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Reconstruction of the Holocene palaeoenvironmental conditions accordingly to the multiproxy sedimentary records from Lake Pilvelis, Latvia

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ABSTRACT

Reconstruction of the Holocene palaeoenvironment conditions in Southeastern Latvia is based on multiproxy records from Lake Pilvelis: pollen, plant macrofossil and microfossil analysis; loss-on-ignition (LOI) measurements; ^{14}C dating; humic substances content; humification index; and elemental composition of gyttja organic mass. The data complex obtained in the result of multiproxy studies of sediments in Lake Pilvelis indicates significant changes in the depositional environment during the lake development. Data from Lake Pilvelis show that the start of organic-rich sediments formation before approximately 9750 cal BP, when birch–pine forest dominated in the surrounding landscape. Diagrams and data sets show six remarkable comparatively short cooling periods during the Holocene, which are related to changes in temperature and water level and influenced values and variability of remains. The investigation recognized the 8.4 ka BP and 4.6 ka BP cold events, while other cooling events can be recognised conditionally. During the events of 4.0 ka BP, the water level decreased extremely and the climate was probably drier, indicated by the comparison of records from Lake Pilvelis, Mazais Svetinu Bog and Lake Razna. A comparison of pollen data from Lake Pilvelis with Lake Kurjanovas, Mazais Svetinu Bog and Lake Razna shows some similarities, revealing features of cooler climatic conditions approximately at the time characterised by an increase of *Betula* and herb pollen.

1. Introduction

Sediment sequences from small lakes without or with limited inflow/outflow of rivers and springs function as archives for studying long-term fluctuations of environmental conditions, palaeoclimate, the history of vegetation in the lakes, and their catchment areas and human impact on them. Sediment accumulation process has been ongoing continually since the formation of these lakes. Therefore, they contain continuous records about the history of these lakes and their surroundings (Meyers, 2003). These insights can be used in forecasting an ecosystem's potential future (Wetzel, 2001).

In eutrophic water bodies, which are common in the North Temperate Zone, primary production, such as algae and aquatic macrophytes, dominates because of increasing nutrient inputs instead of mineralization processes in lakes (Cooke et al., 2005). Intensive sedimentation takes place in relatively small lakes in particular, resulting in development of thick organogenic sediment layers of sapropel, gyttja or dy (terminology is dependent more on historical traditions and differences in the sediment composition) (Hansen, 1959). Gyttja or sapropel is a prospective material for diverse applications (Stankevica and Klavins, 2013). In Latvia, the classification is made only for the term ‘sapropel’ to identify organic limnic sediments as valuable resource with a wide range of possible uses in agriculture, balneology and industry, but the term ‘gyttja’ usually is used to define organic rich lake sediments in limnology and for past climate studies. Sapropel type classification (Stankevica and Klavins, 2013) has been used in the current study to identify differences in analysed sediment samples with aim to

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distinguish environmental changes during the Lake Pilvelis development.

Organogenic lake sediments formed from the remains of aquatic plants, plankton and benthic organisms were transformed through the activity of bacteria and mixed with mineral components supplied from the lake basin (Kurzo et al., 2004). Analysis of lake sediment composition is widely used for paleolimnological, paleoclimatic (Sümegi et al., 2008; Heikkila and Seppa, 2010; Grimm et al., 2011) and environmental pollution studies (Klavins et al., 2011; Tylmann et al., 2011). Multiproxy analysis of sediment composition is of great importance in understanding the transformation processes of organic matter during sedimentary phases and is also helpful in reconstructions of palaeoenvironment conditions and palaeoclimatic changes.

Reconstruction of Holocene palaeoenvironment conditions and vegetation in the territory of Latvia has mainly been conducted using pollen analysis from sediment sequences (Danilans, 1957; Seglins, 2001a, 2001b). However, as Seglins (2001c) and Ozola (2013) have pointed out, it is not possible to detect exact geographic locations of the studied sites, and information about macrofossils and algae is also missing, along the age dating, in a great number of pollen diagrams from studies until the 1980s. Multidisciplinary studies of the Holocene palaeoenvironment started only during last years (Stankevica et al., 2012; Ozola, 2013; Kalnina et al., 2014; Stivrins et al., 2014).

Latgale Upland region was chosen for the study because of a great number of lakes (more than 600), which are of glacial origin, formed instantly after the retreat of the glacier 14–15 thousand calendar years ago (Zelcs and Markots, 2004; Heikkila and Seppa, 2010; Veski et al., 2012; Stivrins et al., 2014). During geological mapping, 6–8 m thick layers of gyttja were found in many lakes of Latgale Upland (Murnieks et al., 2004), including Raznava Hilly Area (Markots, 1997). Glaciolimnic clays and sand has been covered by limnic sediments containing organic material in these lakes, and therefore contain records of environmental condition changes since the beginning of the Holocene. Reconstruction of past palaeoenvironment conditions in Lake Pilvelis not only provides important data about the history of the ecosystem of the lake in the past and about the long-term dynamics of the plant and algae community there, but also helps to understand and predict the development and behaviour of the lake ecosystem. Proxies, including biological parameters, give important information about the development of the lake, dimensional distribution of layers, and properties of sediments. The aim of this study is to analyse and reconstruct the Holocene palaeoenvironmental conditions in Raznavas Hilly Area using the multiproxy records of sediments from Lake Pilvelis.

2. Study area

Lake Pilvelis (Fig. 1) is a small overgrowing lake of a glacial origin at the elevation 156 m asl., situated in the western part of Raznavas Hilly Area, northwest Latgale Upland, in the Eastern part of Latvia. The area of the lake is 8.7 ha. The average water depth is 0.90 m, and maximum 1.00 m. There are no inflow–outflow streams in the lake. Gyttja fills more than 90% of the lake's depression, with an average thickness of 4.50 m, maximum 5.90 m. The total amount of gyttja deposits in Lake Pilvelis is 360,000 m^3 (Geo-Konsultants, 1998). The Lake Pilvelis shore is formed by an approximately 30 m wide reed (*Phragmites*) marsh belt. The lake catchment basin occupies 138.5 ha and is boggy, covered by mixed forest.

Initially, the lake was formed from the discharge of water from the former ice-dammed lake responsible for the modern geomorphology of the area. It is located inside a relatively broad glacial depression occupied by the Rāzna glacier tongue during the earliest deglaciation phases of the Latgale Upland (Zelcs and Markots, 2004; Zelčs et al., 2011). After the melting of the local glacier during the Late Glacial period, individual lakes were formed in the midst of hummocky, morphologically higher-situated hills. The area around Lake Pilvelis is classified as small-sized morainic-hilly relief, where hummocky hills exceed 10 m relative height. Their elevation above sea level exceeds 160–170 m. This area is one of the highest parts of Latgale Upland formed on the Devonian bedrock uplift, where approximately 40 m thick glacigenic till represented by glaciofluvial sand and gravel interlayers cover the dolostones of the Upper Devonian Daugava Formation (Murnieks et al., 2004). These Pleistocene deposits are overlaid by the Holocene lake sediments, including gyttja (Geo-Konsultants, 1998). Westward from the lake, between till and glaciofluvial sediments, a glacier contact slope is located (Meirons, 1975; Zelcs and Markots, 2004).

3. Materials and methods

3.1. Coring and sampling

Sampling points were selected corresponding to the lake characteristics and preliminary data for gyttja layers in the given location. Coring was done from ice at the western part of Lake Pilvelis (56°39′45.21″ N, 27°17′31.40″ E). Sediment coring was carried out by a 10 cm diameter Russian-type peat sampler with a 1.0 m long camera. The sediment thickness reached 400 cm (Fig. 2), of which 390 cm was gyttja. Water depth of the lake was 70 cm. Five parallel overlapping sediment cores were documented according to the protocol for collecting, handling and (Givelet et al., 2004), packed into film-wrapped 1 m plastic semi-tubes and transported to the laboratory for physical, chemical and palaeobotanical analyses. Gyttja monoliths were subsampled with interval 5 cm and 40 subsamples were analysed using each method to get multiproxy data. In total, 240 gyttja samples were analysed.

3.2. Chronology

The lithostratigraphy chronology was based on ^{14}C radiocarbon dates from three 10-cm-thick bulk samples (Table 1). Gyttja samples were dated by means of the conventional liquid scintillation method at the Institute of Geology, Tallinn University of Technology (Tln), Estonia. Radiocarbon dates were converted to calendar years using the Clam 2.1 calibration dataset (Blaauw, 2010) and R2.15.1 programme deposition model (R Development Core Team, 2012) with a 95% confidence level. The ages in the text refer to calendar years before present (cal BP; 0 = AD 1950). For the chronological subdivision of the Holocene, recommendations of the Working Group of INTIMATE (Walker et al., 2012) were used.

Table 1
Radiocarbon dating of Lake Pilvelis sediments.

No	Depth, cm	Laboratory reference	^{14}C yr BP	$\delta^{13}C$, ‰	Model age (cal BP)	Calibrated age (cal BP) 95%	Material dated
1	180–190	Tln3394	4947 ± 60	−30.6	5278	5588–5761	Bulk gyttja
2	240–250	Tln3395	5292 ± 55	−30.4	6520	5931–6207	Bulk gyttja
3	390–400	Tln3396	8983 ± 85	−20.2	9980	9882–10,273	Bulk gyttja