GEOLOGIJA. 2006. T. 54. P. 42–48

Late Glacial and Holocene stratigraphy of Lithuania based on pollen and diatom data

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Kabailienė M. Late Glacial and Holocene stratigraphy of Lithuania based on pollen and diatom data. *Geologija*. Vilnius. 2006. No. 54. P. 42–48. ISSN 1392–110X

The updated proposed Late Glacial and Holocene stratigraphical scheme for Lithuania is characterized. It is better supported by factual data than the former schemes of the author compiled in 1976, 1990, 1993 and 1998. The main stratigraphical units distinguished in the proposed stratigraphical scheme according to pollen data are chronozones. The names of the chronozones reflecting climate and vegetation changes during the Late Glacial and Holocene have been chosen according to the names of climatic periods proposed by A. Blytt and R. Sernander in the 19th century. These names have been used in Lithuania for a long time. Diatom zones are singled out in lake deposits. These regional diatom zones are described according to their characteristic ecological groups of diatoms reflecting variations in ecological conditions, non-diatom species which can at the same time differ due to specific conditions. The ecological diatom groups, under similar environmental conditions, are the same in different lakes. Five chronozones and three diatom zones have been distinguished in the Late Glacial deposits, nine chronozones and five diatom zones have been marked out in the Holocene strata.

Key words: pollen, diatoms, Late Glacial, Holocene, stratigraphy, chronozone, Lithuania

Received 9 January 2005, accepted 17 February 2006

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INTRODUCTION

Climatic changes during the Late Glacial and Holocene are reflected in pollen and spore composition and deposit lithology. Late Glacial and Holocene deposits have been studied by applying the climatostratigraphical method, i. e. the deposits are divided stratigraphically according to variations in climatic conditions. The peculiarity of the Late Glacial and Holocene is that they were very short periods, the Holocene having lasted about 10 thousand years and the Late Glacial only about 3–4 thousand years. The duration of smaller stratigraphical subunits took only a thousand or even several hundred years (Kabailienė, 1998; 2002).

Pollen composition in deposits was investigated in each layer. It reflects the composition of the former plants and climate (Gudelis, Kabailienė, 1958; Kabailienė, 1979; Seibutis, 1963–1964; Seibutis, Sudnikavičienė, 1960; Stančikaitė, 2000; Stančikaitė et al., 2002). Diatomic algae data provide information about variations of water level in lakes, as well as their thermal and chemical regime (Kabailienė, 1993, 1998; Kabailienė, Savukynienė, 1988; Кабайлене, 1965, 1985, 2002). Therefore, not only pollen but also diatom flora data were used in the present work for climatostratigraphical conclusions. Moreover, seeds and macroremains of plants have been analysed in some sections of deposits (Кучайте, 1967; Kisielienė, 2002).

MATERIALS AND METHODS

In the process of stratigraphical division in each section studied, the local pollen zones (palynozones) have been established as deposits characteristic of a certain pollen and spore assemblage.

Table. **Stratigraphy of Late Glacial and Holocene deposits in Lithuania (after M. Kabailienė, 2006)**
Lentelė. **Lietuvos vėlyvojo ledynmečio ir holoceno nuosėdų stratigrafija (pagal M. Kabailienė, 2006)**

Chronological scale 10^3 years	Stage	Chronozone		Index	Characteristic pollen composition in chronozones	Prevailing ecological groups in diatom zone	Index	Archeological periods (after Stančikaitė, 2000)
1	HOLOCENE	Subatlantic	Late	SA2	Picea-Pinus-Betula-Poaceae-Cerealia	Epiphytic - benthic	DZ8	Historical time 800
2			Early	SA1	Betula-Pinus-Picea-Alnus	Planktonic - benthic	DZ7	Late Iron age 1200 Middle Iron age 1600 Old Iron age 2000 Early Iron age 2500
3		Subboreal	Late	SB2	Pinus-Betula-Artemisia-Poaceae-Cyperaceae	Epiphytic - benthic	DZ6	Late Bronze age 3200 Early Bronze age 3700
4			Early	SB1	Picea-Alnus-Carpinus	Planktonic	DZ5	Late Neolithic 4400 Early and Middle Neolithic
5 6		Atlantic	Late	AT2	Quercus-Tilia-Ulmus-Corylus-Alnus			6000
7			Early	AT1	Alnus-Ulmus-Corylus			Mezolithic
8		Boreal	Late	BO2	Pinus-Corylus			
			Early	BO1	Pinus	Epiphytic - benthic	DZ4	
9		Preboreal		PB	Betula			10000
10	PLEISTOCENE LATE GLACIAL	Younger Dryas		DR3	Betula-Artemisia	Littoral planktonic - benthic	DZ3	Palaeolithic
11		Allerød		Al	Pinus Betula-Pinus	Epiphytic - benthic	DZ2	
12		Older Dryas		DR2	Betula-Pinus-Artemisia-Cyperaceae-Poaceae	Benthic - planktonic	DZ1	
		Bølling		BÖ	Betula-Pinus-Cyperaceae-Poaceae			
13		Oldest Dryas		DR1	Poaceae-Cyperaceae-Artemisia-Pinus			

The diatom zones distinguished in Late Glacial and Holocene deposits by occurrence of certain diatom assemblages reflect the ecological association of that time in a lake. Such diatom ecozones (or diatom assemblages) make a weighty contribution into the knowledge of former environmental conditions determined by pollen data. Diatom zones are marked by letters and figures – from DZ1 to DZ8 (Table). Local diatom zones are marked in a similar way as pollen zones, i.e. by figures and first letters of the name of the lake.

For the Baltic Sea deposits, diatom data enabled the author to distinguish strata corresponding to different evolutionary stages of the Baltic Sea. In all cases they were correlated to regional pollen zones – chronozones (Bitinas, Damušytė, 1995; Kabailienė, 1999; Kabailienė, Stančikaitė, Vaikutienė, 1998).

More than 100 lake, bog and sea deposit sections have been covered by pollen data, diatoms in Lithuanian lake deposits were studied in about fifty sections. In this paper one pollen and one diatom diagram from the Leikiškė and Dūba mire sections are shown (Fig. 1).

Fig. 1. Location of the Leikiškė *(1)* and Dūba *(2)* mires in whose pollen and diatoms deposits were studied
1 pav. Leikiškės *(1)* ir Dūbos *(2)* pelkės, kurių nuosėdose ištirtos žiedadulkės ir diatomėjos

Leikiškė mire (24°23'16"; 54°20'32") is situated to the southeast of the Daugai settlement, in the territory of the Dzūkai hill massif. In deposits of the Leikiškė mire, pollen was studied in two sites. In this paper one pollen diagram – Leikiškė-2 – is shown (Fig. 2). Pollen stratigraphy of the Leikiškė mire, especially of the Late Glacial stage, is of great importance, because this mire is one of the several localities in Lithuania where on the bottom of the hollow deposits of the Preboreal time lies (B¸lling and Older Dryas). Besides, the composition of local pollen zones in Leikiškė-2 is very similar to the pollen composition of Late Glacial and Holocene chronozones in Lithuania. The Leikiškė-2 pollen diagram is divided into 11 local pollen zones (LPAZ). In the Leikiškė mire lacustrine deposits were settling only until the Early Atlantic when layers of peat started to form.

The Dūba mire (24°41'14"; 54°02'00"0 is located on the southeast outwash plain. The lake existed from the Older Dryas to the Late Subatlantic. The lake was drained only at the end of the 19th century and then peat started to form. Diatoms were studied in the deposits of two sites. The diatom analysis data of the ancient Dūba lake deposits allow to investigate in detail the diatom stratigraphy and fluctuation of water level during the Late Glacial and Holocene in Lake Dūba. In the paper, the diatom analysis results are given as a diagram showing the succession of the most frequent and ecologically important taxa. Diatom species were grouped according to two criteria: life habit (the proportions of planktonic, benthic and epiphytic diatoms) and pH. The paper shows the diatom diagram of the Dūba-6 site. This diagram is divided into 12 local diatom zones (LDAZ) (Fig. 3).

The hollows of Leikiðkë and Dûba mires are of thermokarstic origin. On the bottom of these hollows lie layers of clastic deposits of the B¸lling and Older Dryas age. During the warmer Aller¸d, over the melting ice blocks sedimentation of gyttja (Dûba mire) and peat (Leikiðkë mire) layers started. These organogenic deposits after melting of ice blocks sank on the bottom of the hollows and were covered by layers of sand (Leikiðkë) and clayey sand (Dûba) of Younger Dryas age. Over these layers gyttja settled.

Correlating separate Holocene sections and their units (zones) distinguished by pollen data, attention was focused on the composition of tree pollen. For the upper deposit layers (from the Early Subboreal to Late Subatlantic chronozone), where a human impact on the vegetation can be seen, the correlation of stratigraphical units (zones) greatly depended on the following pollen data indices: ratio of tree and non-tree pollen sums, as well as data on the pollen of cultivated plants, weeds, and grasses growing by paths and in pastures (Savukynienė, 1974; Stančikaitė et al., 2002). While correlating Late Glacial deposits, both the quantity and composition of herb pollen play a very significant role (Fig. 2). The Aller¸d warming zones are easily correlated; they are notable not only for pollen but also for the lithological pecularities of the deposits (Fig. 2).

Data on the physical age determined by radiocarbon or other methods were also very important for correlation purposes.

MAIN STRATIGRAPHICAL UNITS (CHRONOZONES) OF LATE GLACIAL AND HOLOCENE DEPOSITS

Chronozones are units of undefined regional rank; they do not belong to the hierarchy of chronostratigraphical subdivisions (*Lietuvos stratigrafijos vadovas*, 2003). The names of chronozones typical of Lithuania and reflecting climate and vegetation variations have been chosen according to the names of climatic periods given by A. Blytt (1882) and R. Sernander (1894). It is convenient, since these names have been known and used in Lithuania since older times. Moreover, Blytt–Sernander climatic period names are used in the Late Glacial and Holocene stratigraphical scheme proposed by a group of Nordic researchers in 1974 for NW Europe (Mangerud et al., 1974).

Late Glacial

The first warming fixed in the period corresponding to the B¸lling chronozone (12,300–13,000 BP) was short and small in the sense of climate change. At

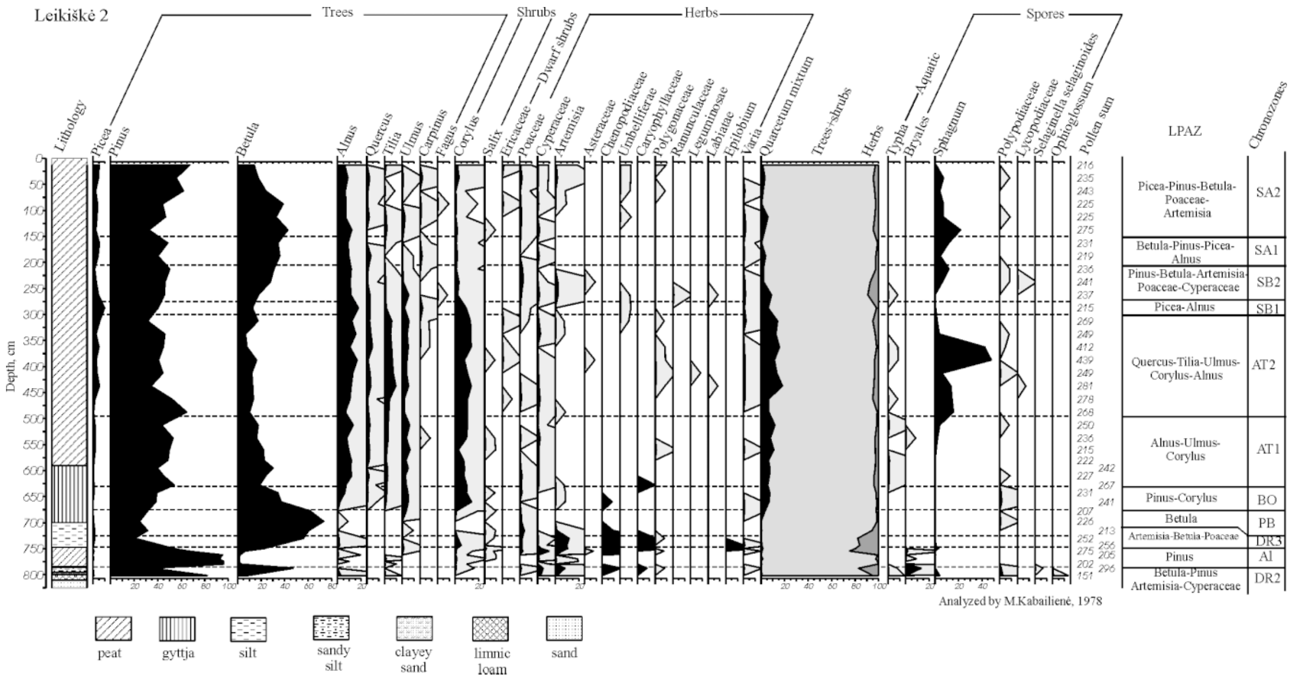

Fig. 2. Percentage pollen diagram from Leikiškė mire
2 pav. Leikiškės pelkės procentinė žiedadulkių diagrama

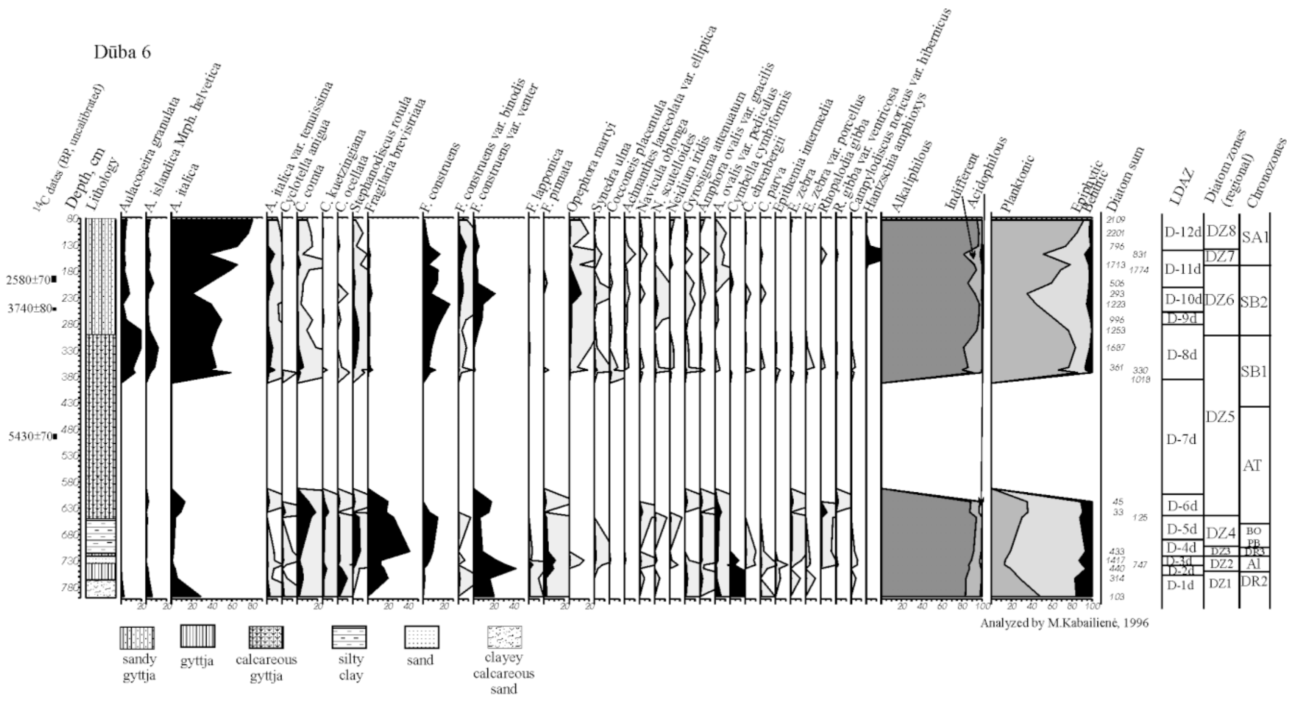

Fig. 3. Percentage diatom diagram from Dūba mire
3 pav. Dūbos pelkės procentinė diatomėjų diagrama

that time, terrigenous sediments (sandy silt, clay, sand) with low organic matter content accumulated in the lakes and formed a 5–10 cm thick layer. The B¸lling chronozone deposits were characterized by a lower content of herb pollen (especially *Artemisia*) and *Selaginella selaginoides* spores but a higher content of tree pollen (*Pinus* and *Betula*, mainly), if compared with the Oldest Dryas and Older Dryas chronozone pollen data. At the very bottom of the deposits in some Lithuanian lakes and bogs, a very low pollen content (with the pollen of herbs and birch bushes (*Betula nana* and *B. humilis*) prevailing against a very low tree pollen content) is found in sand, clay and gravel beds, which reflected the conditions of the cold period that preceded the B¸lling, i.e. the Oldest Dryas chronozone (13,000–14,000 BP). The deposits of the Older Dryas chronozone (11,900–12,300 BP), which separate the B¸lling and Aller¸d warmer intervals, were found to contain mostly herb pollen (Poaceae and *Artemisia*), with *Betula* dominating among tree pollen. The thickness of this layer is about 5–15 cm.

It is a typical case that the Aller¸d (10,900–11,900 BP) is the warmest interval of the Late Glacial and its deposits are rich in organic matter. The lower part of the Aller¸d chronozone deposits often contain peat, peaty gyttja and silt with plant macroremains, sometimes a thin lamina of black soil. These deposits are often overlain by gyttja and lake silt. Two-layer deposits were laid due to thermal karst processes in the Aller¸d. Sometimes Aller¸d deposits are homogeneous. The thickness of this chronozone deposits ranges from several to tens of centimetres. The Aller¸d chronozone deposits are found to have the highest content of Late Glacial pollen and spores – several thousand grains per 1 cm^3 of deposit. Tree pollen prevails, mainly *Pinus*. Other tree pollen, such as *Betula, Alnus, Picea,* etc., are also observed (Kabailienė, 1958; Seibutis, Sudnikavičienė, 1960; Гуделис, 1957; Кунскас, Савукинене, Вайчвилене, 1975). Younger Dryas chronozone deposits (most often silty clay, sand and silt) were formed during the last colder period in the Late Glacial. This is confirmed by a high content of herb pollen, especially *Artemisia* and Chenopodiaceae, which spread widely under dry climatic conditions (Fig. 2).

Holocene

The boundary between the Late Glacial and Holocene beds can be easily drawn according to pollen data. Holocene deposits, if compared to Late Glacial ones, contain significantly more pollen and spores with tree pollen prevailing, at the same time tundra and xerophilous pollen and spores disappear, deposit composition changes, with the organic matter content rising from the beginning of the Preboreal (Гуделис, 1957; Кабайлене, 1968, 1976).

Preboreal chronozone (9,000–10,000 BP) deposits are gyttja, freshwater limestone, silt or sometimes peat; the thickness of this layer ranges from 1–2 to 20 cm. Tree pollen prevails with *Betula* pollen rise, often *Pinus* is also abundant. Early Boreal (8,100–9,000 BP) chronozone deposits are mostly silt, gyttja, fresh water limestone, peat; the thickness of the layer is from several to 50 cm, *Pinus* pollen prevailing. Late Boreal (7,800–8,100 BP) chronozone deposits are most often gyttja, freshwater limestone, peat; the thickness of the bed is 5–70 cm. *Pinus* and *Corylus* pollen prevail. sometimes *Alnus* and *Ulmus* are found (Fig. 2).

Early Atlantic (6,500–7,800 BP) chronozone deposits are peaty gyttja, gyttja, sapropelic freshwater limestone, silt, peat; the thickness of the bed is 10–230 cm, most often 50–70 cm. A significant rise in *Alnus* and *Ulmus* pollen is observed. Late Atlantic chronozone (5,000–6,500 BP) deposits are most often gyttja, silt, sapropelic freshwater limestone and peat. Pollen composition shows a typical maximum of thermophilous tree pollen – *Quercus, Tilia, Ulmus, Fraxinus* and *Corylus*.

Typical deposits of the Early Subboreal (3,700–5,000 BP) chronozone is gyttja, sometimes freshwater limestone; the thickness of the bed ranges within 10–70 cm. The pollen spectrum shows a typical maximum of *Picea* and a high content of *Alnus*. Late Subboreal (2,500–3,700 BP) chronozone deposits are mostly gyttja, sapropelic peat and peat; the thickness of the bed ranges within 10–30 cm. A decline in *Picea* pollen is typical, while *Betula, Pinus* and *Alnus* pollen increased in content. A very clear rise in pollen of herbs related to human activities is confirmed, especially for Cyperaceae, Poaceae and *Artemisia*.

Early Subatlantic (1,000–2,500 BP) chronozone deposits are mostly peat and gyttja; the thickness of the bed is 10–200 cm. There is the second maximum in *Picea* pollen, as well as a rise in total tree pollen content and a decline in herb pollen; the content of *Alnus* pollen is significant. Late Subatlantic (0–1,000 BP) chronozone deposits are gyttja and peat; the thickness of the bed is 10–100 cm. Abundance of *Pinus* and *Betula*, as well as *Picea* pollen is observed.

LATE GLACIAL AND HOLOCENE LAKE DEPOSIT STRATIGRAPHY BASED ON DIATOM DATA AND WATER LEVEL VARIATIONS

Studies of diatoms in Lithuanian lake deposits were started in the second half of 20th century (Kabailienė, 1962, 1963, 1979, 1987, 1990, 1993, 1999, 2002: Kabailienė, Savukynienė, 1988; Кабайлене, 1965, 1968, 1985, 2002). Eight diatom zones (DZ1–DZ8) of regional rank have been distinguished for the Late Glacial and Holocene in Lithuanian lake deposits. Moreover, local diatom zones (in varying numbers) are distinguished in each section of lake deposits (Fig. 3). Diatom zones are set off against the lake development stages. Three diatom zones were established in Late Glacial and five in Holocene lake deposits.

The oldest diatom zone (DZ 1) is established in the deposits of pre-Aller¸d (the Oldest Dryas, B¸lling and Older Dryas) chronozones. The diatom flora is not abundant (less than 1000 shells per 1 cm^3 of deposits) and consists mainly of benthic and planktonic species belonging to the genera of *Cyclotella, Aulacoseira, Amphora ovalis* var. *pediculus,* etc. and showing a high water level in the lakes of that time.

Aller¸d chronozone deposits show species of the genus *Fragilaria (F. brevistriata, F. pinnata, F. construens etc.)* to prevail. Thus, Aller¸d deposits contain mostly bottom and accretion diatoms showing that water level in the lakes was shallow. This is the DZ2 zone of diatoms.

The third diatom zone, DZ3, was distinguished in Younger Dryas deposits. Littoral plankton and bottom diatoms prevail (*Fragilaria, Gyrosigma,* and *Cymatopleura*). Lake water level was higher than in the Aller¸d .

The fourth diatom zone, DZ4, was distinguished in the deposits formed at the beginning of the Holocene – in the Preboreal and Early Boreal. A low diatom concentration, the prevalence of bottom and epiphytic diatoms are typical. The most frequent genera are *Epithemia, Pinnularia, Eunotia, Synedra* and *Fragilaria*. The water level was very low, lakes were overgrowing and bogging.

The fifth diatom zone, DZ5, comprises lake deposits of the Late Boreal, Early and Late Atlantic, as well as Early Subboreal chronozones. An abundance in diatom species and individuals is seen, with planktonic species prevailing (mostly *Aulacoseira, Cyclotella* and *Stephanodiscus*). This zone is heterogeneous, to water level was fluctuating.

The sixth diatom zone, DZ6, corresponds to the Late Subboreal chronozone. Diatoms in the deposits are rarer, bottom and accretion species prevail, mainly *Navicula, Epithemia* and *Cymbella* genera. Lake level was low.

The seventh diatom zone, DZ7, corresponds to Early Subatlantic chronozone deposits abundant in diatoms, mainly *Aulacoseira* and *Stephanodiscus*. Lake water level was high.

And the upper eight diatom zone, DZ8, corresponds to Late Subatlantic chronozone deposits with the diatom concentration lower than in DZ7.

CONCLUSIONS

The updated Late Glacial and Holocene stratigraphical scheme for Lithuania is more detailed and better grounded on factual data than the former schemes of the author from 1976, 1990, 1993 and 1998. Our latest scheme (Table) emphasised chronozones with the names of plants characterising the chronozones and enabled to reject the palynozones and their indices.

In the proposed new stratigraphical scheme, the regional diatom zones are described according to their characteristic ecological groups (assemblages) of diatoms, reflecting variations in ecological conditions, non-diatom species, which can at the same time differ due to specific conditions of each lake. The ecological diatom groups, under similar environmental conditions, are the same in different lakes (Кабайлене, 1970).

The diatom zones are numbered from the bottom to the top, because of the convenience to describe and characterise them, starting from the first (oldest) one. The chronozones in the new stratigraphical scheme are for the first time correlated with archaeological periods to encourage cooperation between archaeologists and natural scientists.

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VĖLYVOJO LEDYNMEČIO IR HOLOCENO STRATIGRAFIJA LIETUVOJE ŽIEDADULKIŲ IR DIATOMĖJŲ TYRIMO DUOMENIMIS

Santrauka

Straipsnio autorė apibendrino savo ir kitų tyrinėtojų ežerų bei pelkių nuosėdų storymių, taip pat ir Vakarų Lietuvoje esančių senųjų Baltijos jūros baseinų nuosėdų daugiamečių žiedadulkių ir diatomėjų tyrimo duomenis, sudarė naują vėlyvojo ledynmečio ir holoceno stratigrafinę schemą (lentelė). Sugretinus ją su ankstesniais metais sudarytomis stratigrafinėmis schemomis (Kabailienė, 1990, 1993, 1998; Кабайлене, 1976), matyti, kad naujausioje schemoje svarbiausias dėmesys skirtas pagal žiedadulkių tyrimo duomenis išskirtoms chronozonoms. Lentelėje pateikti kiekvienai chronozonai būdingų augalų pavadinimai, bet atsisakyta palinozonų bei jų indeksų (jos naudojamos kaip vietinės zonos aprašant atskirų ežerų arba pelkių nuosėdų pjūvius; 1 pav.). Lietuvos regionines diatomėjų zonas (2 pav.) charakterizuoja ekologinės diatomėjų grupės. Mat dėl specifinių sąlygų atskiruose ežeruose vienu metu diatomėjų rūšys gali būti skirtingos, tuo tarpu ekologinės diatomėjų grupės skirtingų ežerų vieno amžiaus nuosėdose bus panašios.

Мейлуте Кабайлене

СТРАТИГРАФИЯ ОТЛОЖЕНИЙ ПОЗДНЕГО ЛЕДНИКОВЬЯ И ГОЛОЦЕНА В ЛИТВЕ ПО ДАННЫМ ПЫЛЬЦЕВОГО И ДИАТОМОВОГО АНАЛИЗА

Резюме

Обобщены данные многолетних исследований пыльцевых и диатомовых водорослей отложений озер и болот, а также отложений древних стадий Балтики в Западной Литве, полученные как автором статьи, так и другими литовскими исследователями. Составлена новая стратиграфическая схема для позднего ледниковья и голоцена. Сопоставив ее с ранее опубликованными схемами (Кабайлене, 1976; Kabailienė, 1990, 1993, 1998), видим, что в новой стратиграфической схеме главное внимание уделено хронозонам, установленным по данным пыльцевого анализа. Представлены названия характерных для каждой хронозоны растений. В схеме нет палинозон и их индексов. Палинозоны используются как местные зоны при описании разрезов озер или болот. Выделены характерные для Литвы региональные зоны диатомей. Они представлены группами видов, выделенными по разным экологическим признакам, так как в одинаковых условиях в различных озерах доминируют одинаковые экологические группы диатомовых. Наличие различных видов диатомей не доказывает наличия разных физико-географических условий и режимов озер.