-$$

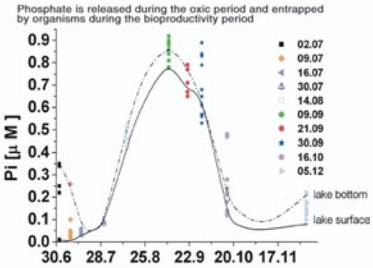
xFe^{2+} → $+ O_2$ → $FeOOH, Fe_2O_3$

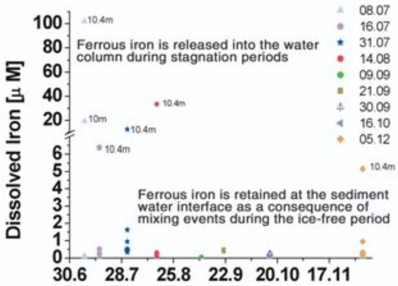
$(x+y+z)\ HCO_3^-$ → Dissolution of Hydroxyapatite

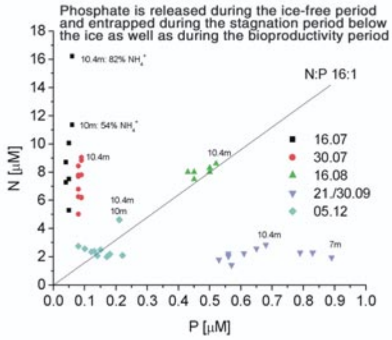
Marino Maggetti, University of Fribourg

How ecosystems retain nutrients

by chemical means
by biological means

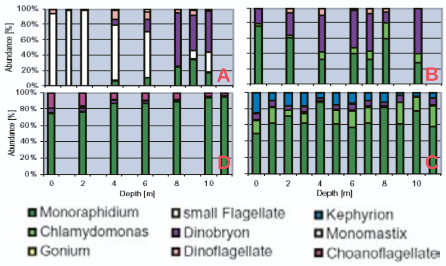




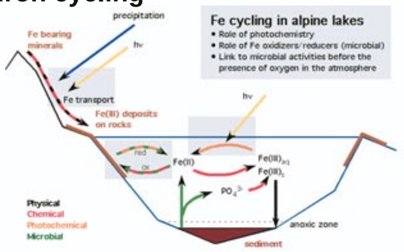


Seasonal and spacial nutrient fluctuations lead to rapid adaptation in community composition

A: July 16, ice melting period
B: July 30, end of ice melting period
C: Sept. 29, height of bioproductivity
D: Dec. 5, beginning of ice cover period

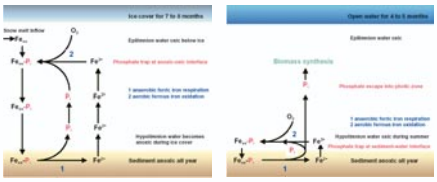


Nutrient entrapment is driven by iron cycling



Self-trophication mechanisms

Winter situation   Summer situation



Ferric oxide coated rocks and ferric oxide layers cover the lake bottom

- While the hypolimnion becomes anoxic phosphate and ferrous iron are released from the sediment.
- In the oxidizing water layers ferrous iron gets re-oxidized, thereby scavenging phosphate into its ferric oxyhydroxide matrix.
- Phosphate is stripped from the water and retained in ferric oxy-hydroxide colloidal nanoparticles.
- When the oxidation zone is compressed at the sediment water interface, ferrous iron is re-oxidized at the lake bottom while phosphate can escape into the water column.
- Thus P no longer limits biosynthe-sis under late summer conditions.

Early earth nutrient scavenging by the iron cycle