GEOLOGICAL DEVELOPMENT OF THE ZEBRUS-SVĒTE DEPRESSION DURING THE LATE GLACIAL AND THE HOLOCENE

ZEBRUS-SVĒTES IEPLAKAS ĢEOLOĢISKĀ ATTĪSTĪBA LEDUSLAIKMETA BEIGU POSMĀ UN HOLOCĒNĀ

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Abstract

The research area, the Zebrus–Svēte depression, is located in the southern part of the Eastern Kursa Upland in western Latvia and is one of many glaciodepressions of similar size and shape characteristic of this upland. All the glaciodepressions are bounded by glacial marginal formations, with their characteristic glacigenic landforms and glaciotectonic structures, which are additionally complicated by the formation of glaciolacustrine sediments. To get an understanding of the geological development and developmental stages of this depression, this study also compiles and clarifies information on the positive landforms around the glaciodepression. Nowadays the largest part of the glaciodepression is occupied by two separate lakes: Lake Zebrus and Lake Svēte. Studies of the depression relief isolines, as well as Lidar data and sediment composition characteristics, it can be concluded that at the end of the Late Glacial, there was a large single lake of glacial origin in the depression, which gradually divided into two separate lakes due to a level decrease. On the elevated belt between the two lakes, sediments – gyttja, silt and carbonatic clay – were covered by the low decomposed peat, and Elku Mire developed.

Keywords: *Eastern Kursa upland, marginal formations, lakes, gyttja, peat*

Introduction

Studies of depressions in Pleistocene sedimentary areas, including radial uplands, are very complicated, as the study area includes not only the lower part of the depression, but also the positive landforms surrounding it, or at least the slopes facing the depression. Each of these depressions is characterised sequentially over time, from the end of the Late Glacial to the present, with the accumulation of genetically distinct sediments and also landforms. Studies of individual, local depressions, especially the study of Holocene sediments and their comparison, provide an idea of the course of geological processes and paleogeographical conditions in at least one natural area: the upland.

The Zebrus-Svēte depression is located in the hilly area of the Eastern Kursa Upland, Western Latvia (Figure 1).

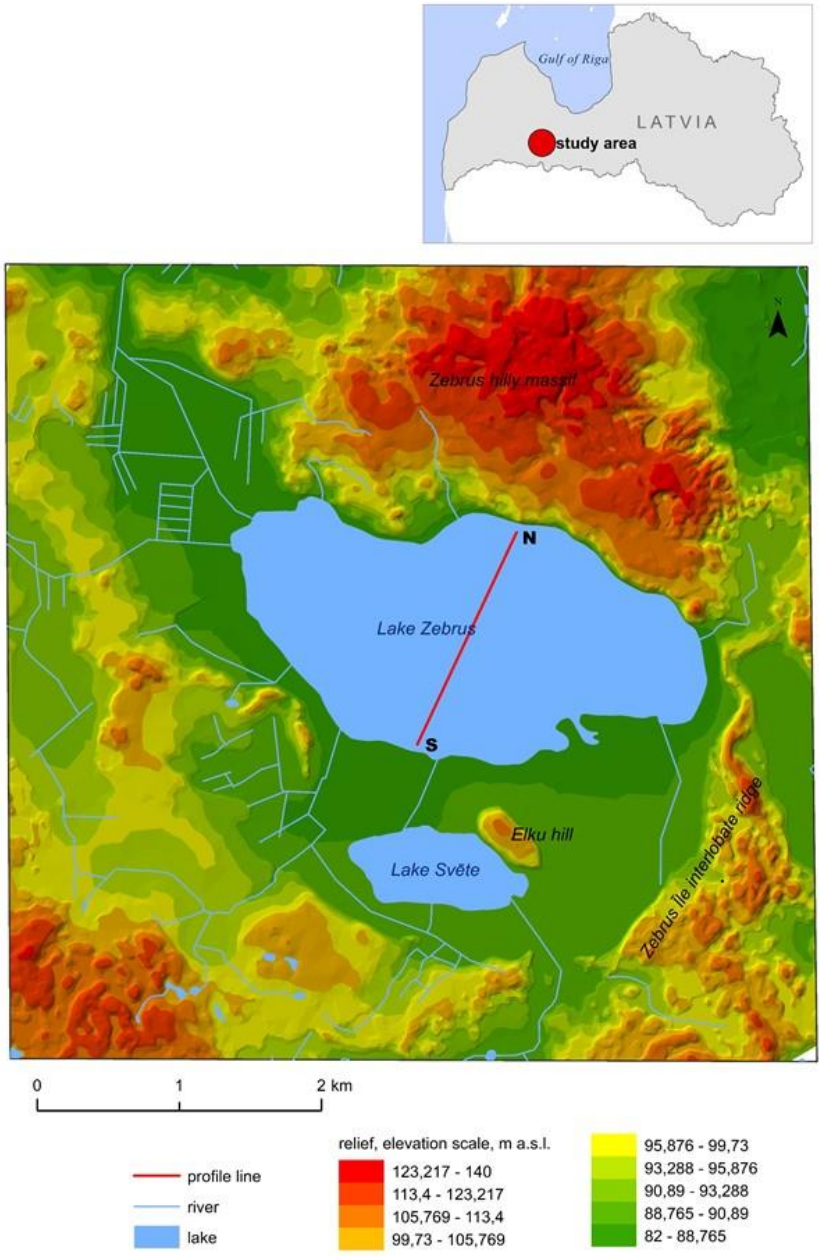

Figure 1. **Location of study area Zebrus hilly massif and Zebrus-Svēte depression** (authors' figure based on open geospatial data collections of LVM Geo, LGIA and Envirotech GIS Latvija 10.2)

It is the one of the morphologically significant glaciodepression in this upland that lies among the moraine ridges and the Zebrus hilly massif; the relative height of the slopes reaches 30–54 m. The glaciodepression has northwest-southeast linearity, corresponding to the direction of ice flow. The study includes an investigation of the lowest part of the depression, including the stratigraphy of the lake and bog sediments, and the genetically connected landforms around the depression, and in adjacent

areas. The study of sediments in the glaciodepression is very important not only in the study of the development of the depression itself, but also provides important information on climate and environmental changes in the Holocene in the southern part of the Eastern Kursa Upland. This area is fascinating from a geological and historical point of view, but still not thoroughly investigated; therefore, the study aim was to find out the nature of the geological development of the Zebrus-Svēte depression during the Late Glacial and the Holocene.

Materials and methods

The article is based on analysed unpublished research data from previous studies (Strautnieks et al., 2016; Daņiļēvičs, 2013), including information available at the State Geological Survey, and information from the latest research has been described. This study of the depression includes studies on glacigenic and glacial sediments, sedimentation conditions, deformation structures and relief formation during the Late Glacial. In order to understand and evaluate the geological processes during the Holocene in the last 11,700 years, sediment probing, coring and sampling were carried out in Lake Zebrus and Lake Svēte and on the elevation between them where the Elku Mire formed.

Lake Zebrus is the largest lake (420 ha) in the Eastern Kursa Upland; 86.5 m above sea level, it is located in an inter-hill depression, which is surrounded from the south by a hillside on the edge of the Eastern Kursa Upland and stretches in a west-east direction to the lake. South from Lake Zebrus is located the significantly smaller (55 ha) Lake Svēte, and after reclamation works, both lakes were connected. Additionally, the small River Zušupīte was deepened, which resulted in the water level dropping by 0.80 m. This also contributed to the intensification of bogging processes and the formation of Elku Mire.

Multidisciplinary study methods have been used, including field studies and laboratory analyses, as well as studies and interpretation of cartographical materials. Field studies include measuring of linear and plane - shaped and spatial structural elements, morphogenetic analyses of landforms, corings and sediment sampling. A statistical analysis of the planar structural elements measurements was carried out using the Stereonet programme. Laboratory analyses include: sediment composition analysis; the loss on ignition (LOI) method; and macroremain, pollen and mollusc analyses", as well as peat botanical composition and decomposition analysis (Krūmiņš et al., 2012).

Results and discussion

In general, the study area includes a complex of glaciotectonic negative and positive landforms that could be classified as a combination of Zebrus-Svēte ice-scooped basin and ice-shoved composite ridge, located distally from the depression.

According to previous investigations (Strautnieks, 1998; Strautnieks et al., 2016; Meirons et.al., 1976), the depression is bounded by marginal formations – a transverse ridge to the south of the depression, and an interlobate ridge and hilly massif on the north-eastern and eastern side. The Zebrus-Svēte depression is elongated and 5.5 km long. Its width varies from 1.2–1.6 km in the north-west to 3.0–3.5 km in the south-eastern part. Its linearity from north-west to south-east coincides with the direction of local ice movement, as evidenced by the opening of the glaciodepression in the northwest and the compression-displacement forms in the southeast. The morphology and genesis of glaciodepression are undoubtedly associated with the formation of pushed moraine ridges and massifs. The hilly slope of the Zebrus (Silakalni) composite massif is adjacent to the glaciodepression in the north for 4 km; its absolute height varies from 86.5 m above sea level at the level of Lake Zebrus up to 136–142 m above sea level, and thus the relative height reaches 30–55 m. Similar steps on the slopes are also observed on the slopes of the hills in the southern and southeastern part. On the slope of the Zebrus massif, the pseudo-terraces are very distinctive at several levels: 100–102, 107–110, 115–117, 120–123 m above sea level, which become progressively older as the height increases. All stair surfaces can be traced both as narrow (50–80 m) pseudo-terraces and as 120–300 m wide strips of lightly wavy morainic plains. The sloping slopes between the pseudo-terraces are the slopes of active ice contact, and were apparently formed during the deglaciation of the Vistula glaciation, decreasing the thickness of the glacier and its activity, and marking the active and passive ice contact. The highest part of the Zebrus massif is the central part, where the height of the undulating surface is mostly 130–135 m above sea level, and glaciofluvial sediments are exposed at the top. The 10–12 m thick walls of the quarry there reveal mainly sand, with a sloping layer characteristic of glaciofluvial deltas and a fall azimuth to the west/north-west (Figure 2). Accordingly, the presence of a delta and local glacial basin at this level means that the Zebrus-Svēte basin was filled with ice blocks. Signs of runoff from a local glacial basin are observed in the proximal part of the hilly massif, north of the glaciofluvial delta. The northern slope is interspersed with a number of dry erosion valleys, while sand and other erosion beds reveal sand with significant amounts of boulders on the surface, indicating sand eroded by an eroded till. In the final, most recent phase of the active glacier, the lowest part of the Zebrus-Svēte glaciodepression developed.

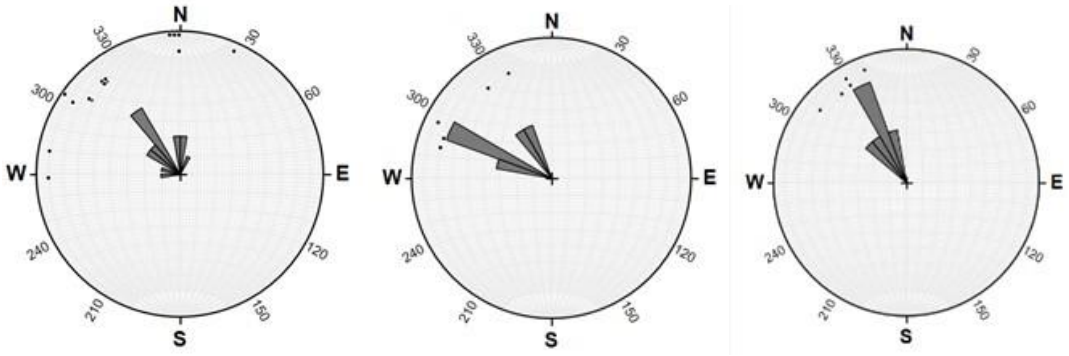

Figure 2. **Strata slope contact lines on the upper part of the Zebrus hilly massif in glaciofluvial sediments according to statistical analysis of measurements of planar structural elements** (authors' figure using Stereonet software)

The beds of the two lakes are separated by an elongated morainic hill (Elku Hill), which is thought to have formed beneath active ice, between glacial micro-tongues (Strautnieks, 1998). The lower part of the glaciodepression is bounded by steep, 10–12 m high ice contact slopes. In the northern and north-eastern part of the depression, the slope reaches 35–45º, and in some places even becomes vertical walls. It can be seen that the morphology of the coastal slopes has been influenced by the slope processes, which were facilitated by wave erosion at higher Zebrus-Svēte palaeolake levels. Along the current shoreline, boulders washed out of the till can be seen, but there are especially many of them near the steep slopes, the ancient erosion cliffs, where a lake terrace can be traced around the depression at an altitude of about 1–1.5 m above the current water level. Depressions on the slopes below the soil, but in places also on the surface, reveal the till of the Vistula with pebbles and erratic boulders. Till and individual boulders can also be seen in the wide shallow water zone in the northern part of Lake Zebrus. Nowadays, two lakes remain in the depression: Lake Zebrus and Lake Svēte.

The surface of the lakes in the depression is 86–87 m a.s.l. The thickness of lake sediment layer reaches 12 m accumulated above till or glaciolimnic clay and fine sand sediments. Studies of depression relief isolines, and use LIDAR data, it can be concluded that at the end of the Late Glacial, there was one large lake of glacigenic origin in the depression, which gradually divided into two separate lakes due to level decrease. In the top interval of gyttja layer in the shallower parts of both lakes, as well as in the overgrown fen area between these lakes, a layer of gyttja with an aquatic gastropod mollusc of the Valvatidae family (*Valvata piscinalis, Valvata pulchella*, also *Lymnea ovata* and *Bithynia tentearlata*) and ostracod remains can often be traced at a similar altitude. The interlayers traceable in the sediments of studied lakes characterise the changes in the sediment composition, indicating the fluctuations of the water level in both lakes. This is also proved by data from sediment composition analyses (LOI) method; and macroremain, pollen and mollusc analyses, as well as a

peat botanical composition, and decomposition analysis. These facts lead us to believe that it was a single lake at this time. The area between both lakebeds excludes the morainic hill, and is covered by clay and sandy-calcareous gyttja, an 8,000 years ago during the Early Holocene, due to the lowering lake level, the formation of reed and sedge fen peat started. Nowadays, a 500–600 m wide transition mire between the lakes with a peat layer more than 2 m thick has developed. The largest and deepest part of the depression is occupied by Lake Zebrus, which takes up 4.43 km^2, and the thickness of the organic lake sediments represented by different types of gyttja reaches 7–11 m (Figure 3). However, currently, it is a relatively shallow lake, so the average depth is 1.5 m, but the deepest point reaches 3.9 m.

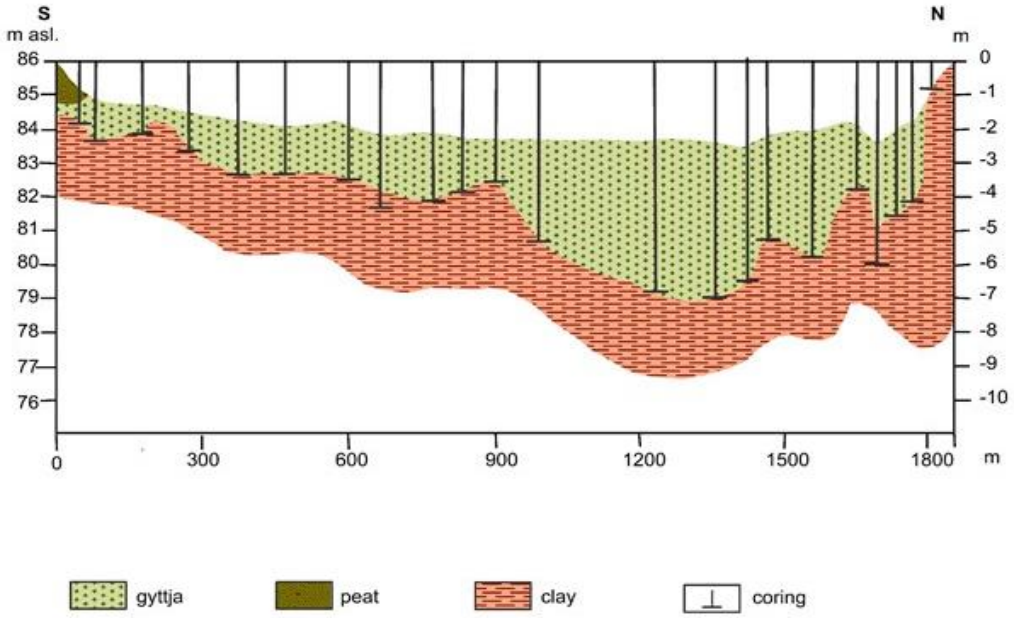

Figure 3. **Geological cross-section S-N of Zebrus Lake. Location shown by profile line in Figure 1** (authors' figure)

Lake Svēte is much smaller than Lake Zebrus, with a water surface of 55 ha and a maximal water depth of 2.2 m. In the western part of Lake Svēte, a layer of gyttja has accumulated above the bluish-grey dense clay, the thickness of which varies from 1.5 m in the shallowest part of the lake to 12 m in the deepest part,

The studies of the geological cross-section of Svēte Lake and Zebrus Lake (shown by the profile line in Figure 1) reveal different lake sediments at their beds – different kinds of gyttja, sand layers and carbonatic clay. Low decomposed peat has been found in an elevated area between the lakes, but beneath it, the limnic sediments lie – gyttja, silt and carbonatic clay, as are found in both lakes. This shows that the sedimentation conditions in this area were the same as in the two lakes, and that during the Late Glacial and the early Holocene, when the water level in the depression was higher, both lakes, as well as the elevation between them, were a single basin.

Conclusion

The sequence of lake sediment accumulation in the Zebrus-Svēte depression has common features. Their composition and distribution indicate that a significant part of the sediments have accumulated over a relatively long period in a single large water body, rather than in two separate ones. Results of the macroremain and pollen analysis indicate similar plant composition pointing to the gradual filling in of the lake with organic sediments rich in carbonates since the Early Holocene, when vegetation developed rapidly on the shores of the lakes and forests formed.

Results of the study indicate very complicated formation conditions for the depression. Therefore, more detailed investigation of the internal structure of landforms is necessary.

Kopsavilkums

Zebrus–Svētes ieplaka atrodas Austrumkursas augstienes dienvidu daļā un ir viena no līdzīga lieluma un formas ledāja ieplakām, kas raksturīgas šai augstienei. Visas glaciodepresijas norobežo ledāja malas veidojumi ar tiem raksturīgajām glacigēnajām reljefa formām un glaciotektoniskajām struktūrām, ko papildus sarežģī arī glaciolakustrīno nogulumu veidošanās. Lai izprastu šīs depresijas ģeoloģisko attīstību, šajā pētījumā apkopota un precizēta arī informācija par pozitīvajām reljefa formām ap glaciodepresiju. Mūsdienās lielāko ledāja depresijas daļu aizņem divi atsevišķi ezeri: Zebrus ezers un Svētes ezers. Izpētot depresijas reljefa izolīnijas, kā arī izmantojot LIDAR datus un nogulumu sastāva raksturojumu, secināts, ka Vislas apledojuma beigās depresijā atradās liels vienots glaciālas izcelsmes ezers, kas, tā līmenim pazeminoties, pakāpeniski sadalījās divos atsevišķos ezeros. Paaugstinātajā joslā starp abiem ezeriem nogulumus – gitiju, dūņas un karbonātiskos mālus – pārsedza zemā sadalījusies kūdra un izveidojās Elku purvs.

Nogulumu, kā arī tajos sastopamo makroskopisko atlieku un putekšņu analīzes rezultāti liecina par līdzīgu augu sastāvu, kas norāda uz pakāpenisku ezera piepildīšanos ar karbonātiem bagātiem organiskiem nogulumiem kopš agrīnā holocēna, kad ezeru krastos strauji attīstījās veģetācija un veidojās meži.

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