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EVIDENCE OF PALAEO-CLIMATE CHANGES AND THEIR IMPACT ON SEDIMENT ACCUMULATION CONDITIONS IN THE LUBĀNS STONE-AGE SETTLEMENT AREAS

Liecības par paleoklimata pārmaiņām un to ietekmi uz nogulumu uzkrāšanās apstākļiem Lubāna akmens laikmeta apmetņu teritorijās

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Abstract. Changes in palaeo-climate and palaeo-geographic conditions have influenced palaeo-vegetation and sediment accumulation conditions during the development of Lake Lubāns. These circumstances have also affected human life conditions and the distribution of Stone-Age settlement sites. To discover notions about evidence of sediment accumulation condition changes and reconstruct the palaeo-geographic

conditions of Lake Lubāns, studies were undertaken in Stone-Age settlement areas and the palaeo-lake's overgrown and paludificated territories.

The investigations for this study were based on field work, including sampling, geological coring and probing, obtaining and documenting samples of sediments, as well as laboratory analysis on aspects such as loss on ignition, pollen and macroscopic remain analysis. The results have allowed us to make the conclusion that the most essential of reasons why Stone-Age people changed the sites of their settlements was due to lake water level fluctuations as well as to overgrowing and paludificating of the lake bays and shores.

Keywords: *Paludification, sediment accumulation, loss on ignition, Stone-Age*

Introduction

The research area is located in the East Latvian Lowland, the Lubāns Plain and the Lubāns Wetland. The lake itself combined with its surrounding territories is situated in the lowest area of the Lubāns Plain. Notable among the characteristics of Lake Lubāns is its complicated geological structure, hydrographic network, large wetland covered areas and rich evidence about Stone-Age settlements. During the late glacial period Lubāns palaeo-lake was at least three times the size it is today (Grūbe 2006).

Due to the complicated geological development of Lake Lubāns and the Lubāns Plain, palaeo-geographic conditions around Lake Lubāns in various places are diverse (Эберхардс 1985). It is essential to mention that Lake Lubāns and its surrounding territories is a unique place not only in Latvia but also in a global context. Around the ancient and present day lake shores and many nearby rivers there have been discovered more than 30 ancient settlement sites. And is is exactly at the Lubāns Stone-Age settlement sites that there have been found the most bone and horn sculptures not only in Latvia but also in the eastern Baltic territory (Лозе 1988; Segliņš et al. 1999). Lake Lubāns is one of the largest of these kind of archaeological research areas not only in the Baltic states but also in Europe. The overall territory covers some 100 000 hectares where 24 nationally protected archaeological sites are located (Loze 1990). For those reasons, further researches into any of this archaeological site's environmental changes are significant to obtain a better overall understanding about the specific territory's geological development and palaeo-environmental changes during the existence of Stone-Age settlements around the ancient Lake Lubāns shore.

During the time period 2016 – 2017, studies were undertaken in the N and NE part of the Lubāns palaeolake – the Iča and Lagaža settlement areas (Paparde et al. 2017). In order to reconstruct sediment accumulation condition changes for the whole ancient Lubāns territory, it was required also to study the W and S parts of Lake Lubāns – the Asne and Sūļagols settlement areas. These additional expeditions took place during 2018 – 2019. Specific settlement sites were chosen because they are interesting in a palaeo-geographic aspect and also because of the lack of any existing geological information about them.

Data and Methods

During the study process different types of data and versatile materials were used, including sediment samples from field works, the author's prepared cartographic materials, performed laboratory analysis and visualised results in conversant diagrams and charts. In addition to obtaining samples for further investigations so as to reconstruct palaeo-geographic and sediment accumulation condition changes during field works, geological coring and probing was also undertaken as was the obtaining and documenting of sediment monoliths, and transportation of these samples to the laboratory of Quaternary Environment studies at the University of Latvia. A combination of different laboratory methods was used to get the best results on aspects such as loss on ignition, pollen and macroscopic remains analysis. A plausible palaeo-geographic reconstruction can be made only by comparison and combination of different laboratory analysis results and data from diverse geological coring sediment samples.

Loss on ignition analyses of the Quaternary lake sediments provide an opportunity to investigate changes in the past environment. Curve fluctuations in diagrams can indicate sediment accumulation condition changes, water level fluctuations, lake shore overgrowing and paludification processes. With these methods seven geological cores were analysed: Sūļagols – U1, Iča – U1, Iča – U2, Iča – U3, Lagaža – U1, Lagaža – U2 and Lagaža – U3 with a total length of 10.6 m of sediment samples. Each sediment monolith was analysed to within a 1 cm accuracy, meaning 1060 samples in total. Loss on ignition analyses was used to estimate organic, mineral and carbonate matter in sediments.

Pollen analysis, the study of fossil pollen and spores, is one of the key methods for reconstruction of past vegetation dynamics and environment changes. The results of this method can provide an insight into long term changes of various plant species and also indicate human influence on vegetation, therefore sediments from two cores were analysed – Iča – U1 (69 samples) and Lagaža – U1 (39 samples). Macroscopic remain analysis can reveal significant information about palaeo-climate and palaeo-vegetation as well as give evidence about early human impact on vegetation and the beginnings of agriculture (Paparde et al. 2017). In total, a macroscopic remain analysis was done for 63 sediment samples and with 5 cm accuracy. Samples from two sediment cores were analysed – Iča – U1 (40 samples) and Lagaža – U2 (23 samples).

Results

During the field work in 2016 at Iča and the Lagaža Stone-Age settlement territories, six sediment cores were made with a total length of 7.6 m - three cores at each Stone-Age settlement area. Field work for this research took place in the northern part of Lake Lubāns. All sediment samples and monoliths were taken to use for further laboratory analyses. As well, from the pit wall of the Iča settlement area 5 extra sediment samples (each approximately 2.0 – 2.5 litres) were collected to use for macroscopic remain analysis. During the 2018 research field work that continued in

the southern and western part of Lake Lubāns, four sediment cores were made with a total length of 10.0 m – one in each research area, including Sūļagols and Asne Stone-Age settlements, Garanču Mire (Sūļagols) and the Kausliena Peisa Mire (Figure 1).

At the Iča - U1 borehole the cultural layer was separated from 0.63 to 1.35 m, hile the Lagaža - U2 borehole cultural layer was in the interval from 0.35 to 0.67 m. According to the results of loss on ignition analyses, changes in percentage values of carbonates, mineral and organic matter have indicated sediment accumulation condition changes in the northern and southern part of Lake Lubāns. Iča – U1 and Lagaža – U2 representing North but Sūļagols – U1 representing South. The results of the loss on ignition analysis of the surrounding area of Sūļagols, Iča and Lagaža settlements are reflected in the drafted diagrams (Figure 2). Depending on the changes in sediment composition, four zones (I-IV) were sub-divided for Sūļagols, seven zones (I-VII) for Iča and four zones (IV-VII) for the Lagaža settlement area.

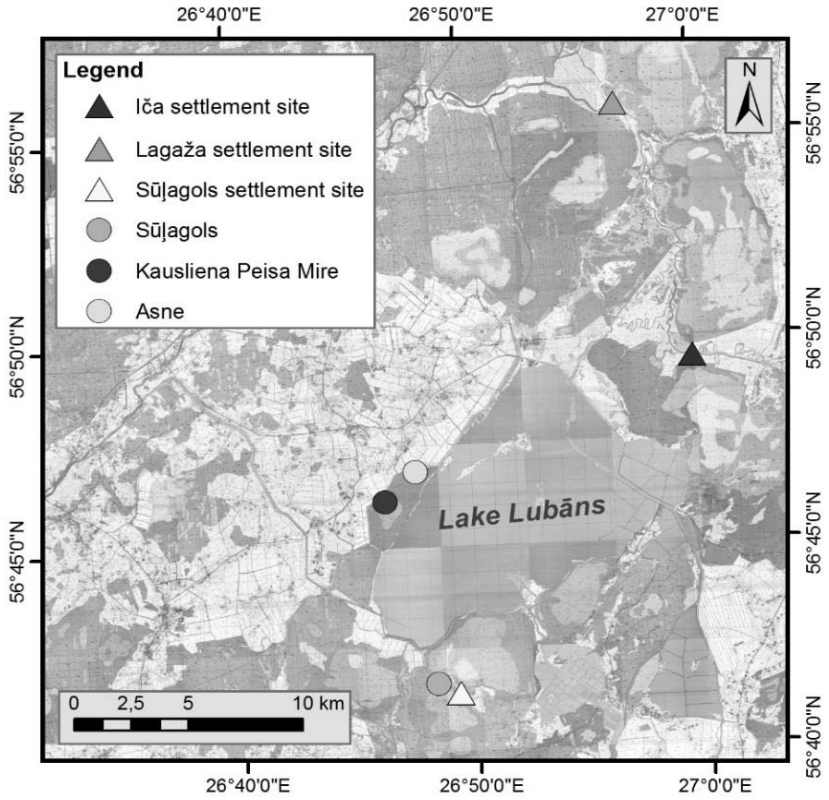

Figure 1. **Surveyed expedition sites and sampling locations, 2016 - 2018** (authors' figure using TOPO 10K PSRS 1979–1980)

Sūļagols – U1 is the deepest borehole that represents sediment accumulation condition changes in the southern part of Lubāns palaeo-lake. Zone I is represented by fine to medium grained sand. This interval reaches up to 98% of mineral matter. These sediments possibly accumulated during the late glacial. Zone II represents a sharp increase of organic matter from 3 to 78%. That shows the evidence of warm climate conditions and rapid development of vegetation. Zone III is dominated by peaty gyttja and organic matter increases from 66 to 88%. Curves of loss on ignition results in

diagrams indicate periodic changes in sediment accumulation conditions that may have been influenced by fluctuations of lake water levels. While in zone IV, dominated by peat, organic matter increases from 82 to 97%. That provides us with the evidence about intensive lake overgrowing and paludification processes. On the whole, Sūļagols – U1 borehole interval carbonates reach up to only 2.5%.

Iča – U1 and Lagaža – U2 boreholes represent sediment accumulation condition changes in the northern part of Lubāns palaeolake. The borehole from the Iča settlement area reveals that the amount of organic matter decreases with the depth of the sediment layers. Zone I – III is represented by sediments that accumulated under water conditions. Carbonates in this interval reach up to 12.5%. Zone II – VI coincides with the distribution of the cultural layer. This indicates that the accumulation of these sediments took place under dryland conditions and were influenced by human activities. Organic matter increases up to 20% in zone VII that indicate paludification processes in the northern part of Lake Lubāns means that during the time of this sediment accumulation the settlement area was no longer inhabited.

The results for the Lagaža – U2 borehole show that sediment accumulation took place in four diverse conditions. Zone IV is represented by the highest carbonate matter that indicates water influence on sediment accumulation processes. Zones V and VII represent evidence of palaeo-lake Lubāns shore overgrowing and paludification processes because in these intervals organic matter reaches up to 20%. Zone VI represents more stationary accumulation conditions and it also coincides with cultural layers of Lagaža Stone-Age settlement inhabitation. A lot of animal, fish bone and charcoal fragments were found.

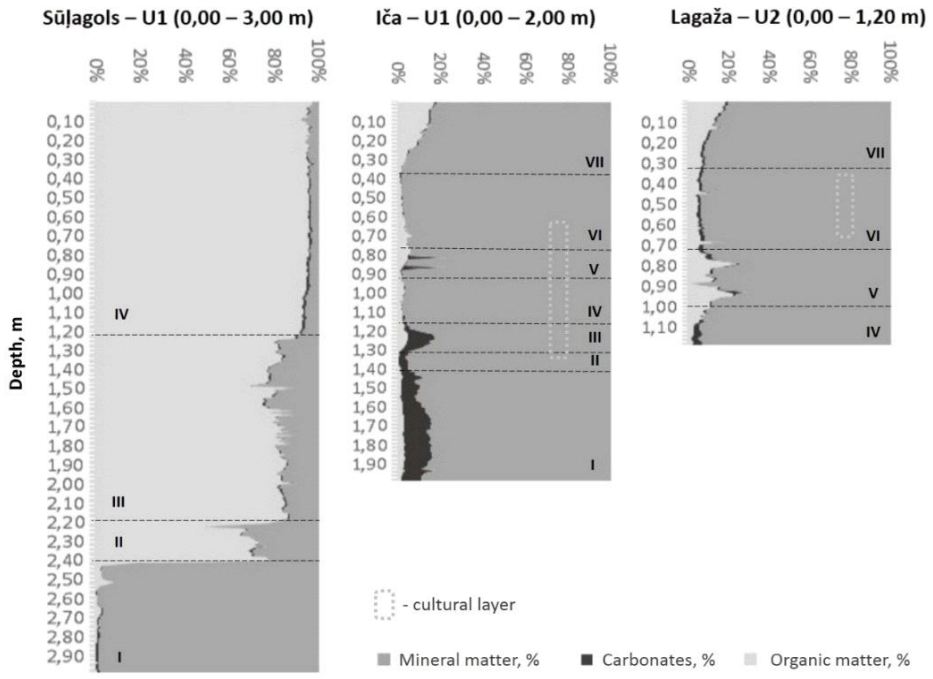

Figure 2. **Loss on ignition results for Sūļagols – U1, Iča – U1 and Lagaža –U2 cores** (authors' figure)

Based on the results of identified pollen percentages in the sediments and the distribution of the species in diagrams, in the Iča - U1 borehole there were four separated pollen zones (Figure 3), while three pollen zones in Lagaža - U2 borehole. Separated zones characterize the composition of palaeo-vegetation and sediment accumulation condition changes around nearby Lake Lubāns and also in the surrounding area. A Lithology description was attached to both analysed borehole sediments. Iča – U1 borehole is represented by silty clay, carbonatic silt, carbonatic sand with charcoal, fine sand and fine sand with plant remains while the Lagaža – U2 borehole is represented by carbonatic silt, fine sand, peaty silt and clayey silt. Results of analysis show what kinds of trees, shrubs, ruderals, cultivated plants and different herb species dominated in the settlement area and it also represents vegetation for Lake Lubāns northern part.

Pollen analysis for the Iča and Lagaža settlement site areas show that the most common growing tree species were birch *Betula*, pine *Pinus*, spruce *Picea* and alder *Alnus*. Grasses *Poaceae,* nettle *Urtica*, sorrel *Rumex* and goosefoot *Chenopodiaceae* covered wide open areas around the besides lake shore while forest groundcover was dominated by mosses *Bryales*, horsetails *Equisetum* and ferns *Polypodiaceae*. The ancient Lake Lubāns coastal area was covered by cattail *Typhaceae,* water lilies *Nymphaceae* and pondweed *Potamogetonaceae*. In both settlement areas water caltrop *Trapa natans* was found indicating that Stone-Age people used it as food.

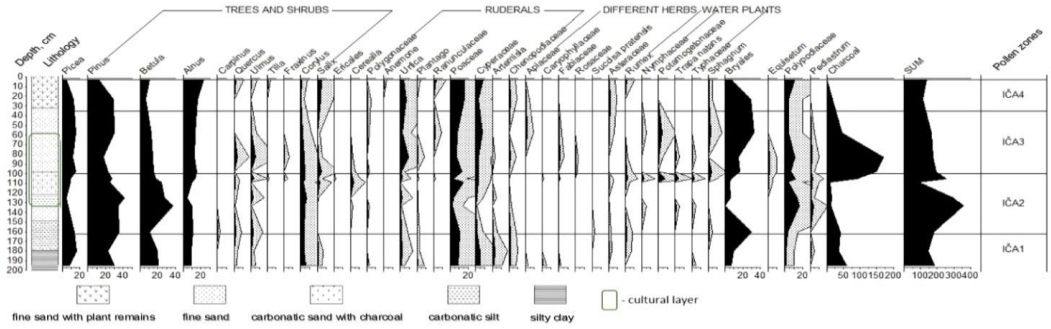

Figure 3. **Pollen results for Iča – U1 core sediments** (authors' figure)

Based on macroscopic remain analysis results the Iča – U1 borehole was divided into five macroscopic zones (MA zones) but Lagaža – U1 was divided into three zones (Figure 4). Results for the Iča – U1 borehole show that the carbonatic interval contains high muskgrass *Chara* concentration. The presence of this species in the lakes indicates clean water with a healthy ecosystem. The muskgrass served as a fish habitat, as they were caught by people who lived in the settlements. The results for the Lagaža – U1 borehole show that the cultural layer interval contains a big concentrations of fish bones together with charcoal and magmatic hearth stones. Also water caltrop *Trapa natans* was found in these sediments indicating what Stone-Age people used for edibles. These evidences prove that during the cultural layer sedimentation processes people used to live nearby the Lake Lubāns shore line.

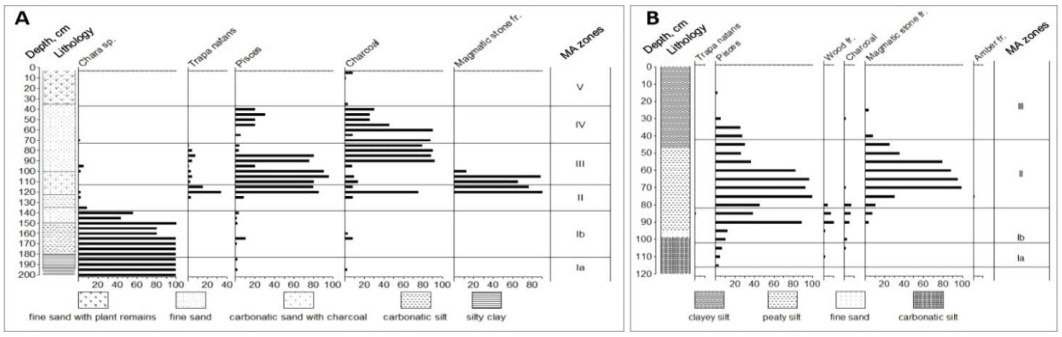

Figure 4. **Macroscopic remains associated with Lake Lubāns Stone-Age inhabitation.** A - Iča – U1 core; B - Lagaža – U2 core (authors' figure)

During field work at the Iča settlement site many macroscopic remains such as ceramic fragments, magmatic hearth stones, animal bone fragments and teeth were found in the pit wall (Figure 5).

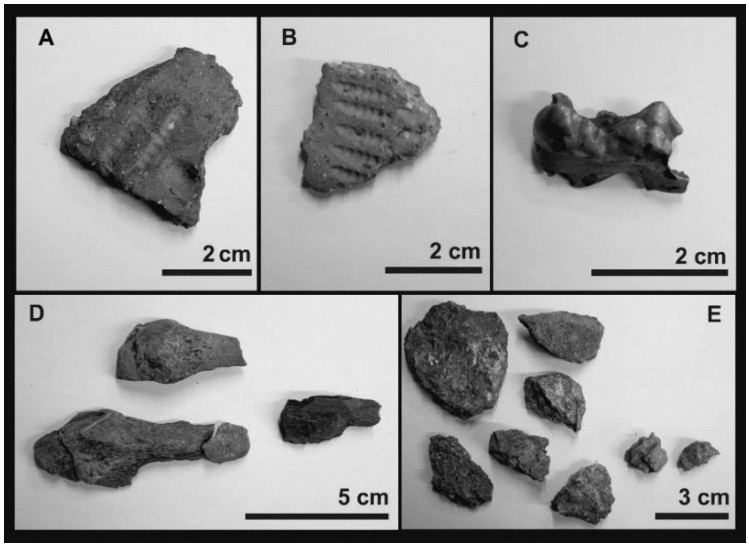

Figure 5. **Archaeological findings from the pit wall at Iča settlement area.**
A, B - ceramic fragments associated with comb ware culture; C - predatory animal tooth; D - animal bone fragments; E - magmatic hearth stones (authors' figure)

These research findings undoubtedly prove the presence of Stone-Age people and their living conditions. The biggest and most important macro remains were documented and well described. Most bone fragments were too small to define its kind and genus. But it was possible to get the idea about what kind of animals people used to hunt and eat during that time, such as sheep, pigs and roes. During the 20th and early 21st century a lot of archaeological excavations were undertaken in the Lubāns Plain. Research data also helps to learn more about palaeogeographic conditions in the area of the ancient Lake Lubāns and about Stone-Age living conditions and occupations.

Conclusion

- Research concludes that among the most essential reasons why Stone-Age people changed the locations of their settlements were in consideration of water level fluctuations, lake shore overgrowth and paludification.

- During field work at the Iča and Lagaža settlement sites, among the obtained borehole sediment monoliths and collected pit wall sediment samples there was found to be a surprisingly large amount of evidence of Stone-Age habitats.
- The results of loss on ignition analysis revealed that in all prospected sections the amount of organic matter increases in the upper layer was related to coastal overgrowing intensification processes in the vicinity of Lake Lubāns.
- The highest values of mineral substances in sediment compositions were found in the lower layers of sections, which have accumulated under water conditions.
- The largest amount of carbonates in sediments is in the lower part of sections below the cultural layer, which shows that sediments before the creation of the settlements, including carbonates, have accumulated in the aquatic environment. The largest amount of carbonates was found in the core sediment samples of the Iča settlement, which is located closer to the lake than Lagaža.
- During the time of Stone-Age settlements, which occurred in the Neolithic Age and also durng the early Bronze Age, sediment accumulation took place in dryland conditions.
- According to analysed loss on ignition results and pollen diagrams the cultural layer sediments from the Iča and Lagaža settlement sites accumulated in the Holocene Climatic Optimum and Late Holocene.
- Research undertaken at the Sūļagols settlement site provides a lot of information about sediment accumulation processes, such as overgrowing and paludification. The composition of these sediments is thought to have been influenced by the rivers Suļka and Malmuta.
- Results of loss on ignition and macroscopic remain analysis reflect changes in sediment accumulation conditions that are closely related to changes in palaeoclimate.

Kopsavilkums

Pētījuma mēķis ir noskaidrot paleoģeogrāfisko apstākļu pārmaiņas Lubāna ezera ģeoloģiskās attīstības laikā. Pētījumā iegūtās liecības pierāda, ka viens no galvenajiem faktoriem, kas ietekmēja nogulumu uzkrāšanās apstākļus, bija paleoklimata pārmaiņas. Lai noskaidrotu Lubāna ezera un tā apkārtnes veidošanās apstākļus, ezerā mītošo dzīvnieku un augu sugas, kā arī vides apstākļus, kādi ir bijuši akmens laikmetā, šeit pētījumus ir veikuši ģeologi, ģeomorfologi, hidrologi, arheologi un biologi. Arheoloģiskajos izrakumos iegūts bagātīgs materiāls, kas sniedz liecības par akmens laikmeta iedzīvotāju sadzīvi un nodarbošanos. Ir pierādījumi par cilvēku nodarbošanos ar zvejniecību, medniecību un vēlāk arī lopkopību un zemkopību. Taču vēl nav pietiekami daudz informācijas par ģeoloģiskajiem procesiem un to, kā klimata pārmaiņu ietekmē mainījušies dabas apstākļi. Šāda veida pētījumi ir ļoti būtiski, lai, izzinot pagātni, varētu izprast mūsdienu situāciju.

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CHANGES OF PEAT PROPERTIES IN DIFFERENTLY AFFECTED PARTS OF THE LAUGA BOG

Kūdras īpašību pārmaiņas dažādi ietekmētās Laugas purva daļās

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Abstract. At the present time much attention on the identification and investigation of degraded peatland areas is mainly being undertaken by studies on growing bog plant species, vegetation cover continuity and character. However, it is also understood that to choose the most effective re-cultivation method it is necessary to know the properties of the remaining peat layers and local hydrological conditions. The aim of this study was to discover the characteristics of peat properties and their changes in three differently affected areas of the Lauga Bog. Field work included geological coring and the collecting of deposit samples for further laboratory analysis including loss on ignition (LOI) analysis, determination of the peat density, pH and magnetic susceptibility measurements. The obtained results reveal that peat properties in the Lauga Bog vary in differently affected areas. In the affected areas (Lauga-1 and Lauga-3) the top layer of the peat section has a higher natural density and larger proportion of mineral matter. Whereas a natural bog section is characterised by peat with lower natural density, a higher percentage of organic matter and lower pH is typical for raised bogs.

Keywords: *natural density, LOI analysis, pH, drainage*