Formation and evolution of the Skrebiškiai karst peat-bog (Northern Lithuania) according to pollen data

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Karst processes were very active in Northern Lithuania during the Holocene. Pollen analysis of sediments filling karst sink-holes is essential for a better understanding of karst processes. However, only a few pollen investigations have been carried out in the study area so far.

The Skrebiškiai karst sinkhole (karst lake) was formed in the Late Atlantic (approx 6.5–5 ka BP) as a result of leaching of gypseous Devonian layers with underground water. The shape of the sinkhole is composite, comprised of at least three joint sinkholes. Intensive abrasion processes took place just after formation – a layer of karst sediments up to 380 cm thick accumulated during several hundred years or even decades. When the abrasion processes stopped (in the end of the Atlantic; roughly 5 ka BP), gyttja started to accumulate in the karst lake. In the Early Subboreal (roughly 4.5 ka BP) the waterlogging of the basin took place. A layer of peat up to 350 cm thick accumulated thereafter. Accumulation in the peat-bog was relatively fast during the Subboreal (approx 4.5–2.5 ka BP), but slowed down during the Subatlantic (latter 2.5 ka) period. An uncomon increase of spruce and lime pollen in the Subatlantic sediments possibly reflects specific soil pecularities common to the whole area of the karst region.

Pollen and palaeoclimatic data show that the Late Atlantic could be one of the most important stages of intensive formation of karst sinkholes during the Holocene.

Keywords: pollen analysis, karst, peat, Holocene, sinkholes, Northern Lithuania

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INTRODUCTION

More than 2000 karst sinkholes are present in the karst region of Northern Lithuania (Taminskas, 2000). Most of these sinkholes are formed during the Holocene, due to the leaching of gypseous Devonian layers by underground or surface water. Karst processes in Northern Lithuania are active even nowadays.

A considerable part of karst sinkholes in the study area are filled with biogenic, karst, glacial or other types of sediments (Narbutas, Pranaitis, 1960). Profound investigations (especially pollen and radiocarbon analyses) of the sediments filling the karst forms could provide a better understanding of formation and evolution of sinkholes, which is very important for the prognoses of possible karst activities. However, very few pollen investigations have been carried out in the area so far.

The first application of pollen analysis in the study area concerned Pleistocene karst (Narbutas, Kondratienė, 1958). In the end of the fifties, four Holocene karst sinkholes filled with peat were analysed in the vicinty of Kirkilai and Ripeikiai villages, Biržai district (Тюремнов, Видмантас, Пранайтис, 1959). Two of the peat-bogs studied were formed late in the Atlantic period (approx 6.5–5 ka BP) and the rest during the Subboreal (approx 5–2.5 ka BP) and the Subatlantic (approx 2.5–0 BP). Further investigations showed that karst processes took place in the beginning of the Holocene as well. It was determined that the Smardonė karst hollow in the vicinity of Likėnai was formed during the Preboreal (approx 10–9 ka BP; Kondratienė, Narbutas, Linčius, 1998).

METHODS

The Skrebiškiai karst peat-bog is situated 5 km northerly of the Biržai town, on the intersection of Drąseikiai–Skrebiškiai highway and the Biržai pipeline route (coordinates in LKS-94 system: 548658; 6235355). The peat-bog is a karst sinkhole of irregular form (about 200 m long, 150 m wide and 8 m deep). It is filled up with sediments. The territory of the sinkhole is overgrown with various species of trees (pine, spruce, birch, alder and lime), herbs, ferns and mosses.

Aerophoto images helped to ascertain the boundaries of the peat-bog and to choose prospective coring sites (Fig. 1). Corings yielded the lithological composition of the sediments of the Skrebiškiai sinkhole. The obtained data were supplemented with lithological data from helical corings carried out several years ago in the same peat-bog with the aim to estimate the probability of underground water pollution in the Biržai pipeline zone (Narbutas, 1998). Lithological data are represented in the lithological cross-section (Fig. 2) and the scheme of thickness of biogenic sediments (Fig. 3). The latter shows the number of jointed sinkholes forming the bottom of the peat-bog.

The sediment core Skrebiškiai-1 was chosen for further pollen analysis. Pollen samples were taken from every 10 or 20 cm of sediment (depending on the significance of the core interval) and prepared according to a standard technique: alkaline L. von Post's treatment, V. Grichiuk's separation with heavy liquids and G. Erdtman's acetolytic preparation (Kabailienė, 1979). At least 500 pollen grains were counted in each sample, including 200 or more tree pollen grains. According to lithological and pollen data processed with a range of software, including Tilia and Tilia Graph (Grimm, 1990; 1992), a pollen diagram (Fig. 4) was drawn.

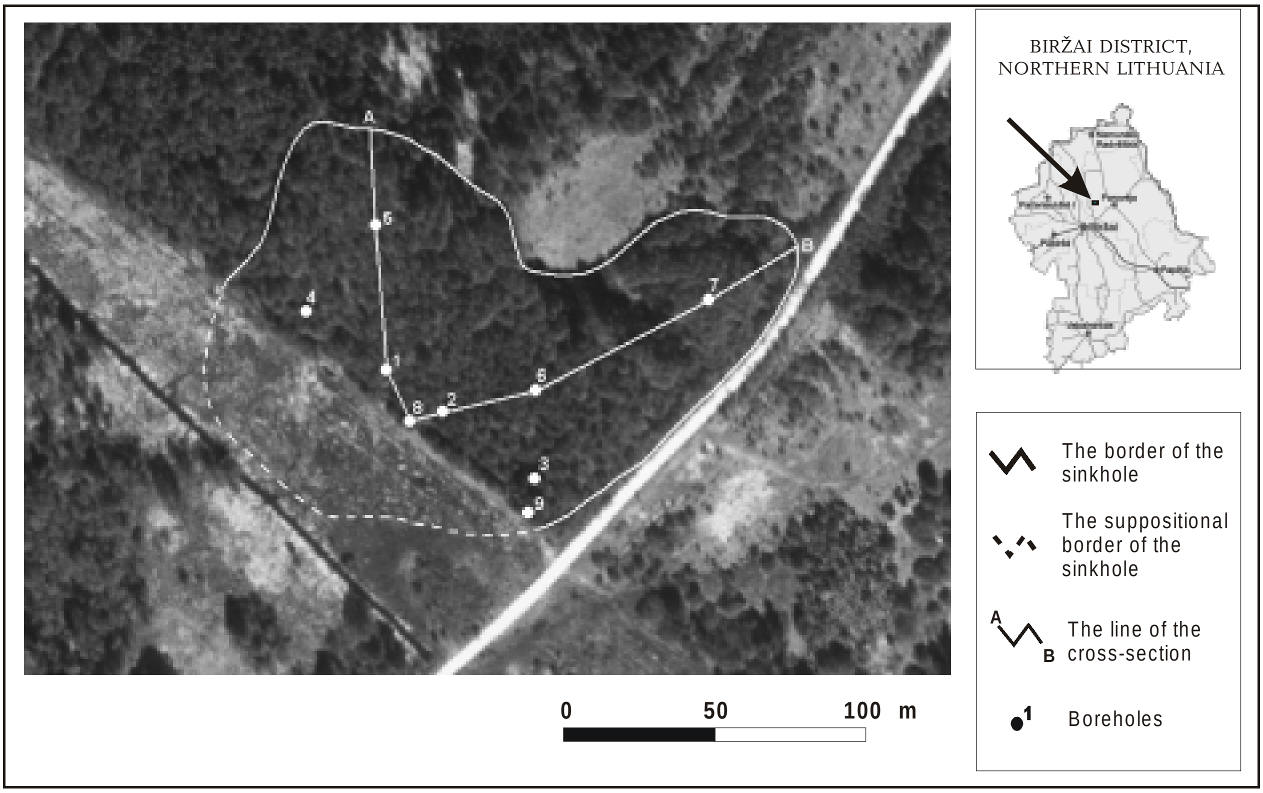

Fig. 1. Situation scheme of Skrebiškiai peat-bog (based on aerophoto image)
1 pav. Skrebiškių durpyno schema (pagal aeronuotrauką)

RESULTS

Lithological composition of the sediments

Coring data (Fig. 2) show that the Devonian rocks affected by karst process (“dolomitic flour” and karst gravel) are covering the bottom of the sinkhole. These layers are covered with lacustrine silt, mixed with karst rocks (debris of dolomite). Above it, a gyttja layer up to 70 cm thick occurs. It is overlain by peat of different types and humification grade up to the top.

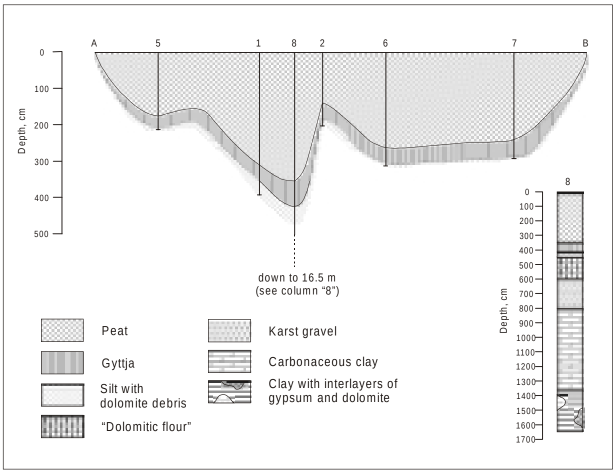

Fig. 2. Cross-section of sediments of Skrebiškiai karst sink-hole
2 pav. Skrebiškių karstinės įgriuvos nuosėdų pjūvis

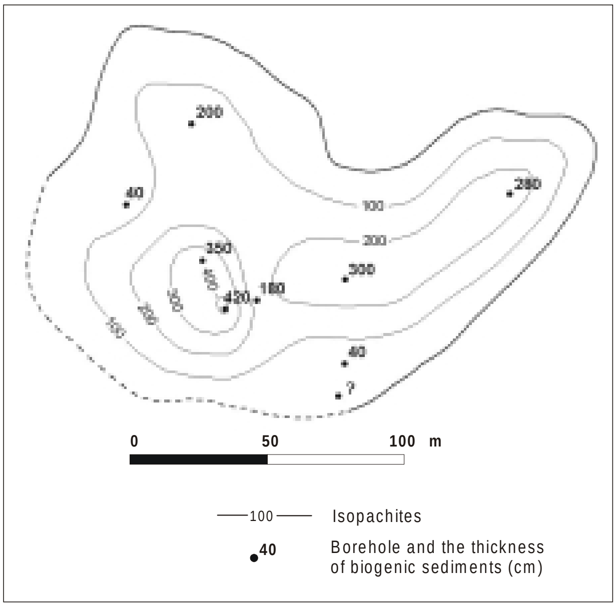

Fig. 3. Scheme of thickness of biogenic sediments in Skrebiškiai karst sink-hole (? – thickness unknown, sediments mixed)
3 pav. Skrebiškių karstinės įgriuvos biogeninių nuosėdų storio schema (? – storis nežinomas, nuosėdos permaišytos)

The total thickness of biogenic sediments in the peat-bog reaches 420 cm in its deapest place, but the depth varies unevenly – several depressions (Fig. 3) corresponding to different sinkholes can be distinguished.

Composition of pollen spectra

Thirty two sediment samples were analyzed from the Skrebiškiai-1 core sequence (390 cm long). Remarkably high Polypodiaceae (fern) percentages (up to 99.03%) are found in the upper part of the diagram (245–0 cm). The values of Polypodiaceae decrease down to 1.16–39.26% in the lower part (390–245 cm). Tree pollen prevails here, mostly *Pinus* (pine) and *Picea* (spruce). Abundance of *Pinus* and *Picea* pollen is typical of the whole length of the sequence except the lowermost silt layer, where *Betula* (birch), *Alnus* (alder), *Corylus* (hazel), *Quercus* (oak), *Tilia* (lime) and *Ulmus* (elm) are found in increased numbers. Among the herb pollen, Poaceae (grass) and Cyperaceae (sedge) prevail. At particular depths, some other species of herbs are present: *Filipendula* (dropwort), *Artemisia* (mugwort) and others. Very few aquatics were found – only single grains. Quite high amounts of *Bryales* (green moss) and *Equisetum* (horsetail) spores are observed.

The pollen concentration varies between 5856 and 4.077×10^7 in the Skrebiškiai-1 sequence. In the upper part of the diagram (the depth of 30–0 cm), the concentration decreases down to 14763 pollen grains per cm^3 and in the lower part (interval of 380–360 cm) to 5686 pollen grains per cm^3. In the rest part of the diagram pollen concentrations are higher than 10^6 pollen grains per cm^3.

Four local pollen assemblage zones (LPAZ) were distinguished in the Skrebiškiai-1 pollen diagram (from bottom to top):

LPAZ *Quercus–Tilia–Ulmus–Corylus–Alnus–Betula*; 390–355 cm. The values of *Quercus* here make 2.22–21.5%, *Tilia* – 4.01–9.29%, *Ulmus* – 7.03–15.82%, *Corylus* – 4.81–19.33%, *Alnus* – 7.41–11.28%, *Betula* – 5.68–10.78%. *Pinus* pollen is most abundant in the lower part of the zone, reaching up to 31.48%. *Picea* makes up to 15.56%. Herb pollen make relatively high percentages (up to 13.33%). Cyperaceae (up to 7.04%) and Poaceae (up to 5.58%) are prevailing among them. Compared to the rest part of the core, quite low values of *Bryales* (up to 3.86%) and Polypodiaceae (up to 22.86%) are present here.

LPAZ *Picea–Pinus* 1; 355–205 cm. *Pinus* (35.81–91.19%) and *Picea* (7.92–59.68%) prevail. In the lower part of the zone, a slight increase of *Betula* (up to 4.31%), *Alnus* (up to 5.74%), *Tilia* (up to 3.11%), *Corylus* (up to 3.83%) and *Juniperus* (up to 2.39%) pollen percentages is discernible. The amount

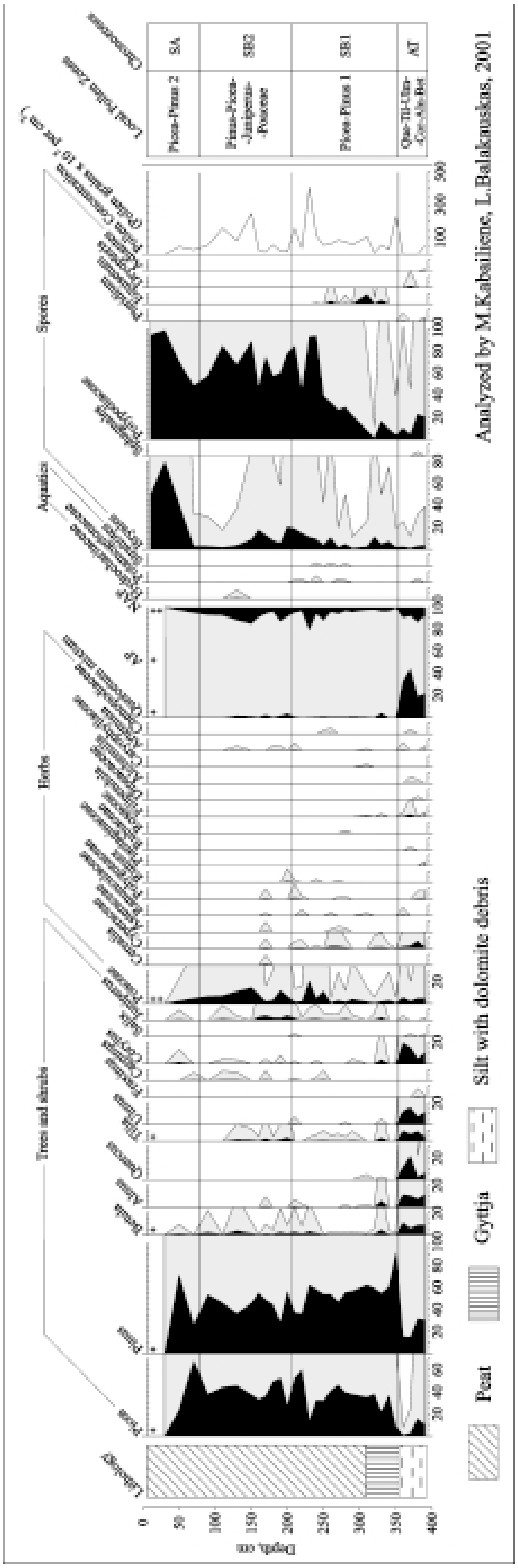

Fig. 4. Pollen diagram of sediments from Skrebiškiai-1 core
4 pav. Skrebiškių-1 gręžinio nuosėdų žiedadulkių diagrama

of herbs decreases. The greatest part among them makes Poaceae pollen (up to 20.52%). The percentages of spores are higher: *Bryales* up to 18.66%, Polypodiaceae up to 93.81%, *Equisetum* up to 9.1%.

LPAZ *Pinus–Picea–Juniperus*–Poaceae; 205–80 cm. *Pinus* – 28.4–56.41%, *Picea* – 26.92–52.53%. Herb percentages are low, excepting Poaceae (up to 14.73%). Up to 3.49% of *Betula* and up to 4.27% of *Juniperus* pollen were found. Extremely high were Polypodiaceae percentages – 47.03–89.07%. The amount of *Bryales* reached up to 20.41%.

LPAZ *Picea–Pinus 2*; 80–0 cm. The amount of *Picea* pollen increases up to 68.27%, *Pinus* – up to 71.04%, Poaceae – up to 6.64%. Only single grains of other herb taxa were found. Polypodiaceae spores still dominate (49.06–99.03%), *Bryales* make up to 80%. Pollen grains in two uppermost samples are severely corroded (most likely as a result of oxidation processes), therefore it was impossible to find a sufficient quantity of analysable tree pollen in these samples, though we can propose that quite a lot of *Tilia*, *Betula* and Poaceae pollen are present here, besides the predominant *Pinus* and *Picea*.

INTERPRETATION

Higher amounts of *Quercus*, *Tilia*, *Ulmus*, *Corylus*, *Alnus* and *Betula* pollen are observed in the lowermost local pollen assemblage zone (including the silt layer) of the Skrebiškiai-1 sequence, suggesting a correlation of the pollen zone with the Atlantic chronozone (AT; app. 8–5 ka BP). Most probably these sediments accumulated during the Late Atlantic (app. 6.5–5 ka BP). High contents of herb pollen are observed here. This is not common to sediments of the Atlantic period. Such a high quantity of herb pollen probably is related to the pecularities of the sinkhole formation. Presumably, the sinkhole was formed in an open area and was not overgrown by trees for some time, like the majority of sinkholes in the Karst Region of Northern Lithuania (Taminskas, 1999). The presence of trees on the bank of the sinkhole would obscure the levels of herb pollen in the sediments. Low pollen concentrations and the type of the sediment itself (silt with dolomite debris) shows that sedimentation rates were high during the studied period.

The local pollen assemblage zone *Picea–Pinus* 1 corresponds to the Early Subboreal (SB1; app. 5–4 ka BP) chronozone. The significant increase of spores (especially Polypodiaceae) at the depth of 310–255 cm is related to the waterlogging process, which took place roughly 4.5 ka BP. Changes in the pollen spectra coincide with lithological changes – mire deposits start to accumulate at the depth of 310 cm.

The prevalence of *Pinus* and a slight increase of *Betula* pollen in *Pinus–Picea–Juniperus*–Poaceae LPAZ are typical of the Late Subboreal (SB2; app. 4–2.5 ka BP) chronozone. The increased values of Poaceae and *Juniperus* in this zone could be related to human activity during this period (Savukynienė, 1974).

In the uppermost zone *Pinus* pollen is dominant. These sediments were accumulated during the latter 2500 years (Subatlantic chronozone; SA). Some uncommon features of pollen spectra are traced in the uppermost samples of the diagram, *e.g.*, an increase of *Picea* and *Tilia* pollen levels. A similar increase of *Picea* and *Tilia* can be traced in the diagram of the Smardonė karst hollow (situated 17 km SW from the Skrebiškiai sinkhole) sediments as well (Kondratienė, Narbutas, Linčius, 1998). These features are probably related to the similarity of soil parameters of the both sinkholes. It is possible that such similarities are common to the whole region. Unfortunately, we cannot trace such increase in pollen diagrams described by Tiuremnov, Vidmantas and Pranaitis (Тюремнов, Видмантас, Пранайтис, 1959) because of a large interval among pollen samples (mostly 50 cm). Though, possibly further investigations of sediments from karst sinkholes of Northern Lithuania will confirm the existence of such pecularities.

FORMATION AND EVOLUTION OF THE PEAT-BOG

Lithological data show that the Skrebiškiai karst peat-bog was formed as a result of leaching of the gypseous Nemunėlis layers (D_3t_{nm}; Narbutas, Pranaitis, 1960). The clayey Kirdonys layers underlying them at a depth of 800–1360 cm formed an aquiclude to the underground water (Narbutas, 1997), hence the conditions for leaching of the Nemunėlis layers were very favourable. As a result of a drop in the underground water level or other climatic factors (*e.g.*, intense precipitation), a thin layer of Quaternary sediments sinked into the leached cavities. A karst lake (karst sinkhole filled with water) was formed in the sinkhole. From the obtained data we can conclude that the Skrebiškiai karst sinkhole has an irregular form, *i.e.* it was formed as a result of sinking of several joint sinkholes. Unfortunately, it is not possible to determine the exact number of the constituent sinkholes, as part of the territory of the peat-bog is covered by the Biržai pipeline, therefore the sediments are mixed in this part. However, the available lithological data and the results of the decoding of aerophoto images show that at least three jointed sinkholes are forming the bottom of the basin.

Like the majority of the other karst lakes (Taminskas, 1999; Narbutas, 2001), the sinkhole studied by us had a small diameter just after formation, though during several decades an intensive karst denudation occurred. The sinkhole singnificantly shallowed and its diameter increased. Due to this process carbonate till (karst gravel) and later "dolomitic flour" accumulated in the sinkhole. After the karst denudation process slowed down, silt at some intervals mixed with biogenic sediments started to accumulate. Even if lithological data show a reduction of the sedimentation rate, low pollen concentrations suggest that this rate was still relatively high. Besides, according to the work of J. Taminskas (1999), very fast sedimentation rates are common to genetically young karst lakes. Hence, a layer of silt up to 0.4 m thick must have been formed in less than a few hundred years, most probably in several decades. Pollen data show that the layer of silt was formed late in the Atlantic (app. 6.5–5 ka BP). As the upper and the lower layers were formed relatively fast, we can assume that the sinkhole itself was formed in the Late Atlantic as well.

In the beginning of the Early Subboreal (app. 5 ka BP), when the sinkhole got its final shape, the denudation process actually stoped. As the sinkhole was still filled with water, lacustrine sediments (gyttja) had accumulated in it for several hundred years. These changes coincide with the overgrowing of the sinkhole with trees.

The basin was rather shallow and isolated, therefore after some time (rougly 4.5 ka BP) anoxic conditions started to prevail and the process of waterlogging took place. During the Subboreal (app. 5–2.5 ka BP) the sedimentation rates were quite high – a sediment layer up to 300 cm thick accumulated during this period, though pollen concentrations show that there could be several significant slowings, even intermissions of sedimentation at some intervals. In the beginning of the period, trees were dominant around the sinkhole and its surroundings. Abundant remains of trees in peat confirm this assumption. Roughly 4500 years BP (when the waterlogging took place), ferns, green mosses and some other spore plants started to prevail in the basin. Black fern peat of different humification grades started to accumulate. Spores of the above-mentioned plants are abundant in sediments as well.

A relatively thin layer of peat acumulated during the Subatlantic and the corroded pollen in the uppermost samples of the Skrebiškiai-1 sequence show that sedimentation rates in the peat-bog slowed down during the Subatlantic (the last 2.5 ka), possibly because of unfavourable hydrogeological conditions in the basin. Pollen analysis shows that the vegetation in the vicinity of the peat-bog was similar to the present one. Coniferous trees, birch, alder, lime, fern and green moss prevailed.

FORMATION OF SINKHOLES IN NORTHERN LITHUANIA DURING THE LATE ATLANTIC

Some of the researchers (Kondratienė, Narbutas, Linčius, 1998), suggest that sinkholes in Northern Lithuania were formed in some stages. As many as 3 of the 5 palynologycally analysed sinkholes from the karst region of Northern Lithuania appeared during the Late Atlantic. This time of formation was perhaps not incidental: the available data on the lake and underground water fluctuations and climate changes in Lithuania during the Holocene (Kabailienė, 1990; Кабайлене, 2000) show that climate was warm and humid during the Late Atlantic and the water levels fluctuated frequently. Conditions of this type are perfect for the development of karst processes. A drop of underground water level or intensive precipitation could result in numerous sinks of Quaternary sediments into the caves leached in gypseous rocks.

The obtained and earlier published data (Тюремнов, Видмантас, Пранайтис, 1959; Kabailienė, 1990; Kondratienė, Narbutas, Linčius, 1998; Кабайлене, 2000) show that the late Atlantic period could be one of the most intensive stages of active karst processes during the Holocene. It is also possible that there were more stages of active karst processes, though to confirm this presumption further investigations of the karst sinkhole sediments are needed.

CONCLUSIONS

The Skrebiškiai karst sinkhole and the karst rocks distributed in the bottom of it (total thickness up to 380 cm) formed in the Late Atlantic (app. 6.5–5 ka BP). The overlying gyttja layer up to 70 cm thick accumulated in the beginning of the Early Subboreal, approx 5–4.5 ka BP. A layer of peat up to 350 cm thick started to accumulate during the second part of the Early Subboreal, approx 4.5 ka BP.

The bottom of the Skrebiškiai peatbog is composite. At least three joint sinkholes are forming it.

The end of the Atlantic (6.5–5 ka BP) could be one of the most intensive periods of the formation of sinkholes in Northern Lithuania during the Holocene.

Pollen analysis proved to be a valuable tool for studying karst sinkholes, determination of their age, evolution and paleoecological conditions of the surroundings.

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SKREBIŠKIŲ KARSTINIO DURPYNO (ŠIAURĖS LIETUVA) SUSIDARYMAS IR RAIDA PAGAL ŽIEDADULKIŲ ANALIZĖS DUOMENIS

S a n t r a u k a

Karstiniai reiškiniai Šiaurės Lietuvoje buvo plačiai paplitę holoceno laikotarpiu. Nuosėdų, užpildančių karstines įgriuvas, žiedadulkių tyrimai galėtų suteikti svarbios informacijos apie karstinius reiškinius Šiaurės Lietuvoje, tačiau kol kas žiedadulkių analizė karstinių įgriuvų nuosėdoms taikyta buvo labai mažai.

Skrebiškių karstinė įgriuva (karstinis ežeras) susiformavo vėlyvajame atlantyje (maždaug prieš 6,5–5 tūkst. metų) gruntiniam vandeniui tirpinant gipsingus devono sluoksnius. Smegduobės forma ir biogeninių nuosėdų storio pasiskirstymas rodo, kad tiriamąją smegduobę sudaro mažiausiai trys tarpusavyje susijungusios įgriuvos. Susidarius smegduobei iš karto pasireiškė aktyvūs ardymo procesai, dėl kurių per kelis šimtus metų (ar net kelis dešimtmečius) susikaupė iki 380 cm karstinių nuosėdų sluoksnis. Galutinai susiformavus karstiniam ežerėliui (atlančio pabaigoje, maždaug prieš 5 tūkst. metų), jame ėmė kauptis sapropelis. Ankstyvojo subborealio (maždaug prieš 5–4 tūkst. metų) metu karstinis ežerėlis užpelkėjo, įgriuvoje susikaupė iki 350 cm storio durpių sluoksnis. Subborealyje (maždaug prieš 5–2,5 tūkst. metų) nuosėdos pelkėje kaupėsi sąlyginai greitai, tačiau subatlantyje (paskutiniai 2500 metų) sedimentacija sulėtėjo. Nebūdingas šiam periodui eglių bei liepų žiedadulkių padaugėjimas nuosėdose, matyt, atspindi ypatingas dirvožemio savybes, galbūt tipiškas visam karstiniam regionui.

Žiedadulkių bei paleoklimatiniai duomenys rodo, kad vėlyvasis atlantis galėjo būti vienas intensyviausių karstinių įgriuvų susidarymo laikotarpių holocene.

Лаурас Балакаускас

ФОРМИРОВАНИЕ И ЭВОЛЮЦИЯ СКРЯБИШКЯЙСКОГО КАРСТОВОГО ТОРФЯНИКА (СЕВЕРНАЯ ЛИТВА) ПО ДАННЫМ ПЫЛЬЦЕВОГО АНАЛИЗА

Р е з ю м е

Карстовые процессы в Северной Литве были широко распространены в течение голоцена. Пыльцевой анализ отложений, заполняющих карстовые воронки, мог бы снабдить нас ценной информацией о карстовых процессах в Северной Литве, но пыльцевой анализ отложений карстовых воронок на исследуемой территории почти не осуществлялся.

Скрябишкяйская карстовая воронка (карстовое озеро) образовалась в позднеатлантический период (около 6,5–5 тыс. лет тому назад) в процессе выщелачивания девонских гипсоносных слоев грунтовой водой. Форма воронки и распределение мощностей слоев биогенных пород показывают, что исследуемую воронку составляют по меньшей мере три соединенные между собой воронки. Сразу же после формирования воронки начались интенсивные процессы денудации, в результате которых в течение нескольких сотен (или даже десятков) лет образовался слой карстовых отложений мощностью до 380 см. После того, как карстовое озеро окончательно сформировалось (в конце атлантического периода – около 5 тыс. лет тому назад), в нем начал накапливаться сапропель. В течение раннесуббореального периода (около 5–4 тыс. лет тому назад) карстовое озеро зарастало торфом. С тех пор в воронке образовался слой торфа мощностью до 350 см. Во время суббореального периода (около 5–2,5 тыс. лет тому назад) аккумуляция в болоте происходила относительно быстро, но в субатлантический период (последние 2500 лет) седиментация заметно замедлилась. Необычным для отложений последнего климатического периода является увеличение количества пыльцы ели и липы, прорастание которых скорее всего отражало специфические параметры почвы, возможно, общие для всей территории карстового региона Северной Литвы.

Пыльцевые и палеоклиматические данные свидетельствуют, что позднеатлантический период мог бытъ одним из самых интенсивных периодов формирования карстовых воронок в течение голоцена.