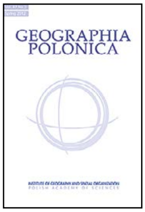

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THE QUESTION OF DRAINAGE OF THE WARSAW ICE-DAMMED LAKE, CENTRAL POLAND

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Abstract

The question of the outflow from the Warsaw ice-dammed lake in Central Poland through the Warsaw-Berlin ice-marginal spillway during the Vistulian (Weichselian) Glaciation is discussed. Many years' research and published concepts expressed in numerous publications since the beginning of the 20th century are presented. A runoff in the Warsaw-Berlin ice-marginal spillway was treated as impossible during the LGM, because of a high watershed zone close to Łęczyca. The floor of this ice-marginal spillway is filled by silt and sand series correlated with the Late Vistulian and sand with peat of the Late Vistulian and Holocene. However, a relation of the glaciolacustrine sediments and the spillway floor indicates that the latter is masked by deposits that postdate the outflow episode. Proglacial and extraglacial waters were collected in the Warsaw ice-dammed lake and were drained westwards through the Warsaw-Berlin ice-marginal spillway.

Key words

Weichselian • Warsaw-Berlin ice-marginal spillway • Warsaw Basin • proglacial drainage • Last Glacial Maximum

Introduction

A role of the Warsaw-Berlin ice-marginal spillway between the Warsaw Basin and the Koło Basin in Central Poland, and its relationship to the Warsaw ice-dammed lake, have been discussed since the beginning of the 20th century (Lencewicz, 1922; Samsonowicz, 1922; Jewtuchowicz, 1967; Różycki, 1967; Karaszewski, 1974; Wiśniewski, 2005). Major landforms in this area, including a wide floor of the Warsaw Basin, deeply incised by the Vistula River to the west of Warsaw, a palaeovalley of the Warsaw-Berlin ice-marginal spillway and the moraine plateaux were formed during the Warta Stadial of the Odranian (Saalian) Glaciation. The Scandinavian ice sheets advanced into this area and blocked the proglacial and extraglacial meltwater outflow. In the proglacial ice-dammed lake in the Warsaw Basin, varved clay and glaciolacustrine silt and sand were deposited (Merta, 1986; Brodzikowski & Van Loon, 1991; Brodzikowski, 1993). They were examined at many sites in the Middle Vistula valley, the lower reaches of the Narew, Wkra and Bzura River valleys, and correlated with the Odranian and Vistulian (Weichselian) glaciations (Merta, 1978). Filling up the ice-dammed lake and its possible draining to the west through the Warsaw-Berlin ice-marginal spillway were also discussed (Samsonowicz, 1922; Galon, 1972; Mojski, 2005; Molewski, 2014).

The aim of the paper is to present a current state-of-art of the afore-mentioned aspects, confronted with the contemporary landscape and geological data, especially from the Łęczyca narrowing of the Warsaw-Berlin ice-marginal spillway. A relatively high altitude of the valley bottom in this area provided numerous interpretation questions and objected the concept of the water runoff through the Łęczyca part of the spillway (Lencewicz, 1922; Mikołajski, 1927; Wiśniewski, 1987, 2003, 2005). The contemporary relief of the ice-marginal valley bed between Sochaczew and Łęczyca (Fig. 1) is crucial to solve this problem. The former valley bottom is inclined eastwards, starting from a topographic watershed at Łęczyca at 101.5-102.0 m a.s.l. (Wiśniewski, 2003, 2005; Turkowska, 2006). A bottom of the spillway descends towards the Koło Basin, but the spillway itself is filled with sediments that postdate the maximum extent of the Vistulian Glaciation. Among others, Jewtuchowicz (1967, 1970) presented several sites along the axis of the ice-marginal spillway in the Łęczyca section, where the Holocene and the Late Vistulian organic-mineral deposits were examined. This clearly indicates that the altitude of the contemporary bottom of this part of the Warsaw-Berlin ice-marginal spillway cannot be treated as a reference one for the water outflow possibility.

Tectonic activity of the sub-Cenozoic bedrock structures, arranged perpendicularly or obliquely to the axis of the valley (Poborski, 1957; Tarka, 1992; Dadlez et al., 1998), was often raised in discussion about the possible impact on the

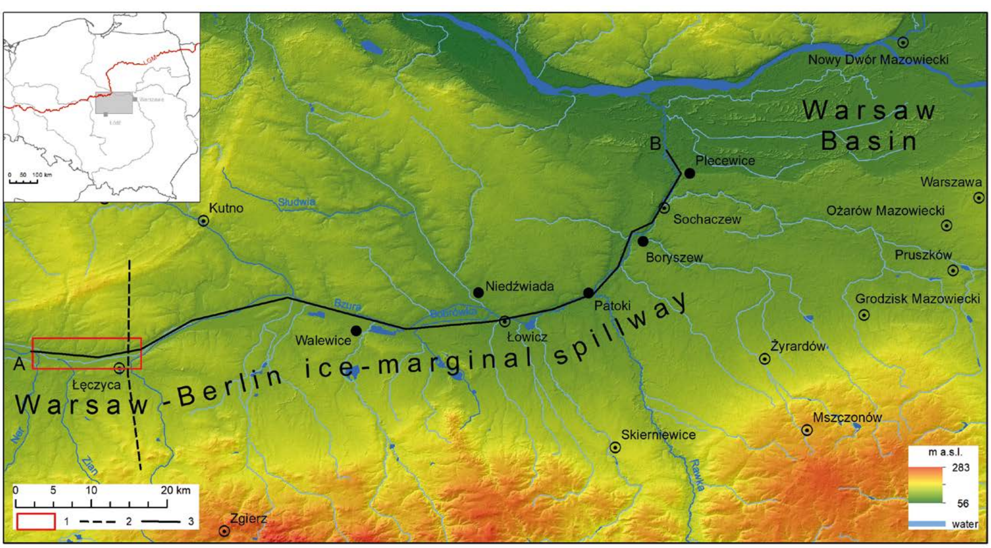

Figure 1. Digital Terrain Model of studied part of the Warsaw-Berlin ice-marginal spillway. 1 – map in Fig. 4, 2 – geological cross-section (Fig. 3), 3 – profiles in Fig. 2

water ouflow formation in the ice-marginal streamways in the Polish Lowland. This problem was discussed by Molewski (2007, 2014) for fragments of the Warsaw-Berlin ice-marginal spillway, the cases of the Łęczyca reach and the Bachorza River valley in the Kujawy Lake District. He suggested a significant uplift of the salt structures zones that could disturb the outflow from the Warsaw ice-dammed lake.

Study area

The Warsaw-Berlin ice-marginal spillway is an outstanding valley in the landscape of the Polish Lowland. Its section between Sochaczew and Łęczyca, located 30-40 km from the margin of the last ice sheet, is the most significant for the outlined problem (Fig. 1). The spillway has a varied width, with extensions to 5-7 km, separated by narrow (~1,5 km) segments. The present spillway bottom descends from ~101,5 m a.s.l. at the watershed in Łęczyca to ~70 m a.s.l. in Sochaczew (Figs 1, 2). At mouths of the Bzura tributaries, it is 95 m a.s.l. for Ochnia and 84 m a.s.l. for Słudwia.

Ice-dammed sediments and their basement

Glaciolacustrine deposits were examined at many sites in the Warsaw Basin and are arranged in 2-3 sequences (Baraniecka & Konecka-Betley, 1987) that suggest a possible three-phase development of the ice-dammed lakes. On the surface or under thin covering deposits there are series of the glaciolacustrine clay of the Vistulian and Odranian glaciations. It makes their chronological separation in isolated occurrences difficult (Merta, 1978) and determination of the age of the underlying deposits is crucial to solve this problem. Sarnacka (1982) and Baraniecka & Konecka-Betley (1987) identified the Eemian deposits below the varved clay at Błonie and Radzymin spillway terraces and considered them to have been formed during the maximum extent of the last ice sheet. The top of the glaciolacustrine series is located there at 80-89 m a.s.l. In the outcrop at Plecewice near Sochaczew, a top of the varved clay (about 10 m thick) occurs

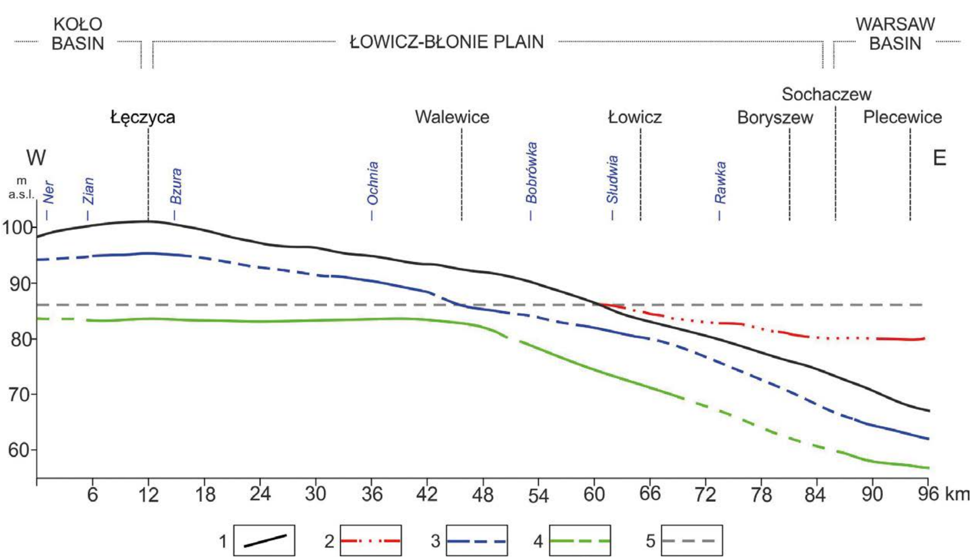

Figure 2. Longitudinal profiles of studied section of the Warsaw-Berlin of ice-marginal spillway. 1 – profile of spillway floor, 2 – top of varved clay of the Warsaw ice-dammed lake, 3 – bottom of Late Glacial and Holocene mineral-organic deposits, 4 – incision of LGM deposits in spillway axis, 5 – altitude of the maximum height of the varved clay top

at 80 m a.s.l. (Kalińska-Nartiša et al., 2016; Zawrzykraj, 2017), but it is an intermediate zone of the ice-dammed lake (Merta, 1986), correlated with the Poznań Phase of the last glaciation. At Marki, in the eastern part of the Warsaw Basin, a top of the varved clay in the outer zone of the lake was noted at 89 m a.s.l. (Dobak et al., 2018). At the edges of the Bzura River valley between Walewice and Sochaczew and in the lower part of the Słudwia River valley at Niedźwiada (Fig. 1), there are clay and silt patches, with their top at 86-87 m a.s.l. and their deposition was connected with the Vistulian Glaciation (Brzeziński, 1991). Such deposits are not found to the west of Walewice, at the bottom and the slopes of the Warsaw-Berlin ice-marginal spillway.

Equally important as the location of the varved clay series are the valley dimensions before the ice-dammed lake was filled up with water (Merta, 1986). Basin parameters can be estimated, based on occurrences of well-recognized fluvial and biogenic deposits. A location of the Eemian deposits in the Warsaw Basin indicates a deeply incised and wide river valley during the Eemian Interglacial (Marks & Pochocka, 1999). Interglacial formations occur at 65-72 m a.s.l. in Warsaw, and at 60 m a.s.l. in Wyszogród. To the west, along the axis of the Warsaw-Berlin ice-marginal spillway, a bedrock of the Weichselian deposits gradually rises. Eemian formations are rare and occur at ~55 m a.s.l. in the mouth area of the Słudwia River and the Vistulian series are underlain by the post-glacial Odranian sediments (Trzmiel, 2012). In the mouth of the Ochnia River, the sediments of the Vistulian Glaciation occur at 84 m a.s.l. (Fig. 2; Trzmiel, 2012).

A discontinuous layer of varved clay series, also occurring as patches, is primarily a result of subsequent fluvial erosion, which began immediately after the ice sheet retreat and initiation of the water outflow to the west, across the Płock Basin. A bottom of the Late Vistulian and Holocene deposits and their distribution indicate the depth of incision, and it is particularly important in the context of the basin palaeogeography during the Last Glacial Maximum (LGM). At present, a bottom of the ice-marginal valley between Sochaczew and Łęczyca, and further to the west, is covered with the Holocene and the Late Glacial biogenic and fluvial deposits, but their thickness and topography of the bedrock are varied. In the valley axis in Łowicz, a river incision after the LGM can be estimated to 72 m a.s.l. (Fig. 2; Brzeziński, 1991), with the modern land surface at ~83 m a.s.l. Jewtuchowicz (1967) documented a sandy series up to 15 m in the Łęczyca-Topola cross-section (Fig. 3). A peat layer at the floor, up to 4 m thick, was noted at several sites, both in the ice-marginal spillway (Łęka, Zbylczyce) and in the mouths of the tributary valleys (Jewtuchowicz, 1970). These deposits were pollen-analysed and assigned to the Late Glacial or the Holocene. In the Łęczyca section, a thickness of the peat in the floor of the Warsaw-Berlin ice-marginal spillway is varied, but the examination in the 1950s proved it to be up to 5 m thick (Fig. 4; Domosławska-Baraniecka, 1968). Then, the pre-Holocene valley floor was located at ~94 m a.s.l. in this section (Fig. 2). Occurrence of peat in the Łęczyca-Topola cross-section and radiocarbon dating of its bottom sample in the Le-1 profile in Łęczyca indicate (11,090±90; GdS4492) that the fen started growing at the end of the Late Glacial. It is important that sandy formations in the same place, with much organic material occur to 5.5 m depth, i.e. ~95 m a.s.l. Sediments of the Bzura alluvial cone in this area, covering a floor of the ice-marginal valley, are significantly reduced along the Bzura River (Forysiak, 2014).

Discussion

Geological and geomorphological research of the Bzura valley and its tributary valleys in the 1980s and 1990s resulted in questioning the proglacial outflow of the meltwaters through the Łęczyca section in the ice-marginal spillway during the Vistulian Glaciation (Wiśniewski, 1987; Andrzejewski, 1991; Wiśniewski & Andrzejewski, 1994). Based on

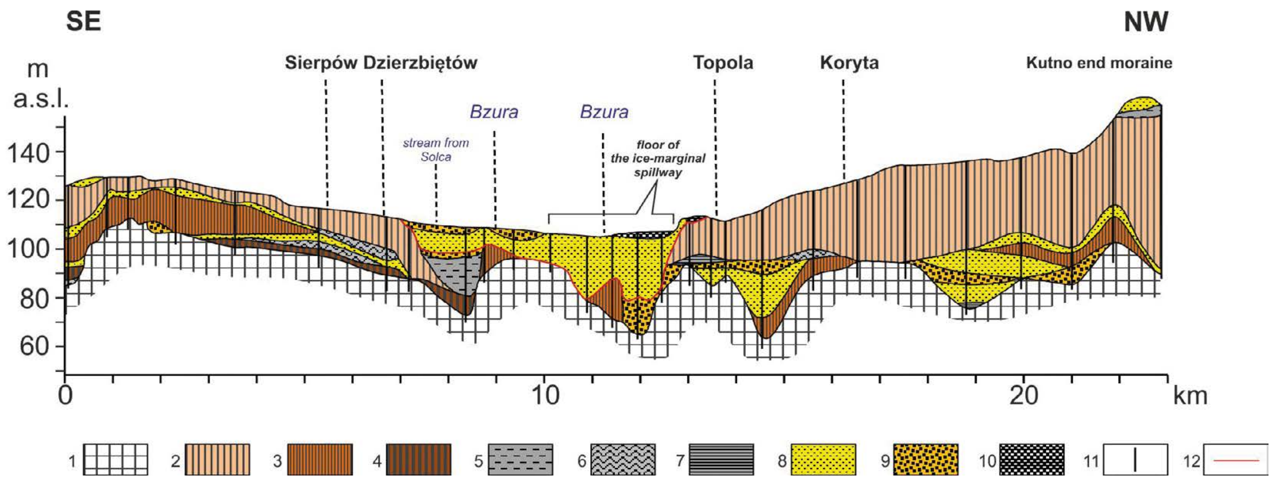

Figure 3. Geological cross-section of the Warsaw-Berlin ice-marginal spillway (after Jewtuchowicz, 1967), modifed. 1 – pre-Quaternary bedrock, 2 – till of Warta Stadial, 3 – till of Odranian Glaciation, 4 – till of Sanian Glaciation, 5 – silt, 6 – clay, 7 – varved clay, 8 – sand, 9 – gravel, 10 – peat, 11 – boreholes, 12 – bottom of Vistulian deposits

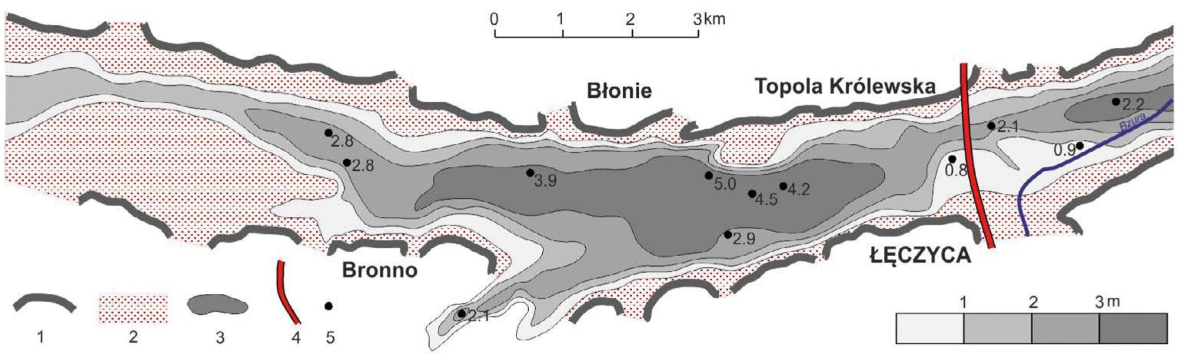

Figure 4. Peat thicknesses in the Warsaw-Berlin ice-marginal spillway (Bzura-Ner valley section) near Łęczyca (after Domosławska-Baraniecka, 1968). 1 – edges of the valley, 2 – range of river sands, 3 – peat isolines (every 1 m), 4 – embankment of road (DK 91), 5 – selected boreholes, confirmed peat thicknesses

the context of age and occurrence of varved clay series in the Warsaw Basin, Wiśniewski (2003) stated that the Warsaw-Berlin ice-marginal valley was inactive in some places during the Vistulian Glaciation. These problems were thoroughly discussed by Molewski (2014), who considered if the Warsaw ice-dammed lake could exist without an outflow. He found a subglacial outflow of proglacial waters, suggested by Wiśniewski (2005), difficult to accept. The estimation of infilling of the ice-dammed lake, carried out by Molewski (2014) showed that proglacial and extraglacial waters could fill the basin during a few years, then the outflow from the ice-dammed lake to the west was critical. There are 2 alternate outflow routes, one through the Warsaw-Berlin ice-marginal spillway at Łęczyca and further west to the Koło Basin and Pyzdry Basin or the other through the Bachorza Valley, as suggested by Wiśniewski (2005) and Molewski (2014). However, the latter could be possible if the ice sheet did not occupy the south-eastern part of the Kujawy Lake District (Molewski, 2014). The outflow route through the Bachorza Valley, proposed by Molewski (2014), could be active only during the Leszno Phase, when this area was not occupied by the ice sheet. On the other hand, it could not be activated during the Poznań Phase when this drainage was blocked by the ice sheet that occupied the entire Kujawy Lake District and the Płock Basin. In the western part of the Płock Basin, there are the Vistulian glaciolacustrine clay and silt series, 10 m thick (Brzeziński, 2015) and further west, already within the morainic plateau, they are mantled with a glacial till. Subsequently, these glaciolacustrine deposits were covered by the ice sheet during the Poznań Phase (Wysota & Molewski, 2011). Remarks and observations of Molewski (2014) and Brzeziński (2015) confirm that the Warsaw ice-dammed lake could exist both during the Leszno and the Poznań phases. It is of primary significance for considerations over the possible outflow from the ice-dammed lake through the ice-marginal spillway in the Łęczyca section.

Based on research in the Słudwia and Przysowa proglacial valleys, tributaries to the Warsaw-Berlin ice-marginal spillway east of Łęczyca (Andrzejewski, 1991; Wiśniewski & Andrzejewski, 1994), both Wiśniewski (2005) and Molewski (2014) postulated the altitude 84 m a.s.l. as the maximum water level of the Warsaw ice-dammed lake. This altitude corresponds to the modern bottom of the Bzura valley at the mouth of the Słudwia River, therefore its relation to the water level in the ice-dammed lake seems incorrect, although it was repeated in other interpretations. It led to a conclusion that considering the bottom level, the outflow of the Warsaw ice-dammed lake through the Warsaw-Berlin ice-marginal valley at Łęczyca could occur at 102 m a.s.l. (Wiśniewski, 2003, 2005; Turkowska, 2006). Such altitudes are actually noted at the topographical watershed in Łęczyca. However, a topography from about 18-24 ka BP should be taken into account in the interpretation. Previously mentioned results, considering the floor of the ice-marginal valley between Łęczyca and Topola prove that the Holocene and the Late Vistulian peat and biogenic deposits occur to 5-6 m depth. A top of a sand series in the valley axis, presumably deposited during the water flow out of the Warsaw Basin, is located at ~95 m a.s.l., then the contemporary river bottom was located at least 6 m beneath the one postulated by Wiśniewski (2005) and Molewski (2014). Another significant shortcoming of the conclusions based on the modern relief features is a reference of the contemporary valley floors at mouths of the Słudwia and Ochnia valleys to the altitude relations during the existence of the Warsaw ice-dammed lake Wiśniewski (2005). Brzeziński (1991) assumes an incision in the mouth of the Słudwia River at least to ~80 m a.s.l. a depth and occurrence of a patch of the Vistulian glaciolacustrine clay at 86-87 m a.s.l. (Niedźwiada site). In the Ochnia River valley mouth, the LGM deposits were eroded to 82 m a.s.l. Therefore, the altitude of the modern valley bottoms does not reflect the altitudinal relationships appropriate to the time when the outflow from the ice-dammed lake occurred.

The unacceptable water level of the ice-dammed lake at 102 m a.s.l. was also considered by Molewski (2014) for his filling-up estimation during the Vistulian Glaciation. Our analysis in the watershed zone in Łęczyca suggests that the maximum altitude was at ~95 m a.s.l. Besides, there are no glaciolacustrine deposits above the altitude of 90 m a.s.l. in the axis of the Warsaw-Berlin ice-marginal spillway. Within the Warsaw Basin, there are varved clay series up to 102 m a.s.l. (Różycki, 1967; Sarnacka, 1982), but they are correlated with the Odranian Glaciation.

In the Warsaw Basin, there is evidence for at least three-phase development of the ice-dammed lakes. Glaciolacustrine deposits on the land surface or under thin surficial deposits are attributed to the Vistulian and the Odranian glaciations, which makes their age assignment difficult. This is also due to the renewed trend to reactivate the north-western outflow of the proglacial and extraglacial waters during a retreat of the successive ice sheets. Fresh glaciolacustrine sediments were eroded and redeposited, and the network of the main river valleys was reactivated in the middle Vistula valley and the Warsaw-Berlin ice-marginal spillway, adapted by the lower Bzura River. During the Warta Stadial of the Odranian Glaciation, the ice sheet occupied the northern hinterland of the Warsaw Basin and a part of the Warsaw-Berlin ice-marginal spillway, thus blocking the water flow along the Vistula valley. It could have been the same ice sheet that formed the Kutno Moraines which, in its the western part, could block the water outflow from the Koło Basin. Then, the ice-dammed lake could occupy both the Warsaw Basin, overflowing into the Koło Basin, and the Uniejów Basin, where glaciolacustrine deposits from the Warta Stadial are well documented (Czarnik, 1972; Petera-Zganiacz et al., 2010; Pawłowski et al., 2013). The Eemian deposits were found beneath a varved clay series at the Błonie and Radzymin valley terraces, which were formed during the LGM and seem to be of key importance for stratigraphy of the varved sequences in the Warsaw Basin (Sarnacka, 1982; Baraniecka & Konecka-Betley, 1987).

An influence of the contemporary and postglacial halotectonic deformations of the ice-marginal spillway in Łęczyca, discussed by Wiśniewski (2003) and Molewski (2014), may have disturbed the original longitudinal profile of the spillway floor, dated at the Poznań Phase. The discussed range of influence of ice masses on the displacements of salt structures and their responses can be justified in the situation of direct encroachment of the ice sheet into the area affected by the halotectonic uplift (Lang et. al., 2014). During the Weichselian Glaciation, the area of salt structures near Łęczyca was approximately 30 km apart from the ice front. However, due to various controversies on the scale of such changes and their reflection in the contemporary topography, this aspect requires a more solid evidence. Anyhow, its impact on the relief of the floor of the Warsaw-Berlin ice-marginal spillway in Łęczyca could be insignificant.

Conclusions

There is no doubt that the Warsaw ice-dammed lake occurred during the Vistulian Glaciation, because a varved clay series is underlain by the Eemian deposits. The water body must have been drained permanently, because its blocking by the ice sheet lasted probably many times longer than a time, needed to fill up the reservoir.

The outflow route through the Bachorza River valley, postulated previously, could only function intermittently and it was not possible during the maximum extent of the ice sheet in the Płock Basin. Then, the only runoff was possible through the Warsaw-Berlin ice-marginal spillway. The several years' discussion, resulting in objection to such a possibility during the LGM, was based on a false assumption that the present altitude of the ice-marginal spillway floor in Łęczyca represents its location during the water outflow from the Warsaw ice-dammed lake.

Organic-mineral deposits of the Late Glacial and the Holocene are 5-6 m thick. Sandy series at the floor of the Warsaw-Berlin ice-marginal spillway between Łowicz and

Łęczyca and correlated with the Leszno and Poznań Phases are 12-15 m thick. Together with setting of a top of the varved clay series in the Łowicz area, it seems obvious that during the LGM, proglacial and extraglacial waters were collected in the Warsaw ice-dammed lake which was drained westwards through the Warsaw-Berlin ice-marginal spillway.

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Editors' note:
Unless otherwise stated, the sources of tables and figures are the author's, on the basis of their own research.

References

Andrzejewski, L. (1991). The course of fluvial processes in the lower Bzura river valley during the last 15 000 years. In L. Starkel (Ed.), *Evolution of the Vistula river valley during the last 15 000 years. Part IV* (pp. 147-154). Geographical Studies. Special Issue, 6. Wrocław: Ossolineum.

Baraniecka, M. D., & Konecka-Betley, K. (1987). Fluvial sediments of the Vistulian and Holocene in the Warsaw Basin. In L. Starkel (Ed.), *Evolution of the Vistula river valley during the last 15 000 years. Part II* (pp. 151-170). Geographical Studies. Special Issue, 4. Wrocław: Ossolineum.

Brodzikowski, K. (1993). *Sedymentacja glacilimniczna. Część I. Procesy depozycyjne oraz charakterystyka litofacjalna*. Acta Geographica Lodziensia, 62. Łódź: Łódzkie Towarzystwo Naukowe.

Brodzikowski, K., & van Loon, A. J. (1991). *Glacigenic Sediments.* Amsterdam: Elsevier. https://doi.org/10.1016/s0070-4571(08)x7049-9

Brzeziński, M. (1991). *Szczegółowa Mapa Geologiczna Polski 1:50 000. Arkusz Łowicz*. Warszawa: Państwowy Instytut Geologiczny.

Brzeziński, M. (2015). *Szczegółowa Mapa Geologiczna Polski 1:50 000. Arkusz Brześć Kujawski*. Warszawa: Państwowy Instytut Geologiczny.

Czarnik, J. (1972). Paleogeografia okolic Turka w górnym trzeciorzędzie i plejstocenie. *Studia Geologica Polonica, 40*.

Dadlez, R., Iwanow, A., Leszczyński, K., & Marek, S. (1998). Mapa tektoniczna kompleksu cechsztyńsko-mezozoicznego 1:500 000. In R. Dadlez (Ed.), *Mapa tektoniczna cechsztyńsko-mezozoicznego kompleksu strukturalnego na Niżu Polskim*. Warszawa: Państwowy Instytut Geologiczny.

Dobak, P., Kiełbasiński, K., Szczepański, T., & Zawrzykraj, P. (2018). Verification of compressibility and consolidation parameters of varved clays from Radzymin (Central Poland) based on direct observations of settlements of road embankment. *Open Geosciences*, *10*(1), 911-924. https://doi.org/10.1515/geo-2018-0072

Domosławska-Baraniecka, M. D. (1968). *Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000. Arkusz Łęczyca*. Warszawa: Państwowy Instytut Geologiczny.

Forysiak, J. (2014). Pradolina warszawsko-berlińska jako główna forma w morfologii terenu okolic Łęczycy. In R. Grygiel, & T. Jurek (Eds.), *Początki Łęczycy. Archeologia środowiskowa średniowiecznej Łęczycy. Przyroda – Gospodarka – Społeczeństwo. T. I* (pp. 23-38). Łódź: Muzeum Archeologiczne i Etnograficzne w Łodzi.

Galon, R. (1972). Główne etapy tworzenia się rzeźby Niżu Polskiego. In R. Galon (Ed.), *Geomorfologia Polski*, *Tom 2*, *Niż Polski* (pp. 35-110). Warszawa: Państwowe Wydawnictwo Naukowe.

Jewtuchowicz, S. (1967). *Geneza pradoliny warszawsko-berlińskiej między Nerem i Moszczenicą*. Prace Geograficzne, 62. Warszawa: IGiPZ PAN.

Jewtuchowicz, S. (1970*). Rozwój rzeźby okolic Łęczycy po zlodowaceniu środkowopolskim.* Prace Geograficzne, 85. Warszawa: IGiPZ PAN.

Kalińska-Nartiša, E., Dzierżek, J., Bińka, K., Borkowski, A., Rydelek, P., & Zawrzykraj, P. (2016). Upper Pleistocene palaeoenvironmental changes at the Zwierzyniec site, central Poland. *Geological Quarterly*, *60*(3), 610-623. https://doi.org/10.7306/gq.1280

Karaszewski, W. (1974). Age of the Warsaw Ice-Dammed Lake sediments. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, *22*(3-4), 151-156.

Lang, J., Hampel, A., Brandes, C., & Winsemann, J. (2014). Response of salt structures to ice-sheet loading: Implications for ice-marginal and subglacial processes. *Quaternary Science Reviews*, *101*, 217-233. https://doi.org/10.1016/j.quascirev.2014.07.022

Lencewicz, S. (1922). O wieku środkowego Powiśla*. Sprawozdanie z Posiedzeń Naukowych PIG, 3*, 21-24.

Marks, L., & Pochocka, K. (1999). River valleys of the Eemian Interglacial in central Poland. *Geological Quarterly*, *43*(2), 163-168.

Merta, T. (1978). Extraglacial varved deposits of the Warsaw Ice-Dammed Lake (younger Pleistocene), Mazovia Lowland, Central Poland. *Acta Geologica Polonica, 28*(2), 241-272.

Merta, T. (1986). Varve sedimentation in extraglacial ice-dammed lakes. *Acta Geologica Polonica, 36*(4), 325-336.

Mikołajski, J. (1927). O powstaniu tzw. pradoliny warszawsko-berlińskiej*. Badania Geograficzne nad Polską Północno-Zachodnią, 2-3*, 53-98.

Mojski, J. E. (2005). *Ziemie polskie w czwartorzędzie. Zarys morfogenezy*. Warszawa: Państwowy Instytut Geologiczny.

Molewski, P. (2007). *Neotektoniczne i glacidynamiczne uwarunkowania wykształcenia plejstocenu Wysoczyzny Kujawskiej.* Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika.

Molewski, P. (2014). Paleogeograficzne uwarunkowania odpływu wód z zastoiska warszawskiego doliną Bachorzy i pradoliną warszawsko-berlińską w czasie stadiału głównego zlodowacenia Wisły. *Landform Analysis, 25*, 105-114. https://doi.org/10.12657/landfana.025.009

Pawłowski, D., Gruszka, B., Gallas, H., & Petera-Zganiacz, J. (2013). Changes in the biota and sediments of glacial Lake Koźmin, Poland, during the late Saalian (Illinoian). *Journal of Paleolimnology*, *49*, 679-696. https://doi.org/10.1007/s10933-013-9692-z

Petera-Zganiacz, J., Czubla, P., Gruszka, B., Forysiak, J., Miotk-Szpiganowicz, G., Olszak, I., & Pawłowski, D. (2010). The Koźmin glacial lake – its origin, age, deposits and palaeoecology. In S. Lorenz, & R. Lampe (Eds.), *35 Hauptversammlung der Deutschen Quartärvereinigung DEUQUA E.V. and 12th Annual Meeting of the INQUA Peribaltic Working Group „Gletscher, Wasser, Mensch – quartärer Landschaftswandel im peribaltischem Raum"* (pp. 141-142)*.* Greifswald.

Poborski, J. (1957). O wstępnych badaniach struktury solnej pod Łęczycą*. Biuletyn Instytutu Geologicznego, 105*, 161-186.

Różycki, S. Z. (1967). *Plejstocen Polski Środkowej na tle przeszłości w górnym trzeciorzędzie.* Warszawa: Państwowe Wydawnictwo Naukowe.

Samsonowicz, J. (1922). Zastoiska lodowcowe nad górną i środkową Wisłą*. Sprawozdania Państwowego Instytutu Geologicznego*, *1*(4-6), 8-9.

Sarnacka, Z. (1982). Age revision of the Warsaw proglacial lake in the Warsaw region. *Biuletyn Instytutu Geologicznego*, *343*, 59-70.

Tarka, R. (1992). *Tektonika wybranych złóż soli w Polsce na podstawie badań mezostrukturalnych.* Warszawa: Państwowy Instytut Geologiczny.

Trzmiel, B. (2012). *Szczegółowa Mapa Geologiczna Polski 1:50 000. Arkusz Sobota*. Warszawa: Państwowy Instytut Geologiczny.

Turkowska, K. (2006). *Geomorfologia regionu łódzkiego.* Łódź: Wydawnictwo Uniwersytetu Łódzkiego.

Wiśniewski, E. (1987). Evolution of the Vistula valley between Warsaw and Płock Basins during the last 15 000 years. In L. Starkel (Ed.), *Evolution of the Vistula river valley during the last 15 000 years. Part II* (pp. 171-187). Geographical Studies. Special Issue, 4. Wrocław: Ossolineum.

Wiśniewski, E. (2003). The problem of outflow from the ice-dammed lake in the Warsaw Basin during the Leszno Phase. In A. Kotarba (Ed.), *Holocene and Late Vistulian Paleogeography and Paleohydrology* (pp. 123-142). Prace Geograficzne, 189. Warszawa: IGiPZ PAN.

Wiśniewski, E. (2005). Problem drogi odpływu wód z jeziora zaporowego w Kotlinie Warszawskiej podczas fazy leszczyńskiej. *Słupskie Prace Geograficzne*, *2*, 131-145.

Wiśniewski, E., & Andrzejewski, L. (1994). The problem of the Warsaw ice-dammed lake drainage through the Warsaw-Berlin Pradolina at the last ice-sheet maximum. *Zeitschrift für Geomorphologie. Supplementband*, *95*, 141-149.

Wysota, W., & Molewski, P. (2011). Chronologia i zasięgi nasunięć lądolodu na obszarze lobu Wisły podczas stadiału głównego ostatniego zlodowacenia. *Przegląd Geologiczny*, *59*(3), 214-225.

Zawrzykraj, P. (2017). Ocena parametrów filtracyjnych i*łów warwowych ze stanowiska Plecewice k. Sochaczewa w warunkach in situ. Przegląd Geologiczny*, *65*(9), 587-596.

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