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STABLE ISOTOPES AS RECORD OF CLIMATIC CHANGES OF DANIGLACIAL IN LITHUANIA

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Abstract: **Development of glaciolacustrine basins and varved clay sedimentation in Lithuania are closely connected with the course of ice retreat during Daniglacial time from 16,000 till 13,000 BP. Isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) of chemogenic carbonaceous samples from glaciolacustrine varved clays, which spread near glacier edge of South-Lithuanian (Balbieriškis section), Middle-Lithuanian (Girininkai section) and North-Lithuanian (Joniškėlis section) Phases of the Baltija (Pomeranian) Stage of Nemunas (Vistulian) Glaciation, has been studied. The obtained stable isotope data well confirm climatic changes of Daniglacial time in Lithuania. The gradual warming of climate is connected with the South-Lithuanian to Middle-Lithuanian and the Middle-Lithuanian to North-Lithuanian Interphasials as well as with the South Lithuanian interoscillations. The Interphasial lacustrine sedimentation with rhythmical lamination of carbonaceous sediments was observed in the middle part of the Balbieriškis section (at a depth of 3.1-5.9 m). The following climatic changes of Daniglacial time in Lithuania are distinguished: (1) stadial (3000-6000), (2) glaciophasial (500-1000), (3) glacio-oscillation (500-1000) years and (1) interstadial (1000-2000), (2) interphasial (250-450), (3) glacio-interoscillation (20-40) years. Regular succession of Daniglacial climatic and sedimentation changes in the local periglacial glaciolacustrine lakes, conditioned by recession of the last Scandinavian ice sheet, was revealed in the glaciolacustrine-lacustrine sediments for the first time.**

1. INTRODUCTION

Varved deposits of glaciolacustrine basins are widely spread in Lithuania. The largest occurrences of them are connected with the glacier edge of its South-Lithuanian, Middle-Lithuanian and North-Lithuanian Phases of the Baltija (Pomeranian) Stadial of Nemunas (Vistulian) Glaciation (Gudelis and Mikaila, 1960).

The proglacial lakes were dammed near the margin of the retreating ice-sheet of the Last Nemunas (Vistulian) Glaciation (Kazakauskas and Gaigalas, 2000). The maximum of the Nemunas Glaciation in Lithuania dates about 20,000-18,000 BP (the first Grūda Stadial). The glacier of the next Baltija Stadial reached its maximum at 16,000 years ago (Gaigalas, 2000). Approximately after 16,000 years ago the glacier of the Baltija Stadial began the retreat from the maximal limits of its spread.

Development of glaciolacustrine basins and varved clay sedimentation in Lithuania are closely connected with the course of ice retreat during Daniglacial time from 16,000 to 13,000 BP (**Fig. 1).** Sedimentation of varved sediments of glaciolacustrine basins in Lithuania went on for 3000 years. The time of the glacier retreat from the North Lithuanian end moraine correspond to the transition from Daniglacial (16,000-13,000 BP) to Gotiglacial (13,000-10,000 BP) epoch. The age of the boundary between the Daniglacial and Gotiglacial was established at 13,200 years BP due to the dating of some interstadial deposits in central Latvia (Raukas, 1993; Gaigalas, 1994).

Approximately 16,000 years ago the recession of the glacier margin of the Baltija Stadial from the maximal limits of its spread began. About 15,000 years ago the glacier stopped on the line of the end moraines of South-Lithuanian Phasial. In South-Lithuanian Phasial there are distinct branches of at least three oscillatory end moraines

and some complexes of varved clays in Simnas-Balbieriškis glaciolacustrine basin of that time. As may be seen from the section of Balbieriškis exposure **(Fig. 2)**, there are 5 different sedimentogenetic series of varved deposits connected with the South-Lithuanian retreating ice cover. The 370 varves were counted in Balbieriškis section. Next stop of the receding ice cover at the Middle-Lithuanian end moraines lasted till 14,000 years ago. The glaciolacustrine basins Kaunas-Kaišiadorys and Jūra-Šešupė were situated between the South Lithuanian and Middle Lithuanian end moraines. The varvometric data show that duration of the Kaunas-Kaišiadorys basin was about 260 years **(Fig. 1).** The Linkuva-Pasvalys glaciolacustrine basin was formed in the moraine belt of North Lithuania after the retreat and during new recession of the glacier. The Joniškėlis section contains about 120 varves **(Fig. 1).** Sedimentation of different litho-types of glaciolacustrine clays was closely related to climatic changes, deglaciation, melting and retreat of the Last Scandinavian ice-sheet. This is confirmed by the study of stable isotope content in varved clays of glaciolacustrine basins. Carbon and oxygen stable isotope composition reflects cold climatic conditions of Daniglacial time.

2. SECTIONS AND SAMPLES STUDIED

The isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) has been studied for chemogenic carbonaceous samples. Eighty-eight samples of glaciolacustrine varved clays were collected from sediments of proglacial basins of the South-Lithuanian (Balbieriškis section, 49 samples), Middle-Lithuanian (Girininkai section, 21 samples), North-Lithuanian (Joniškėlis section, 18 samples) Phases of the Baltija (Pomeranian) Stadial of Nemunas (Vistulian) Stage in Lithuania **(Fig. 1).**

About 15,000 years ago the glacier stopped on the line of the South Lithuanian end moraines and, thus, there are some distinct complexes (Balbieriškis section) of varved clays in the Simnas-Balbieriškis basin. Next stop of the receding ice cover at the Middle Lithuanian end moraines occurred about 14,000 years ago. The Kaunas-Kaišiadorys glaciolacustrine basin (Girininkai section) formed between the South Lithuanian and Middle Lithuanian end moraines. The Mūša glaciolacustrine basin (Joniškėlis section) formed after the retreat and during new recession of the glacier at the moraine belt of North Lithuania.

The investigated glaciolacustrine sediments are attributed to deepwater lithofacies that have generally formed in a proglacial subenvironment. However, in the early stages of the glaciolacustrine basin development, the sedimentation could also take place in terminal (marginal), supraglacial and subglacial environments. During the climatic amelioration in an extraglacial subenvironment, the glaciolacustrine sedimentation could change into lacustrine, and gradually shift back to glaciolacustrine. In such cases, mixed (glaciolacustrine-lacustrine or lacustrine-glaciolacustrine) sediments formed. Largest Lithuanian glaciolacustrine basin sediments were ascribed to facies of proglacial lakes that developed through the interaction of glacial and periglacial environments (Šinkūnas and Jurgaitis, 1997).

3. RESULTS OF THE INVESTIGATIONS AND DISCUSSION

The results of $\delta^{18}O$ and $\delta^{13}C$ analysis are given for Balbieriškis, Girininkai and Joniškėlis sections**.** All of them were calculated versus PDB standard. Carbon isotope ^{13}C content shows, that part of the carbonates is

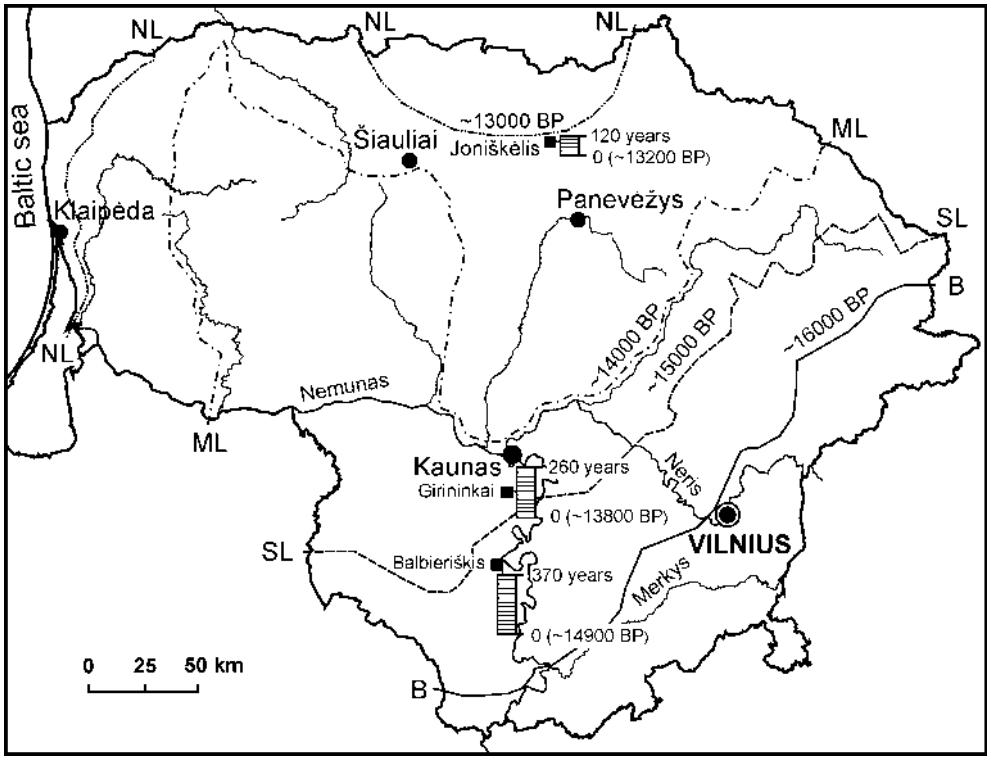

***Fig. 1**. Map showing location of investigated sites: Balbieriškis, Girininkai and Joniškėlis sections of glaciolacustrine clays. Limits of glacier advances: B – Baltija Stadial, SL – South-Lithuanian Phasial, ML – Middle-Lithuanian Phasial, and NL – North-Lithuanian Phasial.*

allogenic – inwashed and redeposited from Late Pleistocene tills.

Different glaciolacustrine sediments, linked with glacier oscillation, recession and re-advance, as well as lacustrine sediments accumulated during interphasials were found. The suspension flows from the thawing glacier, temperature and hydrodynamic conditions of water in oligotrophic lake played a decisive role in sedimentation. Also an activity of organic world, which increased during summer periods, influenced the lacustrine sedimentation. The lacustrine deposits are calcareous and they contain seasonal bands of carbonates in interphasial layers. The lacustrine sedimentation reflects climatic changes within the limits of 120-130 years (the deposits at a depth 3.1-5.9 m in the middle part of the Balbieriškis section).

Balbieriškis section.

As may be seen from the section of Balbieriškis exposure **(Fig. 2)** there are 5 different sedimentogenetic series of varved deposits connected with at least three oscillations of retreating ice cover of the South-Lithuanian Phasial. Five climatic evolutionary stages have been determined: (1) climatic warming and intense glacial retreat, with two oscillations during which climatic cooling took place (sediments at a depth of 6.7-8.2 m); (2) stabilization of climatic conditions with a stable position of the glacier, characterized by sedimentation of homogeneous clays (at a depth of 5.9-6.5 m); (3) sudden climatic warming and fast glacier retreat, characterized by lacustrine sedimentation (at a depth of 3.1-5.9 m); (4) sudden climatic cooling and glacier re-advance, characterized by prevailing glaciolacustrine sedimentation (at a depth of 0.5-3.1 m); (5) final climatic warming and glacier retreat, characterized by the deposition of ablation till (at a depth

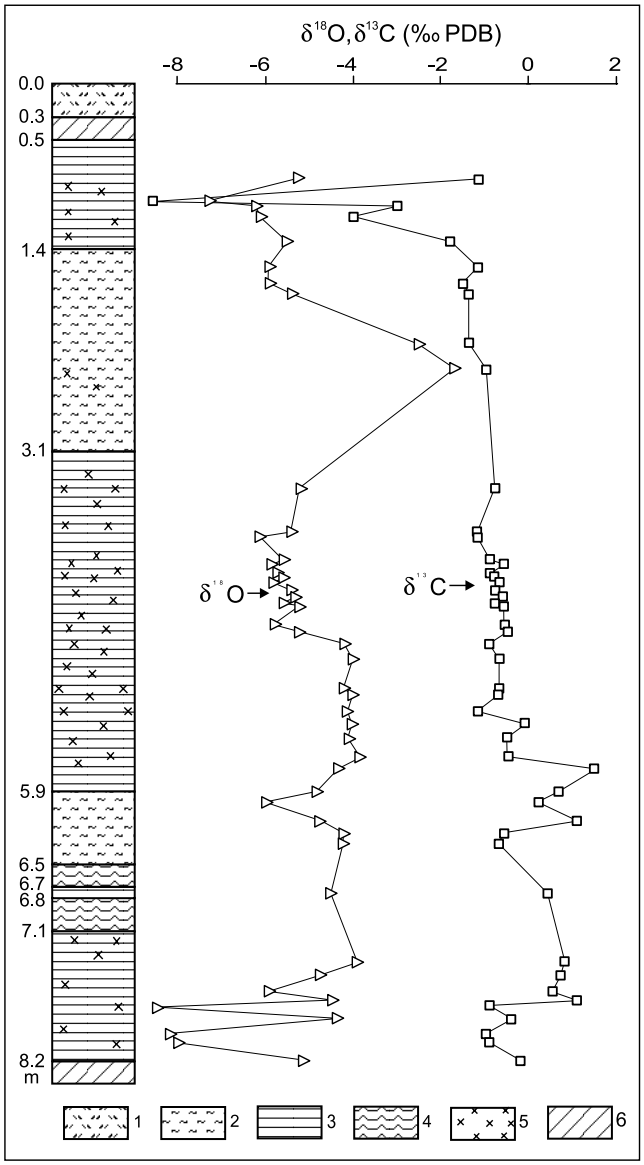

Fig. 2. *Variation of stable isotope composition of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in glaciolacustrine sediments of Balbieriškis section: 1 – soil, 2 – homogeneous clay, 3 – laminated clay, 4 – clay disturbed by cryogenic process, 5 – carbonates, 6 – till.*

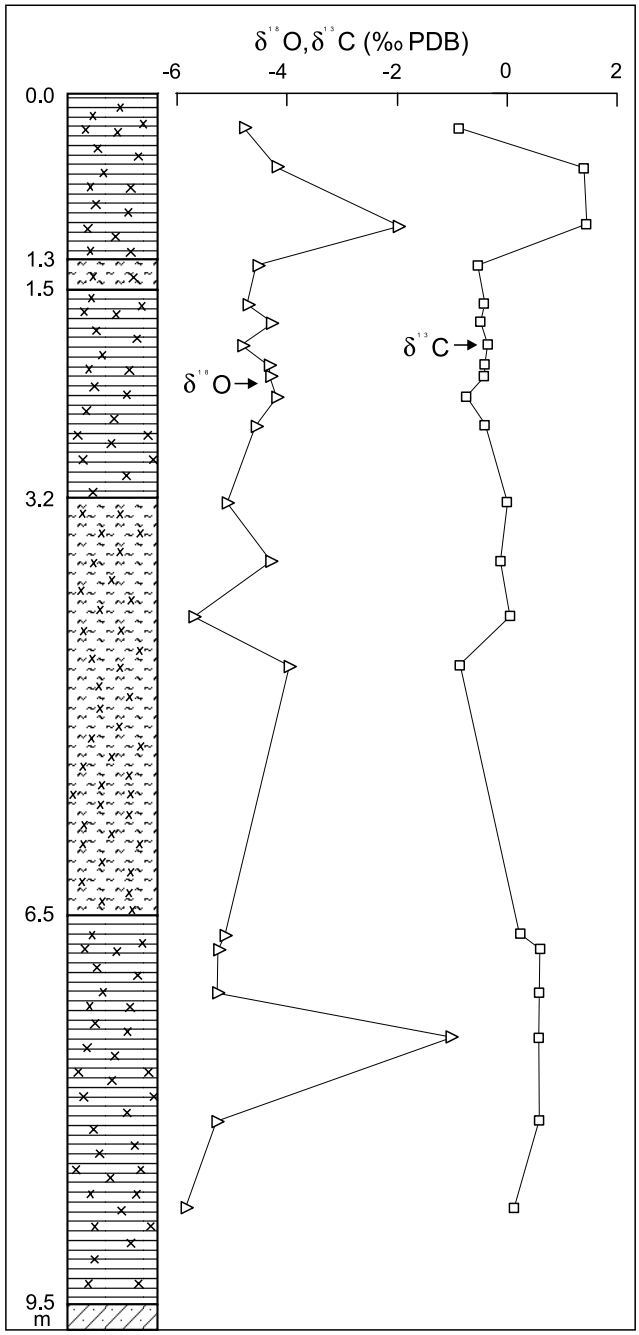

Fig. 3. *Variation of $\delta^{13}C$ and $\delta^{18}O$ in glaciolacustrine sediments of Girininkai section. For lithological legend, see* ***Fig. 2****.*

of 0.3-0.5 m). The isotope data well confirm sudden climatic changes at the South-Lithuanian – Middle-Lithuanian Interphasial and during interoscillations of the South-Lithuanian Phasial. During interphasial climatic warming sedimentation had a completely different character in a glaciolacustrine basin. Deposition of seasonal calcareous laminae is characteristic of lacustrine sedimentation. These layers were deposited during late summer and autumn. Their formation depended not only on temperature, but on pH reaction, organic material content, and regime of CO_2 as well. Such calcareous lamination was observed in sediments of the middle part of the Balbieriškis section (at a depth of 3.1–5.9 m). The occurrence of calcareous layers indicates climatic changes of seasonal character, which had an influence on sedimentation of laminated varved clays. Sediment lamination commonly reflects an annual rhythm of sedimentation, governed by the annual temperature cycle. This cycle not only caused great variations in the physical and biological conditions of a lake, but also in a sediment influx. The variations led to sedimentation of different kinds of material at different times of deglaciation and retreat of the Last Glacial.

In sediments of Balbieriškis section three climatic oscillations and glaciolacustrine deposits related to them are reflected. The megainteroscillation (interphasial) climatic warming (duration *ca* 120-130 years) is represented by lacustrine sediments, lying at a depth of 3.1-5.9 m, between glaciolacustrine sediments of the second and third oscillations.

Girininkai section.

This section starts with varved clays deposited during the Middle-Lithuanian Phasial in the Kaunas-Kaišiadorys glaciolacustrine basin. With warming of the climate, the lamination of clays becomes more expressed.

In Girininkai section **(Fig. 3),** three climatic evolutionary stages have been determined: (1) short climatic warming with an oscillatory retreat of the glacier, characterized by sedimentation of distinctly laminated clays with prevailing winter layers (sediments at a depth of 6.5-9.5 m); (2) more stable climatic conditions, characterized by sedimentation of indistinctly laminated clays (at a depth of 3.2-6.5 m); (3) climatic warming, characterized by sedimentation of laminated silty and calcareous clays (at a depth of 0-3.2 m).

During the climatic warming, when the glacier melted more intensely, frozen till clasts were deposited within summer layers of sediments (lower part of the 6.5-9.5 m interval). The climate of this time interval was marked by warm summers and variable winters. Warm climate conditioned interphasial sedimentation (lower part of the 0-3.2 m interval) as evidenced by traces of organic matter.

Joniškėlis section.

This section is connected with the development of the Mūša basin near the edge of the North-Lithuanian Phasial glacier. Climate changes during the North-Lithuanian Phasial are reflected in the glaciolacustrine clays of the Mūša periglacial basin.

Three climatic evolutionary stages have been determined in Joniškėlis section **(Fig. 4):** (1) short climatic warming period with glacial retreat, characterized by sedimentation of distinctly laminated calcareous clays (sediments at a depth of 1.8-2.6 m); (2) short cooling period and glacial re-advance, characterized by glaciotectonic deformation (at a depth of 1.0-1.8 m); (3) short period of stable climatic conditions and final climatic warming, characterized by indistinctly laminated or homogeneous clays, overlaid by silt and sand (at a depth of 0-1.0). A bed of massive clays finishes the sequence of Joniškėlis section.

4. CONCLUSIONS

Interpretation of analytic data on stable isotope composition of carbonaceous sediments in glaciolacustrine sediments of the Daniglacial in Lithuania helps to solve problems of sedimentation temperature conditions and genesis of the carbonate sediments.

The glaciolacustrine-lacustrine profile of sediments can be subdivided into 3 sedimentary intervals: 1) the time of retreat of the oscillating ice margin (glaciolacustrine sedimentation), 2) interphasial (or interoscillation) lacustrine sedimentation with seasonal warm-cold contrasts, 3) re-advance of the oscillating ice (new glaciolacustrine sedimentation). The distribution of the chemogenic carbonates in glaciolacustrine sediments depended on seasonal character of the climate.

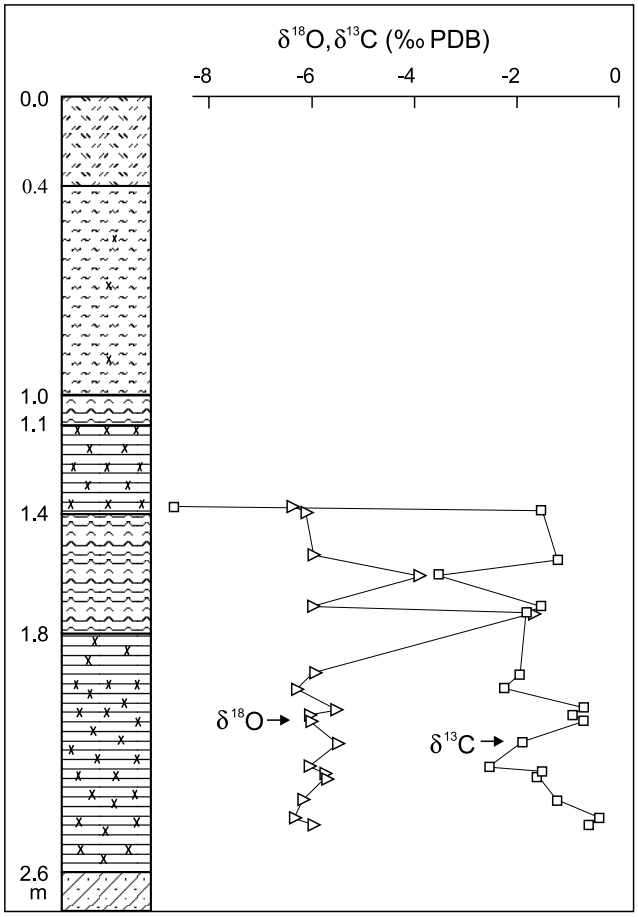

Fig. 4. *Variation of $\delta^{13}C$ and $\delta^{18}O$ in glaciolacustrine sediments of Joniškėlis section. For lithological legend, see* ***Fig. 2.***

Palaeogeographical changes are reflected in an elementary sedimentation cycle by the alternation of different deposits (from the bottom to the top): glacial – glaciolacustrine – lacustrine – glaciolacustrine. The composition of stable isotopes, $\delta^{13}C$ and $\delta^{18}O$ values, reflect the climatic fluctuations during glaciolacustrine – lacustrine – glaciolacustrine sedimentation of the South-Lithuanian, Middle-Lithuanian and North-Lithuanian Phasials of the Baltija (Pomeranian) Stadial of Nemunas (Vistulian) Glacial. Climatic changes are related to glacier recessions during the Daniglacial (16,000-13,000 BP) in Lithuania.

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