

## Short communication

ISSN 2658-3518

LIMNOLOGY  
FRESHWATER  
BIOLOGY

www.limnolwbiol.com

# Regional variations of carbonates in postglacial sediments and response of physical sediment properties to climatic events and vegetation

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**ABSTRACT.** Despite an increasing number of geochemical and palynological data representing the Lateglacial and Holocene sediment sequences that are used to evaluate long-term and short-term interactions between soil and vegetation, the main environmental drivers of these processes are not fully understood so far. Soil composition, vegetation and lake evolution are diverse in all sites analysed in this study. The work was aimed to provide a comparison of the evolution of conifer and broad-leaved plant taxa spread with sediment geochemical data, including organic carbon and CaCO<sub>3</sub> changes during the same sedimentation period. Problems addressed here analyze the increased carbonate mobility initiated by the invasion of conifers and a subsequent drop in soil pH. Together with this, the influence of organic material on accumulation of carbonates and sensitivity of Mn and Fe to redox conditions was evaluated. In general, chronologically defined changes in sediment composition revealed the intervals of more stable environmental conditions during which biotic factors were of greater importance in altering vegetation structure and the periods during which scarce vegetation had a negative impact on soil development leading to its progressive deterioration. Related changes occurred in sediments from different lakes; however, due to geographical position, responses to warming or cold events were a bit asynchronous.

**Keywords:** lake sediments, organic matter, carbonates, conifers, postglacial palaeoenvironmental changes, redox conditions.

## 1. Material and methods

The following contrasting regions representing various watersheds – three sites in Lithuania (Lieporiai, Čepkeliai, and Dūkšteliai) and one site in Kaliningrad Region, Russia (Kamyshovoe) (Fig. 1) – were investigated with the intention of providing information on terrestrial and aquatic environment variations during the postglacial. Standard methods described in Stančikaitė et al. (2019), Edwardsson et al. (2018), Gedminienė et al. (2019), were applied for pollen, LOI, geochemical analyses, and <sup>14</sup>C dating. Radiocarbon measurements were focused on bulk sediments. The chronology of sequences was based on age-depth models constructed applying the P\_Sequence function in the OxCal 4.3.2 software. However, biostratigraphical information also supported the chronological model in Gedminienė et al. (2019) indicating the main stages of vegetation history in the lake catchment. A mean value of the modeled age was used for the calculation of the sedimentation rate. Various statistical and mathematical

methods indicated in Gedminienė and Uogintas (2017) and publications mentioned above were employed to evaluate interrelations between proxies. Significance levels for element correlation were calculated applying StatSoft Statistica 8 MR-3software.

## 2. Results and discussion

In the present study, the LOI<sub>550</sub> and sedimentation rate allowed us to identify the increasing importance of bioproductivity. One of the highest values of the accumulation rate was noted (Fig. 2) over a time span covering an interval between 13 500 and 12 500 cal yr BP, which is coincident with GI-1a, the so-called Alleröd Thermal Maximum. Together with this, the Mn/Fe ratio markedly increased, and a high percentage of LOI<sub>950</sub> and a highly variable but still low concentration of LOI<sub>550</sub> were observed in all the sequences investigated. However, carbonate content varied remarkably throughout this time interval: Lieporiai sediment was composed of purely white and soft calcareous gyttja

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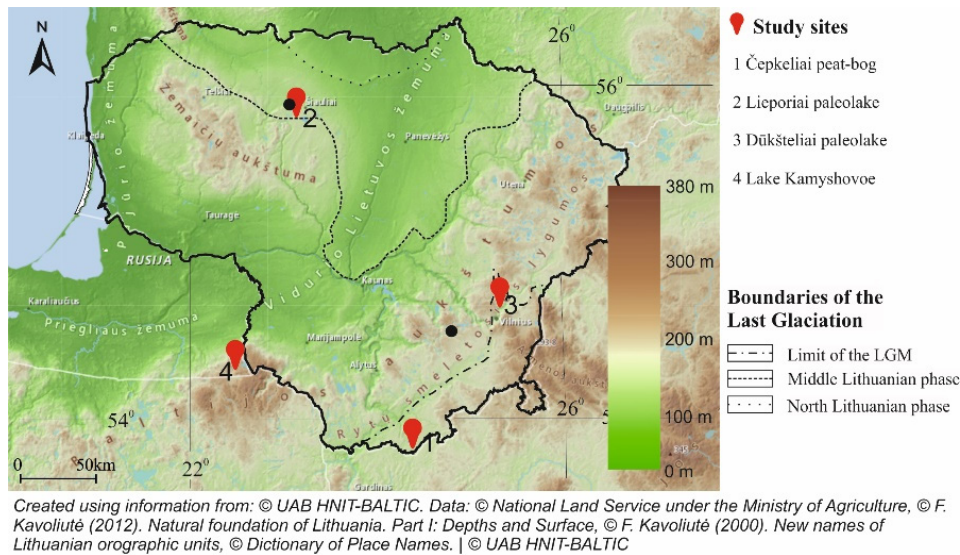


Fig.1. Location of study sites.

( $LOI_{950}$  38%), while Čepkeliai and Dūkšteliai were also calcareous, but sediments were silty and enriched with clay ( $LOI_{950}$  30% and 20%, respectively). The lowest concentration of carbonate was recorded in the Kamyshovoe sequence. Whilst geochemical elements determine allogenic input, pollen carries a more regional signal, which documents the flourishing of the *Pinus*-predominated forest in the region. The presence of *Pinus* and the enhanced mobility of carbonates had previously been investigated by Engstrom and Hansen (1985) and Apolinarska et al. (2012).

A sudden rise in siliciclastic input coincided with the opening of vegetation, i.e. spread of herbs and grasses was noted at about 12 600 cal yr BP in the sequences analyzed. This reversal in the environmental pattern may indicate an intensification of soil erosion processes under more open lakeshores. The interval described might correlate with the GS-1 cooling event.

With the onset of the Holocene, successional changes started in surrounding vegetation (i.e. gradual closing of vegetation and increasing representation of broad-leafed taxa) and in soil composition of the sites investigated. However, the evolution of the investigated sedimentation basins differed remarkably according to information obtained. For example,  $LOI_{550}$  data confirm that overgrowing processes in Čepkeliai started earlier than in other sites. In Čepkeliai, a rise in organic sedimentation started at about 9 500 cal yr BP, and the coring site finally overgrew at about 6 000 cal yr BP according to our data. Meantime, Lake Dūkšteliai transformed into a wetland at about 3 500 cal yr BP, though the representation of organic matter increased from about 8 000 cal yr BP onward. Decreasing participation of siliciclastic sedimentation started after 9 000 cal yr BP in Kamyshovoe. In conjunction, sediments started to consist of a higher concentration of organic matter at that time. Such reversal may indicate that at the beginning deep lake shores got stabilized by overgrowing vegetation, but highly soluble Ca was easily washed from surrounding soils and due to a high biogenic removal of  $CO_2$  and accompanying increase

in pH the production of  $CaCO_3$  could also be increased. This effect was widely studied by Walter E. Dean (1999).

Our data shows two trends of carbonate sedimentation. The first of the trends observed is well seen during the Lateglacial period in all lakes, excluding Kamyshovoe. At that time, increased concentrations of  $LOI_{950}$  and high concentrations of Ca and Ca/Ti were noticed. Simultaneously, *Pinus* played a major role in surrounding vegetation. However, the content of organic matter in the sediments of lakes was very low. Another type of carbonate sedimentation can be seen during the Holocene. At that time, we observed high concentrations of  $LOI_{550}$  which had a correlating trend only with Ca/Ti high values, while Ca and  $LOI_{950}$  values decreased. This means that sediment saturation with the organic matter had an impact on lithogenic elements (i.e. Ti), but enrichment with Ca remained the same. This reversal is directly connected with the trophic stage of lakes, as we see equal trends in different lakes but at different stages of lake development. Together with this, during the Early and Middle Holocene we can see a decreasing *Pinus* curve, which again increased from about 6 000 cal yr BP in Čepkeliai and 4 000 cal yr BP in Dūkšteliai. From about 8 000 cal yr BP, a gradual *Picea* spreading started. However, conifer and Ca/Ti correlation coefficients, which represent this sedimentation period, were a bit lower in comparison with Ca/Ti and  $LOI_{550}$  correlation coefficients.

### 3. Conclusions

During the Lateglacial period, bioproduction onshore was poor; therefore, conifer vegetation could have a direct effect on soil erosion and carbonate migration to lake basins. In the Holocene, the vegetation became intense, and conifer impact on carbonate migration lowered. However, *Picea* migration to the region during the Holocene from about 6 000 cal yr BP could have become the main reason for higher carbonate concentrations in lake sediments, as the



Fig.2. Preliminary results of selected data. QM – *Quercetum mixtum* (thermophilous pollen); *Pinus* – pine; *Picea* – spruce;  $LOI_{550}$  – loss-on-ignition when heating at 550° temperature;  $LOI_{950}$  – loss-on-ignition when heating at 950° temperature.

content of Ca/Ti increased simultaneously. Together with this, some carbonates could also be incorporated in sediments due to a high biogenic removal of  $CO_2$ .

## Acknowledgments

Special thanks are addressed to the Nature Research Centre for a possibility to use the facilities of the Open Access Centre. Part of the investigations was financed by the Research Council of Lithuania Grant, No. S-MIP-17-133, and Russian Foundation for Basic Research, No. 09-06-00150/12-05-33013.

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