Biogeochemical responses of Lake Übeschi (Swiss Plateau) to periods of rapid climate variations during the Late-Glacial

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Introduction

The rapid degradation of freshwater ecosystems worldwide, due to eutrophication and hypolimnetic anoxia, is primarily driven by human activities and climate change. A comprehensive understanding of these processes and their underlying mechanisms is essential. We aim at investigating the responses of lake productivity, redox conditions and chemical feedbacks during periods of rapid climate shifts (Dansgaard-Oeschger events) under natural conditions in the past.

Research questions:

- What were the levels of aquatic primary productivity in the lake during initial stages of its formation (early deglaciation)?
- Are there periods of hypolimnetic anoxia in the lake during the Late-Glacial and in which conditions do these events appear?

Study site

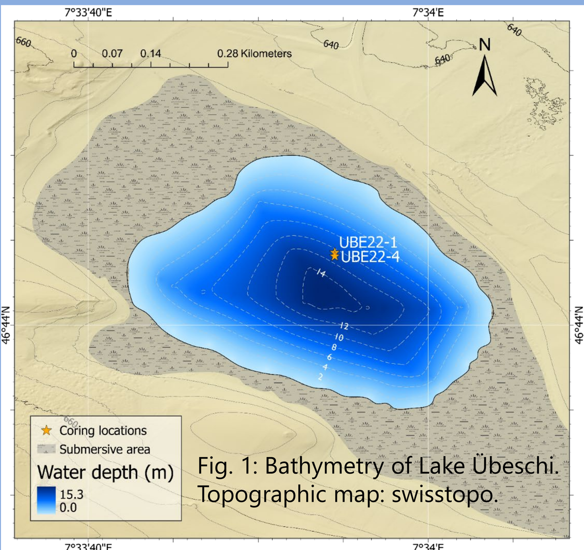

Fig. 1: Bathymetry of Lake Übeschi. Topographic map: swisstopo.

- Kettlehole lake
- 641 m a.s.l
- Area: 14 ha
- Catchment area: 125 ha
- Holomictic
- Currently eutrophic

Main results

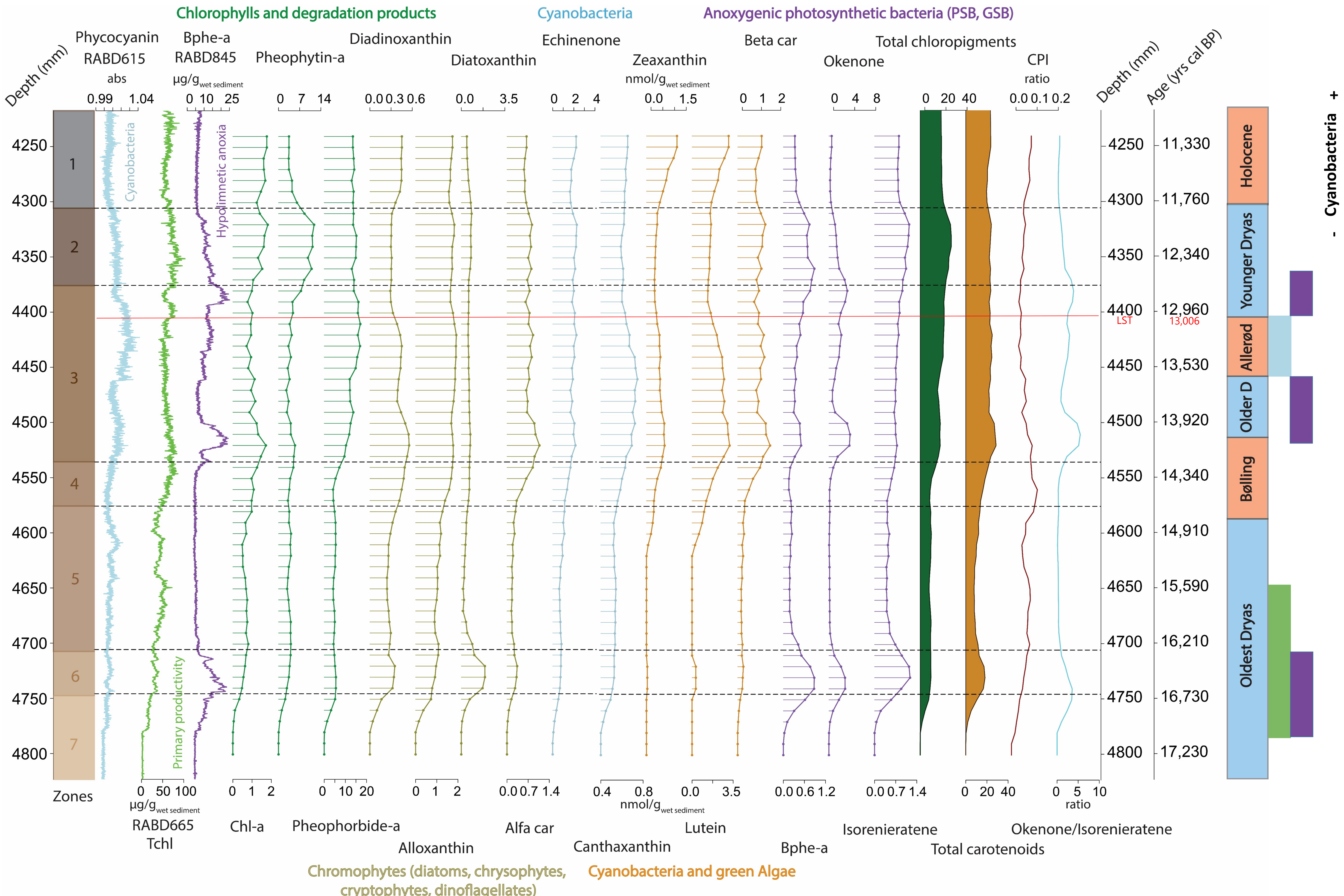

Fig. 3: Hyperspectral indiex values and composition of sedimentary pigments of the Late-Glacial section of Lake Übeschi divided in zones based on a constrained cluster analysis. The pigments are grouped based on their producers (written in colour) [1]. Phycocyanin (RABD615), Tchl (RABD665) and Bphe-a (RABD845) on the left are measured by HI and the other proxies by HPLC-DAD. Older D= Older Dryas, LST= Laacher See Tephra, CPI= Chlorophyll Preservation Index.

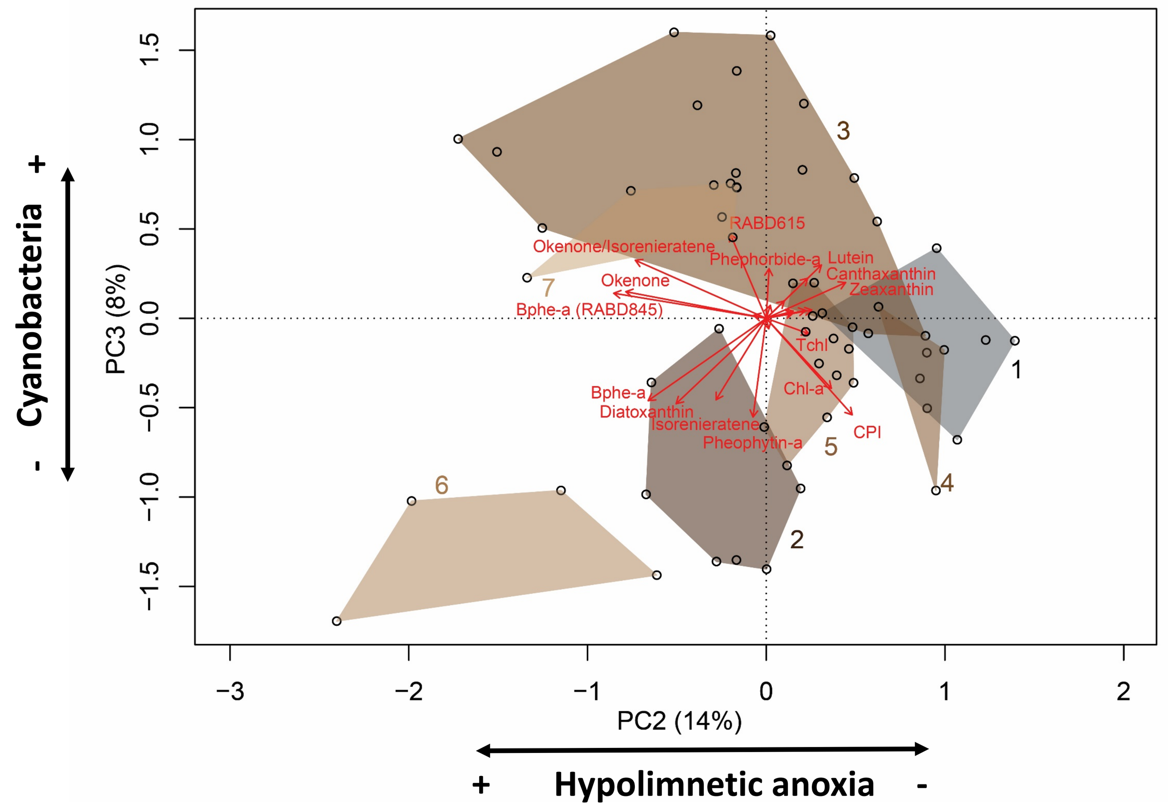

Fig. 4: PCA biplot of the pigments (Fig. 3). The samples are grouped based on the constrained cluster analysis (colours in Fig. 3 left).

Bphe-a (RABD845) and Tchl are anti-correlating (Fig. 4) showing that increased productivity in the lake does not lead to hypolimnetic anoxia.

RABD615, as well as canthaxanthin and echinenone show higher values during the Allerød. Cyanobacteria, able to fix nitrogen, could have benefited from nutrient limitations [3].

Bphe-a shows higher concentrations during cold periods. The hypolimnetic anoxia is possibly a result of very long ice cover [4] with strong lake stratification and a chemocline where PSB could grow.

Total chlorophyll (Tchl), as well as chlorophyll-a (Chl-a), pheophytin-a and pheophorbide-a are already increasing from 17,000 yrs cal BP onward (Heinrich Stadial 1).

Methods

- Hyperspectral imaging (HI):

➢ RABD615 records phycocyanin produced by cyanobacteria.
➢ RABD845 records bacteriopheophytin-a (Bphe-a) produced by purple sulphur bacteria (PSB), anoxygenic photosynthetic bacteria living at the chemocline of lakes [2].
➢ RABD665 records total primary productivity.

- ^{14}C dating
- X-ray fluorescence
- Pigment extraction and high performance liquid chromatography with diode array detector (HPLC-DAD)
- Sequential extraction of Fe, Mn and P and ICP-MS
- CNS analysis

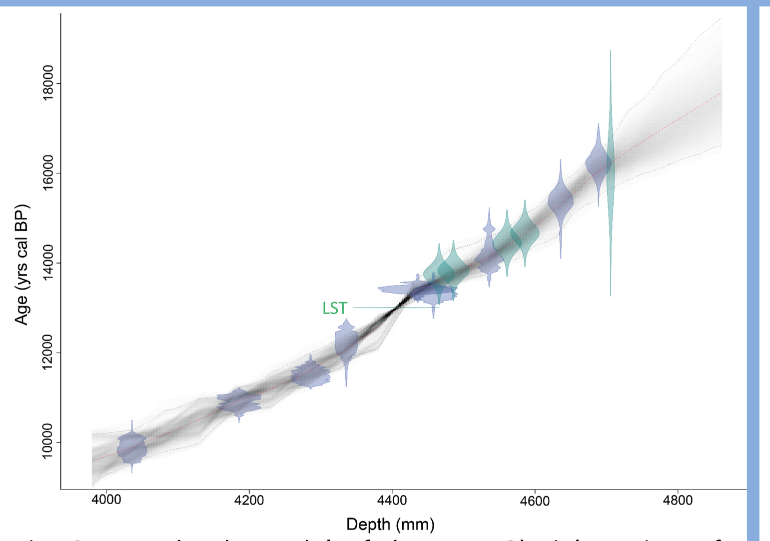

Fig. 2: Age-depth model of the Late-Glacial section of lake Übeschi. In blue calibrated ^{14}C ages and in green palynostratigraphical marker layers.

Conclusions

- Aquatic primary production showed an increase as early as Heinrich Stadial 1, preceding the Bølling warm period (Figure 3).
- Contrary to expectations, hypolimnetic anoxia events occurred during the cold periods of the Oldest Dryas, the Older Dryas and the Younger Dryas (Figure 3).
- Long-lasting ice cover can trigger anoxia in cold lakes [4]. The ice cover induced stratification creates a hypolimnion with low oxygen reaching the chemocline that provides ideal conditions for the growth of purple sulphur bacteria.

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References:

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