Palaeogeography, Palaeoclimatology, Palaeoecology 438 (2015) 34–50

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

A multiproxy study of Younger Dryas and Early Holocene climatic conditions from the Grabia River paleo-oxbow lake (central Poland)

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ARTICLE INFO

Article history:
Received 20 January 2015
Received in revised form 1 July 2015
Accepted 20 July 2015
Available online 30 July 2015

Keywords:
Paleoclimate
Cladocera
Pollen
Chironomidae
Younger Dryas
Early Holocene

ABSTRACT

A multi-proxy reconstruction of water depth, temperature and precipitation inferred from Cladocera, Chironomidae and pollen assemblages has been obtained from Świerczyna paleo-oxbow (central Poland) during the Younger Dryas (YD) and Early Holocene. Results suggest that the YD was relatively cold and comprised two main phases. The first (ca. 12,500–12,000 cal. yrs BP) is characterized by a continental climatic regime and a decrease in winter temperatures and precipitation but an increase in spring/summer precipitation. The second phase (ca. 12,000–11,500 cal. yrs BP) was more mild with a variable continental climate, an increase in summer and winter temperature, a lengthening of the growing season and increased annual precipitation. The reconstructed water level generally follows changes in spring and summer precipitation and length of growing season. The frequency and timing of hydroclimatic oscillations at Świerczyna show strong similarities to records from other sites in Europe. This confirms that oxbows and valley mire ecosystems respond to rapid climate change during the YD and Early Holocene. This study therefore brings new insights into the effects of climate changes on river environments, especially during the YD. We also discuss the limitations of water depth, temperature and precipitation reconstructions inferred from the studied biotic assemblages.

1. Introduction

The Late Glacial, especially the Younger Dryas (12,846–11,653 cal. yrs BP (in Greenland ice cores; Rasmussen et al., 2014); 12,650–11,500 cal. yrs BP (in Poland; Goslar et al., 1993; Starkel et al., 2013)), is characterized by a series of rapid climatic changes that are recognizable in many lake, peatland and riverine records from Central and Eastern Europe (Goslar et al., 1995; Isarin et al., 1998; Brauer et al., 1999; Isarin and Bohncke, 1999; Isarin and Renssen, 1999; Starkel, 2002; Kaiser et al., 2012; Turner et al., 2013). This period is a transition from the Last Glaciation to the interglacial Holocene (Björck, 2006; Lowe et al., 2008) and caused biotic changes in response to fluctuations in temperature (Płóciennik et al., 2011) and changes in river environments (Starkel et al., 2007; Petera-Zganiacz et al., in press). A recent syntheses of paleo-records covering the period between 60 and 8 ka throughout Central Europe suggests that YD cooling in Central and Western Europe was relatively synchronous (Feurdean et al., 2014; Moreno et al., 2014). Unfortunately, there are only a few quantitative and semiquantitative records of past climate and biotic response from Central and Eastern Europe covering the Late Glacial and the YD period with a high temporal resolution (e.g., Coope et al., 1998; Feurdean et al., 2008; Tóth et al., 2012; van Asch et al., 2012; Heiri et al., 2014; Veski et al., in press).

Oxbow lakes and floodplain water bodies are rich archives of past environmental changes on annual or even seasonal time scales (Pithart at el., 2007). They are regularly flooded and mostly eutrophic and contain highly diverse and temporally variable biotic communities (Simões et al., 2013; Vadadi-Fülöp, 2013). Oxbow lakes and valley mire sediments provide a comparable alternative to lake and mire sedimentary deposits (Millet et al., 2012) for the study of past environmental change (Gandouin et al., 2006, 2007; Pawłowski et al., 2012) especially in regions where there are few other records. High sedimentation rates provide fine stratigraphic resolution for the study of long-term patterns

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http://dx.doi.org/10.1016/j.palaeo.2015.07.031

in climate and river behavior. These sediments are important archives of past geological, hydrological and climatic changes in Europe (Dambeck and Thiemeyer, 2002; Schneider et al., 2007; Hoffmann et al., 2008; Gaigalas et al., 2013), and Poland (e.g., Starkel, 1990; Kozarski, 1991; Starkel et al., 1996; Kalicki, 2006). However, these studies have made little use of micropaleontological methods, especially in a multi-proxy approach. Aquatic invertebrates, especially cladocerans, are excellent tools for the reconstruction of past hydrological changes (e.g., water level and floods) (Korhola et al., 2000; Luoto et al., 2011; Nevalainen et al., 2011) and also pH and the trophy of waters (Korhola and Rautio, 2001). Chironomids are useful in reconstructions of summer temperature, especially the temperature of the warmest month (Brooks et al., 2007; Brooks and Langdon, 2014). Although local in-lake changes may influence the composition and abundance of cladoceran and chironomid communities, their abundance and diversity is also influenced by climate fluctuations (e.g., Engels et al., 2008; Pawłowski, 2012; Pawłowski et al., 2012; Brooks and Langdon, 2014). Studies that combine in an integrated approach, using both sedimentological and biological evidence to reconstruct major water-level changes in the paleolakes of Europe, are rare (Pawłowski et al., 2013).

This paper aims to bring new information on past climatic changes in a climatically transitional area between Eastern and Western Europe, and to quantify climate changes during the YD. This study focuses on paleoenvironmental information, especially hydroclimatic events, from a YD fossil oxbow. We provide a multi-proxy reconstruction of temperature, continentality, growing season length and precipitation during the YD from pollen, cladoceran and chironomid assemblages. We aim to connect local habitat changes to regional multi-centennial climate trends. Pollen-based temperature/precipitation transfer functions (Peyron et al., 2005, 2013) have never before been tested on oxbow lake sediments and the results are compared with chironomid and cladoceran inferred environmental changes. Additionally, cladoceran and chironomid assemblages have not previously been used to reconstruct water depth from paleo-oxbows in Central Europe. We discuss in detail the reliability of the cladoceran- and chironomid-based reconstructions, and also compare the inferred water-level changes with the main phases of fluvial activity elsewhere in Europe. Our study brings new insights into the impact of climate change, especially the influence of temperature and precipitation, on river environments.

2. Study area

Świerczyna paleo-oxbow lake is located in the central part of the Polish Lowlands, in the Łódź region (Fig. 1A). The studied site lies on the floodplain terrace of the Grabia River (Fig. 1B), in the outer part of the valley floor and occupies an abandoned paleochannel (Figs. 1B and C). The Grabia is a semi-natural, mostly unregulated, tributary of the Widawka River (within the Odra River catchment). This river belongs to the class of small (81 km long), meandering lowland rivers (Table 1). The main part of the Grabia River valley was filled by Late Glacial and Holocene alluvium. The surrounding area of the valley was formed during the Pleistocene glaciation (Saalian) and is filled by glaciofluvial sand and gravel with the till horizon on top (Figs. 1C and D). General descriptions of the geological setting of the Grabia valley have been presented by Baliński and Gawlik (1986), and Krzemiński and Bezkowska (1987). At present, the vegetation around the site is dominated by alder (*Ribeso nigri-Alnetum*, *Sphagno squarrosi-Alnetum* and *Fraxino-Alnetum* communities).

The study area is located in the temperate transitional climate zone (Woś, 1999) between west-oceanic and east-continental climatic conditions, which causes variable weather conditions (Table 1). These unstable weather conditions, due to the collision of moist, mild air masses from the Atlantic with dry air from the Eurasian continent, cause strong weather contrasts over the year, month, or even days. Atlantic air masses bring humid, cloudy weather to central Poland, more balanced temperatures between winter and summer seasons. Continental air masses bring sunny weather, and more extreme seasonality (high temperatures during summer and very cold conditions in winter). These influences cause significant changes from year to year in the length of the growing season and in winter conditions, which are either wet and cold, or – less often – sunny and dry.

3. Materials and methods

3.1. Field and laboratory methods

A 330-cm long core of the complete oxbow-lake sediment succession was collected (using a manual Instorf corer (Eijkelkamp Agrisearch Equipment BV)) from the paleo-oxbow ($51^{0}28.024'$ N, $018^{0}59.895'$ E; elevation: 145.9 m a.s.l) where the thickest organic deposits were found (Figs. 1B and D). Furthermore, geological drillings (at depths of ca. 200–400 cm, with distance between drillings of ca. 50–100 m) were made in the studied part of Grabia valley.

In the laboratory, the core was sliced into 1-cm intervals.

For the pollen analysis, 1 cm^3 sediment sample was processed according to the standard method of Berglund and Ralska-Jasiewiczowa (1986). In each sample, 500 terrestrial pollen grains were analyzed. The pollen percentages were calculated based on the sum of trees and shrubs (AP) and herbs (NAP, except aquatic and wetland plants). For identification of pollen types, the keys of Beug (2004), Punt and Clark (1984), as well as a reference collection, were used.

For Cladocera analysis 1 cm^3 of fresh sediment sample were processed according to the standard procedure of Frey (1986). A minimum of 200 cladoceran remains per sample was identified. The most abundant body part was chosen to represent the number of individuals for each species, and the relative proportions for all taxa were calculated from this sum of individuals. The identification, taxonomy of cladoceran remains, and methodology of Cladocera analysis follows Szeroczyńska and Sarmaja-Korjonen (2007). Chydorid carapaces (representing asexual reproduction) and ephippia (representing sexual reproduction) were also counted. The total chydorid ephippia (TCE) was calculated from the sum of chydorid carapaces and chydorid ephippia (Sarmaja-Korjonen, 2003).

Chironomid preparation methods followed Brooks et al. (2007). Sample volume ranged from 3 cm^3 when concentration of head capsules in the sediment was high to 60 cm^3 when the concentration of subfossils was very low. In the latter case kerosene flotation (Rolland and Larocque, 2007) was used for head capsules extraction. Up to 209 head capsules were picked from each sample. For chironomid identification, Brooks et al. (2007) was used together with a reference collection.

3.2. Paleohydraulic estimates

The width of the paleochannel was measured from aerial photographs and from core analyses. Paleohydraulic estimations have been made by applying the following methods and formulas (Fig. 2). Bankfull depth of the thalweg is estimated as an equivalent of the thickness of point-bar sands (i.e., fining-up cyclothems with fine sand in lower part and silty sand in the upper one), using the formulae of Bridge and Diemer (1983) and Mohrig et al. (2000). Bankfull depth in the inter-meander reach was estimated from formulae presented by Allen and Mange-Rajetzky (1982). Paleochannel sinuosity and meander radius were estimated from aerial photographs and detailed topographic maps (1:10,000) because the traces of erosional and depositional fluvial processes are still visible on the floodplain (Fig. 1B). The channel slope S_c was estimated from the function of floodplain slope S_f and channel sinuosity sin ($S_c = S_f\, sn^{-1}$). Flow velocity of the YD river was estimated as an average value from the Manning equation and its modifications (Gonera, 1986; Kozarski et al., 1988), as well as Bogardi (1974) and