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Holocene tephrostratigraphy of varved sediment records from Lakes Tiefer See (NE Germany) and Czechowskie (N Poland)

Sabine Wulf [a, b, *], Nadine Dräger [a], Florian Ott [a], Johanna Serb [a], Oona Appelt [c], Esther Guðmundsdóttir [d], Christel van den Bogaard [e], Michał Słowiński [f], Mirosław Błaszkiewicz [f], Achim Brauer [a]

[a] GFZ German Research Centre for Geosciences, Section 5.2 – Climate Dynamics and Landscape Evolution, Telegrafenberg, D-14473 Potsdam, Germany
[b] Senckenberg Research Institute and Natural History Museum, BIK-F, TSP6 Evolution and Climate, Senckenberganlage 25, D-60325 Frankfurt a.M., Germany
[c] GFZ German Research Centre for Geosciences, Section 3.3 – Chemistry and Physics of Earth Materials, Telegrafenberg, D-14473 Potsdam, Germany
[d] Faculty of Earth Sciences, Institute of Earth Sciences, University of Iceland, Strulugata 7, 101 Reykjavík, Iceland
[e] Helmholtz Centre for Ocean Research Kiel, GEOMAR, Wischhofstrasse 1-3, D-24148 Kiel, Germany
[f] Polish Academy of Sciences, Institute of Geography and Spatial Organization, Department of Environmental Resources and Geohazards, Kopernika 19, Torun 87-100, Poland

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ABSTRACT

A detailed Holocene tephrostratigraphic framework has been developed for two predominately varved lake sediment sequences from NE Germany (Lake Tiefer See) and central N Poland (Lake Czechowskie). A total of thirteen tephras and cryptotephras of Icelandic provenance were detected and chemically fingerprinted in order to define correlatives and to integrate known tephra ages into the sediment chronologies. Out of these, three cryptotephras (Askja-AD1875, Askja-S and Hässeldalen) were identified in both records, thus allowing a detailed synchronization of developing high-resolution palaeoenvironmental proxy data. The early Holocene Saksunarvatn Ash layer and the middle Holocene Lairg-B and Hekla-4 cryptotephras in Lake Tiefer See are further important anchor points for the comparison with other high-resolution palaeoclimate records in Central and Northern Europe. Tentative correlations of cryptotephras have been made with a historical basaltic Grimsvötn eruption (~AD890 – AD856) and three late Holocene rhyolitic eruptions, including the 2.1 ka Glen Garry and two unknown high-silicic cryptotephras of probably Icelandic provenance (~1.9 cal ka BP).

1. Introduction

In the light of global warming and possibly related socio-environmental responses it is essential to understand the mechanism and timing of abrupt climate changes. Past climate variability can be best reconstructed by studying high-resolution geological records, e.g. annually laminated (varved) lake sediments. However, such records are rare in northern central Europe and are restricted to either the Lateglacial (e.g. Brauer et al., 1999; Goslar et al., 1999, 1993; Merkt and Müller, 1999; Neugebauer et al., 2012) or the Holocene epoch (e.g. Dörfler et al., 2012; Enters et al., 2010; Zolitschka, 1990).

The Virtual Institute for Integrated Climate and Landscape Evolution Analyses ICLEA (www.iclea.de) aims at the continuous and high-resolution reconstruction of past climate variability and environmental changes in the northern central European Lowlands since the end of the last Ice Age. A current focus is set on two predominately varved sediment sequences from NE Germany (Lake Tiefer See; Dräger et al., 2014) and central N Poland (Lake Czechowskie; Ott et al., 2014). A high-resolution palaeoenvironmental reconstruction and the establishment of independent chronologies of both records is in progress and will enable the determination of effects of spatial and temporal climatic changes due to the existing gradient of increasing climatic continentality from the western (Tiefer See) towards the eastern archive (Czechowskie). Independent chronologies will be achieved by varve counting, radiometric

* Corresponding author. Senckenberg Research Institute and Natural History Museum, BIK-F, TSP6 Evolution and Climate, Senckenberganlage 25, D-60325 Frankfurt a.M., Germany.
E-mail address: Sabine.Wulf@senckenberg.de (S. Wulf).

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dating and tephrochronology. The latter method involves the use of tephra layers (volcanic fallout material) in sedimentary repositories as a dating and synchronization tool (e.g. Lowe, 2011). Several distinct tephras of Icelandic and Eifel provenance have been reported from sites in NE Germany and western Poland, i.e. the Saksunarvatn Ash (Bramham-Law et al., 2013), the Askja-S, Hässeldalen and Laacher See tephras (e.g. Housley et al., 2013a; Juvigné et al., 1995; Lane et al., 2011b; Riede et al., 2011; Wulf et al., 2013). Those tephras, however, are restricted to the Lateglacial and early Holocene epoch. The identification of younger tephras is so far limited to a single finding of the late Holocene Glen Garry cryptotephra (non-visible tephra) in an archaeological site in NW Poland (Housley et al., 2013b).

In this study, we present a comprehensive tephrostratigraphy for the northern central European Lowlands for the last ca 11,500 years, constrained from the ICLEA sites Lake Tiefer See and Lake Czechowskie. The tephra results are used to construct robust tephrochronologies for both records in order to support their varve chronologies. They furthermore provide important anchor points for the synchronization of palaeo-proxy data of these records with each other and with other high-resolution terrestrial records in northern-central Europe.

2. Study area

Lake Tiefer See (TSK = Tiefer See Klocksin) and Lake Czechowskie (JC = Jezioro Czechowskie) are both located in the northern central European Lowlands in the foreland of the terminal moraine of the Pomeranian ice advance of the last glaciation, which is dated at 15.6 ± 0.6 ^{10}Be ka (Rinterknecht et al., 2014) (Fig. 1). Both lakes have a melt genesis, namely lake basins formed by the melting of buried ice blocks (Błaszkiewicz, 2011, 2015; Kaiser et al., 2012; Loon et al., 2012; Słowiński, 2010; Słowiński et al., in press). Lake Tiefer See is a 1.6 km N–S elongated lake located in the natural park of Nossentiner-Schwinzer Heide, NE Germany (53°35.5′N, 12°31.8′E, 62 m a.s.l.). It is part of the Klocksin Lake Chain that formed in a subglacial gully system during the last deglaciation. The lake has a surface area of 0.75 km^2 and a maximum water depth of 62.5 m (Dräger et al., 2014; Kienel et al., 2013).

Lake Czechowskie is situated in the eastern part of the Pomeranian Lakeland in the Tuchola Pinewoods, central N Poland (53°52.2′N, 18°14.1′E, 108 m a.s.l.). The current lake together with the adjacent Trzechowskie palaeolake (TRZ) basin (53°52.4′N, 18°12.9′E, 111 m a.s.l.) developed in a subglacial channel in the outwash plain of the Wda river, which was accumulated during the retreat of the Late Weichselian ice sheet recession between 17 and 16 cal ka BP (Błaszkiewicz et al., 2015; Marks, 2012). Lake Czechowskie has an oval-shaped basin with a surface area of 0.73 km^2 and a maximum water depth of 32 m (Błaszkiewicz, 2005; Ott et al., 2014).

Lake Tiefer See and Lake Czechowskie are both located in a distal position to Icelandic volcanoes (2150–2400 km SE) and the W German Eifel Volcanic Field (500–840 km NE).

3. Methods

3.1. Sediments and developing chronology

3.1.1. Lake Tiefer See

In the years 2011 and 2013, a total of seven parallel sediment sequences and several surface cores were recovered from the deepest part of Lake Tiefer See using an UWITEC piston corer (Fig. 1b). These sequences were used to construct a composite profile of 1083 cm length that reaches the basal glacio-fluvial sand deposits (Fig. 2a). Two sediment gaps probably of several decimetres each occur at 769.5 cm and 956.5 cm depth as a result of technical problems during coring. The chronology of the composite profile is under construction and will incorporate several dating methods, i.e. varve counting, estimation of sedimentation rates in poorly and non-varved sections, AMS-^{14}C dating (Dräger et al., 2014) and tephrochronology (this paper). Lacustrine sediments are characterized by alternating finely laminated and homogenous diatomaceous gyttia with various amounts of calcareous and detrital matter (Dräger et al., 2014; Kienel et al., 2013).

3.1.2. Lake Czechowskie

Four parallel and overlapping sediment sequences as well as numerous short cores were retrieved between 2009 and 2012 from

Fig. 1. Overview map of NE Germany and NW Poland showing the location of Lake Tiefer See (TSK) and Lake Czechowskie (JC). The red dotted line indicates the position of the southerly ice advance of the Pomeranian phase at the end of the Weichselian glaciation. Inlet map is showing the position of European volcanoes mentioned in the text (black triangles) in relation to studied sites (black stars). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)