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The sedimentology of debris within basal ice, the source of material for the formation of lodgement till: an example from the Russell Glacier, West Greenland

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The main objective of this research is to examine in detail the sedimentology of the debris contained within the basal ice of the Russell Glacier (West Greenland). This is of crucial importance as the entrainment and alteration of debris within basal ice provides information on the intial stage of basal till formation. Grain-size analysis was performed using a FRITCH shaker with a set of 19 screens. The obtained data were statistically processed by the Roszkov and Kulikov method using a statistical package SIETAN worked out at the Institute of Geology and Geography. The orientation and dip of the long axes of basal ice debris were measured in five exposures using a geological compass. In 21 samples, the content of debris within the basal ice ranged within 34.33–86.54% producing a mean value of 61%. The results of comparative grain-size analysis indicate that the debris within the basal ice of the Russell Glacier is distinguished by the highest portion of silt and sand fraction in comparison with the flow, till and material of lateral and terminal. These data were compared with the data of grain-size analysis of lodgement till of Lithuania. In the Lithuanian till, the content of clay is very high in comparison to the debris within the basal ice of the Russell Glacier. The index of relative entropy of grain size frequency distribution of the debris within the basal ice of the Russell Glacier. In set of 19 fractions moraines ranges from 0.948 to 0.986 and in the set of 6 fractions from 0.840 to 0.994. Meanwhile, in the aeolian sediments generated as a result of repeated reworking of similar glacial sediments near Kangerlussuaq it is 0.610 and 0.361 respectively. Comparison of varieties of glacial sediments shows that the index of relative entropy is higher for grain-size composition of debris within the basal ice (the average for 19 fractions is 0.972 and for 6 fractions 0.980). The grain-size distribution of material within the basal ice reflects a combination of the petrology of the eroded glacier bed and by debris comminution and mixing associated with ice deformation. During glacier movement, debris material is mechanically milled to a silt fraction. Clay particles appear only when a glacier flows across clay-rich subglacial beds. The increase of the value of relative entropy (index of mixing) of grain-size distribution of eroded material is associated with equalization of the content of debris of different fractions in the mixing process (if the content of all fractions would be equal, the value of relative entropy would be one). The basal ice of glaciers can be viewed as the initial stage of lodgement till formation occurring during plastic flow of glacier which in turn strongly influences the grain-size structure of lodgement till.

Key words: West Greenland, Russell Glacier, sedimentology, glacial deposit, lodgement till, basal ice

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INTRODUCTION

Glacial deposits are widespread in countries of continental glaciation. However, the genetic identification, stratigraphical classification and correlation of glacigenic formations remain problematic (Boulton, 1978; Haldorsen, 1981; Dreimanis, 1989; Gaigalas, 1979, 1995a; Baltrūnas, 1995, 2002; Šinkūnas, Jurgaitis, 1998 and others). Resolution of these issues is further complicated by lithological, petrographical and geochemical variations. It is assumed that the sedimentological variability of tills is related to recurring sedimentation processes during glaciation stages, phases and ice oscillations and with the diverse of sedimentary environments and post-sedimentary processes. Application of the principle of methodological actualism, i. e. investigation of the sediments of old glaciations and identification of old sedimentation environments through study results of sedimentary environments of present glaciers, provides an ideal means of examining the sedimentological characteristics of tills and their association with active glacial processes.

Investigations of the process of erosion, transportation and accumulative activities of glaciers have provided much interesting material about the extent and character of these processes, formation and melting of basal ice, deposition of till and the role of glacier melt water in various glaciological, erosional and sedimentation processes (Brodzikowski, van Loon, 1991; Knight et al., 2000; Evans et al., 2006; Serebryanny, Orlov, 1989; Waller, Hart, 1999, etc.). Unfortunately, publications devoted to utilizing the deposits of modern glaciers in order to reconstruct the dynamic and sedimentation conditions of relict and past ones are scarce (Serebryanny, Orlov, 1989; Waller et al., 2000).

Research of this kind in Lithuania is even scantier. For a better understanding of morainic relief generated by glaciers during the past glaciations on the territory of Lithuania and the deposition of the sediments, the processes of sedimentation associated with modern glaciers in both the Tian Shan (On Tor Glacier) and Polar Urals (IGAN and Obruchev glaciers) were investigated (Baltrūnas, 2007). In 2006, the first observations of till sedimentation at the Russell Glacier in West Greenland were carried out. The preliminary results have been reported previously (Baltrūnas, Šinkūnas, 2007). Investigations were continued in 2007 when samples of basal ice were taken for detailed sedimentological examination (Baltrūnas et al., 2008). The Russell Glacier has been studied in different aspects by experts from various countries (Knight, 1987, Adam, Knight, 2003; Knight et al., 1994, 2000a, b, 2002; Waller and Hart, 1999; Waller et al., 2000; Waller, Tuckwell, 2005 and others). These studies covered the following issues: mechanisms and patterns of motion associated with the basal zone of the Russell Glacier (Waller, Hart, 1999), discharge of debris from ice at the margin of the Russell and Leverett glaciers (Knight et al., 2002), identification of basal layer debris in ice-marginal moraines in the Russell Glacier (Adam, Knight, 2003), the influence of tectonic deformation on facies variability in stratified debris-rich basal ice (Waller et al., 2000), preservation of basal-ice sediment texture in ice-sheet moraines (Knight et al., 2000a), glacier-permafrost interactions and glaciotectonic landform generation at the margin of the Leverett Glacier (Waller, Tuckwell, 2005) and others. The aforementioned studies of the Russell Glacier environment provide a good basis for evaluation of the processes of lodgement till formation at the stage when the material is contained within actively-deformined basal ice. This is the main reason why basal ice near the Russell Glacier was chosen as an object of research during field studies in 2006 and 2007 (Fig. 1).

The main objective of the present work was to evaluate the distribution patterns of debris in the basal ice of the Russell Glacier (West Greenland) as the main stage of lodgement till formation. The following tasks had to be performed: 1 – determining the content of debris in the basal ice and its granulometric composition; 2 – measuring the preferred orientation and dip of the longer axes of debris; 3 – assessing the specific patterns of the structural formation of debris.

METHODS

The samples of debris from the basal part of the glacier were taken *in situ* by melting 1.9–9.6 kg of basal ice containing till material. After removal of water by evaporation at the Kangerlussuaq International Science Support (KISS), the dry debris were delivered to the laboratory of the Institute of Geology and Geography in Vilnius. Grain-size analysis was performed using a FRITCH shaker with a set of 19 screens (2–0.04 mm). The data obtained were statistically processed by the Roszkov and Kulikov method using the SIETAN statistical package developed at the Institute of Geology and Geography.

The grain-size analysis of dry debris (<2.5 mm) was performed using sieves sizing the following fractions: 2.5–2.0; 2–1.6; 1.6–1.25; 1.25–1; 1–0.8; 0.8–0.63; 0.63–0.5; 0.5–0.4; 0.4–0.315; 0.315–0.25; 0.25–0.2; 0.2–0.16; 0.16–0.125; 0.125–0.1; 0.1–0.08; 0.08–0.063; 0.063–0.05; 0.05–0.04 and <0.04 mm. Sediments and their grain-size fractions are described according to the standard classification (Gaigalas, 1995b). To evaluate the degree of mixing, a relative entropy for 19 and 6 fractions (2.5–1; 1–0.5; 0.5–0.25; 0.25–0.1; 0.1–0.05; <0.05) was calculated using a published method (Baltrūnas, Gaigalas, 2004; Baltrūnas et al., 2005).

The orientation and dip of the longer axes of basal ice debris (diameter 10–30 mm) was measured in five sites of the glacier, using a geological compass (50 units in every point). The graphic stereograms were compiled taking into account the deviation of the magnetic field. The stereograms were compiled manually, showing on them every point of measuring. The dip of longer axes of clasts in the basal ice of the Russell Glacier was estimated statistically (Baltrūnas et al., 2008).

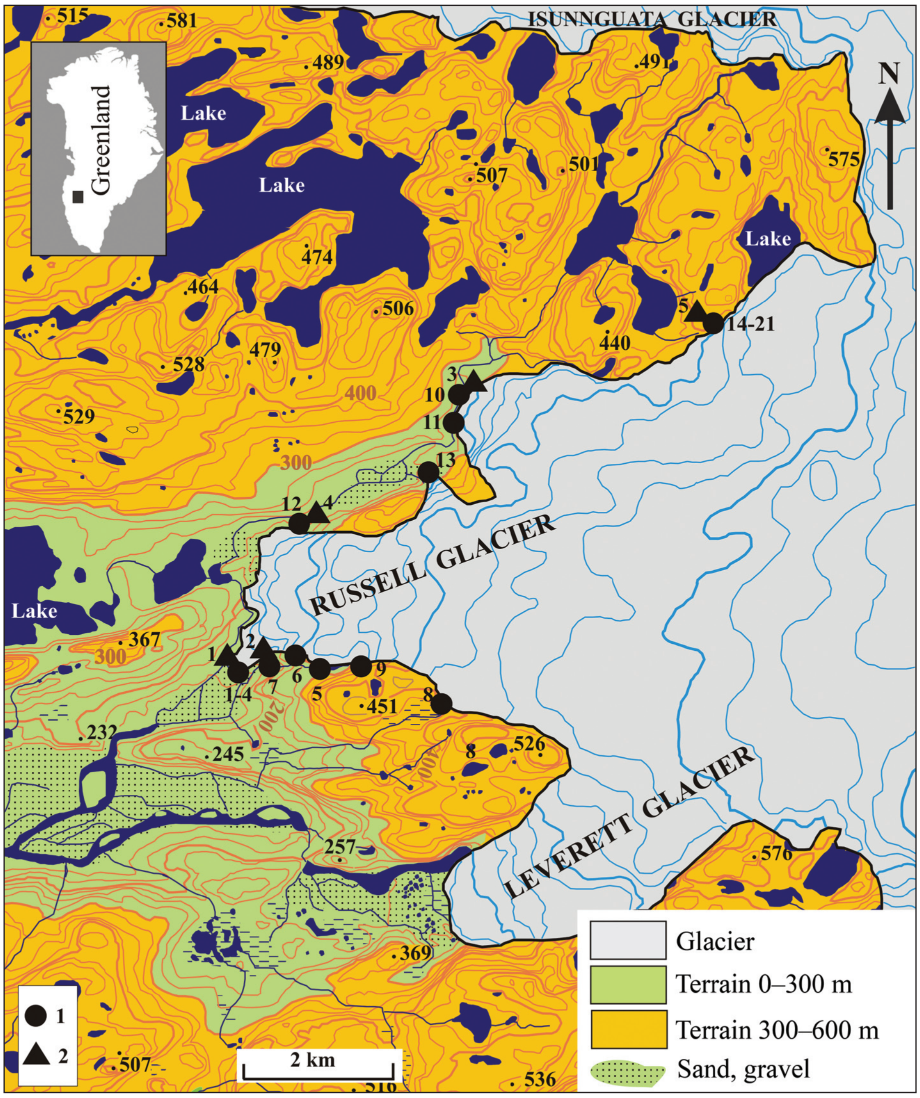

Fig. 1. Basal ice investigation and sampling sites in basal part of Russell Glacier, West Greenland, and their numbers: *1* – grain-size study of clasts from basal ice, *2* – measuring of the orientation and dip of debris longer axes

1 pav. Russell ledyno pamatinės dalies Vakarų Grenlandijoje tyrimų ir ėminių ėmimo vietos bei numeriai: *1* – nuotrupinės medžiagos granuliometriniams tyrimams, *2* – stambianuotrupinės medžiagos ilgųjų ašių orientacijos ir polinkio matavimai

Geological, geomorphological and glaciological setting

The Russell Glacier is situated in the western part of Greenland (67°06' N, 50°15' E) 22 km from the Kangerlussuaq (Søndre Strømfjord). The glacier constitutes a discrete tongue approximately 4 km long, which joins with the adjacent Leverett Glacier to form a larger ice-lobe roughly 10–12 km in length (up to 600 m a. s. l.) (Fig. 1). This type of ice-lobe is characteristic of the mid-western region of the Greenland ice-sheet (Waller, Hart, 1999).

SW Greenland is part of a Precambrian shield. The crystalline basement in the study area is a preserved Archaen craton. A zone of tectonic fault runs along the Søndre Strømfjord and Akuliarusiarsuup Kuua (Watson) River extending from the Russell and Leverett glaciers to the Kongerlussuaq fjord. From a petrological point of view, the Kangerlussuaq Region including the environment of the Russell Glacier is mainly composed of gneiss, Archaean (amphibolite) facies, reworked in early Proterozoic (Bonow et al., 2006). Proterozoic granite occurs to the south of the Leverett Glacier. In general, SW Greenland has two planation surfaces – the lower and the upper ones – which are absent in the study area. The amount of erosion since uplift, calculated as a difference between the upper planation surface and the present relief, reaches 300–500 m near the Russell Glacier (Bonow et al., 2006).

The altitude of mountaintops near the Russell and Leverett glaciers reaches 358–576 m a. s. l. The difference in altitudes between the surfaces of the Watson River mouth and the river near the glacier approximately 200 m. The difference between the planation surfaces of the Russell Glacier from the glacier shield (about 600 m a. s. l.) and the terminus of the glacier, where the river emerges (200 m a. s. l.), is approximately 400 m. This value provides an approximation of the maximum ice thickness of the Russell Glacier. The glacier terminates in a region of active permafrost and is considered to be polythermal in nature, with a warm-based interior and a cold-based margin (van Tatenhove, 1995). The glacier rests mainly on bedrock, with little subglacial sediment being present. The glacier margin is dominated by a large moraine ridge up to 30 m in height, which is currently being overridden in many locations. Knight (1992) reported the velocity of the Russell Glacier to vary from 90.5 ma^{-1} near the margin to 183.0 ma^{-1} halfway towards the centreline. The basal ice layer

Fig. 2. Study sites of basal ice on the northern side of Russell Glacier. *A* – view from the Lower Russell Lake, *B* – sites of detailed investigations

2 pav. Pamatinio ledo tyrimo vietos šiauriniame Russell ledyno šone. *A* – vaizdas nuo apatinio Russell ežero, *B* – išsamių tyrimų vietos

at the site has been described by Sugden et. al. (1987), Knight (1987), Knight et al. (1994), Waller, Hart (1999) who concentrated on its stratigraphy, sedimentology and ice character.

There are data that the majority of surface velocities at the study site was accommodated within the basal region of the Russell Glacier (Waller, Hart, 1999). An estimated 75% of the total surface velocity had been accommodated on reaching the upper boundary of the stratified facies of the basal ice layer, although, relatively little movement (16%) was accommodated by creep within the debris-rich basal ice layer present. This finding has potentially wide-ranging implications for the understanding of the dynamic processes and behaviour associated with polythermal glaciers (Waller, Hart, 1999).

OBSERVATIONS AND RESULTS

Study sites

The basal part of the Russell Glacier is obscured in many places lateral moraine ridges or bedrock outcrops making its examination difficult. Several basal ice exposures on the northern, western and southern sides of the glacier were observed (Fig. 1).

Two exposures were studied in detail by taking a larger number of samples. One of them was located on the northern edge of the glacier between the Upper and the Lower Russell lakes near the mount with the absolute altitude of 476 m (sampling sites 14–21, Fig. 1). Samples from the basal part of the glacier were taken (Fig. 2). The studied exposure (az 340°, length 150 m, height 15–17 m) includes four outcrops of 2–3 m thick layers of stratified facies basal ice. These layers include alternating laminae of debris-rich and debris-free ice (Fig. 3, discontinuous sub-facies ice, see Waller et al. 2000).

Fig. 3. Distribution of debris in the basal ice on the northern side of Russell Glacier

3 pav. Pamatinio ledo nuotrupinės medžiagos pasiskirstymas šiauriniame Russell ledyno šone

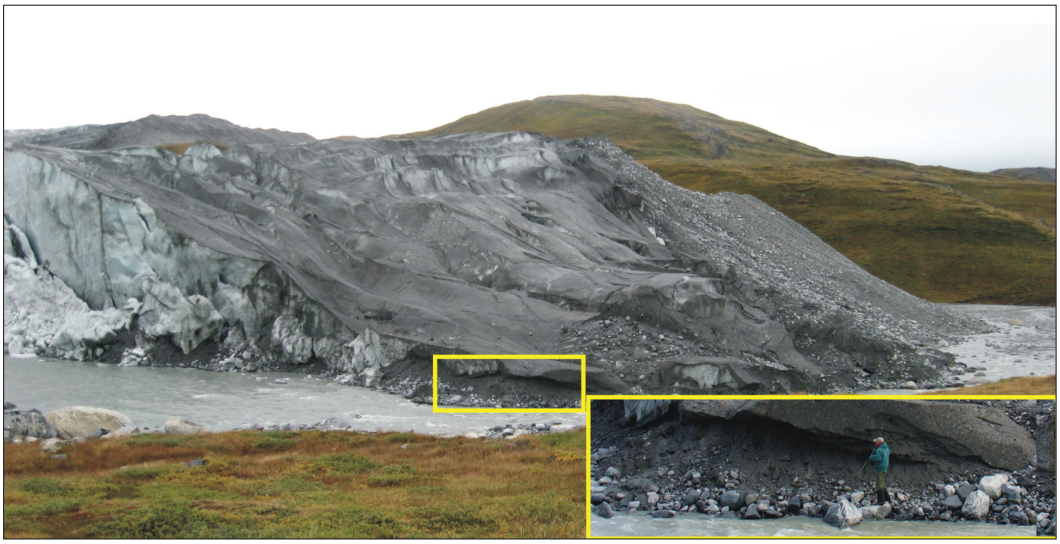

Fig. 4. Study site of basal ice in the south-western corner of Russell Glacier
4 pav. Pamatinio ledo tyrimo vieta pietvakariniame Russell ledyno kampe

Samples were taken from four cross-sections (two samples from each section). The space between the sections was 45–65 m. In the eastern section, the orientation and dip of the longer axes of debris were measured (Fig. 1, measuring site 5). The preferred orientation is NNE–SSW with a typical dip of 0–20° towards SSW. In order to compare the debris within the lateral moraines and the basal ice two samples were taken from the lateral moraine ridge extending parallel to the glacier exposure (see the article about glacigenic landforms in this volume (Šinkūnas et al., 2009)). Three samples of ablation (flow?) till were also taken from the glacier surface above the exposure.

The other exposure studied in detail was situated at the western terminal part of the Russell Glacier near its south western corner. At this locality, the glacier thins to only 3–5 m in thickness and is covered by a thin layer of flow till (Figs. 4, 5, sampling sites 1–4). In the exposure (az 80°), the glacier cross section is composed of three parts: the lower one (0.5–1.0 m thick) – massive facies basal ice with a high concentration of debris (solid sub-facies ice); the middle one (up to 0.6 m in thickness) – subhorizontally stratified basal ice with interlayers of clean ice (discontinuous sub-facies ice); the upper one (0.5–2.0 m thick) – clean ice with the base (lower contact) split from the stratified facies basal ice and having a southward (az 180°) inclination of 18–32°. The samples of basal ice were taken from the two sections spaced 10 m in the upper and central parts. The orientation and dip of the longer axes of debris were measured in the lower part (Fig. 4, 5).

An end moraine, parallel to the western terminus of the Russell Glacier and separated from it by a glaciofluvial river, was observed not far from the mentioned exposure. For comparison, samples for grain-size analysis were taken from four highest parts of the moraine ridge (see the article about glacigenic landforms in this volume (Šinkūnas et al., 2009)).

Fig. 5. Sample (monolith) of debris-rich basal ice from south-western corner of Russell Glacier
5 pav. Nuotrupine medžiaga prisotinto pamatinio ledo monolitas iš pietvakarinio Russell ledyno kampo

One sample for grain-size analysis was taken from each of the other study sites (Fig. 1, sampling sites 5–13). In three more sites, the orientation and dip of the longer axes of debris were measured additionally (Fig. 1, measuring sites 2–4).

The content of debris within the basal ice and its grain-size distribution

In 21 samples, the content of debris within the basal ice ranged from 34.33–86.54%, with a mean value 61% (Fig. 6). Presumably, this high amount of debris within the basal ice influences the mechanical behaviour of the ice, however the shear strain of basal ice still remains unclear and controversial (Lawson, 1996; Echelmeyer, Zhongxiang, 1987).

The results of grain-size analysis showed that the clast material of the basal ice of the Russell Glacier is distinguished by the highest portion of silt and sand fraction in comparison with the ablation (flow) till or material of lateral and end moraines (see the article about glacigenic landforms in this volume (Šinkūnas et al., 2009)). These data were compared with the data of grain-size distribution of basal till in Lithuania. In the Lithuanian till, the content of clay is very high if compared with the clast material of the Greenland glacier (Figs. 7–9) (Baltrūnas et al., 2008).

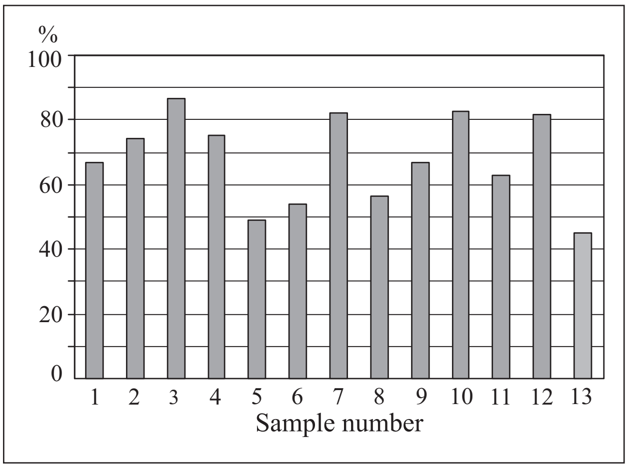

Fig. 6. Content (weight, %) of debris in basal ice of Russell Glacier

6 pav. Nuotrupinės medžiagos kiekis (svoris, %) Russell ledyno pamatiniame lede

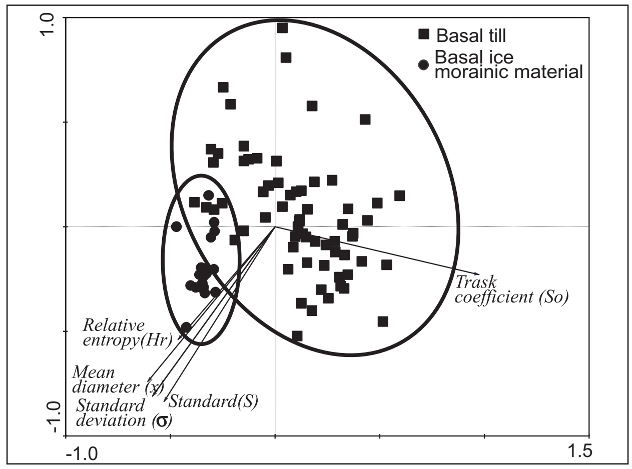

Fig. 8. Diagram of principal component analysis (PCA) of the grain-size distribution of debris of the Lithuanian lodgement till and within the basal ice of Russell Glacier

8 pav. Lietuvos pagrindinės morenos ir dabartinio Russell ledyno (Vakarų Grenlandija) pamatinio ledo nuotrupinės medžiagos dalelių pasiskirstymo pagal dydį pagrindinių komponentų analizės (PCA) diagrama

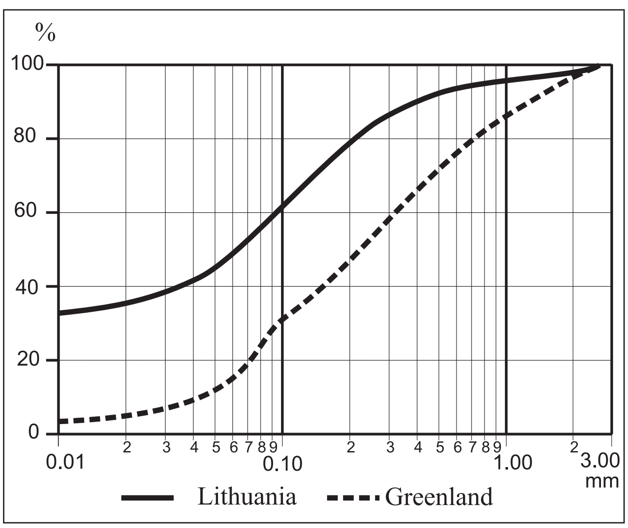

Fig. 7. Generalized cumulative curves of the distribution of debris material according to grain size in the Lithuanian lodgement till and in the basal ice of Russell Glacier (West Greenland)

7 pav. Lietuvos dugninės morenos ir dabartinio Russell ledyno (Vakarų Grenlandija) pamatinio ledo nuotrupinės medžiagos dalelių pasiskirstymo pagal dydį apibendrintos kumuliacinės kreivės

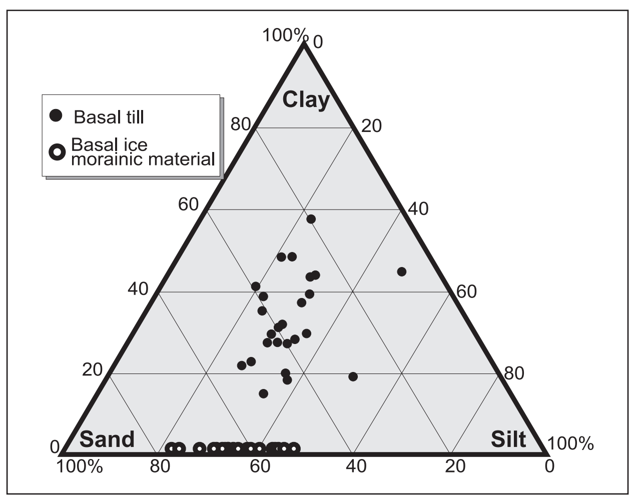

Fig. 9. Grain-size data of sand-clay part of diamicton from basal ice of Russell Glacier and subsurface lodgement till from Lithuania

9 pav. Russell ledyno pamatinio ledo nuotrupinės medžiagos pasiskirstymas lyginant su dugninės morenos nuotrupinės medžiagos pasiskirstymu Lietuvoje

The textural differences between subglacial fills in Lithuania and debris contained within the basal ice of the Russell Glacier can be partly explained by differences in bed lithology in general and the high incidence of clay sediments in Lithuania in particular.

To evaluate the role of mixing within the basal ice of the Russell Glacier, relative entropy was calculated for sand and silt fractions (<0.25 mm), a set of 19 fractions and a set of 6 fractions (2.5–1; 1–0.5; 0.5–0.25; 0.25–0.1; 0.1–0.05; <0.05). The data show that, in general, the grain-size composition of glacial sediments is marked by a high index of relative entropy. In the set of 19 fractions it ranges from 0.948 to 0.986 (Table) and in the set of 6 fractions from 0.840 to 0.994. Meanwhile, in aeolian sediments generated as a result of repeated reworking of similar glacial sediments near Kangerlussuaq, it is 0.610 and 0.361, respectively. A comparison of different types of glacial sediments shows that the index of relative entropy is higher for the grain-size composition of debris within basal ice (the average for 19 fractions is 0.972 and for 6 fractions 0.980).

DEBRIS WITHIN BASAL ICE AS A SOURCE OF INFORMATION ON THE DEVELOPMENT OF TILL PROPERTIES

Investigation of the amount and texture of debris within basal ice of the Russell Glacier and their comparison with the amount and texture of subglacial tills relating to past glaciations in Lithuania provide important insights into the detailed processes of till deposition.

Grain-size composition as a function of comminution and mixing of eroded material. The grain-size characteristics are predermined by the subglacial lithologies initially eroded by the glacier and subsequently by debris comminution and mixing within the actively deforming basal ice. During glacier movement, debris within the basal ice are mechanically milled to silt fraction. Clay particles appear only when a glacier flows across clay-rich lithologies. The increase of the value of relative entropy (index of mixing) of the grain-size distribution of debris is associated with equalization of the content of eroded fractions in the mixing process (if the content of all fractions would be equal, the value of relative entropy would be one). Its variations in the direction of ice flow are evidently related to ice saturation with debris, lasting until the mixture reaches its highest density, i. e. close to optimal (Baltrūnas et al., 2005). The grain-size composition of debris in the basal ice of the Russell Glacier has been modified by deformation of the basal ice, which caused the debris to move towards the mixture of an optimal composition (maximal entropy). The structure of basal ice serves as a proof of this assumption (Fig. 10).

The fact that the values of relative entropy in all samples of basal ice are comparable indicates similar formation conditions and degrees of debris comminution and mixing which is presumably active beneath the interior of the glacier where its thickness reaches 500 m. Meanwhile, for both sets of 19 and 6 fractions of the flow, lateral and end tills, this index amounts to 0.977 and 0.944, 0.978 and 0.952, and 0.963 and 0.904 respectively. This is related with the high variations of the content of fraction <0.05 mm in different samples (from

Table. **Grain-size distribution coefficients of debris within basal ice of Russell Glacier**
Lentelė. **Russell ledyno pamatinio ledo nuotrupinės medžiagos dalelių pasiskirstymo koeficientai**

Samples number	Relative entropy (H_r)	Standard (S)	Trask coefficient (S_0)	Mean diameter (x)	Standard deviation (σ)
1	0.955	0.506	2.774	0.386	6.058
2	0.978	0.544	2.687	0.478	6.451
3	0.976	0.515	2.622	0.427	6.162
4	0.968	0.512	2.542	0.435	6.144
5	0.967	0.541	2.928	0.439	6.338
6	0.961	0.457	2.53	0.376	5.672
7	0.953	0.478	1.677	0.369	5.86
8	0.948	0.448	2.582	0.334	5.558
9	0.99	0.555	2.626	0.464	6.382
10	0.979	0.539	2.622	0.414	6.185
11	0.984	0.554	2.582	0.466	6.411
12	0.975	0.552	2.472	0.437	6.147
13	0.986	0.52	2.582	0.454	6.233
14	0.981	0.624	2.449	0.618	7.063
15	0.977	0.545	2.473	0.434	6.263
16	0.95	0.391	2.251	0.31	5.154
17	0.986	0.541	2.582	0.454	6.339
18	0.981	0.526	2.544	0.434	6.167
19	0.955	0.432	2.523	0.315	5.448
20	0.978	0.553	2.449	0.487	6.465
21	0.982	0.557	2.32	0.513	6.482

Fig. 10. The structure of basal ice on the northern side of Russell Glacier revealing its formation at the stage of plastic movement of ice (observation point 3). *A* – general view, *B* – the study site where the orientation and dip of the longer axes of debris were measured

10 pav. Pamatinio ledo šiauriniame Russell ledyno šone tekstūra, žyminti jo susiformavimą ledo plastiško judėjimo stadijoje (3-ias stebėjimo taškas). *A* – bendras vaizdas, *B* – vieta, kurioje atliktas stambianuotrupinės medžiagos ilgųjų ašių orientacijos ir polinkio matavimas

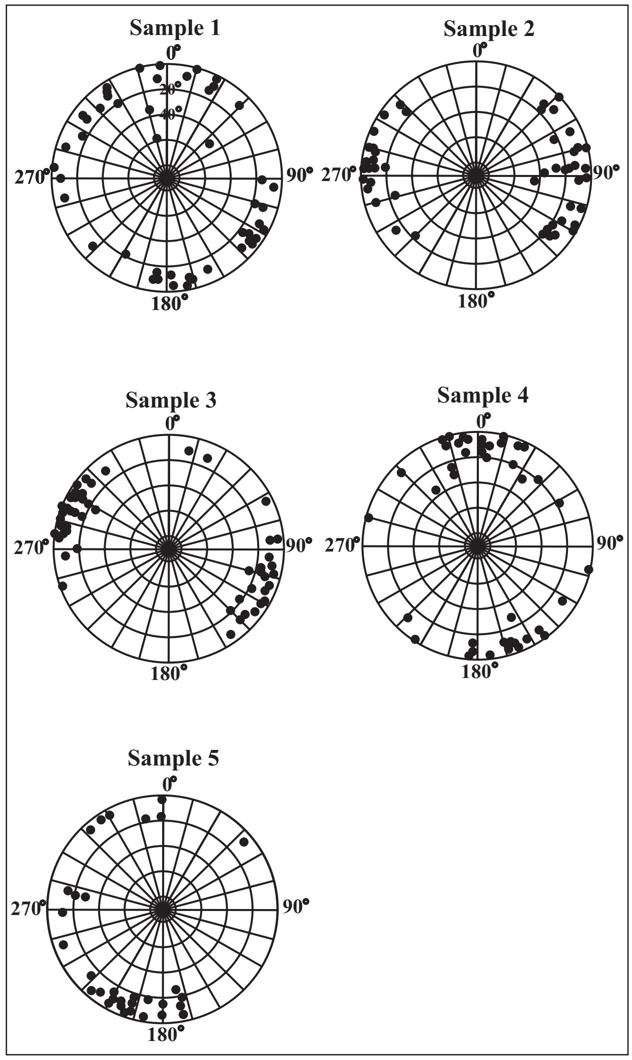

Fig. 11. Orientation and dip of clast longer axes in basal ice of Russell Glacier

11 pav. Russell ledyno nuotrupinių dalelių ilgųjų ašių orientacija ir polinkis pamatiniame lede

1.38 to 13.7%) and highlight differences in the depositional environment.

Orientation and dip of long axes of debris in basal ice of the Russell Glacier are caused by directions and, possibly, the modes of glacier ice movement: the plastic (ice creep) and the movement by planes of internal cleavage. For example, the preferred orientation (az 165 to 225°) of the longer axes of debris in the basal ice near the Lower Russell Lake (observation point 5) can reflect a concurrence of plastic movement and movement by planes of internal cleavage (Fig. 11, sample 5).

In the other two exposures (observation points 3 and 4) on the same northern side of the glacier, this kind of concurrence of movements was also observed. Meanwhile, measurements carried out at south-western terminus of the glacier show two preserved dominant directions: one of them is almost western and the other is SSE in which the blocks of basal ice are inclined (Fig. 11, samples 3 and 4). In the neighbouring exposure (observation points 1 and 2) where the ice block is inclined N, orientation of the long axes of debris in the same direction was not observed (Fig. 11, samples 1 and 2). The available data on the orientation and dip of the longer axes of debris represent an integrated view of plastic flow (movement) and movement by planes of internal cleavage also largely dependent on the relief of the glacier bed.

Lodgement till usually develops after melting of basal ice (especially during areal deglaciation) and under favourable conditions. Its physical properties are predetermined by the properties of debris contained in the basal ice, under- and overlying sediments and syngenetic and epigenetic processes (Baltrūnas et al., 2008).

CONCLUSIONS

The accomplished work leads to the following conclusions:

1. The diversity of sedimentary environments and the influence of identifiable depositional processes on the sedimentological characteristics of tills at the margin of the Russell Glacier (West Greenland) prove the viability of application of the principle of methodological actualism for gaining knowledge about past glacigeneous processes and for reconstruction of palaeogeographical and palaeoclimatic conditions.

2. The grain-size composition of debris in the basal ice of the Russell Glacier has been formed by plastic ice movement which predetermined the formation of the debris as a mixture of an optimal composition (maximal entropy).

3. The available data on the orientation and dip of the longer axes of debris represent an integrated view of ice movement.

4. Investigation of modern day sedimentary environments at the glacier margin provides important information on the sediments and relief generated by retreating glaciers. The information on the formation of debris in an advancing glacier is fixed in the debris of basal ice.

5. The basal ice of actual glaciers can be viewed as the initial stage of lodgement till formation occurring during active glacier flow which predetermines the initial grain-size structure of lodgement till.

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PAMATINIO LEDO NUOTRUPINĖS MEDŽIAGOS KAIP ŠALTINIO PAGRINDINĖS MORENOS FORMAVIMUISI SEDIMENTOLOGIJA REMIANTIS RUSSELL LEDYNO VAKARŲ GRENLANDIJOJE PAVYZDŽIU

Santrauka

Šio darbo tikslas – įvertinti Russell ledyno (Vakarų Grenlandija) pamatinio ledo, kaip pagrindinės morenos formavimosi stadijos, nuotrupinės medžiagos pasiskirstymo ypatybes. Siekiant jį įgyvendinti buvo: 1) nustatytas nuotrupinės medžiagos kiekis pamatiniame lede ir šios medžiagos granuliometrinė sudėtis; 2) nustatyta stambianuotrupinės medžiagos ilgųjų ašių vyraujanti orientacija ir polinkis; 3) įvertintos nuotrupinės medžiagos struktūros formavimosi ypatybės. Iš pamatinės ledyno dalies nuotrupinės medžiagos ėminiai buvo imami ištirpinus vietoje 1,9–9,6 kg moreningo ledo. Išgarinus iš ėminių vandenį, sausoji nuotrupinė medžiaga buvo atgabenta į Geologijos ir geografijos instituto laboratoriją Vilniuje, kurioje buvo atlikta granuliometrinė analizė panaudojus 19 sietų komplektą su kratytuvu FRITSCH. Penkiose atodangose geologiniu kompasu buvo atlikti pamatinio ledo stambios nuotrupinės medžiagos ilgųjų ašių orientacijos ir polinkio matavimai. Tirtos atodangos šiauriniame, vakariniame ir pietiniame ledyno šonuose. Dvi atodangos ištirtos nuodugniau paimant daugiau ėminių.

Nuotrupinės medžiagos kiekis 21 pamatinio ledo ėminyje sudarė nuo 34,33 iki 86,54% (vidutiniškai – 61%). Matyt, toks nuotrupinės medžiagos kiekis reikšmingai padidina pamatinio ledo svorį, dėl kurio sumažėja ledyno plastiško judėjimo greitis. Tai lemia tokio pamatinio ledo atsiskyrimą nuo lengvesnio ir greičiau judančio ledo. Granuliometrinės analizės rezultatai rodo, kad didesnė Russell ledyno pamatinio ledo nuotrupinė medžiagos dalis yra aleuritinė ir smėlinga, skirtingai nei paviršinė, šoninė ir galinė morenos. Šie duomenys buvo palyginti su Lietuvos pagrindinės morenos granuliometrinės analizės duomenimis. Lietuvoje moreninėje medžiagoje molio labai daug, palyginus su Grenlandijos ledyno morenine medžiaga. Granuliometrinės sudėties struktūrą lemia egzaruojamo ledyno guolio uolienų petrologija, taip pat nuotrupinės medžiagos smulkinimas ir maišymas ledyno slinkimo metu. Ledynui slenkant nuotrupinė medžiaga yra mechaniškai smulkinama iki aleurito frakcijos. Nuotrupinės medžiagos granuliometrinės sudėties santykinės entropijos (kaip išmaišymo rodiklio) didėjimas yra susijęs su išskiriamų dalelių (frakcijų) kiekio vienodėjimu maišantis. Pamatinio ledo nuotrupinės medžiagos ilgųjų ašių krypties orientacija bei polinkis Russell ledyno atveju gali liudyti du ledo judėjimo būdus: buvusį plastišką ir šiuo metu vykstantį blokinį. Apskritai dabartinių ledynų pamatinis ledas traktuotinas kaip dugninės morenos formavimosi pradinė stadija, pasireiškusi ledo plastiško tekėjimo metu bei lėmusi dugninės morenos granuliometrinę struktūrą.

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ОСОБЕННОСТИ РАСПРЕДЕЛЕНИЯ ОБЛОМОЧНОГО МАТЕРИАЛА БАЗАЛЬНОГО ЛЬДА КАК ЭТАПА ФОРМИРОВАНИЯ ДОННОЙ МОРЕНЫ В ЛЕДНИКЕ РУССЕЛЛ, ЗАПАДНАЯ ГРЕНЛАНДИЯ

Резюме

Цель настоящей работы – оценить особенности распределения обломочного материала базального льда ледника Русселл в Западной Гренландии. Для этого решались следующие задачи: 1) определение количества обломочного материала в базальном льде, а также гранулометрического состава этого материала; 2) определение преобладающей ориентировки и наклона длинных осей крупнообломочного материала; 3) оценка особенностей формирования структуры обломочного материала. Образцы обломочного материала отбирали из базальной части ледника, на месте растворяя 1,9–9,6 кг базального льда. Высушенный обломочный материал далее изучался в лаборатории Института геологии и географии в Вильнюсе, где был осуществлен гранулометрический анализ с применением комплекта 19 ситов FRITSCH. В пяти обнажениях геологическим компасом измерялись ориентировка и наклон длинных осей крупнообломочного материала. Изучались обнажения базального льда на северном, западном и южном склонах ледника. В двух обнажениях проведены более детальные исследования (отбирали больше образцов).

В 21 образце базального льда количество обломочного материала составило от 34,33 до 86,54 %, в среднем 61 %. По-видимому, такое количество обломочного материала значительно увеличивает вес базального льда, что способствует снижению скорости пластического движения льда и отщепления его от более легкого и быстрее движущегося льда. Результаты гранулометрического анализа показали, что обломочный материал базального льда ледника Русселл характеризуется большим количеством песчано-алевритовой части, в отличие от поверхностной, боковой и конечной морен того же ледника. Эти данные также сравнивались с данными гранулометрического анализа донной морены Литвы, где обломочный материал значительно более глинистый. Структуру гранулометрического состава ледниковых отложений обусловливают петрология экзарируемых пород ледникового ложа, а также механизм дробления и перемешивания обломочного материала во время движения ледника. В процессе ледникового дробления материал измельчается до частиц мелкого алеврита. Увеличение относительной энтропии гранулометрического состава как показателя перемешивания связано с выравниванием количества размерных частиц в процессе перемешивания обломочного материала в массиве движущегося ледника. Измерения ориентировки и наклона длинных осей крупнообломочного материала в базальной части ледника Русселл могут свидетельствовать, что существуют два способа движения льда: бывшего пластического и современного (настоящего) в виде чешуй по плоскостям внутренних сколов ледника. По сути, базальный лед современных ледников можно трактовать как начальную стадию формирования донной морены (донного тилла), проявившуюся еще в процессе пластического движения льда и обусловливающую структуру гранулометрического состава обломочного материала.