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THE SUWAŁKI

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The Szeszupa depression, situated in the southern part of the Szeszupa Subglacial Valley, through which the waters of the glacial floods flowed towards the Bachanowo and Szeszupka Gates (A), and the flat bottom of the Szelment Wielki Subglacial Valley, feeding the outflow of the glacial floods via the Prudziszek Gate (B)

The landscape near the town of Suwałki in northeastern Poland shows intriguing signs of super-massive catastrophic flooding at the end of the last ice age

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The study of the geological past allows scientists to understand the processes that will likely be shaping the relief of the Earth's surface in the future, in response to climate change. This core principle of "geological actualism" is particularly important in the study of dynamic climate changes in past eras, which in the past of ten led to catastrophic alterations to the landscape. Understanding ancient geological processes is especially important when they triggered supra-regional changes in the natural environment. But are there still breakthrough discoveries to be made in the field of the Earth sciences, given the wide availability and extensive scope of our extant knowledge about the morphology and geological

CATACLYSM

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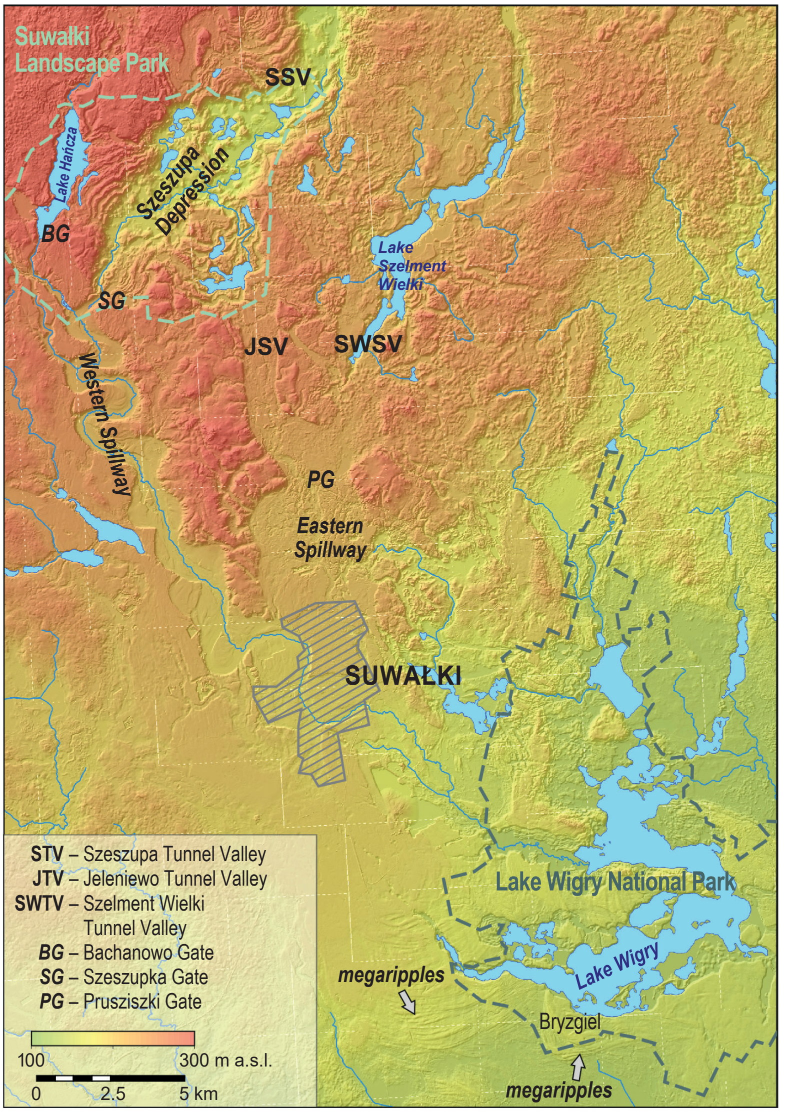
structure of the surface of the continents? Are there still major turning-points in geological history still waiting to be discovered?

New methodology – new findings

The use of LIDAR (Light Detection and Ranging) data, derived from laser scanning of the land surface, has indeed recently brought about a true breakthrough in scientific research in the field of Earth and environmental sciences, especially in the study of the origin of landforms. LIDAR data makes it possible to image the Earth's surface in the form of a high-resolution digital model and analyze it in detail in three dimensions. Such analysis has opened up new avenues of geomorphological research, making it possible to detect features of landforms that were previously unnoticeable out in the field or on topographic maps. Multidimensional analysis of numerical terrain models (NMTs) is a dynamically developing, modern method of studying landforms that lets us recognize many hitherto unknown indications of past phenomena of catastrophic impact and groundbreaking significance for the interpretation how modern landscapes emerged to be as they are. A new era of great discoveries in this field has therefore been ushered in by the application of these new methods in geomorphological, geographic, and geological research is the recognition of new genetic types of landforms. Many of these terrains were shaped at the end of the last glaciation, when an increasingly warmer climate touched off a rapid loss of glacier mass and the rapid disappearance of extensive ice sheets.

Glacial megafloods

The kinds of geological processes capable of making abrupt, large-scale, catastrophic changes to the Earth's landscape include the erosional and accumulation activity of rivers that have extremely large discharg-



The relief of the land surface and the main elements of the morphogenetic system left behind by the Suwałki glacial megaflood

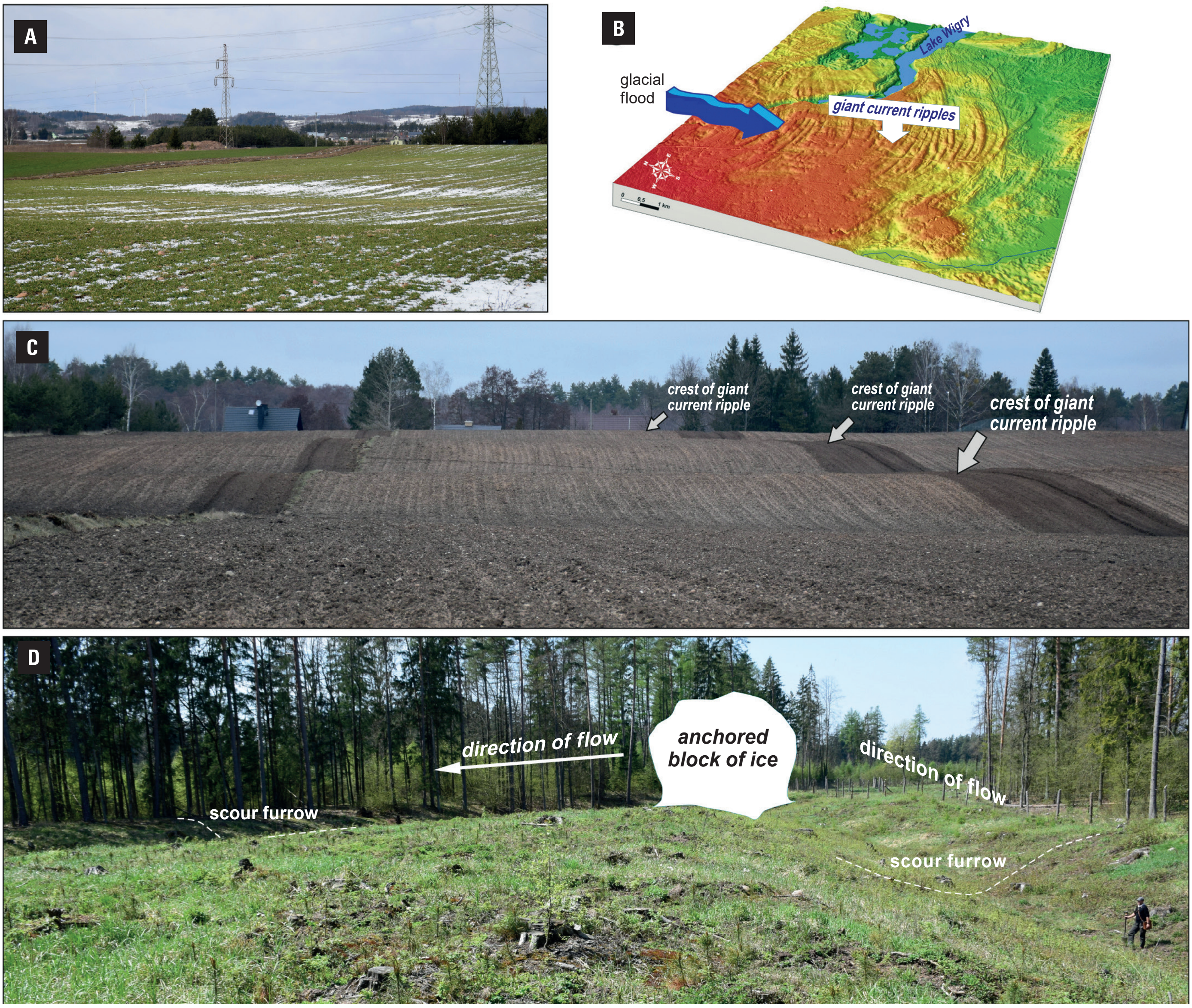
es. Both today and during the last ice age, such high outflows are only evident in glacial outburst floods, which can occur when large lakes formed by the accumulation of water from melting glaciers are abruptly released. The most spectacular and catastrophic glacial floods occur today in Iceland, where rivers fed by subglacial lakes have reached flows of up to nearly 1 million m^3/s. Evidence of much larger glacial floods has been uncovered in the United States, where meltwater collected in the glacial lakes Lake Missoula and Lake Agassiz – when these massive water bodies were released, the outburst flood was up to several million cubic meters per second. To compare the scale of these extreme processes, consider that the modern average flow of the Amazon River in its lower reach is estimated at 209,000 m^3/s. The large volumes of fresh meltwater that entered the Atlantic Ocean from the Scandinavian and Laurentian ice sheets at the end of the last glaciation disrupted the circulation of ocean currents and reduced the transmission of heat from low to high latitudes, and thus significantly contributed to global climate change. Finding evidence of these glacial megafloods has been crucial to our understanding of the genesis of the landscape of many regions of the world and indeed fundamental to explaining the causes of climate change at the end of the last glaciation.

Nearly 100 years after the initial discovery of the largest glacial outburst floods known on Earth, which occurred during the last glaciation in the eastern part of the US state of Washington (in the Columbia River basin), a pioneering study was undertaken in the Eastern Suwałki Lakeland and the Augustów Plain in the northeastern corner of Poland. The purpose of the research was to clarify the nature of the highly enigmatic landforms found in the district (to shed light on their morphological features, geological structure, age and origin). The first results led to the groundbreaking discovery of relief forms created in the forefield of the last Scandinavian ice sheet, as a result of the outflow of large amounts of water from a glacial lake, having the character of a glacial flood. These forms form a complete, coherent and spatially ordered system, formed as a result of the drainage of a subglacial lake during the last glaciation – a type of landform previously unknown in the European Lowland.

The evidence

Geomorphological studies conducted near the town of Suwałki located in NE Poland have identified specific landscape forms known to be typical for the aftermath of glacial flooding. They consist of two interrelated systems of glacial flood flow. The first is a subglacial drainage system (beneath the ancient ice sheet), draining a subglacial lake that probably existed in the area of modern Lithuania. This system comprises two subglacial valleys (the subglacial valley of today's Szeszupa/Šešupė river, and the valley today occupied by Lake Szelment Wielki), which show evidence of glacial flood flows in the form of deep depressions in their bottoms and mega-scale glacial curvilineations. The latter take the shape of large, elongated ridges running parallel to each other, forming clusters in the western and northern environs of the Szeszupa depression. These ridges reach up to 1.5 km in length, up to 300 m in width, and the channels separating them range up to nearly 40 m deep. Occurring on the surface of some of these ridges are boulder fields (the Łopuchowo Boulder Field being a prominent example), which are the result of the erosion of the substratum under the ice sheet by the waters of the glacial flood.

The second system, in turn, consists of landforms in the proglacial zone (in the forefield of the ancient ice sheet). These phenomena came to be recognized as signs of glacial flooding near Suwałki, and the vast scale of this ancient event began to be understood,



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Selected landforms located in the glacial foreland as a result of the Suwałki glacial megaflood:
A. the flattened bottom of the Eastern Spillway north of Suwałki,
B. a field of giant current ripples formed on the riverbed about 20–24 m deep as a result of the accumulation of sediments carried by the glacial flood south of Suwałki,
C. a field of giant current ripples located in the vicinity of Bryzgiel (south of Lake Wigry),
D. furrows formed as a result of the scouring flow around a ice block transported by the waters of the glacial flood, which became stranded on the riverbed in the final stage of flooding

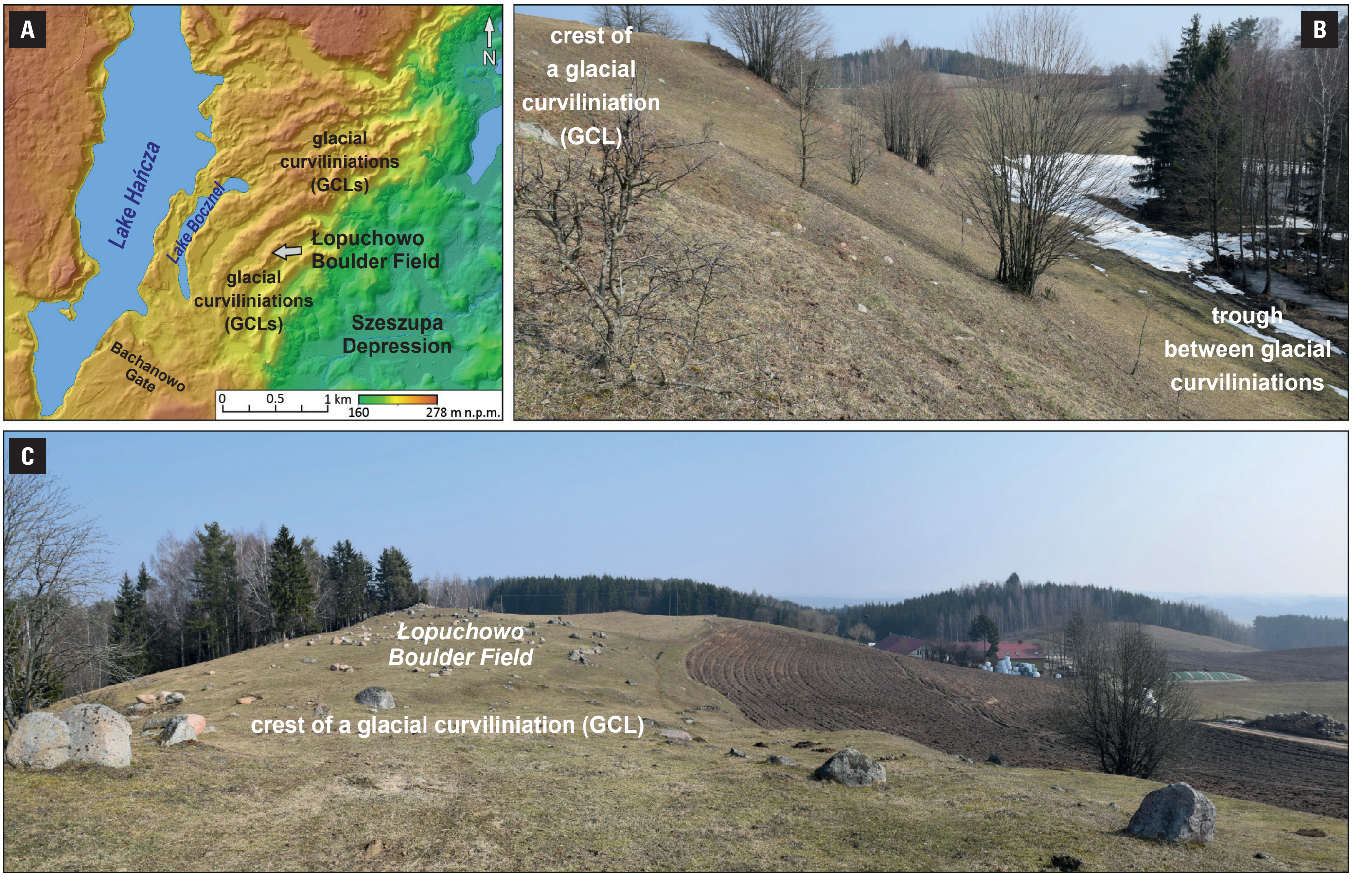
as a result of our geomorphological studies. In this zone there are two main proglacial valleys (eastern and western spillways), through which the waters of the glacial floods followed southward, starting from the glacial gates through which they flowed out from under the ice sheet. The Bachanowo and Szeszupka gates fed the western spillway, while the Prudziszki gate gave rise to the eastern spillway. The two spillways were the main arteries through which meltwater flowed toward Suwałki, where they formed a common outflow of glacial floodwaters. There the waters left behind an extensive and mostly flat surface, comprised of sand and gravel deposits carried in by the flow. South of Suwałki, this surface shows some variation, with a number of groups of similarly-shaped ridges bent into arches. They are also composed of sands and gravels accumulated by the meltwaters. The transverse profiles of these ridges are asymmetrical – the slopes on the northern side of each crestline have twice the slope of those on the southern side. These forms are interpreted as giant current ripples left behind by the massive flow, formed along the bottom of a wide and deep river fed by the waters of glacial floods. Morphologically similar current ripples, albeit many times smaller in scale, are found at the bottom of many rivers today. While the current ripples in modern rivers do not exceed tens of centimeters in height, the megaripples found south of Suwałki reach heights of up to 8.5 m (average 3.1 m) and widths of up to 420 m (average 163 m). Based on the size of the Suwałki megaripples, the depth of the glacial floodwaters flowing near Suwałki has been estimated at about 21 m. The magnitude of the flow of these waters reached up to 2 million m^3/s – allowing it to be classified as a glacial megaflood (as it is above 1 million m^3/s). Thus, the Suwałki glacial megaflood ranks among the largest such extreme events discovered on Earth to date.

The unique landscape system associated with the Suwałki glacial megaflood also includes other landforms typical of such events. A particularly characteristic element of the initial section of the eastern valley – one that is unique on a European scale – is a "scabland" type landscape (a landscape of hills and depressions formed by very rapid water flow), which was first recognized in the case of glacial floods in North America (in state of Washington). North of Suwałki, at the outlet of the Prudziszki gate, this type of landscape is dominated by a set of elongated or oval enclosed depressions, potholes formed as a result of erosion of the substrate by vortex systems (known as "kolks") propelled by the extremely fast water flow. In addition, the landforms that can be considered appropriate for glacial megafloods in the Suwałki area also include clusters of kettle holes. They form characteristic linearly oriented complexes, comprising up to a dozen circular or oval depressions with an average width of 29 m and length of 32 m. The sizes of these depressions correspond to the diameters of ice blocks that were carried by glacial waters during floods until the flow energy necessary for their further transport became spent. This occurred during the final phase of the glacial flood and resulted in the stranding of the ice blocks on the riverbed.

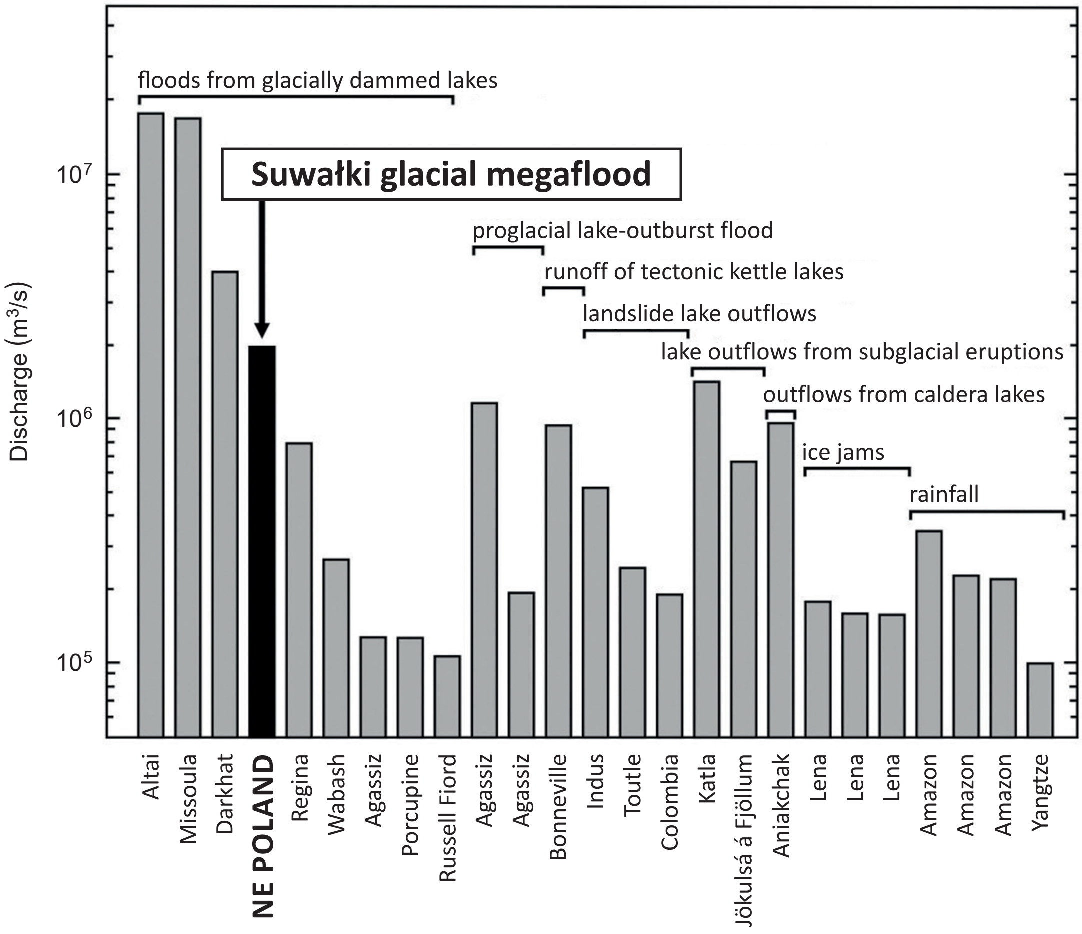
The successively decreasing depth of the flowing meltwater also led to the development of further evidence of glacial megafloods in the landscape around Suwałki. These signs include distinctive elongated depressions, formed symmetrically on the downstream side of the anchored glacial ice blocks. These depressions have the character of narrow and long "V" shaped furrows open in the direction of water flow and are called scour furrows (or scour marks). The scour furrows formed in the Suwałki area reach up to 760 meters in length.

The significance of the discovery

The landforms whose genesis is related to the immense glacial floods that occurred near Suwałki at



A. Location of the complex of winding glacial embankments ("glacial curviliniations" – GCL) in the western part of the Szeszupa Tunnel Valley.
B. The slope of the trough between two glacial curviliniations, formed as a result of glacial flooding beneath the Łopuchowo ice sheet.
C. The crest of one of the glacial curviliniations with the Łopuchowo Boulder Field located on it, which is the result of erosion of the substrate of the ice sheet during the glacial flooding



The magnitude of the flow of meltwater in the Suwałki glacial megaflood, as compared to other modern and past major flooding events around the world (based on O'Connor et al., 2002 and Herget, 2005)

the end of the last glaciation together form a complex and unique landscape system. Its uniqueness lies in its completeness, consisting of two integral parts – a set of subglacial forms (from under the ice sheet) and a set of proglacial forms (in front of the ice sheet) attesting to the flow of meltwater in catastrophic, megascale glacial floods. The discovery of this landform system was made possible by the application of modern methods of geomorphological research, in which the analyses of high-resolution numerical terrain model, developed on the basis of LIDAR data, were of considerable importance. Nowadays, such models have become one of the basic tools for making breakthroughs in earth and environmental sciences.

Alongside the discovery of a system of relief forms associated with glacial floods in northeastern Poland, the results of our reconstruction of the great magnitude of the flow of glacial flood waters has proven to be of breakthrough importance for understanding the genesis of the post-glacial landscape of Central Europe. Because the flow can be estimated at more or less 2 million m^3/s, it is appropriate to describe this as the "Suwałki glacial megaflood." Moreover, the results have enabled us to better appreciate the role of meltwater flows of extreme magnitude in the development of the river valley system in Europe, and also to recognize the extent of the contribution of the large-scale supply of fresh meltwater to the North Atlantic and its role in global climate change at the end of the last glaciation. The geomorphological results obtained so far have made it possible to correlate in time and space, and to determine the relationship of the catastrophic glacial floods of Suwałki with the main stages of relief formation in the European Lowlands and the stages of recession of the last ice sheet.

Thus, we can recognize the Suwałki glacial megaflood as a previously unknown, but major turning point in the geological history of Central Europe. It had a significant impact on the development of the basic arteries of the Central European valley system, supplying huge amounts of meltwater at the end of the last glaciation. ■

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Further reading:

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