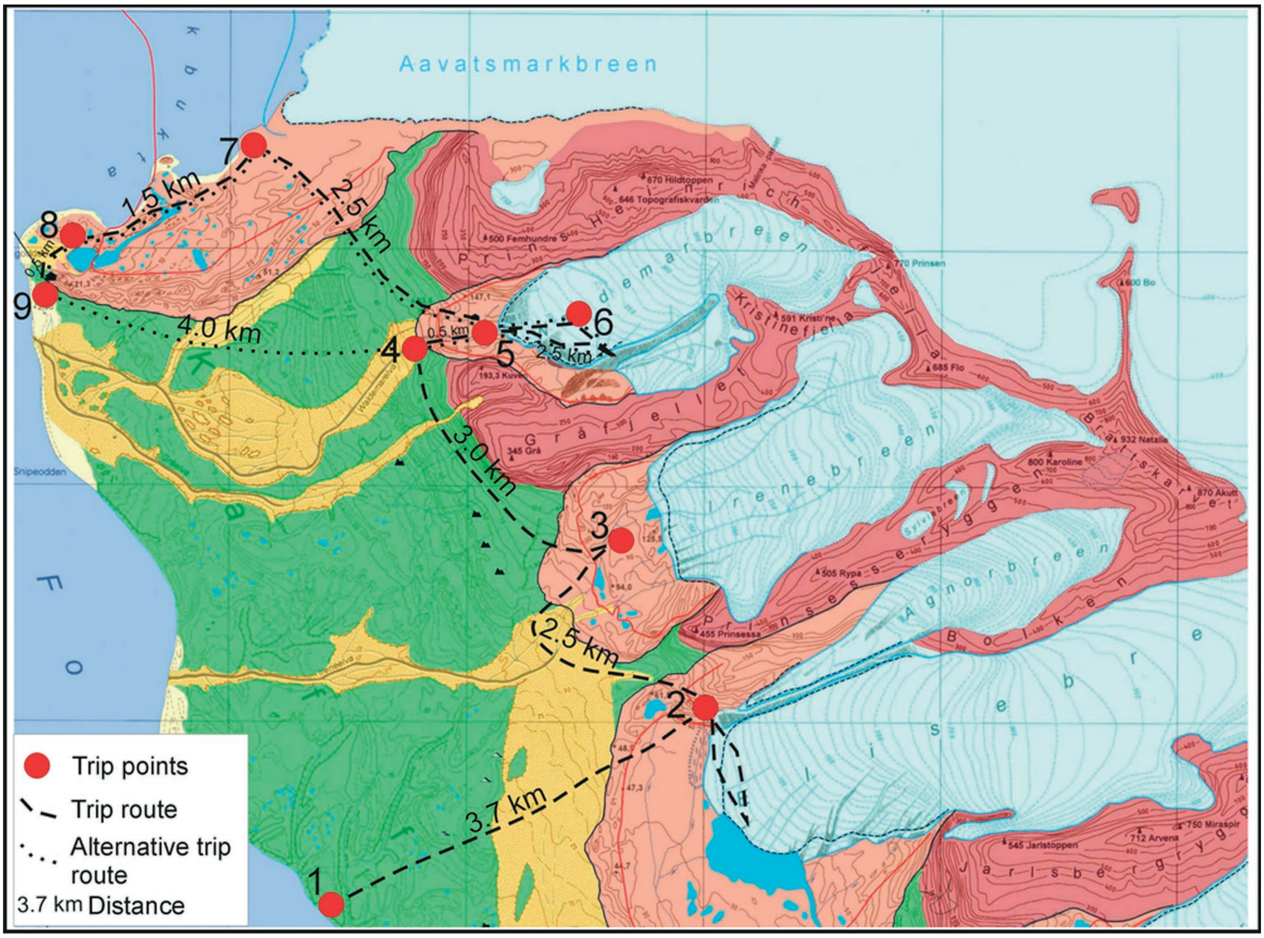
Glaciology, hydrology and geomorphology in the Kaffiøyra region – Leader Ireneusz Sobota



Point 1 – KAFFIØYRA 78° 37’ 45” N 11° 56’ 59” E
Marek Grześ, Ireneusz Sobota – Geography of Kaffiøyra

Point 2 – ELISEBREEN 78° 38’ 44” N 12° 05’ 38” E
Ireneusz Sobota – Summer balance of Elisebreen

Point 3 – IRENEBREEN 78° 39’ 24” N 12° 03’ 26” E
Ireneusz Sobota – Summer balance of Irenebreen

Point 4 – WALDEMAR RIVER 78° 40’ 23” N 11° 58’ 10” E
Point 4a – Marek Grześ – Naledi of the Kaffiøyra
Point 4b – Ireneusz Sobota – Discharge of Waldemar River and outflow from glacier
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Point 5 – WALDEMARBREEN 78° 40’ 30” N 11° 59’ 28” E
Point 5a – Ireneusz Sobota – Mass balance monitoring of Kaffiyra glaciers
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Point 6 – ICE DRILLING 78° 40’ 31” N 12° 01’ 50” E
Erich Heucke, Ireneusz Sobota – The sample ice drilling on Waldemarbreen with Heucke Ice Drill – the demostration

Point 7 – AAVATSMARKBREEN 78° 41’ 07” N 11° 53’ 39” E
Marek Grześ, Michał Król, Ireneusz Sobota – Subaqual recordings of the changes in the range of glaciers in the Forlandsundet region (NW Spitsbergen)

Point 8 – GÓRNE LAKE 78° 40’ 42” N 11° 50’ 19” E
Ireneusz Sobota – Selected problems of changes in morphometry, bathymetry and thermal conditions in the lake complex at the forefield of Aavatsmarkbreen

Point 9 – NICOLAUS COPERNICUS POLAR STATION 78° 40’ 33” N 11° 49’ 36” E
Marek Grześ, Ireneusz Sobota – www.stacja.arktyka.com

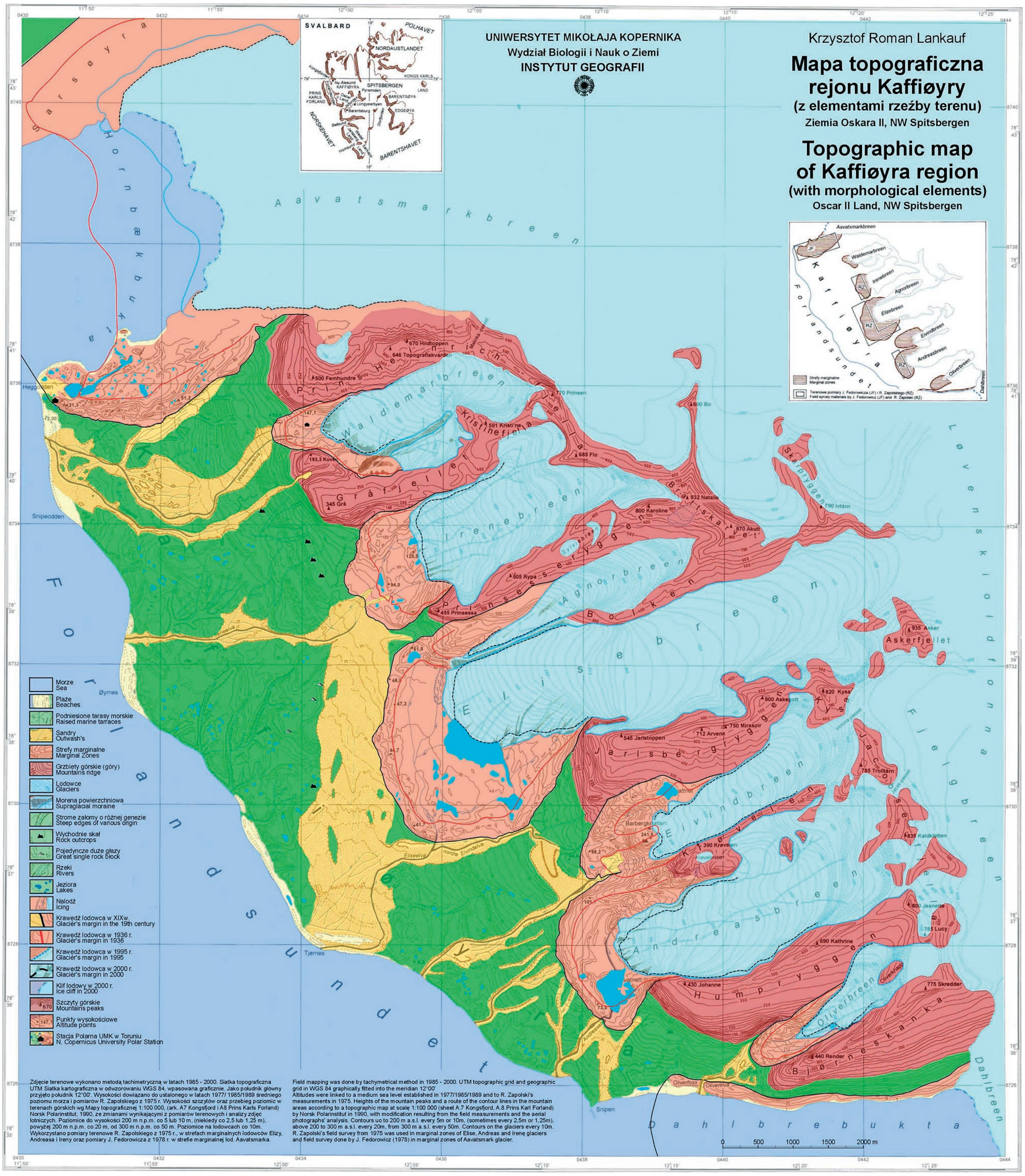

Fig. 1. Map of Kaffiøyra – K.R. Lankauf

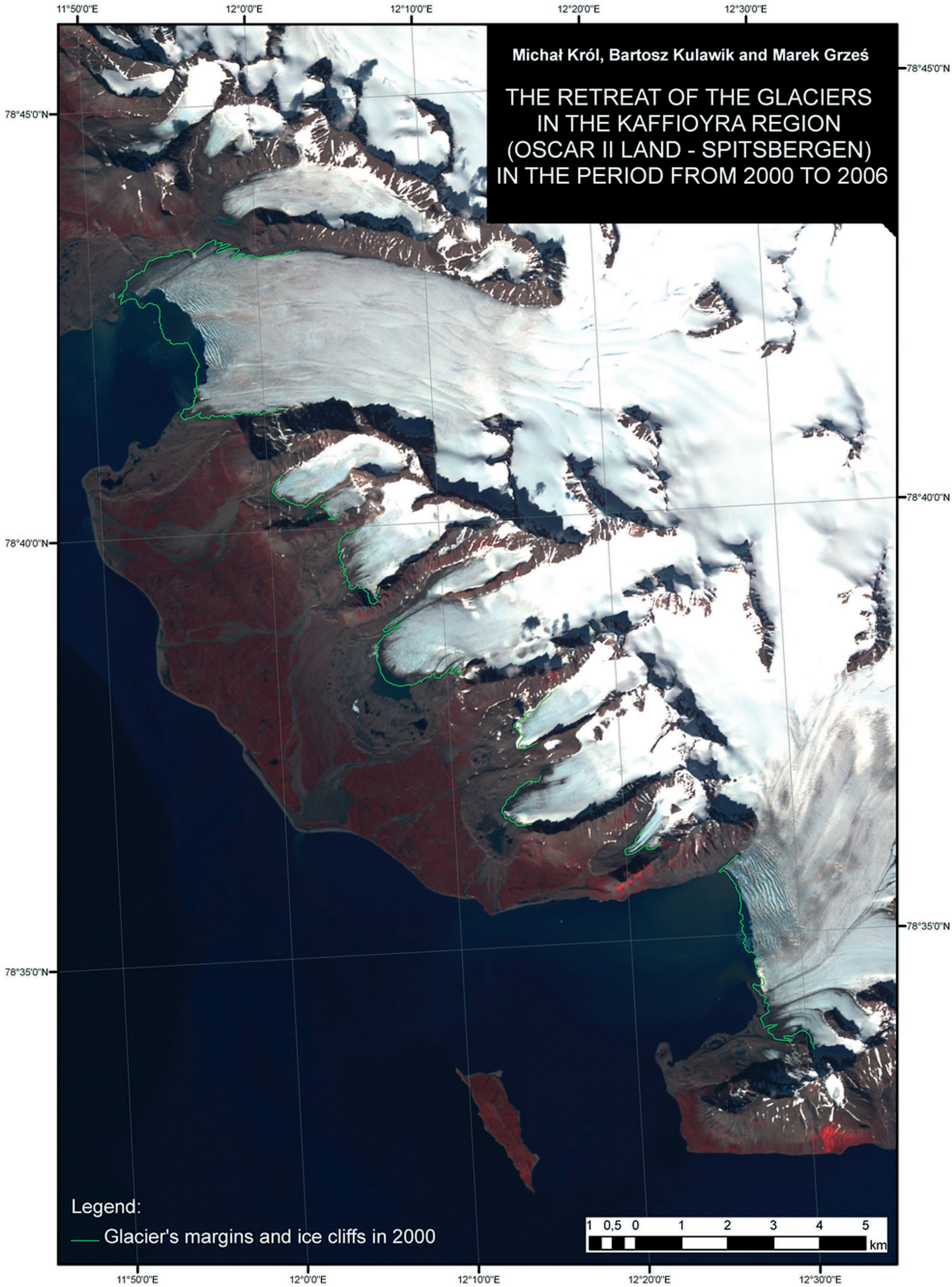

Fig. 2. The retreat of the glaciers in the Kaffiøyra region (Oscar II Land – Spitsbergen) in the period from 2000 to 2006 – M. Król, B. Kulawik and M. Grześ

Point 2 – Elisebreen *78° 38' 44" N 12° 05' 38" E*

Summer balance of Elisebreen

Ireneusz Sobota*

Department of Cryology and Polar Research, Institute of Geography, N. Copernicus University, Toruń, Poland

The studies of ablation of Kaffiøyra glaciers refer to Waldemarbreen, Irenebreen and Elisebreen. In 2006 the studies of ablation of Elisebreen began.

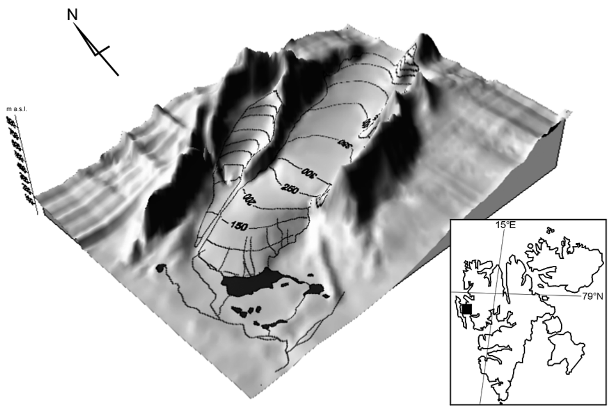

Fig. 1. Topographical draft of Elisebreen

These researches are continued (Sobota, 2004, 2005a). The measurements of surface ablation were made from July to September each year. All ablation poles were drilled 10 m deep with a steam driven Heucke Ice Drill (Heucke, 1999). Snow, firn and ice ablation were converted into water equivalent (w.e.).

Elisebreen area is 11.9 km^2. Its length is about 7 km, while its width is up to 1.8 km. To the north the glacier borders Agnorbreen which is often treated as part of Elisebreen. The northern border of the glacier is marked by the ranges of the Prinsesserygen and Prins Heinrichfjella, while the southern border by the ranges of thr Jarlsbergryggen, Kysa and Askerfjellet. In the east the glacier is connected with the Løvenskiold Plateau. The altitude of the frontal part of the Elisebreen is about 30–60 m above sea level (a.s.l).

Fig. 2. Frontal part of Elisebreen during summer time (photo I. Sobota)

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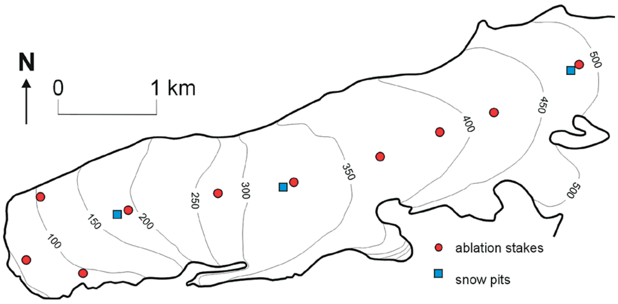

Fig. 3. Map of ablation stakes and snow pits on Elisebreen

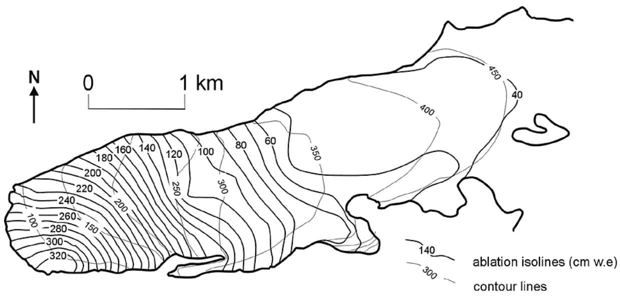

Fig. 4. Map of ablation of Elisebreen in 2006

Spatial diversity of ablation of Elisbreen shows clearly that the largest values were reached in the front part; they decreased towards the accumulation field, where snow cover was found throughout the entire summer season. The size of ablation in the frontal part of glacier (about 3 m of w.e.) was much higher than those of both Waldemarbreen and Irenebreen. This mainly resulted from the fact the altitude of this part of glacier is lower.

In 2006 the summer balance of Elisebreen was –135 cm w.e. Such large negative values during that period resulted from a very early beginning of the ablation season.

The weather conditions of the summer season of 2006 conditioned earlier, compared to previous years, ice- and snow-melting processes in lower parts of the glaciers. Thus, in spite of a large snow accumulation in winter, the mass balance of all the analysed s was negative.

Point 3 – Irenebreen *78° 39' 24" N 12° 03' 26" E*

Summer balance of Irenebreen

Ireneusz Sobota*

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The studies of the summer balance of Irenebreen were taken between 2001 and 2006. This researches are continued (Sobota, 2004, 2005b). The measurements of surface ablation were made every 5–7 days from July to September each year. All ablation poles were drilled 10 m deep with a steam driven Heucke Ice Drill (Heucke, 1999). Snow, firn and ice ablation were converted into water equivalent (w.e.).

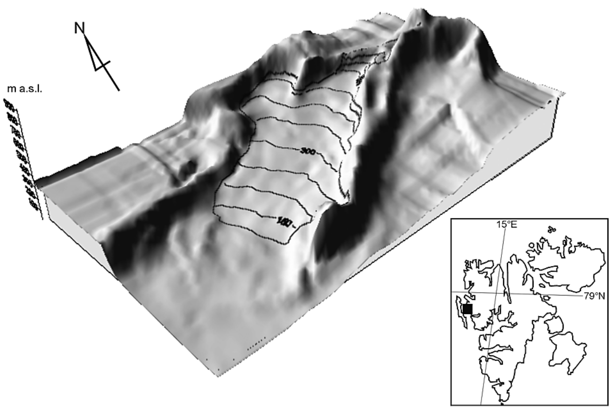

Fig. 1. Topographical draft of Irenebreen

Irenebreen is a valley glacier located to the south of Waldemarbreen, flows down towards the Kaffiøyra plain. In the north it borders the mountain chain of the Gråfjellet and Kristinefjell Range, in the east with the Prins Heinrichfjell Range, while in the south with the Prinsesserygen Range. The area of Irenebreen amounts to 4.2 km^2, its length to 4 km, while its width ranges from about 1 km in its frontal zone to about 1.5 km in the east section. Irenebreen has two significant accumulation zones. Ice masses flowing from them join into a glacier tongue which moves to the south west and ends on the Kaffiøyra.

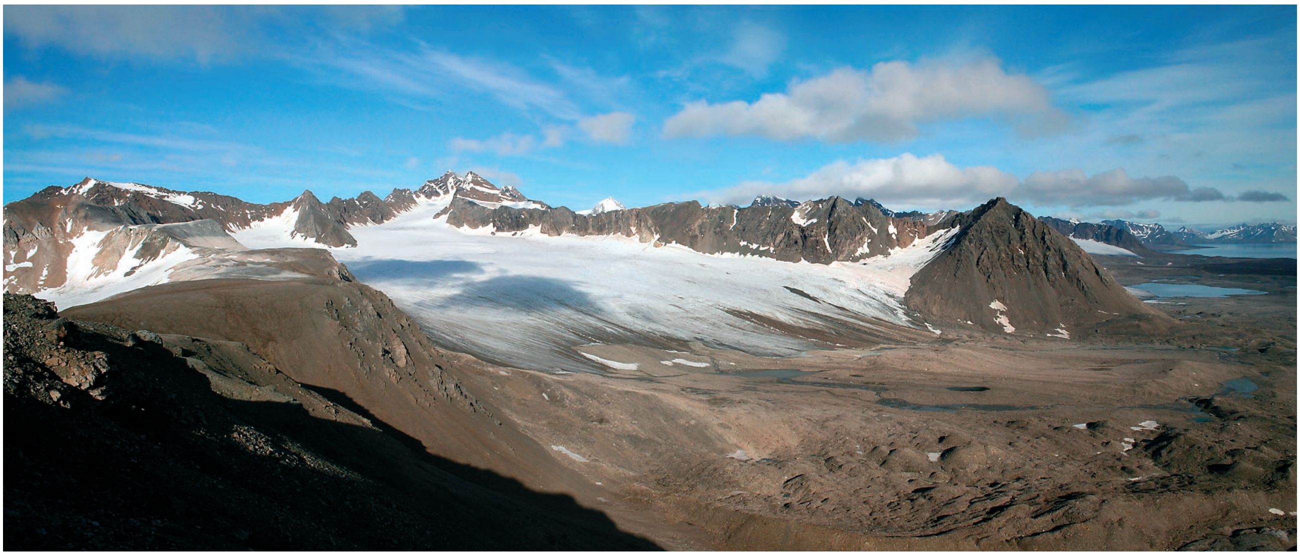

Fig. 2. Irenebreen during summer time (photo I. Sobota)

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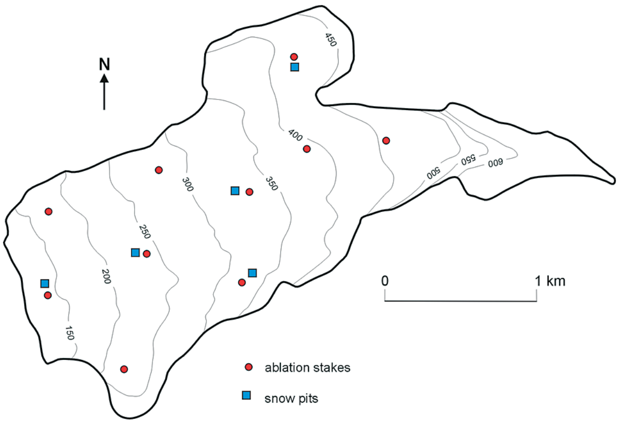

Fig. 3. Map of ablation stakes and snow pits on Irenebreen

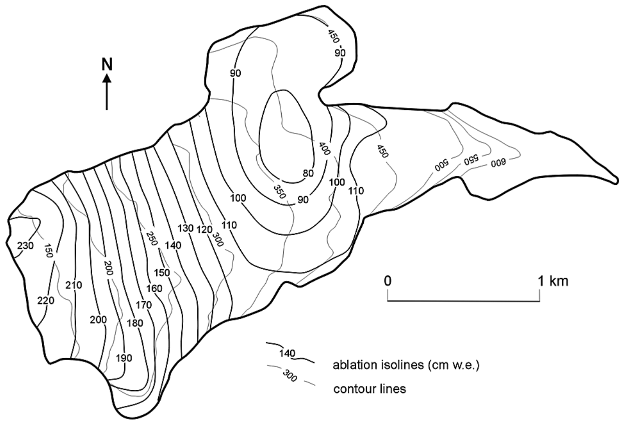

Fig. 4. Map of ablation of Irenebreen in 2006

Time changeability of ablation Irenebreen at various latitudes was significantly diverse. The greatest changeability was observed in the lowest parts of glacier. With the growing altitude the fluctuations decrease. There is a large difference in ablation intensity between the frontal part of the glacier and its accumulation part. This is mainly connected with the diverse weather conditions in these parts of glacier. The parts of glacier which are located high are influenced by lower air temperatures and thus ablation there are either much less intense or non-existent. The lowest part of glacier, however, is often located in the zone of much warmer air masses, and thus ablation are much more intensive there. Very often the altitude-related ablation is also influenced by local conditions of a given glacier, such as the slope aspect, its exposition, surrounding mountain slopes, the amount of morainic material on glacier and the system of supraglacial streams.

Spatial differentiation of ablation on Irenebreen also shows some regularity. The most intensive ablation was recorded in the northern part of the frontal section of glacier, while the least intensive was recorded on the accumulation field. Lower values of ablation intensity were also recorded in the south-central part of glacier. It is located at the foot of the mountains which means sunrays are blocked there. Such a situation influences the intensity of ablation.

The average summer balance of Irenebreen amounted to –124 cm w.e. for the period of 1996–2006. In the years 1996–2006 the cumulated total ablation of Irenebreen was about –740 cm w.e.

Point 4a – Waldemar River *78° 40' 23" N 11° 58' 10" E*

Naledi of the Kaffiøyra

Marek Grześ*

Department of Cryology and Polar Research, Institute of Geography, N. Copernicus University, Toruń, Poland

Most studies into the naledi of a glacial origin in the Svalbard were conducted to the summer season, that is when the naledi subject to greater disintegration or warnningg. The research focusec upon a morphogenetic role of the naledi.

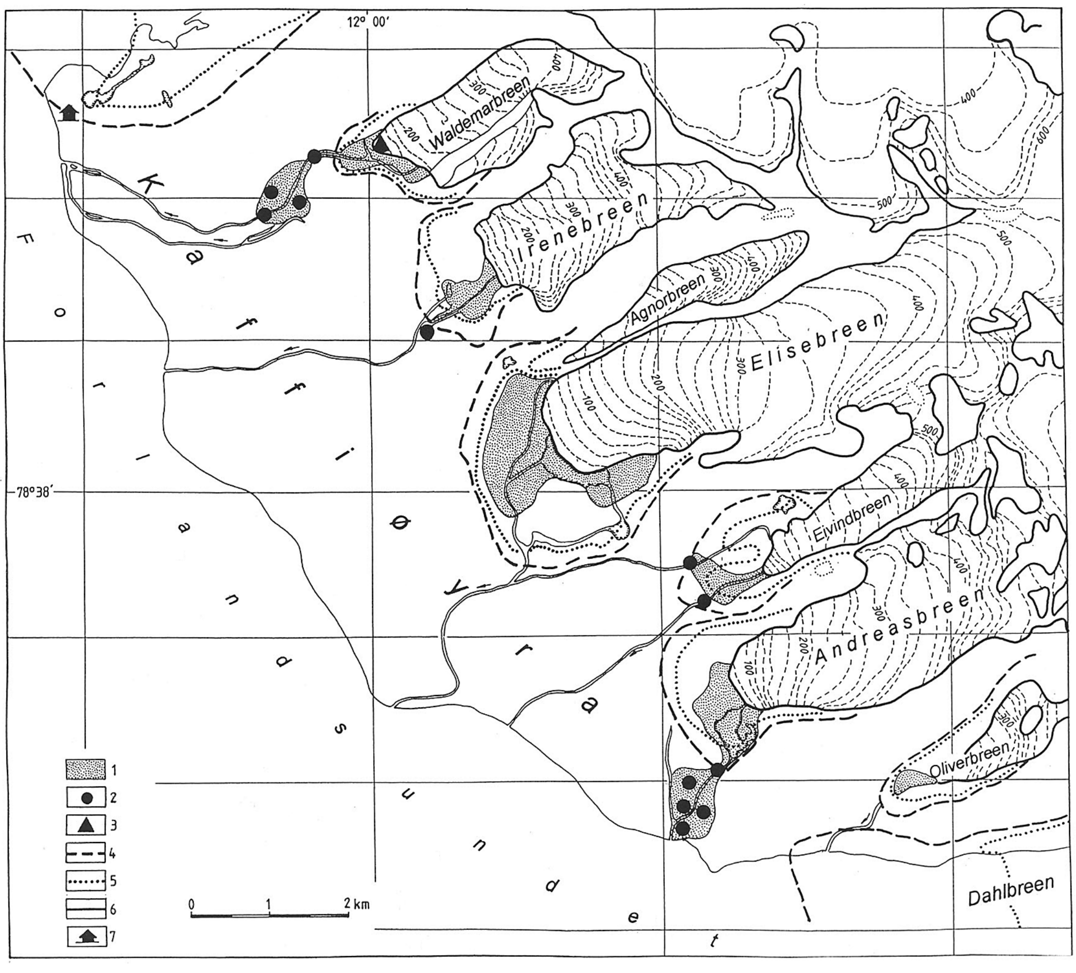

Fig. 1. Naledi of the Kaffiøyra
1 – areas occupied by naledi, 2 – icing mounds, 3 – supraglacial naled, 4 – extents of glaciers In the 18th/19th centuries, 5 – extents of glaciers in 1936, 6 – extents of glaciers in 1995, 7 – Nicholas Copernicus University Polar Station. The naled map was made on the grounds of the map of glacier extents by K.R. Lankauf (1999)

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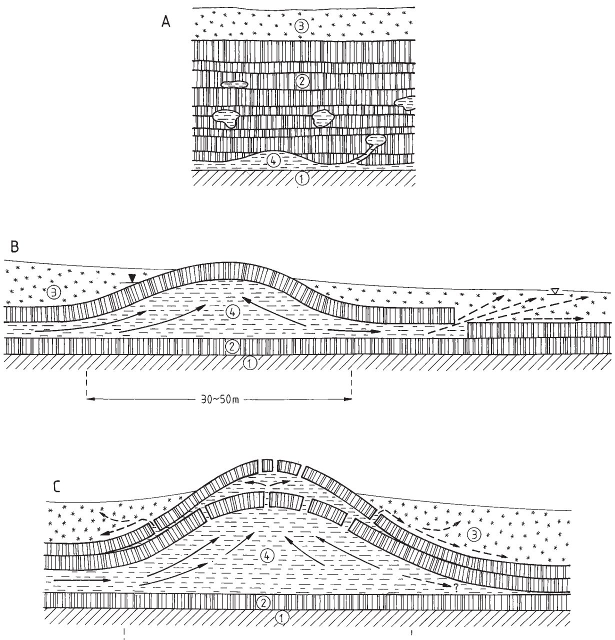

Fig. 2. Naled drainage schemes
A – Typical naled cross-section, B – Cross-section of a closed icing Mount, C – Cross-section of an open icing Mount; 1 – bedding, 2 – naled ice, 3 – snow, 4 – water

The present investigations were carried out in the forefields of six glaciers in the Kaffiøyra., in the the north-west of Spitsbergen.

The observation have been carried out since 1975, during spring time (April–May) and summer time (July–August). All the the glaciers were found to be accompanied by naledi.

However, it is only inthe case of the Waldemar and Andreas glaciers tht the naledi partially covered the outwash plains (see map). The studies explained this was related to the capasity of accumulating glacier waters in the marginal zone. The phenomenon was defiined as the marginal zone capacity and was was found to depend upon its configuraion. It must be assumed that at the time of the glacier progressing recession, naled cannot be formed in the extra-marginal zones.

It is very difficult to determine the area of the naledi precisely. They are mantled with a snow cover which plays decisive role in the migration of the outflowing water from the glacier. It was found that sesonal changes in the area of the naledi amounte to 15–20% front of the particular glaciers. The results of the investigations in the Kaffiøyra led to a conclusion that the naledi of a glacial origin reached the larges sizes in the winter and spring protected by a warmer and humid summer seasons

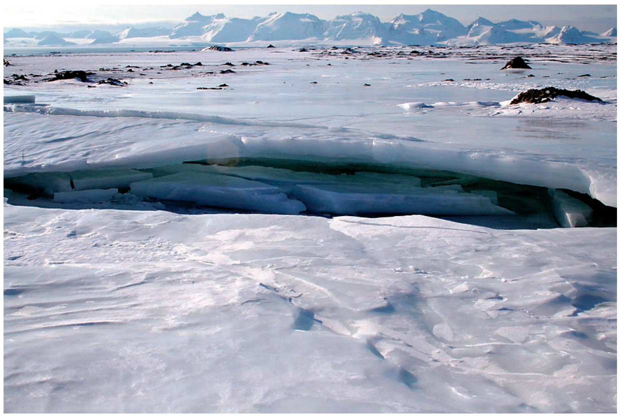

Fig. 3. Naledi (photo I. Sobota)

Every spring the naledi of the Kaffiøyra reaached the area of approximately 4.5 km^2 on average.

The comparison of values, that bigger galciers are accompanied by bigger naledi.

The volume of a naledi ice should be taken into consideration while making these estimates. It is complicated to establish the plume of a winter discharge from glaciers on the grounds of the naled ice.This results from a huge portion of water saturated snow (up to 80%). At the time of a naled-formation there are two systems of water migrations in them: free (gravitational) and forced (under pressure). Ice mounds are characteristic elements of a naled surface configuration.

One supraglacial naled was found on the Waldemar Glacier, but it was seasonal winter outflow only. It has had a consderable influuence upon the course of the glacier retreat. Very important problem concerning the volume of water trapped in naledies. In May 1998 it was equal to about 0.5 mln m^3. The average winter outflow from the Waldemar Glacier was estimated to 0.024 m^{-3} s i.e l km^{-2} (Grześ, Sobota 2000).

The wanning of the naledi was not the subject of the authors investigations. It was concluded, however, that the intensity of this phenomenon was determined by the disintegration of the naled sheets, division into smaller fields. This disintegration can occur in sub-naled and in-naled channels of winter drainage.

Point 4b – Waldemar River *78° 40' 23" N 11° 58' 10" E*

Discharge of Waldemar River and outflow from glacier

Ireneusz Sobota*

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Catchment basins of six rivers can be distinguished on the Kaffiøyra plain. The catchment basin of Waldemar River is the smallest; its area takes 4.4 km^2, 62% out of which is taken by Waldemarbreen. The measurement site was located at the point where the river enters the outwash plain, about 500 m from the glacier frontal part. The length of Waldemar River from that place is about 1 kilometre. Below that point the river shows anastomosing character. The main factor shaping the catchment basin of Waldemar River is fluvioglacial water of the Waldemarbreen. Its area includes the streams fed both by the ablation water and precipitation water.

The largest intensity of the discharge corresponded with the period of highest ablation level. The closest correlation was visible when a few-day values were analysed. Additionally, there were periods when increased intensity of discharge was recorded later than the maximum of ablation. This mainly resulted from temporary retention of melted snow in the form of slush, large patches of which were found on glaciers. During every summer season ablation exerted distinct influence over the size of the discharge of Waldemar River. This is proved by the correlation between ablation and discharge.

Mean discharge of Waldemar River between 1996 and 2006 was 1.21 m^3s^{-1}, while in 2006 was 1.08 m^3s^{-1}.

In order to measure water stages and water temperatures at 5-minute intervals the HOBO logger was used. This enabled the author to estimate the discharge rate, both daily and mean for the entire summer season.

The mean outflow from Waldemarbreen between 1996 and 2006 was 4,578,641 m^3s^{-1} of water, which was carried away by Waldemar River. The share of the ablation within the outflow was, on average, 56%. The remaining part was made up by rainfall, outflow from the ice covers as well as other local sources of water (inter-glacier outflow, melting of snow from the mountain slopes).

Fig. 1. Waldemar River in 2006 summer (A) and 2007 spring (B), (photo I. Sobota)

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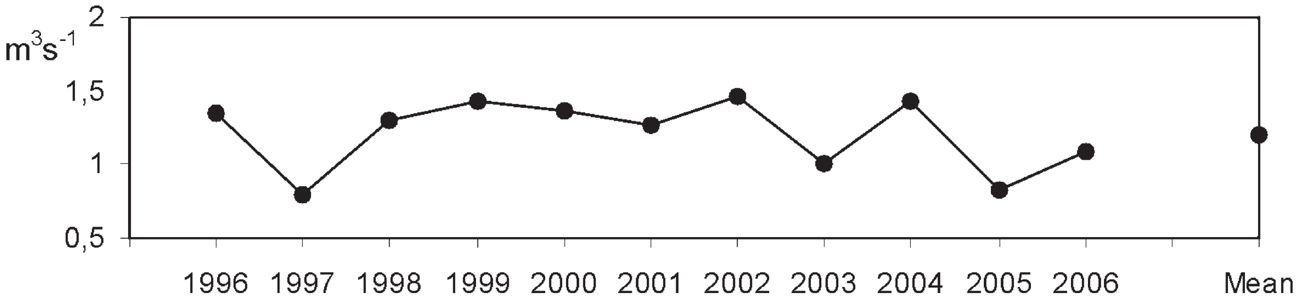

Fig. 2. Mean discharge of Waldemar River in 1996–2006

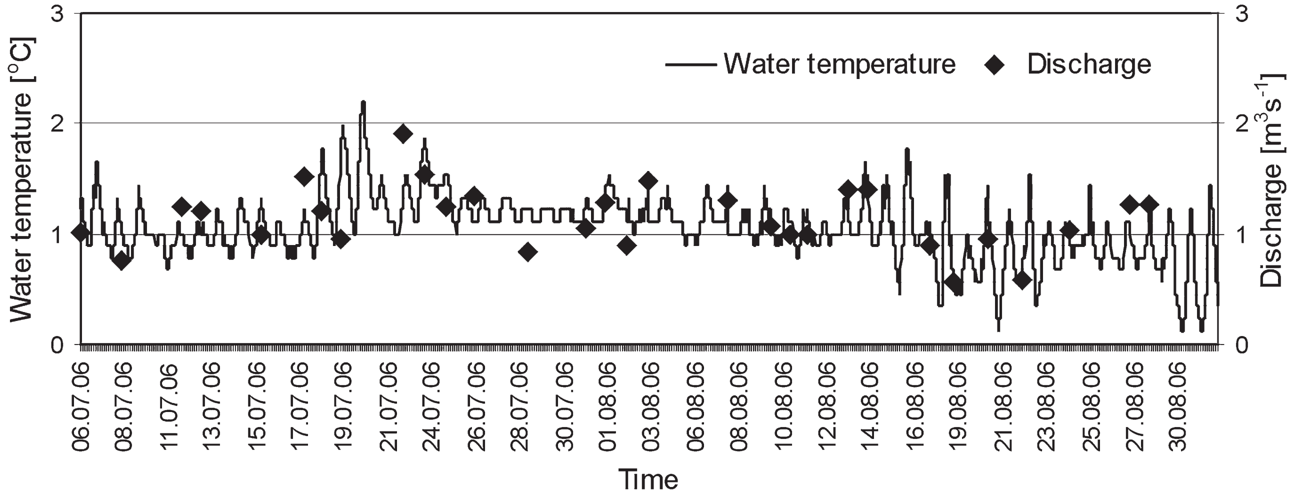

Fig. 3. Water temperature in Waldemar River against discharge in summer 2006

Point 4c – Waldemar River *78° 40' 23" N 11° 58' 10" E*

Thickness of mineral covers on the ice-cored moraine and an active layer of permafrost on the western coast of the Oscar II Land (Svalbard)

Marek Grześ*

Department of Cryology and Polar Research, Institute of Geography, N. Copernicus University, Toruń, Poland

Ice-cored moraines belong to the dominating forms in the landscape of the glaciers marginal zones. The relict glacial ice existence in in the ice-covered moraines depends on climatic conditions, the thickness of mineral covers and their seasonal thawing. In the case of the active layers contacting the top of the relict ice, its disappearing is quicker. Mass movements uncovering ice play the greatest role then. That phenomenon is much more important at the initial phase of ice-cored moraines degradation. When the thickness of the mineral cover increases, the rate in which ie thaws decreases. As a result, slope processes slow down distinctly. At that moment ice-cored moraines reach the mature stage, which is indicated by numerous thermokarst hollows with no drainage.

The top parts of the ice-cored moraine lack snow covers throughout the whole year. The process of thawing last about 1.5 months longer as compare to the surrounding area. Its begins as early as in the second part April and gets to he depth of 0.3–0.4 m in first ten of May. Besides climatic conditions slope layers character play a significant role in relict ice degradation. Four characteristic phases distinguished in evolution of ice-cored moraine.

The questions arise: How long can the ice-core moraine exist? What geomorphological effects occur after the ice-core melting? Known that the outer series of ice-cored moraine were formed at the turn of the 19th century. These are "mature" forms which, however, contain ice inside.

The depth of summer thaw in various kind of ground has been presented as a scheme on the fig. 2. From the analysis of a set of estimates available, it follows that at least seven different environments which differ in the course and of thaw, i.e. the thickness of the active layer, my be recognized:

Ia, Ib) ground varying in particle, size distribution, with a blanketing continuous organic layer, more than 20 cm thick,

II) tills with high moisture contents which are colonized by luxuriant tundra vegetation,

III) gravels, sands and silts within depressions at marine terraces, which are occupied by luxuriant tundra vegetation,

IV) modeled (patterned) ground, the interior of which is build up of predominant earth particles and which is colonized by extremely luxuriant tundra vegetation,

V) sands, gravels of which marine terraces covered with sparse tundra vegetation are built up,

VI) gravels and sands forming present-day outwash fans,

VII) mineral mantle (boulders, silts, ...) over ice-core moraine.

The established pattern of seasonal thaw in various kind of ground at an 60 m a.s.l. provides the basis of plotting of eight (Ia, Ib, ... VII) empirical curves, the approximations of which are given by the formula:

$$h = a \lg (T \pm c) - b$$

where h is the depth of a thawed layer, a and b are constants coefficients defining a thawing layer, T is the duration of thaw in days, c is allowance for earlier (+) or a later (-) disappearance of snow at given locality. Index c is calculated in the following way: the actual number of the 24-hour of delay divided by 4.

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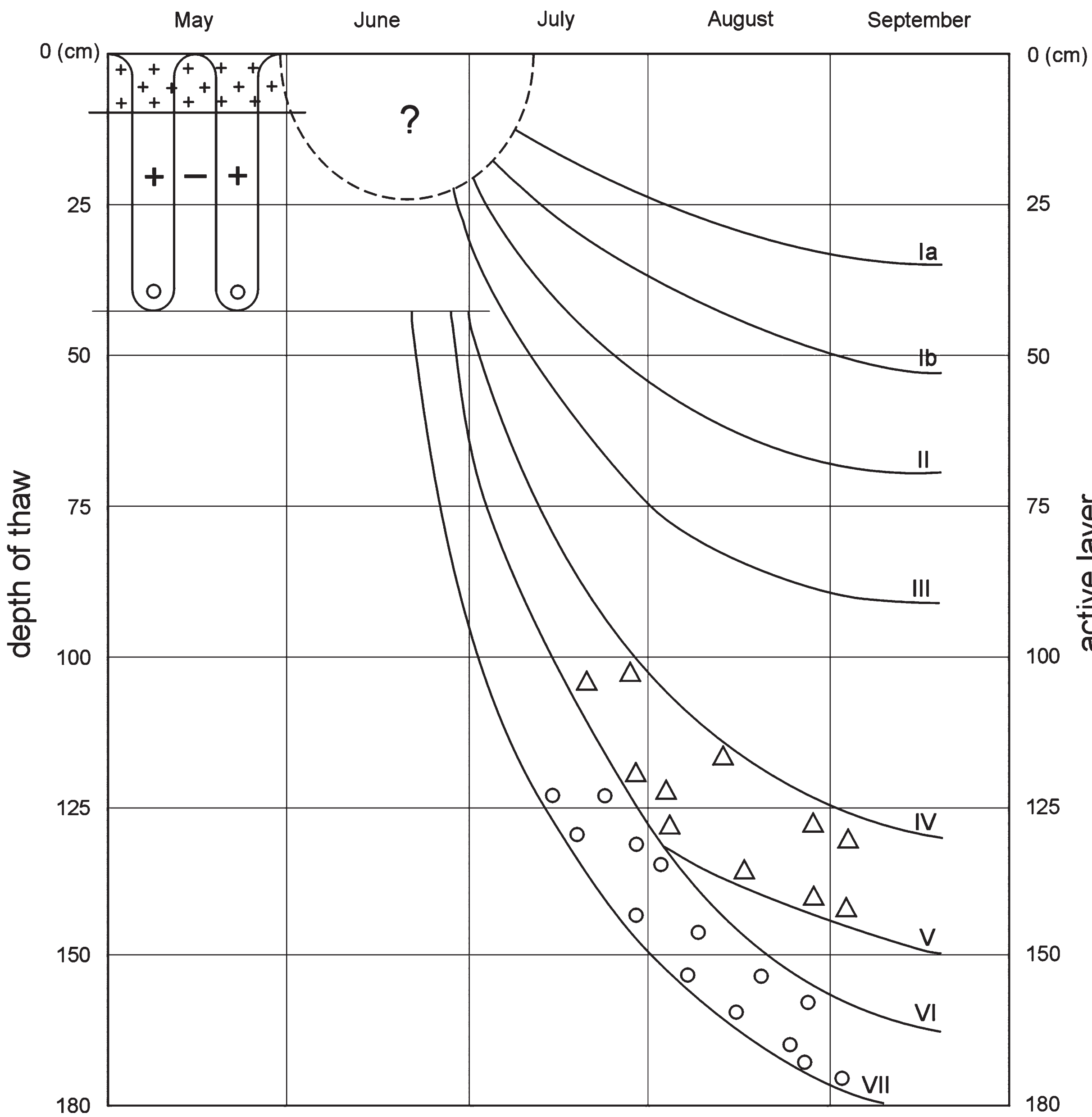

Fig. 1. Degradation scheme of ice-core moraine
1 – initial heiht (H1), 2 – formation of the initial thermokarst hollow with a small lake, 3 – formation of the complex of thermokarst hollows, 4 – formation of the therokarst hollows parallel to the ridge lines of the ice-core moraine, 4a – the final stage of the ice-core moraines degradation, the division of the ice core into two parts and their height H2, W1 and W2 – initial and final wi width of the form base

If the duration of thawing in a selected kind of environments is known, the above formula permit determination of the thickness of the active layer with high precision.

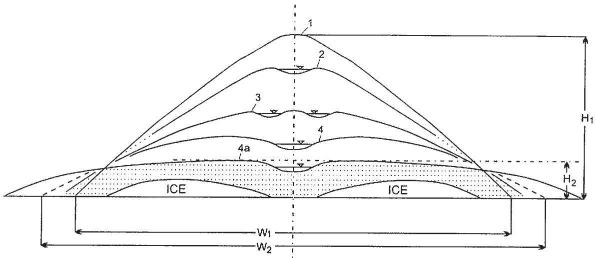

Fig. 2. Scheme of summer thaw (explanation in the text)

Point 5a – Waldemarbreen 78° 40’ 30” N 11° 59’ 28” E

Mass balance monitoring of Kaffiøyra glaciers

Ireneusz Sobota*

Department of Cryology and Polar Research, Institute of Geography, N. Copernicus University, Toruń, Poland

The studies of the structure of mass balance of Kaffiøyra glaciers refer to the Waldemarbreen, Irenebreen and Elisebreen. The data on the structure of the mass balance of Waldemarbreen were based on the direct field measurements conducted from 1996 to 2006 (Sobota, 1999, 2000, 2004, 2005a, Sobota and Grześ, 2006). The studies of the mass balance of Irenebreen were taken between 2001 and 2006. In 2005 the studies of the mass balance of Elisebreen began. This research is continued. At the same time geodetic and cartographic measurements were carried out (Lankauf, 2002, Bartkowiak et al., 2004).

Glaciers are located in the northern part of the Oscar II Land, Kaffiøyra, north-western Spitsbergen. Waldemarbreen is about 3.5 km long and has an area of 2.6 km^2. The ice originates in one cirque and flows from an elevation of more than 500 m to the present terminus at 130 m a.s.l.. Irenebreen, a valley glacier located to the south of Waldemarbreen, flows down towards the Kaffiøyra plain. The area of Irenebreen amounts to 4.2 km^2. Elisebreen area is 11.9 km^2. Its length is about 7 km, while its width is up to 1.8 km. To the north the glacier borders Agnorbreen which is often treated as part of Elisebreen.

In order to estimate the mass balance of Kaffiøyra glaciers the method of direct measurements was used. It was based on a set of ablation poles completed with the studies of the snow cover in the snow profiles. Twenty-two poles were placed on Waldemarbreen; Irenebreen and Elisebreen had ten poles installed each.

Spatial diversity of mass balance of Waldemarbreen, Irenebreen and Elisebreen is mainly influenced by the weather conditions in a specific part of glacier and by local morphological conditions. The areas of the glaciers may be generally divided into the part of the negative mass balance and the part of the positive mass balance. In the case of Waldemarbreen the year 1998 was exceptional, as the entire glacier showed negative mass balance. Irenebreen shows more positive mass balance in its both accumulation parts. The accumulation part of Elisebreen also shows positive mass balance. This results from the fact that they both are located at higher altitude than Waldemarbreen.

Thanks to the direct measurements, the average location of the equilibrium line (ELA) on Waldemarbreen was estimated at the altitude of 397 m in 1996–2006. From 2002 to 2006 the annual equilibrium line altitude was 421 m a.s.l. for Irenebreen, while for Elisebreen it was 365 m a.s.l..

The average mass balance of Waldemarbreen amounted to –57 cm w.e. in 1996–2006. Between 2002 and 2006 the mean annual mass balance of Irenebreen was –71 cm w.e. In 2006 the mass balance of Elisebreen was –73 cm w.e. These values are close to other Svalbard glaciers of similar size.

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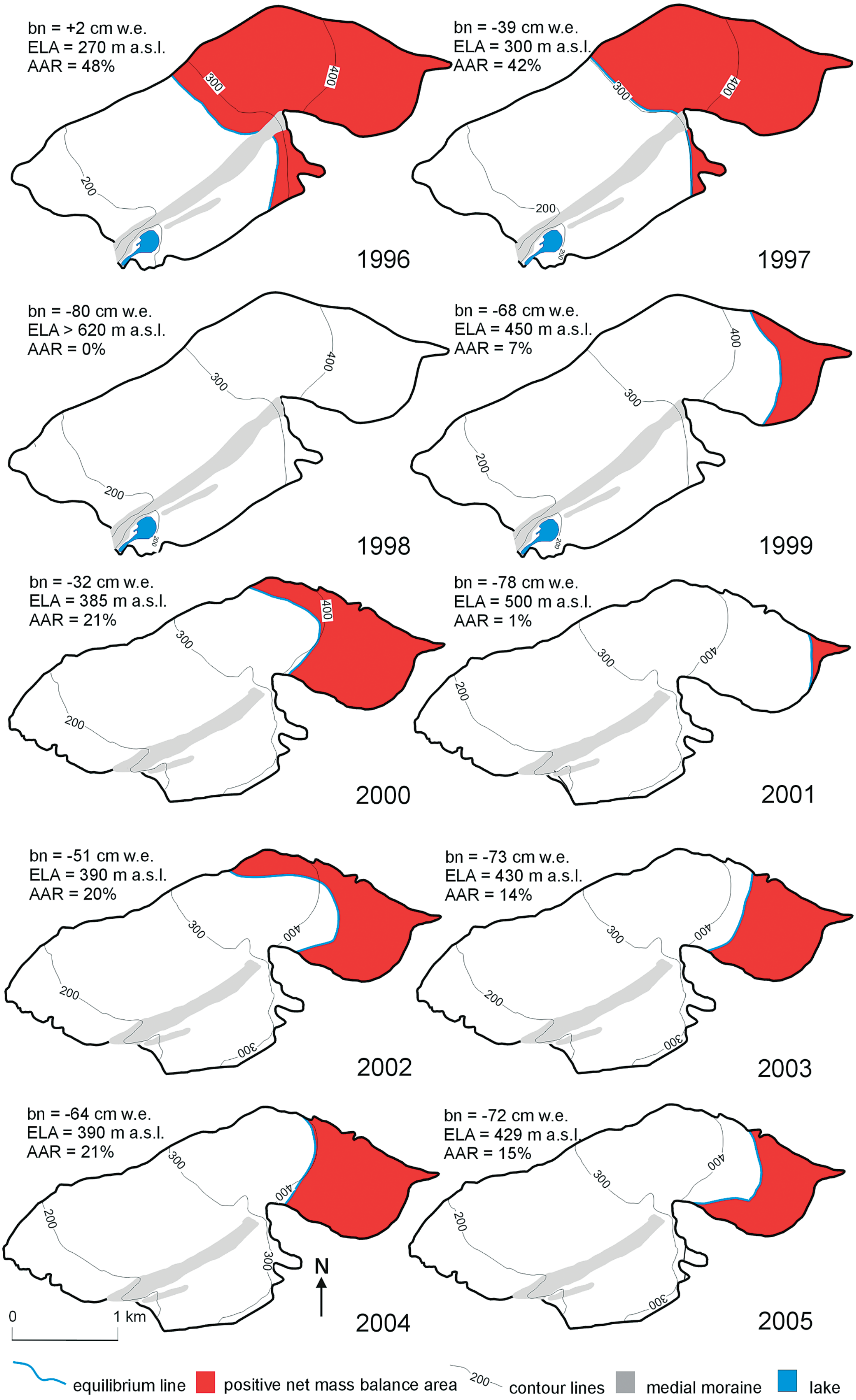

Fig. 1. Positive net mass balance area and equilibrium line (ELA) location maps of Waldemarbreen in 1996–2006

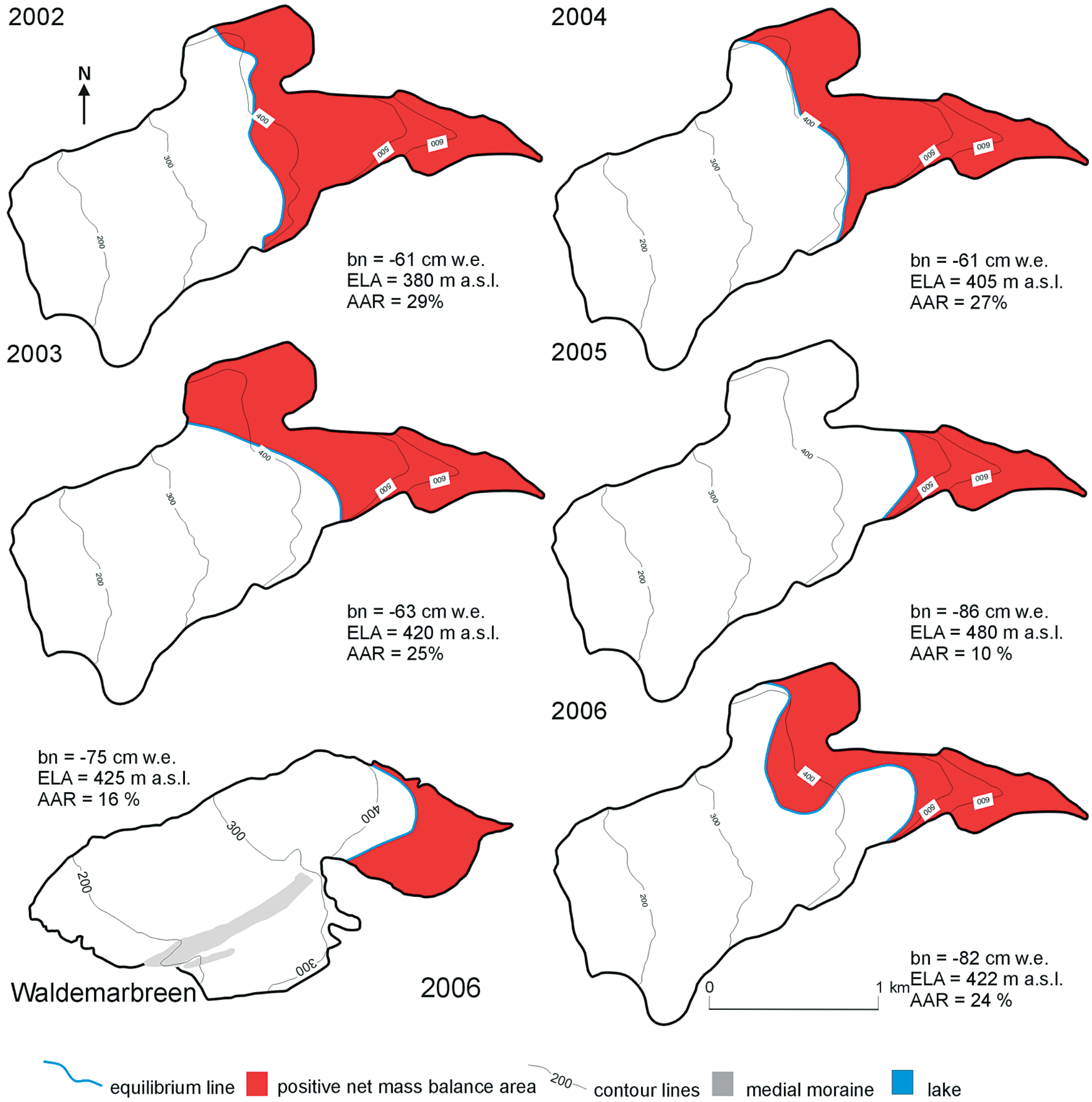

Fig. 2. Positive net mass balance area and equilibrium line (ELA) location maps of Irenebreen in 2002–2006

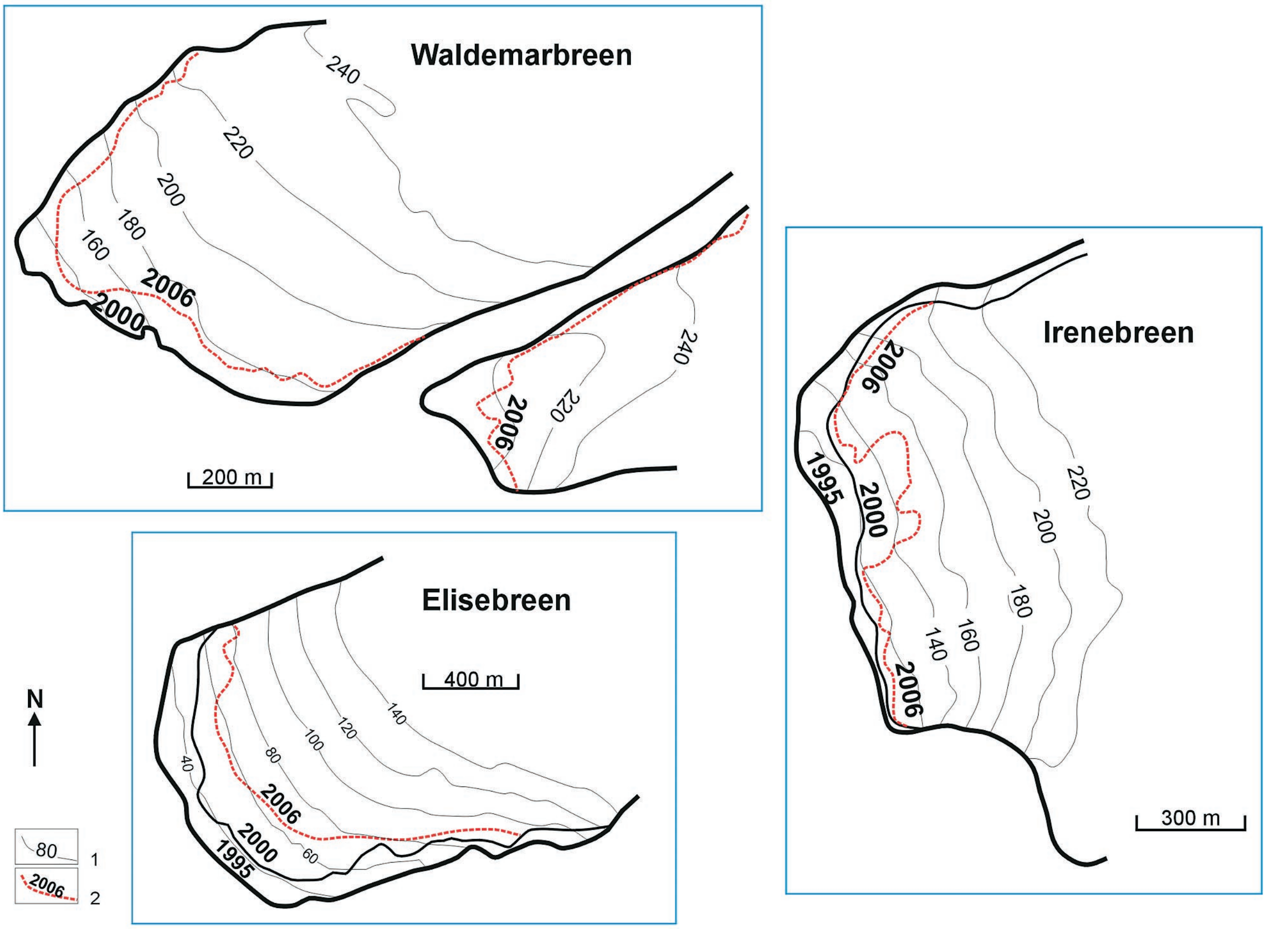

Fig. 3. The retreat of Kaffiøyra glaciers in the period from 2000 to 2006. Based on Lankauf's topographical map from 1995 (2002) and GPS measurements
1 – contour lines, 2 – location of glacier front in 2006

Point 5b – Waldemarbreen *78° 40' 30" N 11° 59' 28" E*

Summer balance of Waldemarbreen

Ireneusz Sobota*

Department of Cryology and Polar Research, Institute of Geography, N. Copernicus University, Toruń, Poland

Waldemarbreen is located in the northern part of the Oscar II Land, Kaffiøyra, north-western Spitsbergen. Waldemarbreen is about 3.5 km long and has an area of 2.6 km^2. The ice originates in one cirque and flows from an elevation of more than 500 m to the present terminus at 130 m a.s.l..

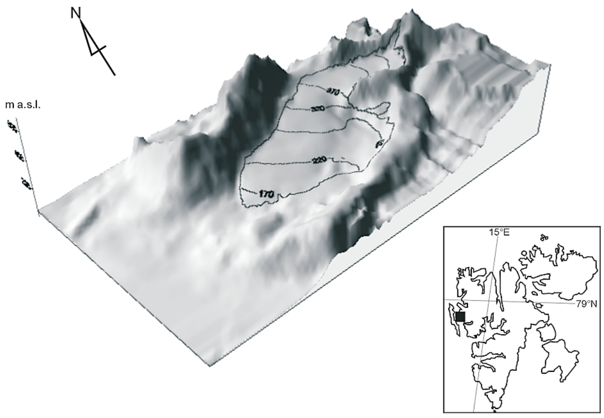

Fig. 1. Topographical draft of Waldemarbreen

The measurements of surface ablation of Waldemarbreen were made every 5 days from July to September each year for the period 1996–2006. The measurements were taken at 22 points of glacier. This is a large number if compared to the area of glacier. Such a dense network of the poles enabled us to estimate precisely the value of ablation at a given altitude, as well as the influence of the local conditions on its size. All the ablation poles were drilled 10 m deep with a steam driven Heucke Ice Drill . Snow, firn and ice ablation were converted into water equivalent (w.e.). The ice density of 0.9 g cm^{-3} was used to convert ablation thickness to water equivalent. Where snow was found on glacier the appropriate snow density was applied to the computations.

Time changeability of ablation processes of Waldemarbreen at various latitudes was significantly diverse. With the growing altitude the fluctuations decrease. There is a large difference in the ablation

Fig. 2. Waldemarbreen during summer time (photo I. Sobota)

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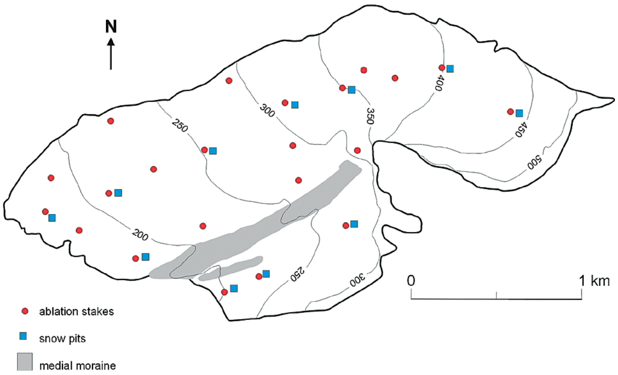

Fig. 3. Map of ablation stakes and snow pits on Waldemarbreen

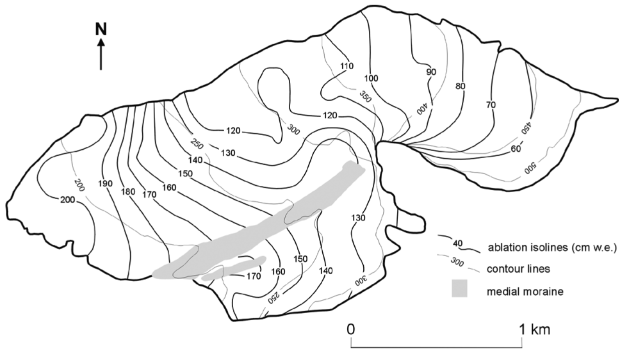

Fig. 4. Map of ablation of Waldemarbreen in 2006

intensity between the ablation part of the glacier and its accumulation part. This is mainly connected with the diverse weather conditions in these parts of the glacier. As far as Waldemarbreen is concerned, the highest ablation level throughout the studied period was found at the altitude of up to 250 m a.s.l. Above that level ablation decreases.

Spatial diversity of the ablation processes of Waldemarbreen was large. It was mainly caused by weather conditions in the individual parts of the glacier, as well as by the relief. Waldemarbreen is strongly inclined not only in its frontal part but also towards the medial moraine. Such a situation means a larger area of the glacier has southern exposition; additionally, the system of supraglacial streams develops and the amount of the moraine material on the glacier's surface increases. As a result, ablation processes in this part of glacier intensify.

The most negative mean summer balance of the glacier was –120 cm w.e. in 1998 and –130 cm w.e. in 2006, while the least negative was –63 cm w.e. in 2000. The average ablation of Waldemarbreen amounted to –104 cm w.e. for the period of 1996–2006. In the years 1996–2006 the cumulated total ablation of Waldemarbreen was about –1148 cm w.e.

Point 5c – Waldemarbreen *78° 40’ 30” N 11° 59’ 28” E*

Snow accumulation on Kaffiøyra glaciers

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Studies of winter mass balance mainly referred to the estimation of the size of the snow accumulation on glaciers, as well as its selected physico-chemical properties. Soundings of the snow depth on Waldemarbreen, Irenebreen and Elisebreen were carried out in about 150 measurement points. They gave a very detailed picture of the spatial diversity of the winter snow accumulation at about 50 measurement points per 1 km^2. Measurement points were located relatively close to one another as the differences in the snow depth is often significant, which mainly results from topography and anemometric conditions. Location of the measurement points was based on both geodesic and the GPS measurements. The measurements were made in the selected snow profiles in accordance with the International Commission on Snow and Ice (ICSI) standards. Additionally, according to the above standards, the selected physical and chemical properties of the snow cover were measured. This mainly referred to the snow structure, graining, hardness and density.

Spatial distribution of winter snow accumulation on Waldemarbreen shows some regularity. The largest accumulation is found in the accumulation part and at the foot of the mountain slopes. The smallest accumulation, however, is observed in the front part of glacier up to the altitude of 220 m and at the foot of the medial moraine. Such a distribution is conditioned by anemometric situation and a larger inclination of this part of glacier. Some asymmetry in the snow cover depth was recorded. In the accumulation part of glacier the main factor influencing the depth of the snow cover was precipitation, while in the lower parts of glacier – local conditions (aspect) as well as wind directions and velocity (snow redeposition). The depth of the snow cover lowers from north east towards south west, i.e. in the direction of the medial moraine. Next in grows again towards the Gråfjellet Range. In the case of Irenebreen snow accumulation increases significantly from the front

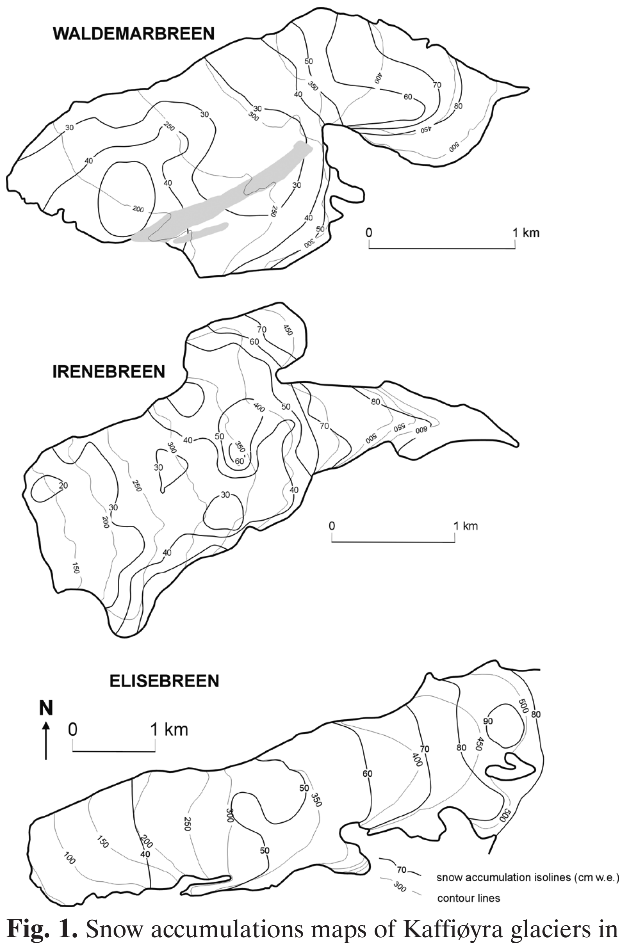

Fig. 1. Snow accumulations maps of Kaffiøyra glaciers in 2005

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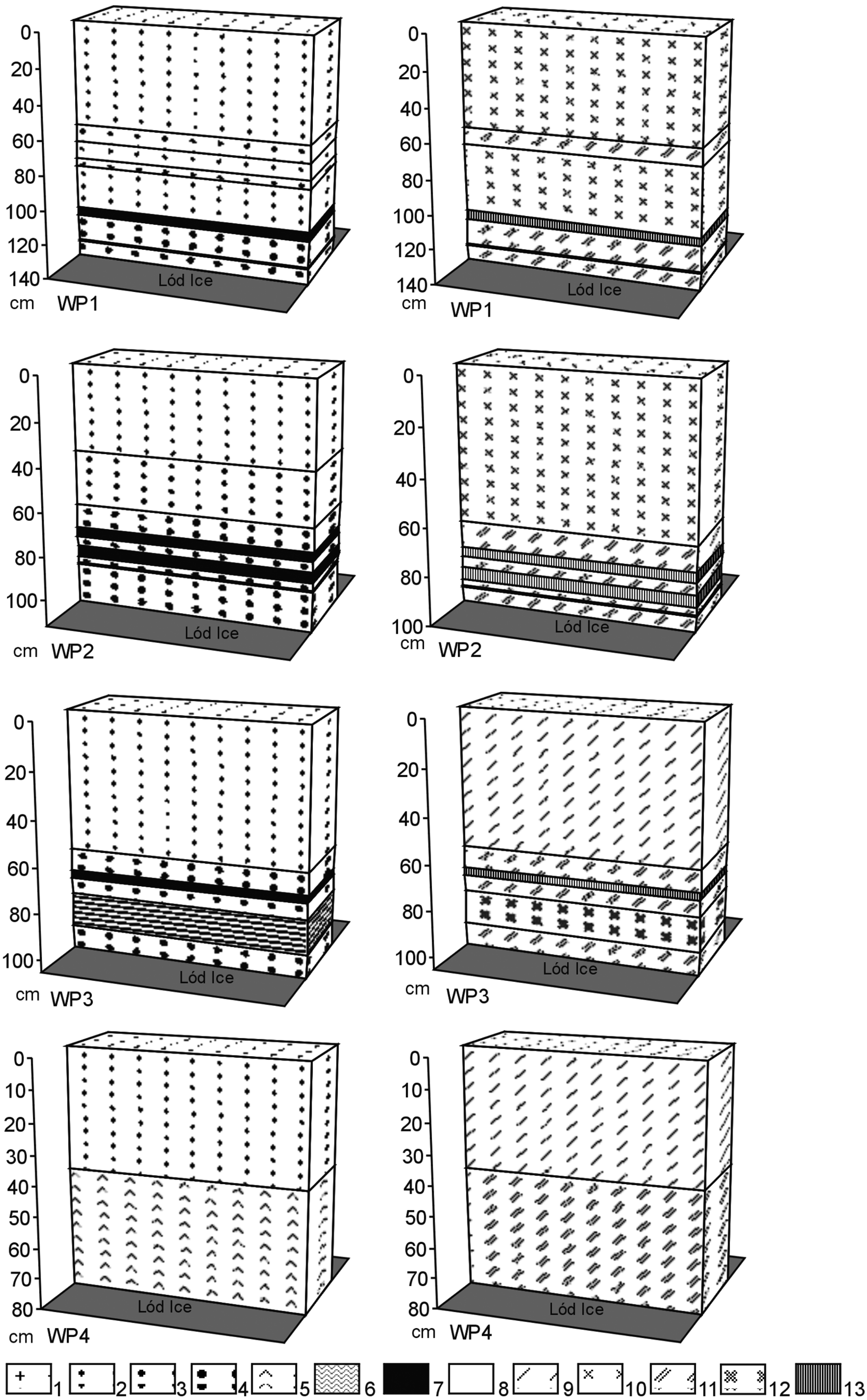

Fig. 2. Snow profiles at selected parts of the Waldemarbreen according to ICSI in May of 2005

Snow grain sizes and types: 1 – fresh snow, 2 – fine grained snow, 3 – medium grained snow, 4 – coarse grained snow, 5 – coarse grained snow, intesively matamorphosed (hoar snow), 6 – frozen snow with ice layers, 7 – ice layer. Hardness of deposited snow: 8 – very low (R1), 9 – low (R2), 10 – medium (R3), 11 – high (R4), 12 – very high (R5), 13 – ice (R6)

Fig. 3. Mesurements in snow pit (photo M. Grześ)

part of glacier towards the accumulation fields. On Elisebreen snow accumulation increases considerably with altitude until the ice-shed, i.e. from 40 cm w.e. to 150 cm w.e.

The measurements of structure and graining of the snow cover were not undertaken during all of the analysed periods. When undertaken, the studies included making a few snow profiles in the selected parts of both Waldemarbreen and Irenebreen. Snow cover shows some specific physico-chemical properties. Its vertical profile shows a variety of snow types of diverse level of metamorphosis, hardness and wetting. Snow structure reflects prevailing weather conditions at the time when the snow cover formed.

Snow density on Waldemarbreen ranged from 310 kg m^{-3} to 520 kg m^{-3} maximum. The mean snow density on both Waldemarbreen, Irenebreen and Elisebreen is similar and it amounts to about 400 kg m^{-3} on average. In the individual years the snow cover of the studied glaciers was dominated by fine-grained and medium-grained snow, while the layer above ice contained coarse-grained snow. Numerous ice layers were also found.

From 1996 to 2006 the mean snow accumulation on Waldemarbreen was 47 cm w.e. Cumulated value of accumulation for the entire glacier was 521 cm w.e. Between 2002 and 2006 the mean snow accumulation value for Irenebreen was 52 cm w.e., while the cumulated value of the winter balance for this period for the entire Irenebreen was 262 cm w.e. In 2005 the snow accumulation for Elisebreen was 59 cm w.e., while in 2006 it was 63 cm w.e. These values are similar to those estimated for other studied Svalbard glaciers.

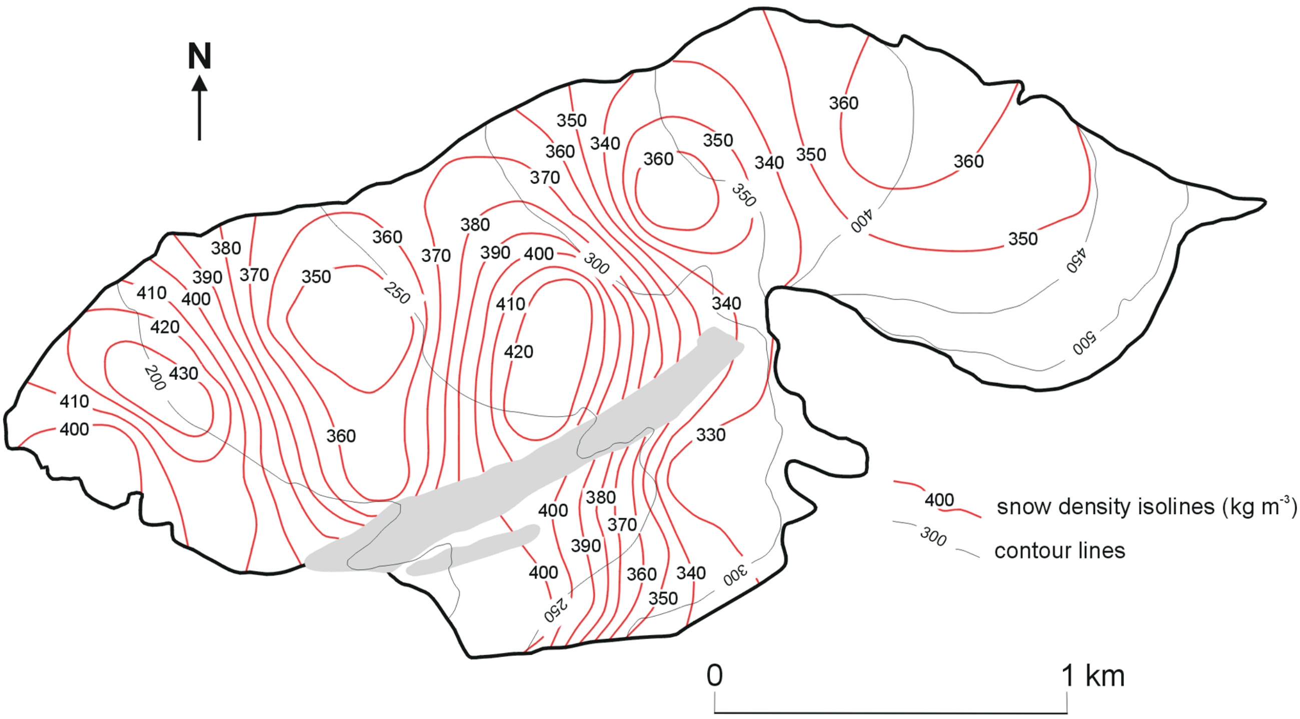

Fig. 4. Surface snow density map of Waldemarbreen, April 2007

Point 6 – Waldemarbreen-Ice Drilling *78° 40' 31" N 12° 01' 50" E*

The sample ice drilling on Waldemarbreen with Heucke Ice Drill – the demostration

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All the ablation poles on Kaffiøyra glaciers were drilled 10 m deep with a steam driven Heucke Ice Drill . Thanks it is possibility to install mesurements points for the long time period. It is necessary for this kind of investigations.

The purpose of this contribution is to explain the characteristics of a newly developed ice drill which is particularly geared to the needs of glaciologists. It is primarily designed fordrilling holes for ablation stakes and for measuring water levels or temperatures in fim areas. Its distinguishing features are its light weight, making it easy to cany even over long distances, and the variety of tasks to which it can be adjusted. Furthermore, it is easy to operate even by one person.

Water is heated in a boiler by two gas flames to produce steam, which flows through an insulated hose to a nozzle. When the valve is opened the issuing steam condenses, and the heat released in the process melts the ice. The heater is constructed in such a way that it caneasily be adapted to any formof gas supply locally available. It can be used for drilling in ice as well as in fun. The maximum drilling depth is 13 m in ice and 30 m in firn; hole diameters range from 25 to 45 rnrn.Mean drilling time is 16 min for 6 m, 35 min for 12 m in ice. The total weight is somewhat less than 16 kg, including all parts needed for drilling holes of 10 m in depth as well as the gas supply for one day. In recent years, devices of this type have been used successfully by scientists in various glaciated regions.

Fig. 1. Ice drilling with Heucke Ice Drill on glacier (photo M. Marciniak)

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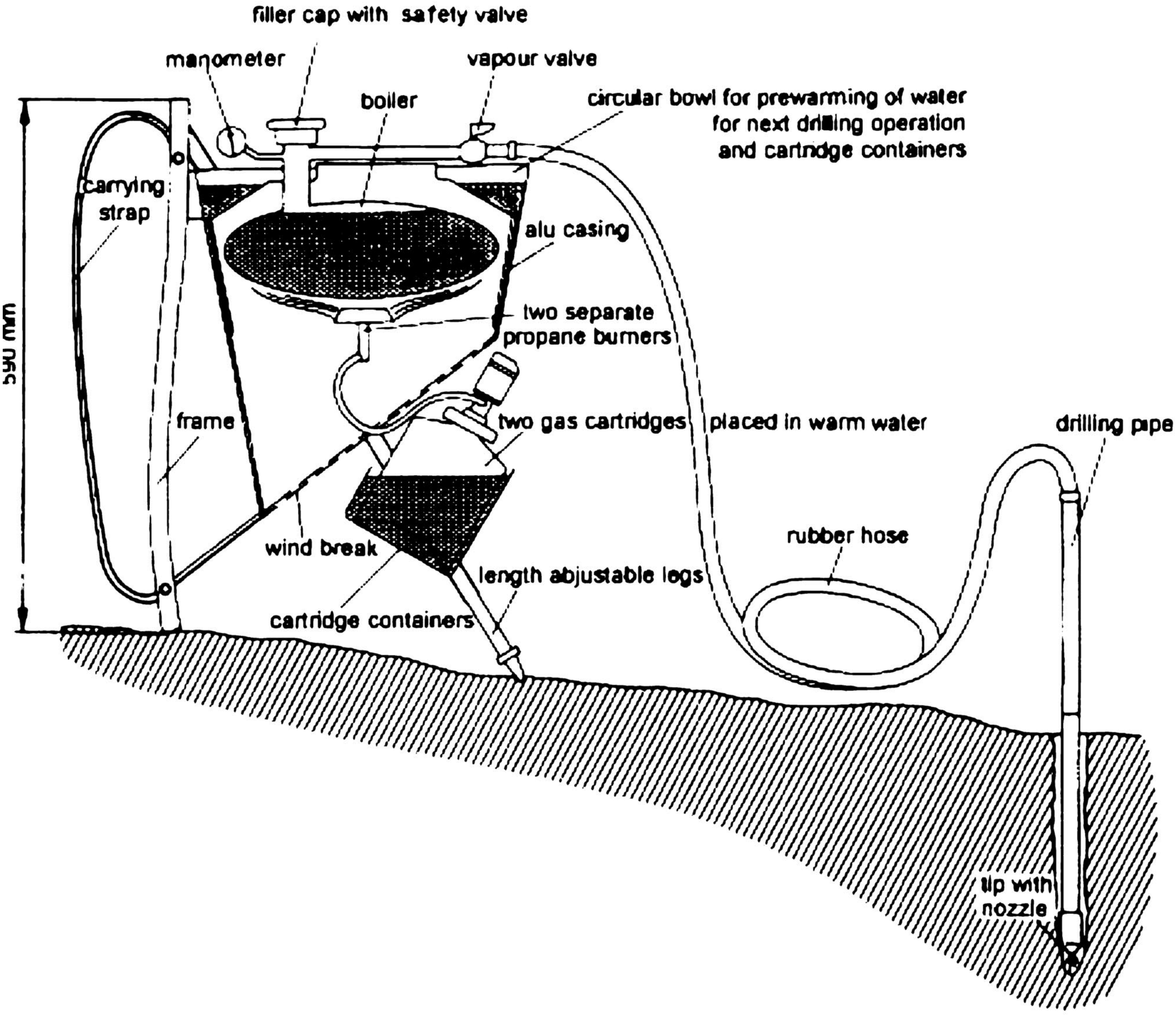

Fig. 2. Diagram of the entire drilling device

Point 7 – Aavatsmarkbreen *78° 41’ 07” N 11° 53’ 39” E*

Subaqual recordings of the changes in the range of glaciers in the Forlandsundet region (NW Spitsbergen)

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The main goal of the studies is to try and answer the following questions: Do the cliffs of the selected glaciers in the Forlandsundet area re-advance in winter and does this result in the development of subaqual relief? Are subaqual forms concordant with the location of ice cliffs during the selected peri-

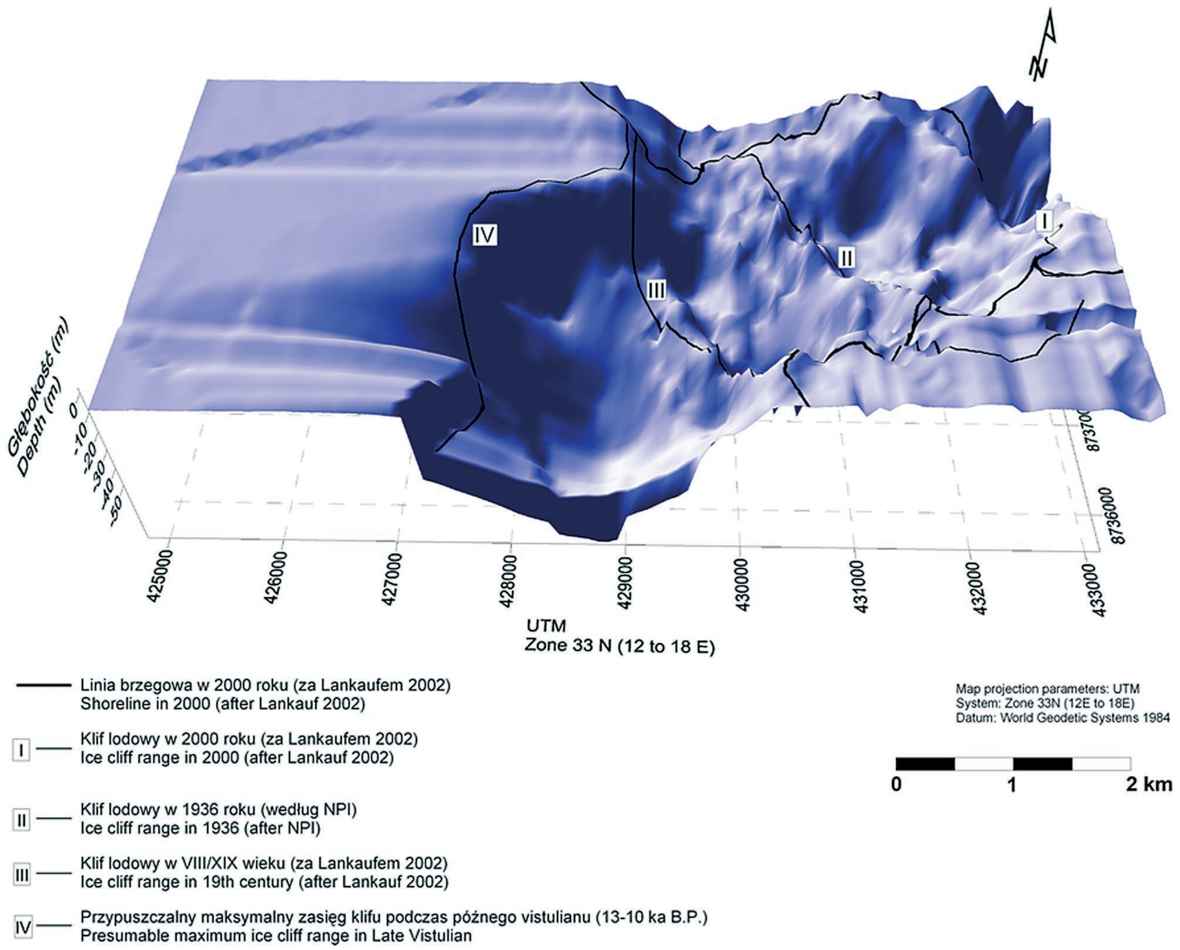

Fig. 1. Subaqual relief in forefield of Aavatsmark glacier with ice cliff ranges in different periods

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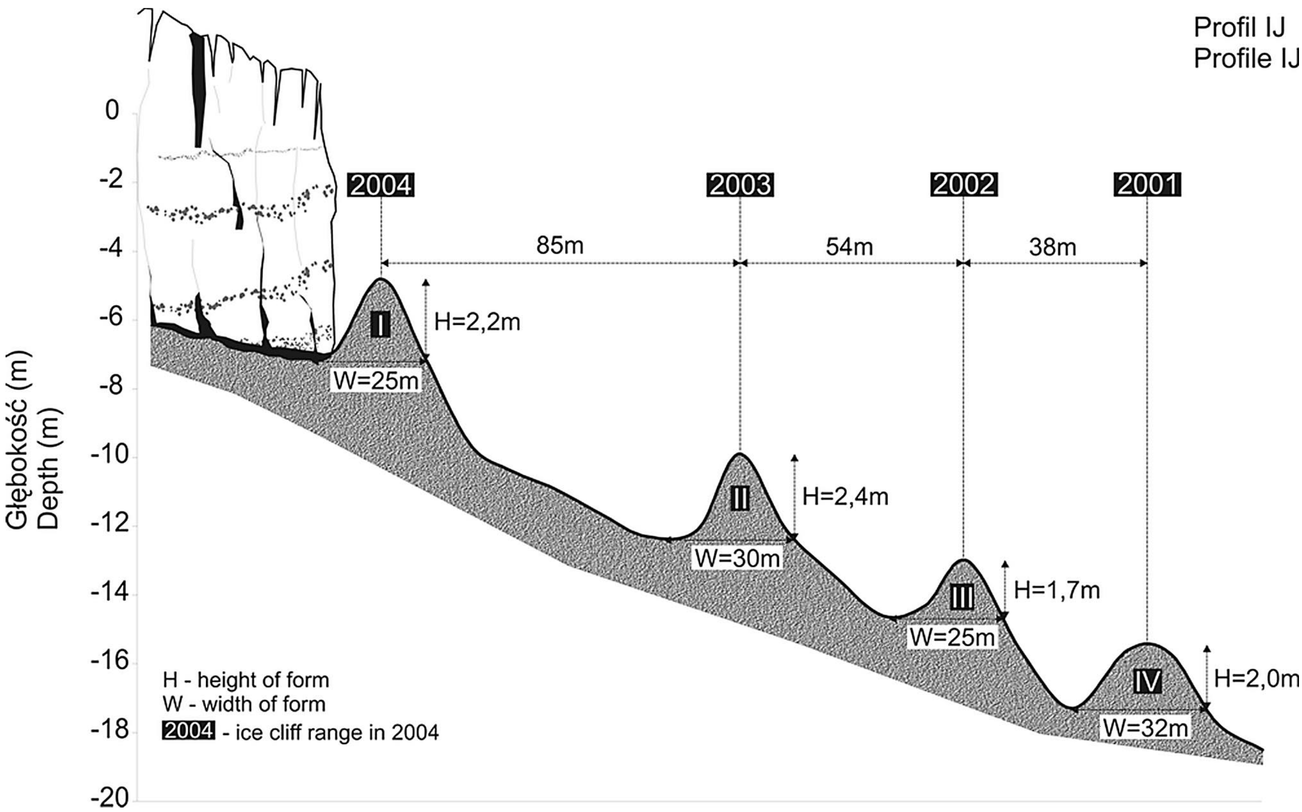

Fig. 2. Annually push moraines formed between 2001 and 2004
H – height of form, W – width of form, 2004 – ice cliff range in 2004.

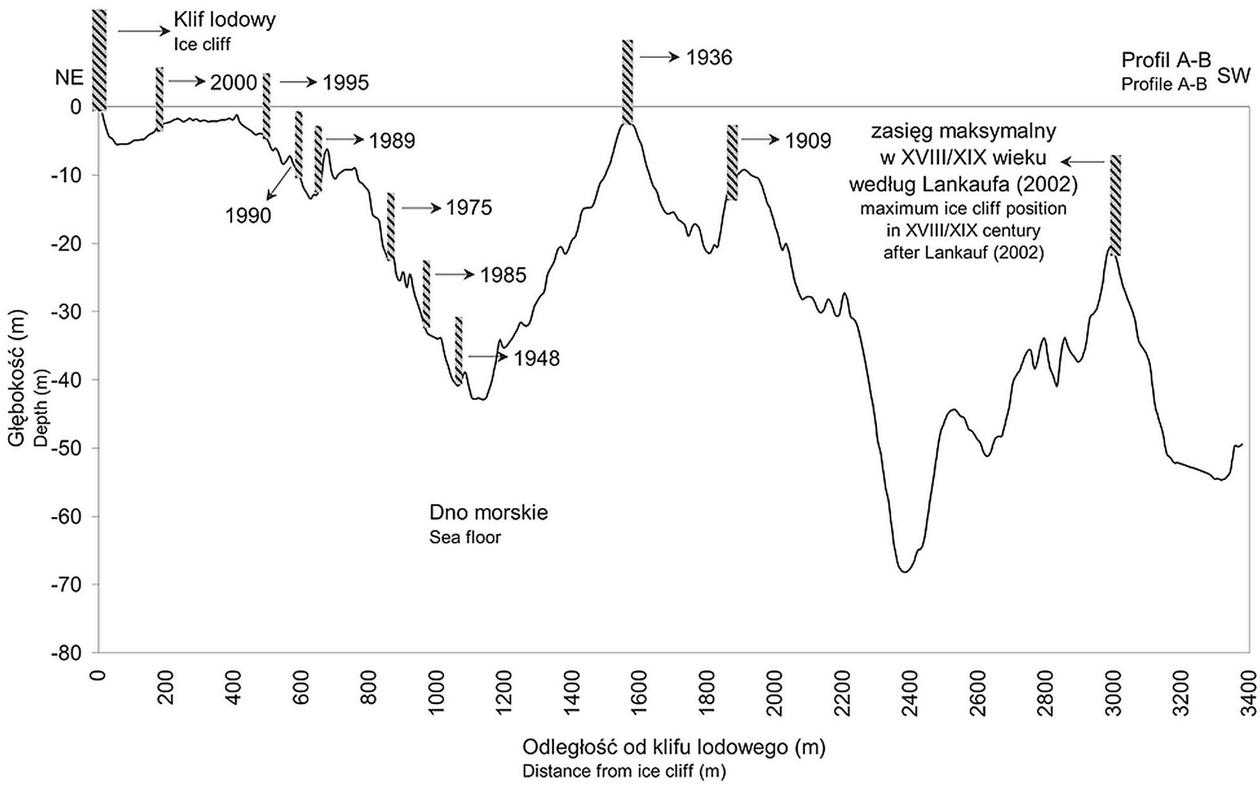

Fig. 3. Subaqual relief in forefield of Aavatsmark glacier, profile A–B

ods of advance, such as the Little Ice Age, the glacial episode (3.0–2.5 ka BP) or the late Vistulian (13–10 ka BP)? What forms are connected with the periods of significant glacier advances, such as the Little Ice Age, the glacial episode (3.0–2.5 ka BP) or the late Vistulian (13–10 ka BP)? What forms develop as a result of an annual winter re-advance of a cliff? What forms develop at a surge advance? Can bathymetry of the bays in which the glaciers end limit significantly a glacier advance? The paper presents the results of the echo sounders made in the summer seasons of both 2004 and 2005 at the selected glaciers which end in the sea in the Forlandundet region. The measurements included the following glaciers: Aavatsmarkbreen, Dahlbreen, Gaffelbreen, Konowbreen, Osbornebreen and Buchananisenbreen. According to literature and the archival cartographic materials, the changes in the range of the researched glaciers were studied. For the echo soundings at the glaciers an echo sounder correlated with the GPS Map 178C by Garmin was used. For the long profiles of the glaciers the trace method was used, while for the studies of the data the GPS Utility 4.20.4 was used.

Morphogenetic analysis of the subaqual forms of the sea bottoms where the studied glaciers end needs further research. However, their sequence as well as the fact that they correspond with the old ranges of glaciers proves their glacial genesis. Echo sounders' results of the surging Aavatsmarkbreen are also interesting. The paper contains the results of the echo sounders made at Buchananisenbreen, which in the 1930s was a piedmont glacier.

Selected problems of changes in morphometry, bathymetry and thermal conditions in the lake complex at the forefield of Aavatsmarkbreen

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The lakes are located in the marginal zone of Aavatsmarkbreen. These are the following: Upper, Middle and Lower. They all have a connection with the sea and thus show untypical thermal and salinity conditions.

The vertical range of lake water temperatures shows rare thermal conditions. Heat flow in the water mass is mainly dependent on and influenced by characteristic layers of both fresh and salty water, which are the result of the water exchange between the lake and the sea. The water layer of high salinity intensifies heat accumulation, which results in a sudden temperature jump at a certain depth. The highest and most stable water temperature was found at the depth of 4 to 6 metres, irrespective to the thermal changes taking place in the layer above. It posed a barrier to heat coming in from both the layer above and from the lake bottom. The range of water temperatures was similar to the range of electrical conductivity. This means the main cause for shaping thermal phenomena in the lake was salinity. A similar layout of the heat layers in the studies lakes was also recorded by Pietrucień and Skowron (1983).

In summer 2004 (August 26) a spatial measurement of surface diversity of water temperatures was taken. According to the results, the values of temperatures were similar; the highest were recorded at the shore section of the lake as well as at the throat of the Lower Lake.

In summer 2004 GPS, a receiver with the built-in echosounder, was used to take bathymetric measurements.The results were referred to the average water level during summer. Additionally, measurements were taken in order to establish the course of the lakeshore. The bathymetric plan was used to find out that the area of the lakes is similar to the value from the year 1982 (Pietrucień, Skowron 1987) and totals 8.03 ha. Some differences stem from the natural changes in the water reservoirs as well as certain errors connected with the measurement techniques. The average depth of all the discussed water bodies was 2.6 m. The largest differences in depth were recorded in western section of the Upper Lake. Two new deeps were found in northern part of the Middle Lake and at the connection with the Upper Lake.

Morphometric changes of the analysed water bodies result in periodical disappearance of the features characteristic for meromictic lakes. This means thermal conditions of water masses of the lake have a significant influence on both physical parameters and dynamics of water, as well as the changes in its bathymetry, including parameters which describe the lake basin.

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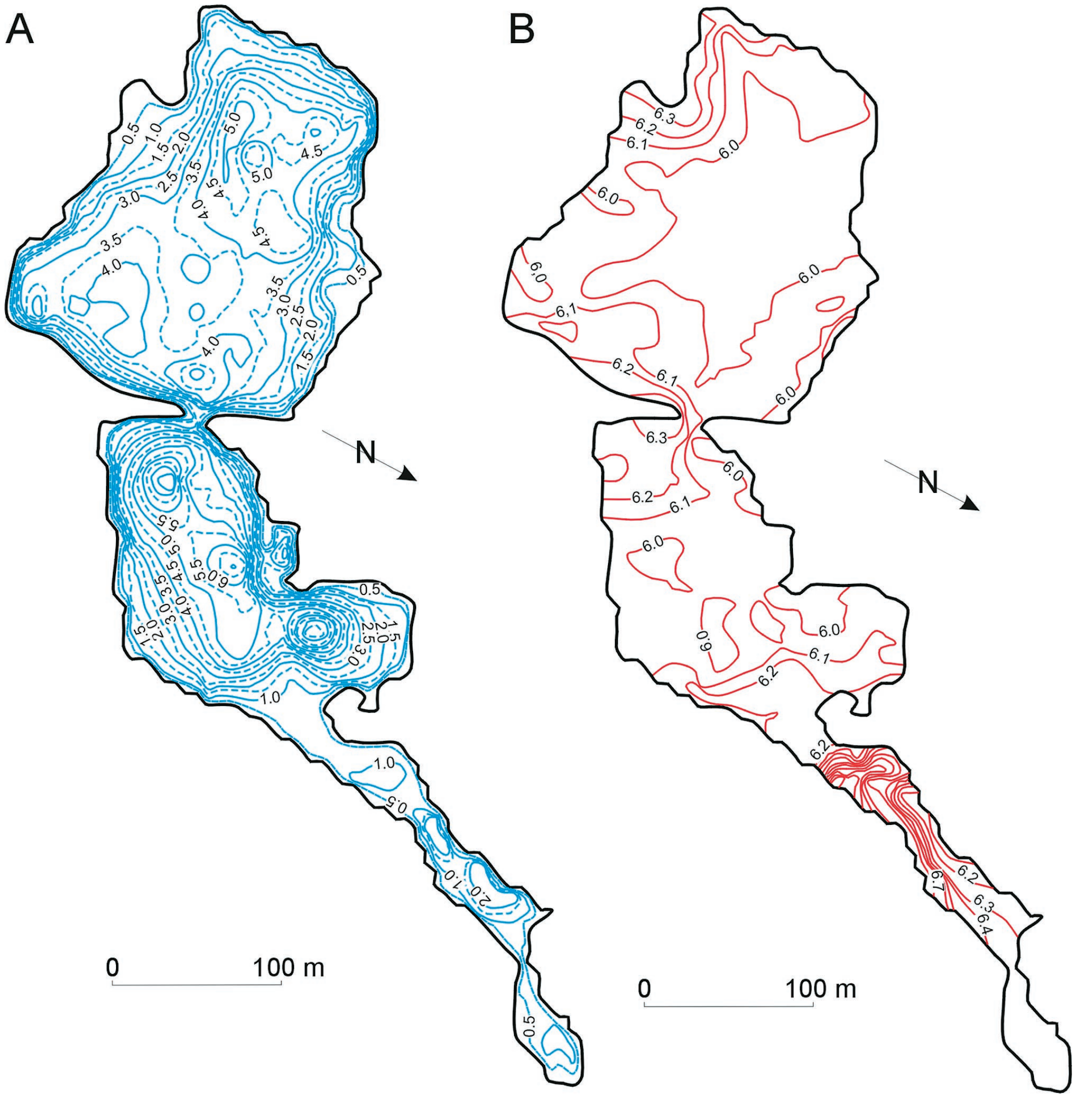

Fig. 1. A – bathymetry (m) and B – surface water temperature (°C) of moraine lakes at the southern forefield of Aavatsmarkbreen

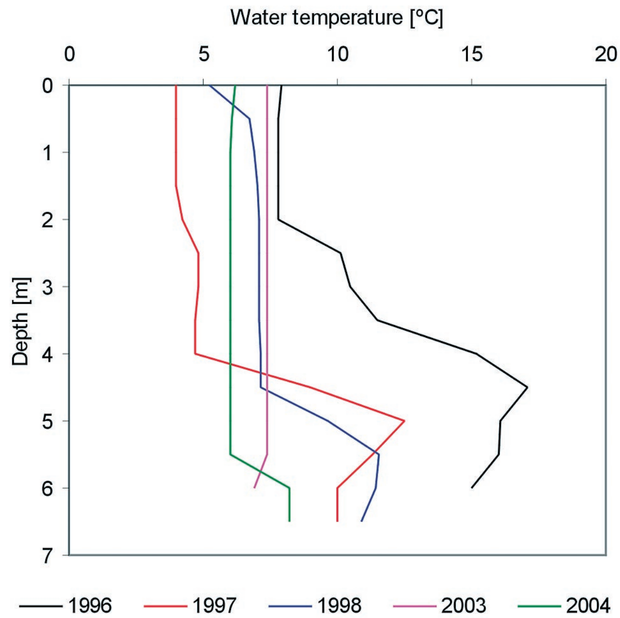

Fig. 2. Water temperature in the Upper Lake in selected years during summer season

Point 9 – Nicolaus Copernicus Polar Station *78° 40' 33" N 11° 49' 36" E*

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The first glaciological expedition to Oscar II Land was organised in 1938 on the initiative of Professor Antoni Bolesław Dobrowolski, the chairman of the Polar Club of the Exploration Expeditions Association. Ludwik Sawicki from the Geological Institute in Warsaw chose the area to be explored. Stefan Bernardzikiewicz, who took part in the 1934 expedition to Torell Land, became the person in charge of the whole expedition. Bronisław Halicki, DSc from the Stefan Batory University in Vilnus and Mieczysław Klimaszewski, DSc from the Jagiellonian University were among other participant of that expedition. They had a big motor boat sailed by a Norwegian trapper Sverre Hansen. The investigations were carried out on the glaciers and their forefields between Eidem Bay and Engels Bay (English Bay), yet predominantly in the Kaffiøyra region (the Coffee Plain). Unfortunately quite a substantial amount of the investigation results vanished during the war. The expedition to Oscar II Land remained forgotten for many years. The first investigation results, Geomorphologic Studies in the West Part of Spitsbergen between Kongs-Fijord and Eidem-Bukta, were published by Professor Mieczysław Klimaszewski only in 1960. Detailed description of glacial phenomena, post-glacial forms and deposits provided an excellent material for conducting comparative studies. In 1975 the Geography Institutes of both Nicolas Copernicus University and the Polish Academy of Sciences together with Geography Students' Scientific Society attempted to perform these investigations. Under the supervision of Professor Jan Szupryczyński a group of 12 people set off to Spitsbergen. It consisted of two groups: geomorphological and hydrological. The hydrological group of five persons brought a wooden house in separate elements. Professor Czesław Pietrucień was responsible for its design and constructions. The house was set up at the the foot of the end moraines of the Aavatsmark Glacier, in the north part of the Kaffiøyra, at latitude 78° 40'33''N and longitude 11° 49'36''E.

The Nicolas Copernicus University Polar Station is situated beyond the borders of the protected areas (parks). It allows a greater freedom for the exploration of the neigh bourning regions. During the summer there is not any blockade phenomenon of the Forland Strait due to ice pack. The straits is not covered with ice as early as at the end of June. It is very important while planning a journey. The neighbourning Ny Alesund with an internaltional exploration centre and the airfield (two flight a week) put the polar station in a favourable light. It takes 2–3 hours to cover the distance from Ny Alesund to the station by boat. In winter it takes almost the same time by scooters.

In July and August there is regular navigation traffic though the Forland Strait from Longyearbyen to Ny Alesund (once a week). Ship unloading is easy due to the sand shores near the polar station. Deep Hornbaek Bay allows even those bigger sailing units to take shelter against heavy storms.

Nicolaus Copernicus University started to take part in polar research in 1975 using its own polar station located on north-western Spitsbergen. The position of this station was chosen because of its big scientific value. People often ask us why do we do a research on polar territories, Spitsbergen in particular. The answer is that glaciers are almost ideal "climate thermometers". It refers especially to their range changes. They became matter of research being conducted by our Institute of Geography – just because they cover almost 60% of Spitsbergen. To understand post-glacial reliet of the earth's surface

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in Poland it is very useful to observe contemporary sediments and glacier forms. In such way Spitsbergen became a natural laboratory for geographers of various specialities.

Nicolaus Copernicus University Polar Station is northenmost polish scientific institution. It is situated on northern part of the Kaffiyora, close to the Aavatsmarkbreen. This station was used by 30 expeditions and 100 people so far. Effects of these expeditions are shown in 350 publications and on topographic and thematic maps.

In 1995 we started to do a sistematic study of mass balance of Waldemarbreen, and next in 2001 Irenebreen and in 2005 Elisebreen. These studies are part of the international programms and projects (WGMS, CALM).

NCU Polar Station is suitable to whole year work. It has three independent sources of energy (fuel engine, wind power station and sun battery). Means of transport are: fibre glass, rubber motor boats and snow scooters. Radio communication is ensured by FM radiostation with its call signal LH3MB.

In 30 year existence the station was visited by about 400 people: 150 Poles, 120 Norwegians and Germans, Dutch, Russians, Americans and even Australians. All other information about our station you can find on the internet: www.stacja.arktyka.com.

Fig. 1. Nicolaus Copernicus Polar Station (photo I. Sobota)

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