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Late Weichselian and Holocene record of the paleoenvironmental changes in a small river valley in Central Poland

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ABSTRACT

The developmental history, from the Oldest Dryas to the Late Holocene, of a paleolake and mire located in a river valley in Central Poland was studied using high-resolution records of pollen, macrofossils, Cladocera, sedimentology, and geochemistry from a ^{14}C dated sediment core. We inferred temperature and water level dynamics using cladocerans and palynological and geochemical methods were employed to investigate natural fluvial activity, particularly for these elements that are difficult to find through sedimentological methods. Our research demonstrates how climate fluctuation in the Late Glacial and Holocene periods influenced the development of a paleolake and mire in a small river valley and shows the importance of long-term research to establish hydroclimatic conditions in biogenic sediments. We propose that water level fluctuations were important in modifying biotic assemblages. The results of our multiproxy analysis clearly suggest that the main driver of changes in aquatic and terrestrial ecosystems, as well as in geomorphological processes in the valley, was climate: reconstructed temperatures generally follow the known trends, showing an increase at the beginning of the Bølling, Allerød, and Holocene and a decrease at the beginning of the Oldest and Younger Dryas. Similarly, periods of water level increase are synchronous with climatic changes. However, the local environmental forces were a significant factors affecting biotic diversity in the studied time span. Fish predation, macrophyte structure, pH, and calcium content partly influence the results of the cladoceran-based water depth reconstruction in particular. Interestingly, the cladoceran-inferred summer temperature reconstruction for Pawłowa appear realistic. Although the temperature trends can be considered reliable, our results indicate the important role of local factors which control the species composition of the subfossil assemblages.

1. Introduction

The Late Glacial (Late Weichselian) contains distinct periods of climate fluctuations, such as the warmer Bølling/Allerød and the cooler Oldest, Older and Younger Dryas, which are well recorded in the Greenland ice core NGRIP δ18O (%) results (Rasmussen et al., 2014). This time span is also known as a transition from the full glacial mode of the Last Glaciation to the interglacial state, and is therefore an interesting period for climate reconstruction studies

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(Björck et al., 1998; Lowe and Hoek, 2001). Climate is also the main environmental factor affecting river ecosystems; varying roles of climate on river dynamics for the reconstruction of past hydrological changes have been documented. Multiple phases of higher flood frequency are recognized in the Late Glacial and Holocene, and have been compared with a range of climate proxies (Dambeck and Thiemeyer, 2002; Kalicki, 2006; Macklin et al., 2006; Starkel et al., 2006; Notebaert and Verstraeten, 2010). However, the Late Glacial poses difficulties in interpretation, because its duration depends on local conditions (Blockley et al., 2012). In addition, during the Holocene, the impacts of climate, local environmental factors and humans are sometimes very difficult to distinguish, because they act at the same time. Local environmental forces, such as the influence of rivers, the lengthening of the wet period, habitat modification, macrophyte abundance, biotic interactions, predation, and eutrophication are all factors that affect biota diversity in floodplain areas (Wiklund et al., 2010; Pawłowski et al., 2015a). Similarly, the response of river systems to both climate change and landscape alteration by humans is very dynamic (Kalicki, 2006).

Oxbow lakes and valley mires are suitable sites for examining climate changes in river valleys (Rotnicki, 1991; Pawłowski, 2012a; Pawłowski et al., 2012) and they allow us to record regional processes (Gandouin et al., 2006, 2007). Engels et al. (2008) showed, on the basis of chironomid assemblages, that there was no difference in the temperature inferences for lakes situated on the floodplain in contrast to those isolated from fluvial influence. The cladocerans, another group of aquatic invertebrates that are very common in lakes, floodplains, and fens in river valleys, seem to be excellent tools for the reconstruction of past climate changes, such as changes in summer air temperature (Pawłowski et al., 2015b), hydrological changes (e.g., water levels, floods), pH, and the trophy of waters (Pawłowski et al., 2015a), as well as for the archaeological investigation of floodplains (Pawłowski et al., 2015c). Despite the fact that local changes may produce a response in the cladoceran community composition and abundance (Pawłowski, 2012b), it is probable that the diversity of these groups is also subject to changing conditions, due to long-term climate fluctuations (Pawłowski et al., 2015b).

The multidisciplinary studies presented here, which incorporate paleobiological, geochemical, and radiometric data, investigate the interrelationships between climatic and local changes for the purpose of reconstructing the paleolake and mire development in the floodplain of a small river valley. For this reason, we also attempted to quantify air temperature dynamics with the use of subfossil Cladocera assemblages that has never before been tested on oxbow lake sediments older than the Younger Dryas. The objectives of this paper were (1) to recognize how major climate shifts in the Late Glacial and Holocene periods influenced paleolake and catchment development in small river valley, (2) to recognize local changes in a small river valley, (3) to estimate the usefulness of paleoecological research, especially cladoceran based reconstructions, of floodplain paleolakes and mires in climate studies.

2. Regional setting

The Pawłowa site is located in the central part of the Polish Lowlands, in the Łódź region (Fig. 1A) near to the town of Łask. It lies in the middle part of the Grabia River's course and covers the area about of 7.7 ha. The studied site is located within the valley reach, forming a wetland basin approximately 4 km long and 0.5–1.2 km wide (Fig. 1B). The paleolake is located in a marginal part of the valley floor and occupies a slight depression within the floodplain (Fig. 1C,D). It is presently covered by an alder swamp. The Grabia River is a natural river that inflows to the Widawka River (the tributary of the Odra River). In the studied area, the Grabia is mostly regulated, but detailed geomorphological analysis demonstrates its sinuous channel pattern. The floodplain is characterized by the presence of meadows and swamps. The study site is situated within an area that was covered by ice sheet during the Warthian Stadial of the Odranian Glaciation. Glacial and glaciofluvial deposits are present on an area surrounding the valley. Fluvial sediments (Late Glacial and Holocene alluvium) make up a large part of the valley fill. General descriptions of the geological and geomorphological characteristics of the Grabia valley have been presented by Klatkowa (1984) and Turkowska (2006).

3. Material and methods

3.1. Fieldwork

Two sediment cores for the paleobiological and geochemical studies were collected from the Pawłowa site (51°30′19″ N; 19°19′59 E) where the thickest organic deposits were found, in the deepest depression lying in the southern part of the Grabia floodplain (Fig. 1C,D). The sediment cores to be analyzed were taken using a manual Instorf corer with a diameter of 5 cm and length of 50 cm. A parallel coring hole, approximately 0.5 m away from the main core, was extracted to ensure that a complete record was recovered; the samples for macrofossil analysis and radiocarbon dating were collected from this core. Furthermore, geological drillings (at depths of ca. 200–400 cm, with a distance between drillings of ca. 50–100 m) were made in this part of the Grabia valley.

The 450-cm thick Pawłowa depositional sequence consists of fluvial sands, gyttja, and various types of peat (Fig. 1D). The bottommost sediments in the depression are sands. Above, at a depth of 444–256 cm, is gyttja with sand intercalations at the bottom (444–432 cm). Peat is found from 256 cm upward.

In the laboratory, the cores were sliced into 4-cm interval sections for further investigations and stored in a cold room.

3.2. Geochemical data

Sediment samples were dried at 105 °C and homogenized in an agate mortar. The organic matter (OM) content was determined by loss on ignition (LOI) at 550 °C, following the protocol described by Heiri et al. (2001). Terrigenous (SiO_{2ter}) and biogenic (SiO_{2biog}) silica were analyzed as in Woszczyk et al. (2009). The Scheibler volumetric method was used to determine the carbonate content of the sediments. The amounts of Al, Na, K, Mg, Ca, Fe, Mn, Pb, Zn, and Ti in the sediments were measured as soluble concentrations using an atomic absorption spectrophotometer. The proportions of these compounds can serve as the basis for reconstructions of environmental changes in the biogenic accumulation reservoir and its surroundings. Because K, Mg, Al, and Ti may be passively supplied to the lakes through the crystal structures of aluminosilicates, or as ions absorbed by clay minerals, their frequencies can serve as indicators of the relative changes in mechanical denudation processes. In turn, increasing Ca/Mg and Na/K ratios may indicate a considerably higher temperature and humidity in the environment and an increase in chemical denudation. We also use the Fe/Mn ratio as an indicator of the changes in the water table in the mire; theoretically, the higher the water table, the lower the redox potential within the deposit-forming environment.

3.3. Paleobiological data

For palynology, sediment samples of 1 cm^3 were prepared for microscopic analysis following the standard methods (Berglund and Ralska-Jasiewiczowa, 1986), including treatment with cool HF for the removal of mineral components and acetolysis for three