

Sedimentary record of a late Saalian jökulhlaup: Case study in Siedlątków outcrop, Central Poland

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ABSTRACT

The aim of the research conducted in an outcrop of late Saalian sediments in Siedlątków (Central Poland) was to reconstruct extreme meltwater flows during a jökulhlaup on the basis of the geological record. A combination of field and laboratory lithological methods was used, which included: lithofacies analysis, analyses of grain-size distribution, shape and roundness of gravelly clasts. Examination of sediments made it possible to recognise palaeohydrological, sedimentation and deformation processes during and immediately after the flood. In particular, the simultaneous operation of water flows in four paths in the immediate foreland of the ice-front was reconstructed. Mechanisms of transport and sedimentation of deposits were determined.

Characteristic features of the analysed jökulhlaup deposits include erosional and deformational contact with the substrate, a high content of very coarse sediments, poorly sorted with predominant massive clast-supported gravels and boulders, the presence of rip-up clasts, inverse grading in the lower part of the profile, normal grading in the upper part, and similarities in clast shape and roundness and the ratio of local rocks to Northern origin rocks when compared to the surrounding Saalian till. The documented features allow for the following phases of jökulhlaup to be distinguished: initial, rising, high stage, and waning stage. During the reconstructed event, hyperconcentrated flow was dominant, whereas fluvial flow and debris flow were of lesser importance. The release of meltwater in the marginal part of the ice sheet came from the depression of the Koło Basin, to the north of the analysed sites. Complex deformation processes which occurred in the flood deposits and their substratum were also interpreted. The analysed jökulhlaup event resembles some minor glacial floods in the ice-contact zone of present-day Icelandic glaciers. Further research in marginal zones of Pleistocene ice sheets should account for their occurrence, as the analysed example indicates that jökulhlaups might have had considerable influence on the course of sedimentation processes in the marginal zones of ice lobes of Pleistocene ice sheets as well as in the marginal valleys and sandars.

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1. Introduction

The phenomenon of a jökulhlaup is best analysed and understood thanks to contemporary observations in the forelands of glaciers (e.g., Björnsson, 1992; Gudmundsson et al., 1995; Russell and Marren, 1999; Tweed and Russell, 1999; Carrivick et al., 2004; Marren and Schuh, 2009; Carling, 2013). In the Middle European Plain, traces of palaeo-jökulhlaups have only been presented by several authors. There are relatively few known sites within the extent of the Vistulian (Weichselian) glaciation in northern Poland (Zieliński, 1993; Zieliński and Van Loon, 2000, 2003; Szafraniec, 2008; Wysota et al. 2017). Deglaciation of the late Saalian ice sheet has left numerous traces of meltwater activity, recorded in various relief forms: end moraines, sandars, eskers, kames and marginal valleys. They cover vast areas, especially in central and eastern Poland. However, only a few studies have so far presented

evidence for the record of short and rapid events of jökulhlaup character (Rdzany, 2009; Godlewska, 2014; Frydrych, 2016). It follows that there is a gap in the recognition of the record of jökulhlaups in central Europe, especially as regards smaller-scale events. It is not clear whether such events were extraordinarily rare or not much attention has been paid to them to date. This encouraged the authors of this study to undertake detailed research, assuming that it could provide new data on meltwater dynamics in the ice-contact zone, that is in the marginal part of the ice sheet lobe and in its direct foreland.

The main aim of the research conducted in Siedlątków, central Poland, was to reconstruct by semi-quantitative methods, extreme meltwater flows and the accompanying processes on the basis of the geological record.

2. Geological and geomorphological setting

The study area is located in central Poland within the margin of the late Saalian ice sheet (Fig. 1A). Analysed outcrops are situated on the

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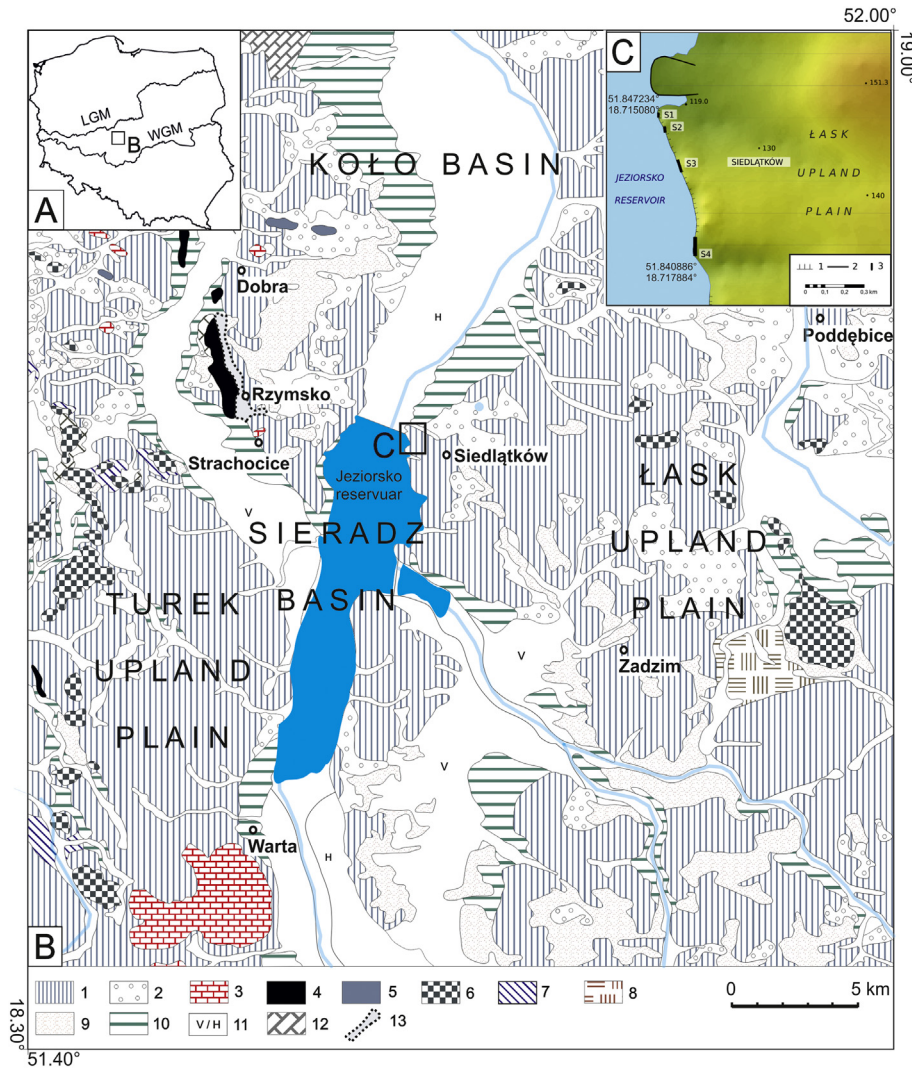


Fig. 1. The study area (research sites) against a background of: (A) maximum extent of the late Saalian glaciation (WGM) and Late Glacial Maximum (LGM); (B) landforms on the basis of modified geomorphological sketch (Klatkova and Załoba, 1992; Klatkova et al., 2007; Czyż et al., 2008; Kamiński and Forysiak, 2011): 1 – moraine plateau, 2 – glaciofluvial plains, 3 – moraine hills, 4 – eskers, 5 – forms of crevasse accumulation, 6 – kames, 7 – kame terraces, 8 – glaciolacustrine plains, 9 – dunes and sand plains, 10 – high terraces, 11 – bottoms of river valleys and flood plains (V – Vistulian, H – Holocene), 12 – excavations, 13 – tunnel valleys and meltwater valleys, (C) the location of the study sites (S1–S4), 1 – cliff, 2 – concrete barrier, 3 – sites.

border of the Łask Upland Plain and broadening of the Warta river valley called the Sieradz Basin (Fig. 1B). The examined glaciofluvial associations occur in four segments (from S1 to S4) of the cliff of Jeziorsko reservoir in Siedlątków (Fig. 1C), at elevations between 121 and 132 m a.s.l.

Quaternary deposits in the region of the Siedlątków sites are 15–60 m thick. The superstratum is built of Maastrichtian formations, with the prevalence of grey and white marls and limestones (Czyż et al., 2008; Rdzany et al., 2015). The lithofacies associations, revealed in the Siedlątków outcrop, are classified as late Saalian sediments, although it is possible the cores of diapiric structures originally came from older glaciations (Klatkova and Załoba, 1992). The main glacial sediment of the late Saalian is till, whose thickness reaches 5.0–10.5 m within the outcrops. In the vicinity of the cliff, a flat and undulating moraine plateau occurs. Its surface is built of glacial till, flow tills, and glaciofluvial associations, covered in places with aeolian sediments (Fig. 1). Thus, the analysed area, despite being located on the edge of a uniform moraine plateau, is found within the belt of considerable genetic diversity of landforms: glaciofluvial end moraines, kames, eskers and glaciotectonic ridges. This indicates a significant variability of ice sheet dynamics with the record of processes typical of the marginal zone (Czyż et al., 2008), including an ice sheet oscillation with features of glacial surge near Siedlątków (Rdzany, 2009).

3. Methods

Sediments were evaluated taking into account their structure and texture, with the use of the lithofacies codes (Miall, 1978) as modified by Zieliński (2014) (Table 1). The examined sections included glacial, glaciofluvial and glaciolimnic sediments of late Saalian glaciation with thickness of up to 10.5 m (Klatkova and Załoba, 1992; Czyż et al., 2008). The research concentrated on bouldery, gravelly and gravelly-sandy glaciofluvial sediments, which fill the erosional cuts in glacial till. Grain-size distribution of the sediments was analysed using direct measurements at the outcrops and in laboratory. Fractions exceeding 16 mm were subjected to photographic analysis using Digital Gravelometer software (Graham et al., 2005). For fractions finer than 16 mm, their grain-size distribution was analysed using the dry and wet sieving methods. Statistical parameters of the grain-size distribution were analysed on the basis of modified graphical measures by Folk and Ward (1957). They were calculated in GRADISTAT 8.0 (Blott and Pye, 2001). In order to investigate the flood sediment characteristics, gravelly clasts in the 8–128 mm fraction were analysed for shape, roundness and the ratio of Northern erratics to rocks of local origin. For determining the shape, axes of 100 clasts in each sample were measured (their length D_L , width D_I and thickness D_S). On this basis the

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