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Morphology and sediments of ice-dammed lake after its outburst, West Greenland

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Formation of glaciolacustrine basins during glacier recession is predetermined by abundance of supraglacial, inglacial and subglacial waters. Replenishment of glaciolacustrine basins is followed by their sudden drainage associated with glacier outbursts and melting of buried ice in the areas of end moraines, or capture of glaciofluvial streams. The outburst flood that appeared on August 31, 2007 in the periphery of the Russell glacier (West Greenland) caused a rapid drainage of an ice-dammed lake, which exposed a large part of the bottom and the slopes of the basin. The water level in the basin during the drainage subsided by 55 m, and in 11 hours of outburst flood 20 900 000 m^3 of water escaped from the basin. The exposed bottom of the glaciolacustrine basin allowed evaluating the sediment complexes. The impact of glaciofluvial stream on the forms of relief was established as well.

Key words: glaciolacustrine basin, glaciofluvial stream, Outlet Lake, delta, outburst flood, diatoms, Russell Glacier, West Greenland

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INTRODUCTION

Glaciolacustrine basins form during the recession phase of glaciers. Intensive melting causes a sudden flood of glacial water. Especially strong water streams are observed at the end of a warm season when not only the surface of the glacier (supraglacial waters), but also its total ice mass (inglacial waters) and even its bottom layer (subglacial waters) are thermally degraded.

Replenishment of glaciolacustrine basins is always followed by another process: their sudden drainage. This is associated with formation of outburst in the body of ice, melting of buried ice in the areas of end moraines and capture of glaciofluvial streams (Baltrūnas et al., 2008; Briner et al., 2007; Kalesnik, 1963; Mernild et al., 2008; Overeem and Syvitski, 2008; Russell, 1993, 1994, 2007).

One of such events – upheaving and breaking of the ice barrier – was observed in August 31, 2007, during the fieldwork in the peripheral part of the Russell Glacier (West Greenland) (Fig. 1). The basin was suddenly drained through an outlet in the ice barrier, exposing the bottom and the slopes of the basin. The situation that occurred after the drainage allowed evaluating the impact of water streams on not only the existing forms of relief under periglacial conditions, but also on sediment complexes deposited on the bottom of the glaciolacustrine basin.

Diatom investigations were carried out to establish the palaeoecological conditions of the lake. Arctic lakes have a relatively simple biological structure and a very small anthropogenic impact on the catchment areas, so they are ideally suited for quantitative palaeoecological approaches.

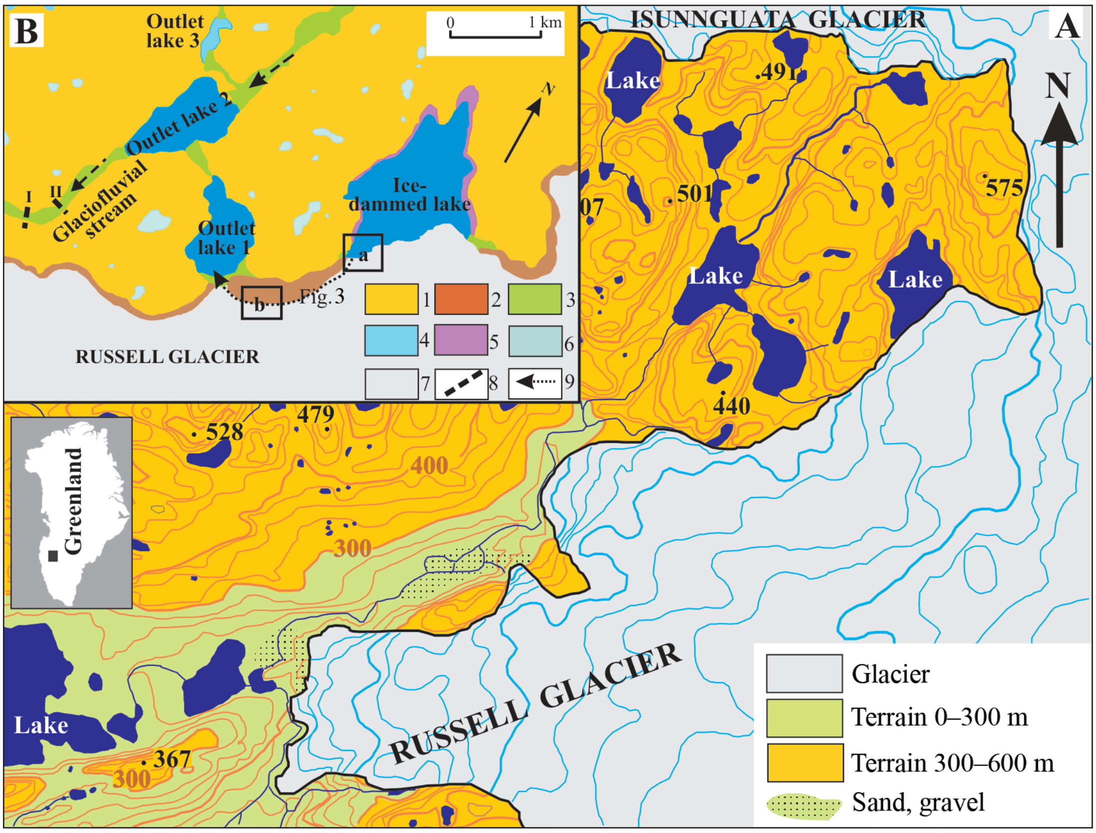


Fig. 1. Study area, sites at the margin of Russell Glacier (West Greenland): Hiking Map 1 : 100 000 (*A*), study area (*B*): *1* – exarated ridges, *2* – end moraine, *3* – glaciofluvial deltas and stream valley, *4* – glacial lakes, *5* – upper terrace of glacial lake, *6* – exarated depression of lakes, *7* – glacier, *8* – places of glaciofluvial stream measurement (I – in 1987 (by Rusell, 2007), II – in 2007), *9* – subglacial routeway

1 pav. Tyrimų plotas: *1* – eroziniai gūbriai, *2* – galinė morena, *3* – fliuvioglacialinė delta ir tėkmės slėnis, *4* – prieledyniniai ežerai, *5* – viršutinė prieledyninio ežero terasa, *6* – egzaracinės ežerų depresijos, *7* – ledynas, *8* – fliuvioglacialinių srautų matavimų vietos (I – 1987 m. (pagal Russell, 2007), II – 2007 m.)

METHODS

The drainage of a glaciolacustrine basin by direct observation and surface mapping was investigated. The water level of the outflow stream, the cross-section of the reference segment of the outflow stream and sediments deposited in the stream bed and slopes were examined *in situ*. The water surface (area) of the glaciolacustrine basin before and after the drainage was mapped using GPS eTrex. The accuracy of planar coordinates fixed by it reached 3 m and of vertical coordinates 1 m. The water level of glaciolacustrine basin before and after the drainage was fixed in the geographical system of coordinates. The obtained data were later recalculated for conversion to the orthogonal system of coordinates, which is more convenient for the compilation of large-scale topographic plans.

The outlines of the basin were fixed at the highest point of water level before the drainage and at the lowest point after the drainage. The obtained values of the area and the difference of altitudes between them allowed determining the runoff volume.

The energy estimation of the outflow stream was based on the stream yield. Using the GPS device, the cross-section of the bed was measured in the reference segment of the stream. The average yield was determined based on the dates of the beginning and end of drainage. Its ratio with the cross-section of the stream bed allowed evaluating the stream velocity. The stream velocity was also evaluated indirectly from the grain size of transported and deposited sediments.

Diatom slide preparation followed the conventional manner described by Battarbee (1986), Miller and Florin (1989). For examination of the slides, a light microscope with an oil immersion objective at a magnification of 1000× was used. The identification of species mainly followed Krammer and Lange-Bertalot (1988; 1991a, b; 1997).

SEDIMENTS OF GLACIOLACUSTRINE BASIN AND ITS DRAINAGE

The area of the glaciolacustrine basin was mapped after the drainage, which took place on 31 August 2007. The surface of the depression of the basin bore distinct marks of the highest water level before the drainage (Fig. 2).

The drainage of glaciolacustrine basin that took place on 31 August 2007 was caused by a crack in the glacier edge,

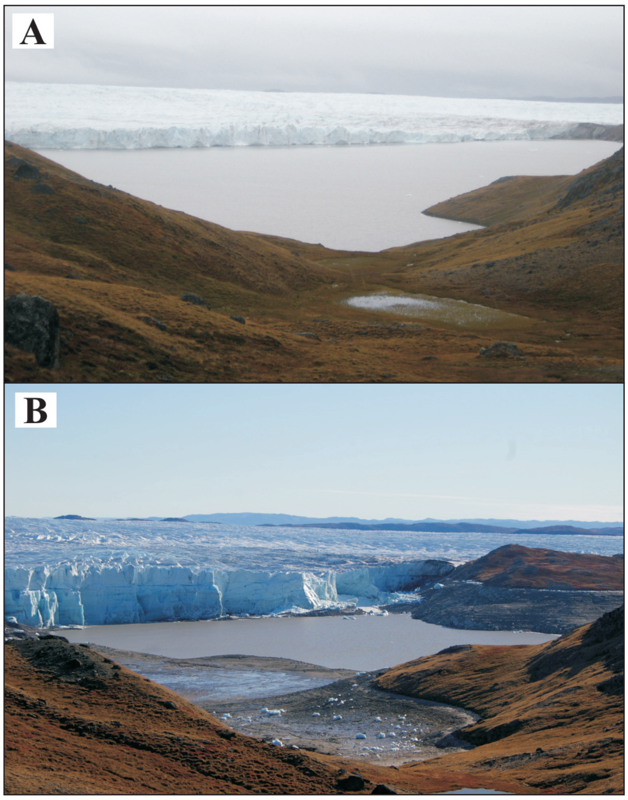


Fig. 2. Ice-dammed lake before (*A*) and after (*B*) outburst

2 pav. Prieledyninis ežeras prieš (*A*) ir po (*B*) prasiveržimo

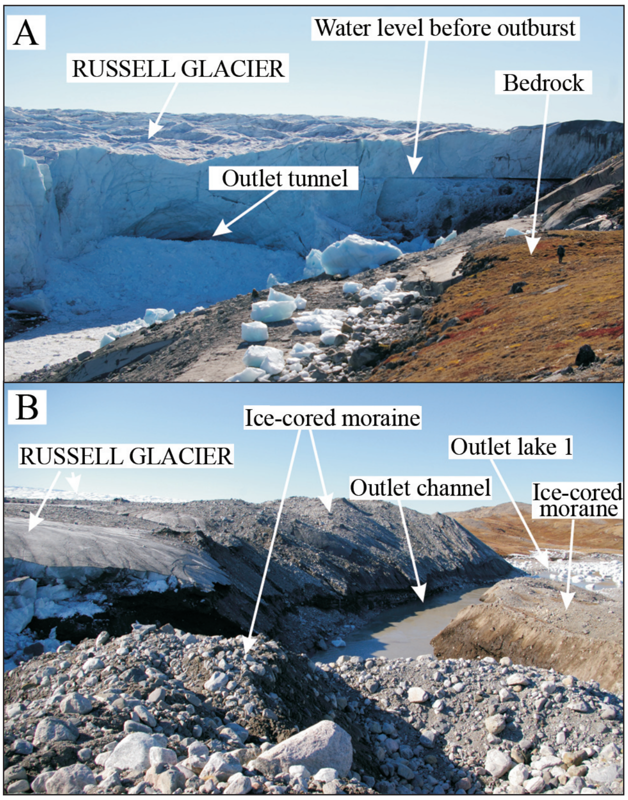


Fig. 3. Entry (*A*) and ending (*B*) of glaciofluvial stream routeway

3 pav. Fliuvioglacialinio srauto pradžia (*A*) ir pabaiga (*B*)

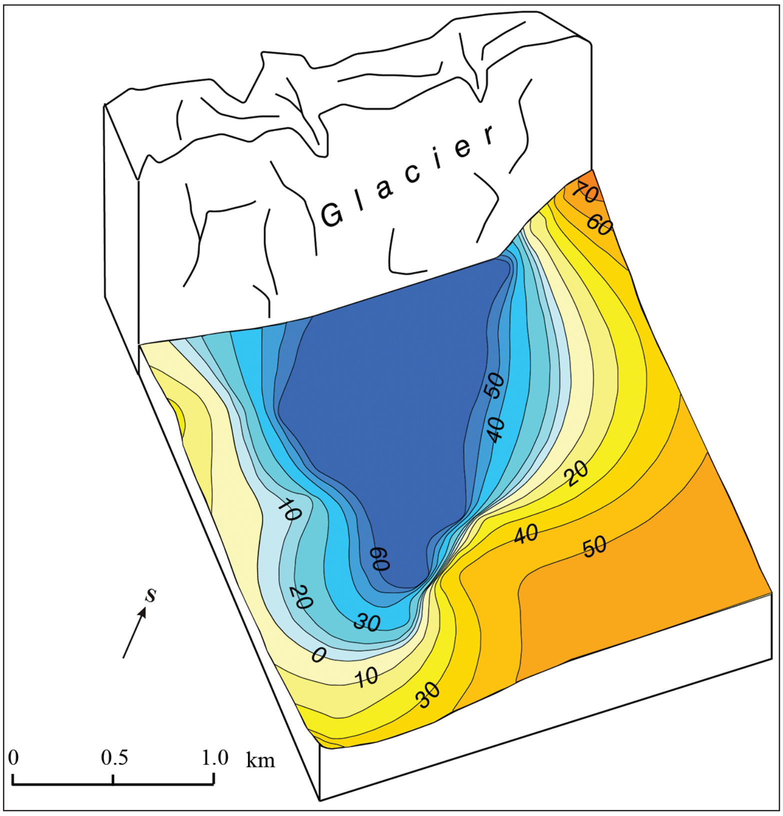


Fig. 4. Three-dimensional view of glacial lake. Isoline "0" indicates the former water level

4 pav. Tridimensinis prieledyninio ežero vaizdas. 0 izolinija rodo buvusį vandens lygį

which appeared when the water mass lifted the glacier edge. A very powerful subglacial stream surged forward through the gap between the basal surface and the glacier base. It used a 20 m wide and 10 m deep tunnel formed by the previous drainage. The mouth of the tunnel opened to the secondary glaciolacustrine basin (outlet lake) situated below (Fig. 3). In 11 hours of the flood, 0.0209 km^3 of water escaped from the basin. The water level in the basin subsided by 55 m. The flood ended when the water level of the glaciolacustrine basin became lower than the absolute altitude of the drainage tunnel (365 m above sea level) (Fig. 4).

Mapping of the contour of the lowest water level showed that the area of the glaciolacustrine basin reduced almost two-fold: from 0.77 to 0.39 km^2 (Fig. 5).

The subsiding water exposed the depression of the glaciolacustrine basin. It appeared to be a mesoform with sophisticated contours, i. e. affected by exaration, erosion, littoral and sedimentation processes.

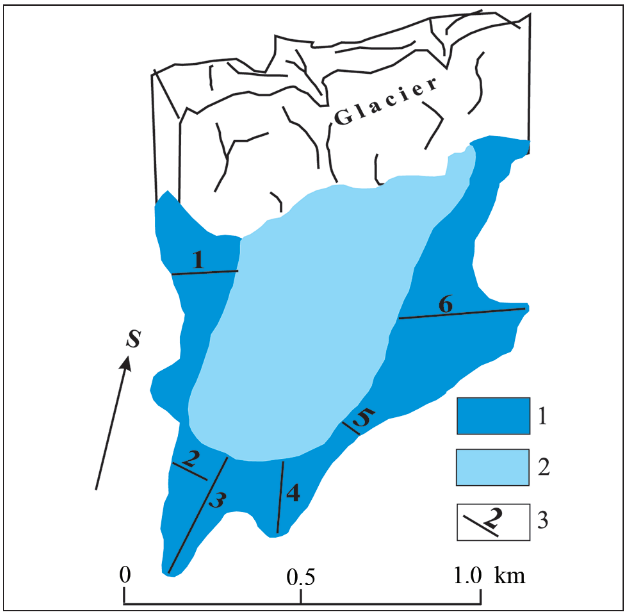


Fig. 5. Places of bottom profiles and comparison of glacial lake area: *1* – before glacial lake outburst, *2* – after the outburst, *3* – number of profiles

5 pav. Dugno profilių vietos ir prieledyninio ežero ploto palyginimas: *1* – prieš prasiveržimą, *2* – po prasiveržimo, *3* – profilių numeriai

The depression had two levels of glaciolacustrine terraces. The terrace levels were related with transformations of the form of depression. The lower terrace level was fixed at the absolute altitude of 390–395 m and the upper at the absolute altitude of 400–405 m (Fig. 6).

These terrace levels are related with a regularly recurring (approximately every 20 years) replenishment and drainage of the glaciolacustrine basin. The form of the depression radically changes at an absolute altitude of approximately 385 m. Above this level, the depression is considerably wider and has two large bays. The latter are a result of exaration and erosion processes. The sudden expansion of the depression area slows down the replenishment of the basin. In summer when the basin surface is free of ice, there occur favourable conditions for littoral (wave) processes. Wave action in the littoral zone abrades the thin cover of morainic material surrounding the lake depression, and the products of abrasion are redeposited under the water. The small slope angles in the bays contribute to formation of a littoral zone where coarse-grained sand-aleurite sediments are depositing. Fine-grained aleurite–mud sediments are depositing in the deeper parts of the basin (Fig. 7).

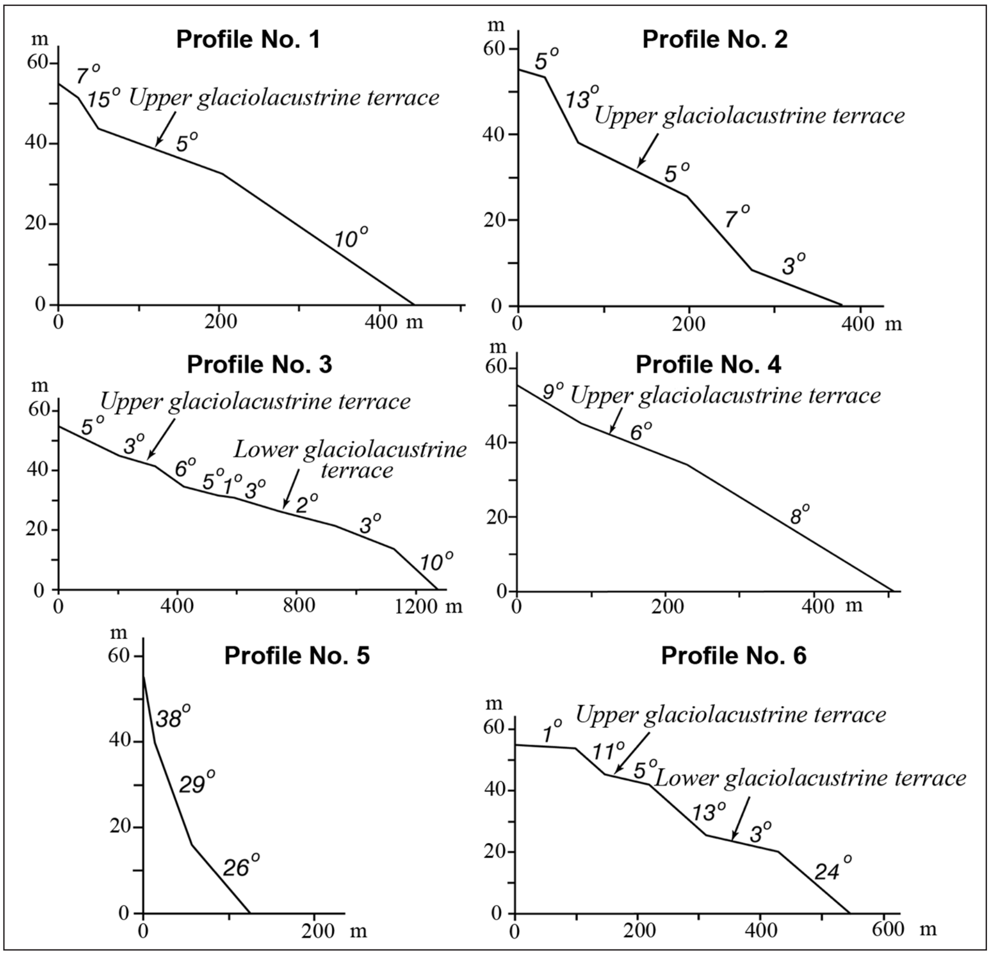


Fig. 6. Profiles of glacial lake bottom

6 pav. Prieledyninio ežero dugno profiliai

A glaciofluvial stream collecting the glacier meltwater falls into the south-eastern part of the glaciolacustrine basin. A 0.08–0.10 km^2 delta composed of sand, gravel, pebbles and boulders has developed in the stream mouth area. The layer of delta deposits reaches 4–6 m (Figs. 8, 9). After the drainage, the delta was intensively eroded by a glaciofluvial stream which in two days deepened the bottom by 2–6 m.

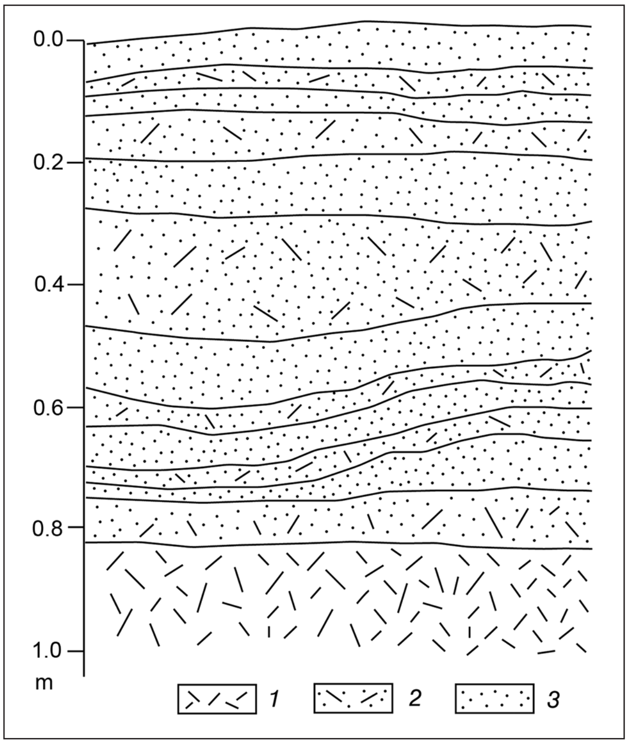


Fig. 7. Glacial lake bottom sediment section: *1* – peat, *2* – silty peat, *3* – silt

7 pav. Prieledyninio ežero dugno nuosėdų pjūvis: *1* – durpė, *2* – aleuritinga durpė, *3* – aleuritas

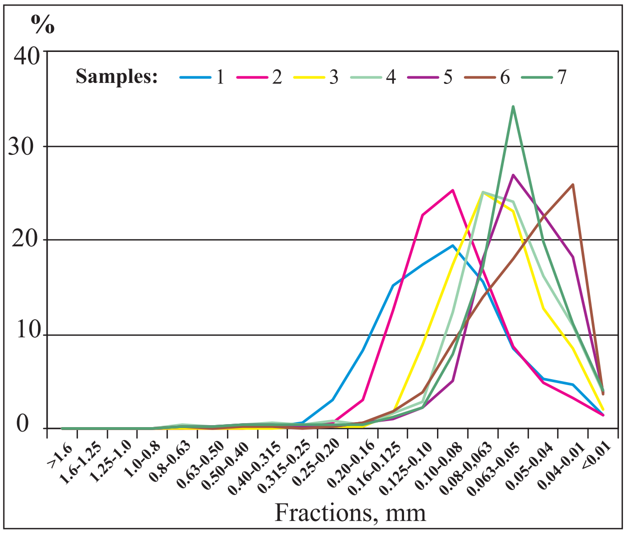


Fig. 8. Grain-size distribution of glacial lake sediments

8 pav. Prieledyninio ežero nuosėdų granuliometrinė sudėtis

Intensive erosion processes also took place in the flat slopes of the bays of the glaciolacustrine depression. The water-saturated surface of peat with aleurite and sand was furrowed by 0.3–1.0 m deep, 0.3–1.5 m wide and 5–50 m long washouts. They developed due to the water remaining in the basin bottom after the drainage.

Analysis of sediments in the area of former bays implies that intensive sedimentation took place under the conditions of a rather calm aquatic environment. Almost 1 m thick assemblages of mineral deposits on peat layers show that accumulation took place during one glaciolacustrine cycle, i. e. no longer than for 20 years. The peat inclusions imply that subaquatic reworking of older sediments had taken place (Fig. 6).

After the collapse, on the opened glacial lake's bottom (in the southeastern part) a rather thin (20–30 cm thick) bed of glaciolacustrine laminated (varved) sediments was observed (Fig. 9). These varved sediments were deposited on the uneven surface of glaciofluvial or deltaic sandy sediments. The glaciolacustrine sediments were observed in four sites at a 100 m distance. The lamination in all investigated sites was of a similar character, but in sites 3 and 4 the sediments were very wet, and the observation of lamination in these sites was problematic. We suggest the lamination to be of annual character. The varved sediments in the study section 1 (Fig. 9) are 27 cm thick, varves are commonly 1–2 cm thick with prevailing summer layers composed of greenish gray sandy layers, and winter layers composed of light gray silt. Summer layers are 1–4 cm thick mostly (1–2 cm), and winter layers are 0.1–0.2 cm thick. The thickest summer layers are bedding in the lower part of the glaciolacustrine laminated bed. The number of varves varied from 15 (section 4) to 19 (section 1), but, as mentioned earlier, the varve counting was complicated due to sediment wetness in sections 3 and 4. We suggest that the investigated bed of glaciolacustrine varved sediments was deposited during the last 19–20 years between two jökulhlaups which took place in 1987 and 2007.

The delta sediments are considerably coarser. Seasonal layers of homogeneous granulometric composition, texture and colour can be distinguished in them. The sequence of seasonal layers of delta sediments allows making an attempt to determine the relative age of the delta (Fig. 8).

DIATOM INVESTIGATIONS

Three samples were analysed for diatoms from the annually laminated (varve) sediment section (Fig. 9). A diverse (48 species and varieties) diatom complex was established in the sediments studied (Table 1). Diatom flora is dominated by oligotrophic, north-alpine, epiphytic and benthic species. The benthic *Pinnularia* spp. *Pinnularia borealis* dominated in all samples; it favours low nutrient concentrations and is very sensitive to pollution. *Pinnularia viridis* and *Pinnularia viridis* var. *aestuarii* are also quite characteristic. Other significant taxa are *Eunotia*: *E. praerupta, E. praerupta* var

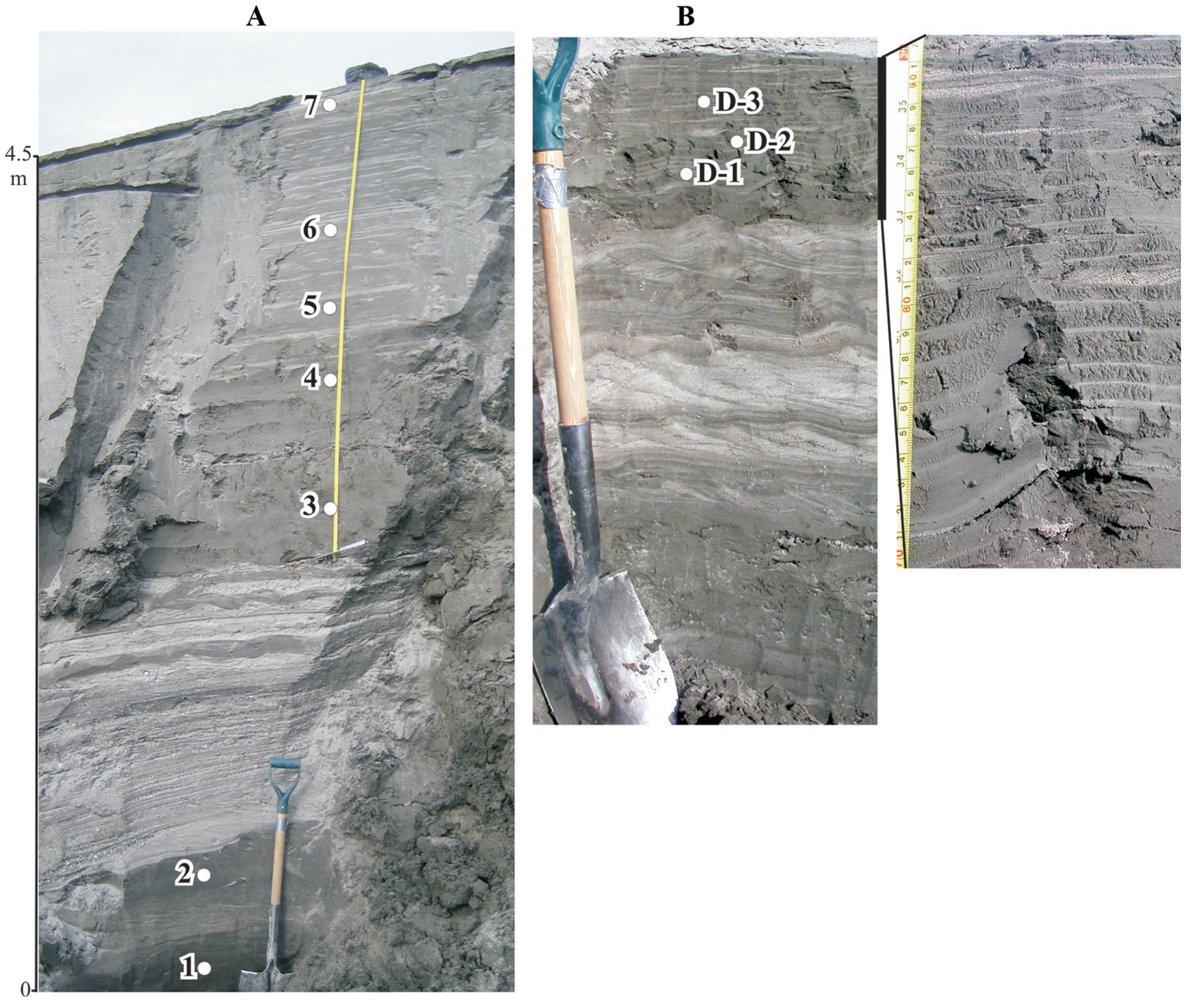


Fig. 9. Laminated sediments observed on the bottom of the glacial lake: *A* – central and *B* – peripheral parts of glaciofluvial delta body: D-1, D-2, D-3 – samples of diatoms

9 pav. Juostuotos nuosėdos prieledyninio ežero dugne: *A* – vidurinėje ir *B* – periferinėje fliuvioglacialinės deltos dalyse: D-1, D-2, D-3 – diatomėjų ėminiai

bigibba, *E. implicata* and *E. monodon*. *Eunotia praerupta* thrives from circumneutral to slightly acidic, humic, shallow water with a high dissolved organic carbon (Pienitz & Smol, 1993). The genus *Fragilaria* is represented by *Fr. brevistriata, Fr. construens, Fr. construens* var. *venter* and *Fr. virescens*. These small species are more competitive in lakes with long periods of ice cover and in extremely oligotrophic or nutrient-limited lakes (Smol, 1988; Laing et al., 1999). They are also typical of early postglacial diatom assemblages (Haworth, 1976).

The high presence of aerophilous diatoms (e. g., *Pinnularia borealis, Hantzchia amphioxys*) may indicate inwashing from the surrounding area. It is also possible that at least part of them belong to the basic diatom flora of the lake, because during very cold periods only the diatoms that are characteristic of aerophilic or very shallow water may thrive (Smol, 1988).

In addition to the small Arctic diatom taxa, large pennate benthic diatoms such as *Stauroneis phoenicenteron* and *Rhopalodia gibba* appear, indicating quite warm summers. *Rhopalodia gibba* together with *Achnanthes minutissima* suggest higher pH values.

The plankton diatom taxa are represented by *Cyclotella radiosa*, *Aulacoseira subarctica* and *Aulacoseira alpigena* and are present only in the uppermost sample (70–76 cm). Here, the highest diversity of species is observed. It may suggest more favourable conditions for planktonic diatoms, such as turbulence, a longer ice free period and higher surface water nutrient concentrations.

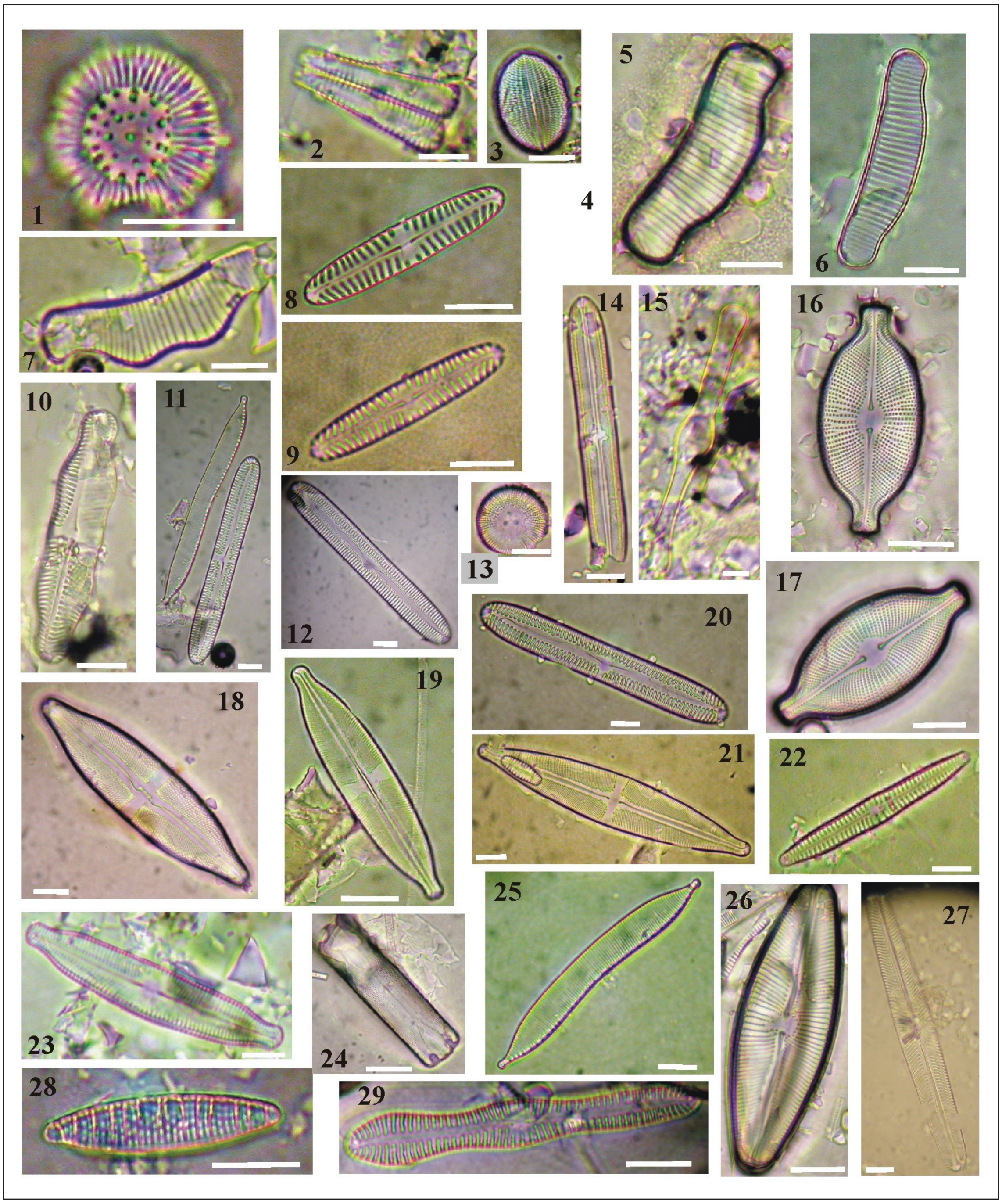
The diatom complex found in the sediments is typical of cold, oligotrophic, nutrient limited waters and could serve for indicating postglacial conditions.

RELIEF RESCULPTED BY GLACIOFLUVIAL STREAMS

The drainage of the glaciolacustrine basin that took place on 31 August 2007 essentially changed the hydrodynamic conditions of the glaciofluvial stream (the Wilkinson River). An especially huge water mass (0.0209 km^3) surged down towards the lower stream in a comparatively short time span – 11 hours. The drainage water flew through the valley and across two outlet lakes.

Table 1. **Most characteristic diatom species identified in laminated sediments (scale 10 μm)**

1 lentelė. **Būdingiausios diatomėjų rūšys juostuotose nuosėdose (mastelis 10 μm)**



1 – Cyclotella radiosa (Grunow) Lemmermann; *2 – Meridion circulare* (Greville) Agardh; *3 – Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow; *4 – Fragilaria pinnata* Ehrenberg; *5 – Eunotia praerupta* Ehrenberg; *6 – Eunotia implicata* Norpel et al.; *7 – Eunotia praerupta* var. *bigibba* (Kutzing) Grunow; *8, 9 – Pinnularia borealis* Ehrenberg; *10 – Pinnularia interrupta* W. Smith; *11 – Hantzschia amphioxys* (Ehrenberg) Grunow, *Pinnularia viridis* (Nitzsch) Ehrenberg; *12 – Pinnularia viridis* (Nitzsch) Ehrenberg; *13 – Cyclotella ocellata* Pantocsek; *14 – Neidium bisulcatum* (Lagerstedt) Cleve; *15 – Tabellaria fenestrata* (Lyngbye) Kutzing; *16, 17 – Navicula pusilla* W. Smith; *18 – Stauroneis javanica* (Grunow) Cleve; *19 – Stauroneis anceps* Ehrenberg; *20 – Pinnularia aestuarii* Cleve; *21 – Stauroneis phoenicenteron* (Nitzsch) Ehrenberg; *22 – Gomphonema angustum* Agardh; *23 – Cymbella hybrida* Cleve; *24 – Eunotia* sp.; *25 – Hantzschia amphioxys* (Ehrenberg) Grunow; *26 – Navicula semen* Ehrenberg; *27 – Navicula radiosa* Kutzing; *28 –* Denticula tenuis (Kutzing) Hustedt; *29 – Gomphonema accuminatum* Ehrenberg

In the northern part of the Russell Glacier, recurrent drainages of the glaciolacustrine basin take place, inducing catastrophic floods. The latter substantially change the mesoforms of the relief in the glaciofluvial valley and modify the outlines and sometimes the locality of the valley itself. An exhaustive analysis of the drainages of glaciolacustrine basins that took place in this region earlier has been carried out by A. J. Rusell (2007). The data obtained during the Lithuanian expedition in 2007 are in good correlation with the results reported by Rusell.

The maximal rise of the water level of the glaciofluvial stream fixed in the reference segment of the valley (Fig. 1) reached 4.8 m. At that time, the cross-section of the stream reached 120 m^2. The average yield of the water mass equalled to 528 m^3/s. The glaciofluvial flow was distinguished for an especially explosive flood. On the other hand, the abruptness of the flood was slightly mitigated by two outlet lakes. The first basin occupies an exaration depression situated between the Russell Glacier and the glaciofluvial valley extending along the glacier edge. The maximal depth of this basin exceeds 22 m (Rusell, 1994, 1993). The second basin is shallower and occupies the depression of the glaciofluvial valley. The water flow had to cover a distance of about 5 km before reaching the reference segment. The starting velocity of the stream reached 6 m/s and later slowed down to 4.4 m/s. In about 15 min, the flood wave crossed the cross-section. In the next 5 min, the water level in the cross-section reached 4.8 m above the regular water level. The results of the floods observed on 31 August 2007 and in 1987 (Rusell, 2007) are presented in Fig. 10 and Table 2.

The sudden flood formed a few new forms of relief on its way. The glaciofluvial delta was reworked and modified into the mouth of a subglacial tunnel (channel). Sand, gravel, pebbles and small (20–30 cm in diameter) boulders were washed out from it. Large boulders remained, representing the dominant delta deposits. Yet they were also dislocated by the powerful stream: blocks and boulders with the long axes reaching up to 1.0–1.2 m changed their position.

An even stronger washing out took place between the first and the second outlet lakes. The stream connecting the lakes is strongly inclined. The difference between the altitudes of the stream source and the mouth reaches 26 m, the total length of the stream being only 480 m. The bed angle is 28° or 54‰. Blocks and boulders in the stream bed with the long axes reaching up to 1.8–2.3 m were reworked.

Downstream the second outlet lake, the flood stream eroded a channel, washing out sand and gravel completely. Only larger pebbles and boulders remained intact, comprising at present a uniform complex. The flood histogram downstream the second outlet lake has a distinct asymmetric peak (Fig. 11). The flood back was a few times slower than the flood rise, yet it also lasted for short.

After the subsequent drainage of the glaciolacustrine basin, the bed and slope sediments of the glaciofluvial stream changed. The bed was smoothened and covered with boulders. The sand and gravel were washed out completely during the flood. The outlines of the channel also changed. A morainic ridge (100 × 10 × 8 m) in the front part of the Russell Glacier was washed away (Fig. 12). Boulders sized 1.0–1.5 m accumulated in the bed and near the bed downstream. The ridges (50 × 8 × 5 m) of the lateral moraine that used to be near the western end of the Russell Glacier were also washed away.

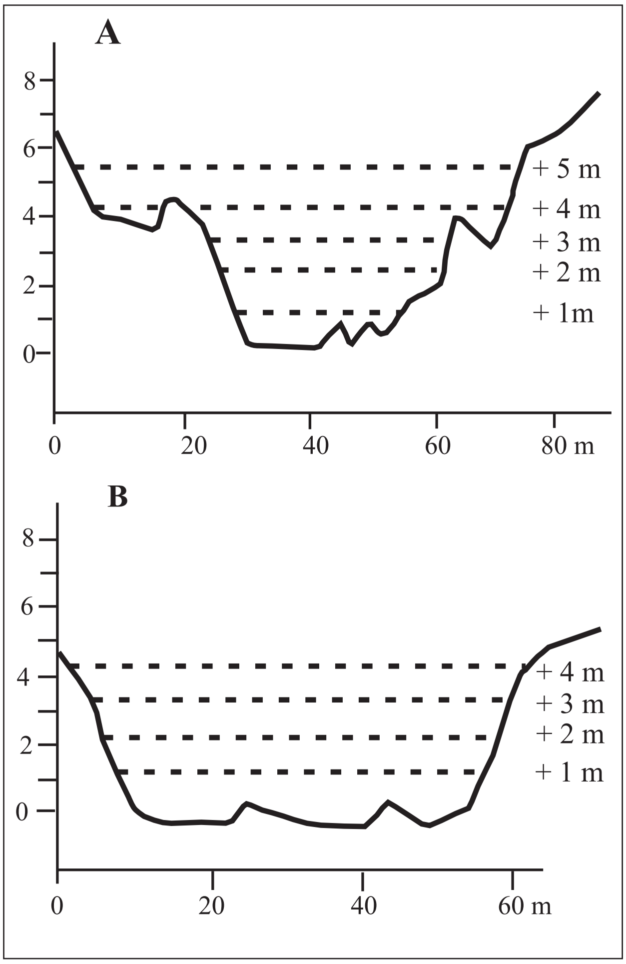


Fig. 10. Cross-section of glaciofluvial stream channel: *A* – in 1987 (by Russell, 2007), *B* – in 2007

10 pav. Fliuvioglacialinio srauto tunelio skersiniai pjūviai: *A* – 1987 m. (pagal Russell, 2007), *B* – 2007 m.

Table 2. **Correlation between water level and water discharge (by Russell, 2007)**

2 lentelė. **Vandens lygio ir iškrovos palyginimas (pagal Russell, 2007)**

Water level above normal, m	Cross-section of glaciofluvial channel, m^2	Estimate discharge, m^3/s	Water level above normal, m	Cross-section of glaciofluvial channel, m^2	Estimated discharge, m^3/s
1	19	52	1	20	73
2	50	188	2	40	137
3	88	413	3	65	184
4	142	668	4	80	357
5	211	1150	4.8	120	528
5.4	225	1250			

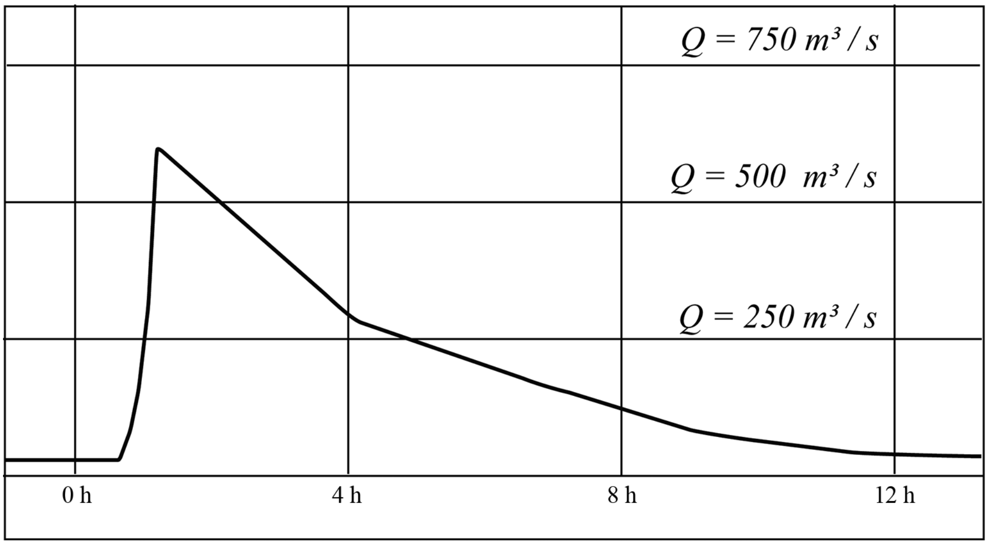


Fig. 11. Hystogram of glaciofluvial stream flood

11 pav. Fliuovioglacialinio srauto poplūdžio histograma

Identical changes in and near the channel of the glaciofluvial stream have been reported by A. J. Rusell who analysed the outcomes of the sudden drainage of a glaciolacustrine basin in 1987 (Rusell, 1989, 1993, 1994, 2007). The jökulhlaup was observed by the author between 16 : 00 h and 17 : 00 h on July 18, 1987 near the flood peak. Flows were observed emanating from the outlet channel and spreading out over most of the delta surface. Only small clusters of coarse material could be seen above the peak water level. The flow separated into two main channels around an area of high ground immediately opposite the tunnel mouth. Numerous ice blocks, up to 5 m in diameter, released from the area around the tunnel outlet, travelled down the channel, grounding audibly. A jet of high velocity turbulent water observed entering the lake basin, extended 100–150 m beyond the delta edge in front of each of the main channels. Small tributary embayments on the western margin of the main delta were submerged by relatively slack water characterised by large-scale, eddy circulation within which numerous ice blocks were caught. The maximum level of Outlet Lake 1 during the jökulhlaup was 5.4 m above its normal level.

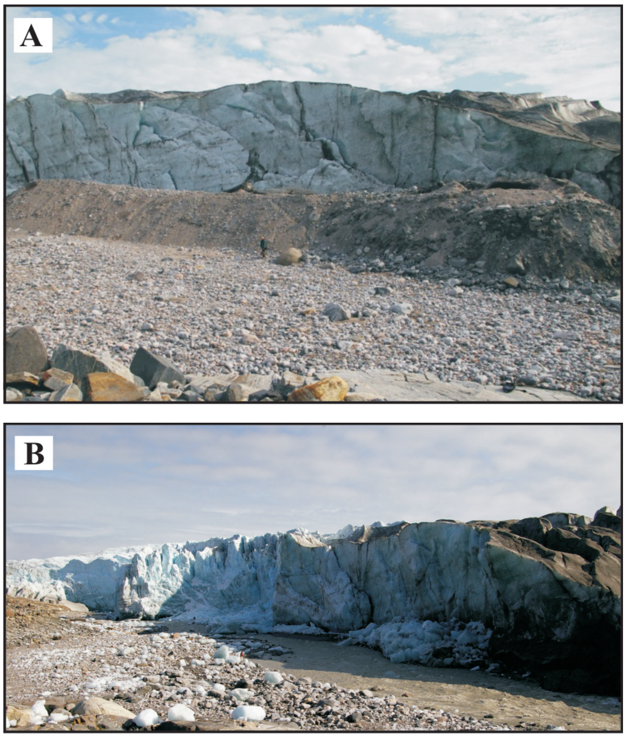


Fig. 12. Washed-out end moraine: *A* – before outburst, *B* – after outburst

12 pav. Nuplauta galinė morena: *A* – prieš prasiveržimą, *B* – po prasiveržimo

It should be noted that the flood of 1987 was even more powerful because the yield of the glaciofluvial stream reached 1080–1300 m^3/s, whereas the average yield of the flood that occurred in 2007 was twice as low – 528 m^3/s.

CONCLUSIONS

The drainage of a glaciolacustrine basin that occurred in 2007 due to a crack in the glacier edge generated a powerful subglacial stream which in the interface of the glacier base and basal moraine washed out a 20 m wide and 10 m deep channel. In 11 hours of the flood, 20 9000 000 m^3 of water escaped from the glaciolacustrine basin. After the flood, the water level in the glaciolacustrine basin subsided by 55 m. The flood ended when the water level in the glaciolacustrine basin subsided lower than the absolute altitude of the drainage tunnel – 365 m above sea level.

The exposed basin depression had two terrace levels. Their altitudes were related with the changes of the general form of the depression. At an absolute altitude of about 385 m, the form of depression changes. Above this altitude, the depression is considerably wider and has two large bays. The sudden increase of the size of depression slows down the basin replenishment rates in the summer time, creating favourable conditions for littoral processes. Due to these processes, the cover of morainic sediments surrounding the basin depression is reworked under subaquatic conditions.

The small slope angles of the basin contribute to formation of a littoral zone composed of sand–aleurite sediments. The deeper parts of the basin are composed of aleurite–mud sediments. The glaciofluvial stream falling into the south-eastern part of the glaciolacustrine basin forms a 0.08–0.10 km^2 delta composed of sand, gravel, pebbles and boulders. The thickness of delta sediments reaches 4–6 m. After the collapse of the glaciolacustrine basin, the delta was intensively eroded by the glaciofluvial stream. The rates of erosion reached 1–3 m per day.

The measurements made in the channel of the glaciofluvial stream allowed evaluating the stream velocity and water yield. Two minutes after the beginning of flood, the water level in the channel rose to 4.8 m. In the measuring point, the cross-section of the stream was 120 m^2. The average water yield amounted to 528 m^3/s. Especially high stream velocities – up to 6 m/s – occurred at the beginning of the flood. Some time later it slowed down to 4.4 m/s.

The sudden flood changed the sediments of the channel bed and slopes and destroyed or transformed the forms of relief on its way. Sand, gravel, pebbles and small boulders (20–30 cm in diameter) were washed out from the delta in the mouth of the subglacial tunnel. The larger boulders (long axes 1.0–1.2 m) were dislocated. The most intensive washing out of sediments took place in the sector between the first and the second outlet lakes. Blocks and boulders with long axes reaching 1.8–2.3 m were dislocated in the stream channel. The flood also changed the outlines of the channel. A morainic ridge in the front part of the Russell Glacier was completely washed away. Downstream, boulders sized 1.0–1.5 m accumulated in and near the channel of a wide glaciolacustrine valley.

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PRASIVERŽUSIO PRIELEDYNINIO EŽERO MORFOLOGIJA IR NUOSĖDOS (VAKARŲ GRENLANDIJA)

Santrauka

Limnoglacialinių baseinų formavimąsi ledyno recesinės fazės metu lemia supraglacialinių, inglacialinių ir subglacialinių vandenų gausa. Limnoglacialinių baseinų prisipildymą lydi ir staigus jų drenažas, susijęs su pralaužų susidarymu ledyne, palaidoto ledo tirpimu pakraštinių morenų ruožuose ar fliuvioglacialinių tėkmių kaptažu. 2007 m. rugpjūčio 31 d. Russell ledyno pakraštyje (Vakarų Grenlandija) susidariusi pralauža sukėlė staigų limnoglacialinio baseino drenažą ir apnuogino didelę baseino dubens dugno dalį bei šlaitus. Atsidengęs limnoglacialinio baseino dugnas leido įvertinti susikaupusių nuogulų kompleksus; taip pat įvertintas fliuvioglacialinio srauto poveikis jau sukurtoms reljefo formoms.

Drenažo metu vandens lygis baseine pažemėjo 55 metrais, o per 11 poplūdžio valandų iš baseino ištekėjo 20900000 m^3 vandens. Baseino dubenyje užfiksuoti du limnoglacialinių terasų lygmenys 390–395 m ir 400–405 m absoliučiame aukštyje. Terasų nuogulų analizė atskleidė, kad jos kaupėsi vieno limnoglacialinio ciklo metu, o durpingi aleurito intarpai liudija ankstesnį povandeninį nuogulų perklostymą. Į baseiną įtekančių srautų suklostytose deltose išsiskiria sezoniniai sluoksniai, pasižymintys nuogulų homogeniškumu (granuliometrinė sudėtis, sluoksnelių tekstūra, spalva).

Poplūdžio metu nustatytas maksimalus – 4,8–5,0 m – fliuvioglacialinio srauto vandens lygio pakilimas. Vidutinis vandens masės debitas buvo lygus 528 m^3/s. Pirminis srauto greitis siekė iki 6 m/s, o vėliau sulėtėjo iki 4,4 m/s. Poplūdžio metu buvo performuotos fliuvioglacialinio srauto vagos dugno ir krantų nuogulos. Vagos dugne liko tik stambūs rieduliai, dugnas išsilygino. Poplūdis visiškai išplovė smėlį ir žvirgždą, o slėnio prievaginėje ir vaginėje dalyse buvo akumuliuoti 1,0–1,5 dydžio rieduliai. Pakito ir vagos konfigūracija: Russell ledyno vakarinėje frontalinėje dalyje visiškai nuplautas 100 × 10 × 8 m dydžio moreninis gūbrys bei palei šiaurės vakarinį ledyno galą buvę 50 × 8 × 5 m dydžio šoninės morenos gūbriai.

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МОРФОЛОГИЯ И ОТЛОЖЕНИЯ ПРИЛЕДНИКОВОГО ОЗЕРА (ЗАПАДНАЯ ГРЕНЛАНДИЯ) ПОСЛЕ ЕГО ПРОРЫВА

Резюме

Формирование лимногляциальных бассейнов в рецессионной фазе ледникового покрова определяет объем супрагляциальных, ингляциальных и субгляциальных вод. Наполнение лимногляциальных бассейнов, как правило, сопровождается внезапным их дренажом, обусловленным формированием в ледниковом покрове проломов, таянием погребённых ледниковых глыб, а также каптажом флювиогляциальных потоков. 31 августа 2007 г. на окраине ледника Русселл (Западная Гренландия) образовался крупный пролом, приведший к быстрому дренажу лимногляциального бассейна. Вследствие этого обнажились берега и дно бассейна. Создавшаяся обстановка позволила оценить седиментационные комплексы донных отложений. Также было оценено воздействие флювиогляциального потока на ранее образовавшиеся формы рельефа.

Во время дренажа уровень воды в лимногляциальном бассейне понизился на 55 м, а в течение одиннадцати часов из бассейна вытекло приблизительно 20900000 кубических метров воды. В блюдце бассейна фиксированы два уровня лимногляциальных террас, их абсолютная высота достигала 390–395 и 400–405 м. Анализ террасовых отложений показал, что накопление осадков осуществлялось в течение одного цикла накопления лимногляциального бассейна. Торфяные прослои отложений указывают на подводное переотложение ранее накопившегося материала. В дельтовых отложениях временных потоков, впадающих в лимногляциальный бассейн, ярко выражены гомогенные сезонные слои с одинаковыми гранулометрическим составом, текстурой, цветом.

Во время прорыва ледяной дамбы фиксировано быстрое поднятие уровня воды в флювиогляциальном потоке на 4,8–5,0 м. Средний дебит потока составил примерно 528 м^3/с. Скорость потока в начальной фазе прорыва достигла 6 м/с, позднее – 4, 4 м/с. Во время наводнения изменились донные и береговые осадки и русловые формы рельефа. Дно потока было выравнено, а на дне русла остались лишь крупные валуны. Во время наводнения со дна русла целиком были размыты и унесены песок и гравий, а в русловой и прирусловой частях долины аккумулированы валуны объемом 1,0–1,5 м^3. Изменилась и конфигурация русла: в западной фронтальной части ледника Русселл полностью смыта моренная гряда размером 100 × 10 × 8 м, а в боковой северо-западной части ледника – несколько гребней боковой морены размером 50 × 8 × 5 м.