POLISH POLAR RESEARCH (POL. POLAR RES.) POLSKIE BADANIA POLARNE	5	3—4	241—253	1984

Marek GRZEŚ Mieczysław BANACH

Department of Geomorphology and Hydrology of Lowland,
Institute of Geography and Spatial Organization,
Polish Academy of Sciences, Toruń

The origin and evolution of the Goes Lake in Sørkapp Land, Spitsbergen

Abstract: The Goesvatnet is a lake whose water is dammed by the Gas Glacier. It undergoes periodic subglacial and inglacial drainage, usually in winter. When fully filled it is about 60 m deep and has the surface of about 1 km^2. An attempt was made to explain the mechanism of the drainage of the lake. Changes in the situation and range of the lake over the period of 81 years were investigated. The magnitude and character of the deglaciation of the front part of the Gås Glacier were determined. A strict relationship was found between the drainage of the lake and the presence of naled ice in the extramarginal outwash (Gåshamnoyra).

Key words: Arctic, Spitsbergen, glaciology, ice dammed lake

1. Introduction

The Goes Lake lies in the southern part of Spitsbergen, in the area of the Gås Glacier (Fig. 1) which dams it. The investigation of the evolution of this lake was permitted by the cartographic research performed here. The first materials date from 1899–1900 when a Russian-Swedish expedition wintered in the Gås Bay (Gåshamna) (Vassilev 1925). A 1:50000 map made by this expedition (de Geer 1923) also includes the Goes Lake. It was verificad photogrammetrically by a German expedition in 1938 (Pillewizer 1939). This expedition carried out extensive geodetic maesurements, particularly of the Gås Glacier and its forefield. The 1:100000 Norwegian map published in 1948 (Topografisk kart... 1948) was based on measurements in 1936. The aerial photographs taken by the Norwegian Polar Institute on 15 August, 1980 (Aerial photo... 1960) were also analyzed. The geodetic research carried out in 1978 and 1980 under the programme of the expeditions of the Polish Academy of Sciences to Spitsbergen permitted the investigation of the changes which have taken place in the area of the Goes Lake over the recent 81 years.

2. The origin of the lake

The large changes in the range of the glaciers in the area of the Goes Lake discerned in the cartographic material substantiate the thesis that it is difficult to assign this lake definitely to one of the types distinguished by Maag (1969). It follows from de Geer's map of 1899 (Pillewizer 1939) that the Goes lake was formed by the damming of a lateral valley by the Goes and Port Glaciers (Fig. 1). They concluded with a cliff in the lake with a maximum measured depth of 59 m. The northern

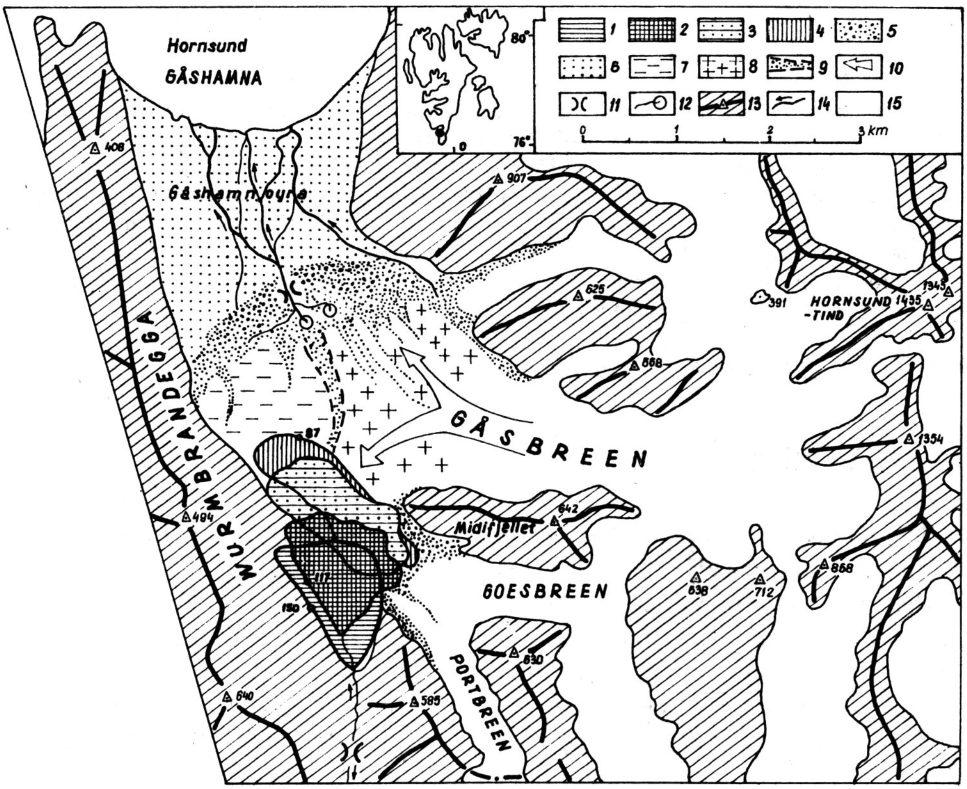

Fig. 1. Environment of Lake Goes. Exstand of Goesvatnet in: — 1899, 2—1936, 3—1960, 4—1980, 5—morraine ridges and medial moraines, 6—Sandour of Gas Glacier, 7—passive ice, 8—active ice, 9—contact zone, 10—directions of the main currents of Gås Glacier, 11—break in the morraine ridges of Gas Glacier, 12—glacier gap, 13—mountain ranges, 14—streams, 15—glaciers

and northeastern part of the shoreline (cliff) describes a distinct bay into the glaciers. This would indicate that the process of the enlarging of the lake is well advanced. In its evolution it has not yet reached the Midifjellet. It should be supposed that the development of the lake originated in a little unglaciated valley in the southern part of the lake. In Pillewizer's map of 1938 the lake cut its large bay into the Goes Glacier, with a cliff shore 1450 m long. It had reached the Midifjellet, i.e. more exactly the point where the lateral moraines of the Gås and Goes Glaciers join. The area formed as a result of the retreat of the Port and Goes Glaciers has to date been periodically filled by the lake. At present it is dammed only by the Gås Glacier and therefore it would be justifield to call it the "Gås Lake". The same ice dammed lake can therefore be assigned to different types, depending on the stage of its development.

3. The evolution of the lake

The changes in the range and depth of the lake are closely related to the deglaciation process in this area. There is a feedback type interaction between the water and the glacial environment. The regime of the lake is strictly connected to the regime of the Gås Glacier which prevents the free drainage of its water.

3.1. Changes in the range of the Gås Glacier

Fig. 2 shows the changes which have taken place over 81 years in the part of the Gås Glacier near the lake. From 1899 to 1938 (39 years) the surface of the glacier in the area of the lake dam decreased by 33 m, i.e. at an average rate of 0.84 m/year; and by another 64 m, i.e. about 1.5 m/year since 1938 (42 years). Similar time intervals for which the surface ablation (expressed in ice thickness) make these two values comparable. If, however, the Gås Glacier advanced rapidly between 1899 and 1939, as Baranowski believes (1977a), these values will not be comparable. The relatively small lowering of the glacier surface in the initial period may, on the hand, have been the result of its elevation caused by the "surging" effect, but, on the other hand, by the fact that it occurred over the altitude range 200–150 m over the sea level where ablation is distinctly weaker (Baranowski 1977a). A gradual decrease in the absolute height causes an acceleration of the phenomenon. The calculation results given above can involve error caused by the different course of the profile lines.

Over 81 years (1899–1980) the ice cliff of the northern shore of the lake

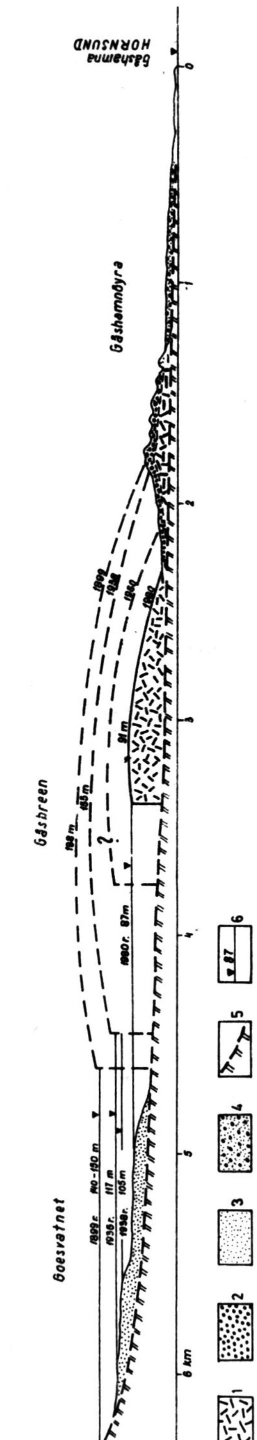

Fig. 2. Cross-section of the ice dam of Lake Goes 1—ice, 2—glacial sediments, 3—limniglacial deposits, 4—glacio deposits, 5—glacier basis, 6—water level in m over sea level, the levelling was carried out by S. Dąbrowski and S. Mroczek in 1980.

moved 1200 m towards the marginal zone. The glacier reatreats much more rapidly in the cliff zone than at the front. It is most intensive when the lake bed is filled. The ice from the front of the glacier as a result of "calving" is carried away by the lake water (Fig. 4).

Over this period the retreat the glacier at its front in the marginal zone was 500–600 m; 425–500 m according to Jania et al. (1981). This small

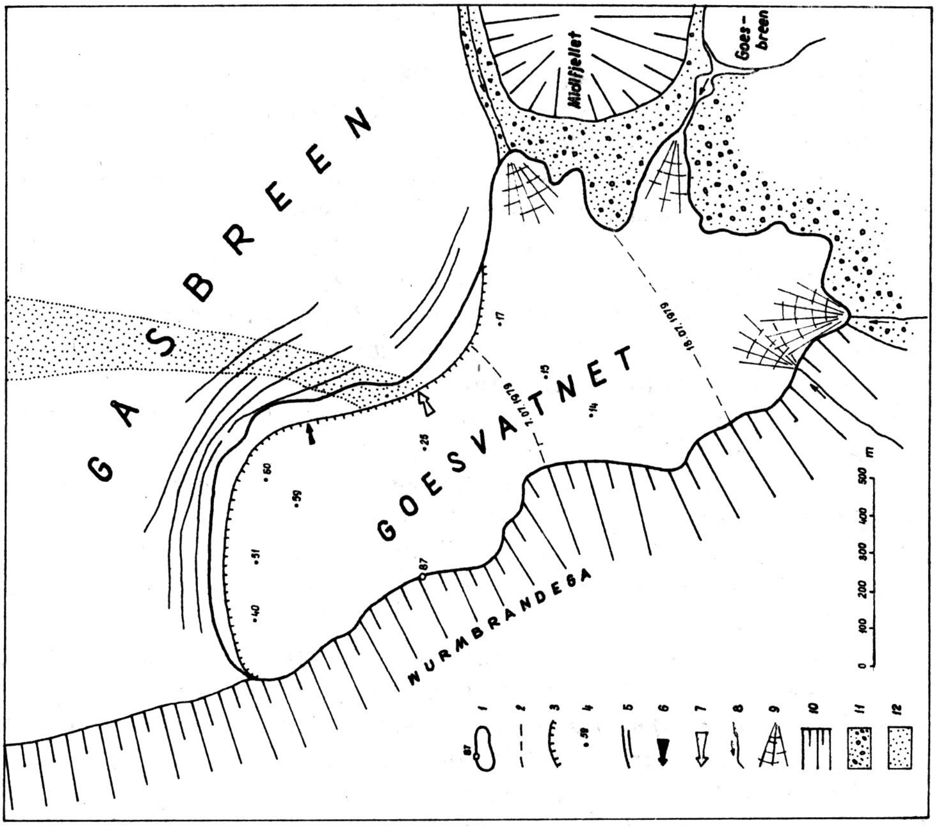

Fig. 3. Lake Goes in 1979–1980
1—maximum lake range (28.08.79) with the water level, 2—stages of lake fill-up, 3—ice cliff, 4—probed lake depths at maximum atate, 5—cracks in the ice, 6—subglacial tunnel 7—inglacial tunnel, 8—strems, 9—alluvial fans, 10—mountain slopes, 11—glacial sediments, 12—medial moraine. The outline of the lake in 1979 was recorded by W. Mizerski

rate of retreat is the result of the considerable cover of the ice by moraine material. The part of the front zone of the Gas Glacier from the slopes of the Wurmbrandegga to the median moraine branching off from the Midifjellet is probably passive. This is indicated by the system of the median moraines and by the relation of the main glacial stream to this part of the glacier. The median moraine originated at the slopes of the Midifjellet, until the glacier underwent "surging" (Fig. 4. and 5). In the passive part there are no cracks, crevices, or outcrops of flow lines to suggest motion. Ablation and precipitation water is drained mainly over the surface of the glacier.

3.2. Changes in the Goes Lake (Goesvatnet)

The lake moves following the downgrade of the slope, most rapidly in the northern direction, i.e. towards the damming passive ice. The north-eastern shore of the lake does not show such large changes because of the steady ice supply—there is a branch of the main glacial stream here (Fig. 1). This is indicated distinctly by the system of cracks and surface moraines visible in Pillewizer's map (1939), aerial photographs (Aerial photo.... 1960) and the photography shown here (Fig. 4).

When the lake is full the water infiltrates into the active part of the glacier, decreasing its friction against the base and simultaneously the thermal regime in some area. Another force, called the "floation mechanism" by Thorarinsson (1939), acts here. Therefore the retreat of the cliff shore of the lake in the northeast is slower because of the steady ice supply.

The investigations performed in 1978 and 1980, when the lake was drained, and in 1979 and 1980, when it was full, permit its more specific characterization. The bed of the Goesvatnet has two distinct basins: the northern 50–60 m deep, with a layer of silt sediments, and the southern 15–17 m deep, with delta type gravel and sand (Fig. 3).

In 1979 the lake began to fill on 15–20 June and on 28 August it was close to its maximum state in this ablation season. The water level established on the ordinate 87 m over the sea level. The area of the was 98.2 ha length 2 km and width 0.5 km, thus close to its size in 1938, i.e. 95 ha with the ordinate of the water level at 105 m over the sea level (Pillewizer 1939). The degree of the bed fill achieved by the lake in 1979–1980 was one of the highest; the ice cliff was fully submerged (Fig. 3).

As the lake moved following the inclination of the base, the ordinate of the water level lowered. Over 81 years it lowered by 63 m; from 150 m over the sea level in 1899 to 117 m in 1936, from 105 m in 1938 to 87 m in 1979 an 1980, with maximum depths of the same order. It is difficult to evaluate exactly to what extent the ordinates of the water level of 1899, 1936 or 1938 are close to the maximum states in the given ablation seasons.

Some information about the Goes Lake was provided by Szupryczyński (1963). He stated that "...the Goesvatnet is a dammed lake between the cliff of the Gås Glacier and mountain slopes of the Wurmbrandegga... In the water

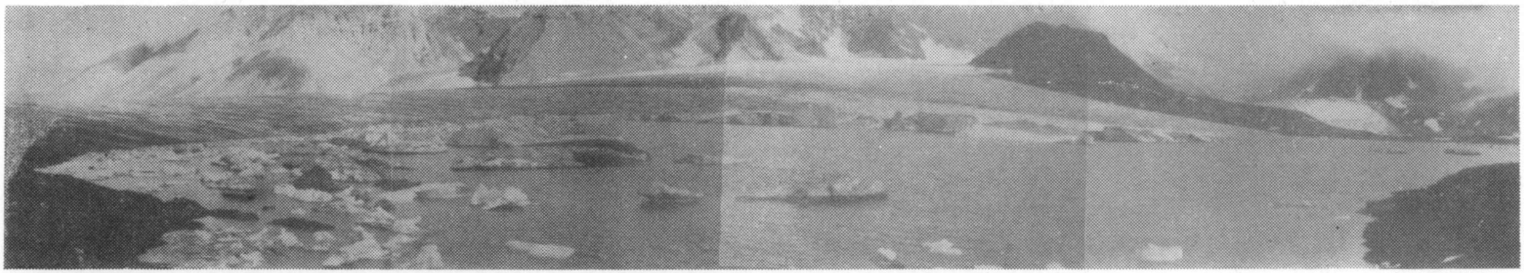

Fig. 4. Filled-up area of Lake Goes, 19 .August 1980.

Fig. 5. Empty area of Lake Goes, 10 August 1979.

at the foot of the cliff of the glacier there were large ice blocks and the surface of the lake was covered by the ice floes" (p. 53). Another piece of information provided by this author, who was told it by S. Siedlecki in private communication, is also interesting: "... In 1956 in the place of the lake there was a holly filled with moraine mud with dead ice blocks sunk in it. (p. 53). This is the first information about the occurrence of the empty lake bed. Pillewizer (1939) had previously written about a drainage of the lake and its effects but did not mention such a fact.

4. The drainage mechanism of the lake

The periodic filling and the partial or total drainage of icedammed lakes is a complex phenomenon. Chronological information about the presence of drainage of the lake is given below. Most of the data apply to summer months (July-August).

Date	Presence or absence of water in the lake	Ordinate of the water level m over the sea level	Source
1899	full	150	de Geer 1923
1936	full	117	Topografisk karte 1948
1938	full	105	Pillewizer 1939
1956	empty	–	Siedlecki, see Szupryczyński 1963
1959	full	–	Szupryczyński 1963
1960	empty	–	Aerial photo...1960
1970	full	–	Birkenmajer 1975
1975	full	–	Grześ, Banach
1977	full	–	Grześ, Banach
1978	empty	–	Grześ, Banach
April 1979	empty	–	Grześ, Banach
July 1979	full	87	Grześ, Banach
July 1980	full	87	Grześ, Banach
August 1980	empty	–	Grześ, Banach
July 1981	empty	–	Grześ, Banach
August 1982	full	–	Jania-private communication

The above data show a distinct variation in time of the phenomenon of the filling and emptying of the lake bed. It is, however, impossible to determine exactly when, at what maximum water level or depth, or alternatively at what ordinate of the water level the lake begins to drain and how long this lasts.

There have a number of attempts to explain the drainage mechanism of the ice-dammed lakes. On the basis of the literature, Post and Mayo (1971) give seven hypothese. The complete and rapid drainage of the Goes Lake when it becomes full supports the theory of Thorarinsson (1939). As a result of hydrostatic lift the ice dam goes up and the water drains subglacially and inglacially. The dam is lifted when the depth of the lake is about nine tenths of the height of the ice dam. The maximum depth of the lake found before its drainage in the summer of 1979 and 1980 was close to the height of the ice cliff. No outflow of the lake water was found in the forefield of the passive part of the glacier, which dammed the lake, which is the shortest wam to the marginal zone. The tunnels and gates of water drainage were found at its interface with the active ice, i.e. along the line of the median moraine from the Midifjellet. The water is drained through the interface zone between the active and passive parts of the glacier. In August 1978 two tunnels, subglacial, were found in the eastern part of the ice cliff, a few metres over the lake bottom (Fig. 3). Both tunnels are in the contact zone. There are no tunnels, however, in the cliff of the passive ice. In addition, the main current draining the basin of the Goes Lake flowed into the subglacial tunnel.

Most authors who investigate the problem of the periodic drainage of ice-dammed lakes agree that the gradual elevation of the increasingly wide zone of the ice dam as a result of hydrostatic lift starts subglacial drainage of the lakes through the previously active channels (e.g. Liestøl 1955, Marcus 1960, Aitkenhead 1960, Gilbert 1971).

The water meeting the first initial outflow starts the drainage mechanism of the lake. The inglacial or subglacial channels are rapidly enlarged by the thawing of the walls. The channels continne to enlarge until the whole lake is drained (Liestøl 1955, Mathews 1973).

The Goes Lake has for some years drained in the very same way. This indicated by the same ice gates through which the lake water flows (Fig. 1). It can therefore be supposed that, in addition to the hydrostatic lift affecting the part of the ice dam afloat in the lake, the contact zone between the active and the passive ice is particularly suitable for the way of the periodic drainage of the lake. The enlargement of the inglacial tunnels leads to considerable changes in the conditions of the water drainage (Stenborg 1969, Golubev 1976). The greatest changes in the drainage system occur inside the glacier. Walley (1971) believes that the glacier itself causes with its own drainage system the outflow of the lake.

The Goes Lake usually drains in winter or early spring. On 19 July 1978 the empty lake bed was covered with patches of the ice cover ice floe of the lake prior to the drainage. The subglacial drainage was under way till the end of the ablation season. It took 14–15 months for the drainage through the ice dam to be closed. The lake bed began to fill on 15–20 June, 1979 and continued till the end of July 1980. Thus the lake lived for about 13–14 months.

It seems to be guite regular for the Goes Lake that it does not fill in the summer following the winter drainage. This is indicated not only by the data given in the table above, but also by the lack of the annual presence of naled ice in the forefield of the lake.

Each ice-dammed lake has its own drainage system which depends on the changes within the glacier and the lake itself. The starting of the drainage is related to the maximum filling of the lake. The more exact cognition of the whole process of the drainage of the Goes Lake requires further investigations.

5. Remarks on the naled ice in the forefield of the Gås Glacier

The first information about the presence of naled ice in the forefield of the Gås Glacier was given by Baranowski (1977a, 1977b). He stated (1977a) that "...Characteristically, almost every year naled type ice occurs in the forefield of the Gasbreen, which can indicate the presence of a warm thermal regime in the base of the glacier" (p...). The naled ice does not occur in the forefield of the Gas Glacier every year. If the naled ice in the shore and extramarginal zones were the result of the presence of the warm thermal regime in the base of the glacier, they should occur each year. In the winters 1978/1979 and 1980–1981 the authors observed the formation of naled ice in the forefield of the Werenskiold Glacier, in its size close to the Gås Glacier. It covered at most 10 per cent of the internal area of the marginal zone. The question therefore arises as to how it is possible for naled ice to emerge in the area of several hundred hectares in the forefield of the Gås Glacier in the course of one season. According to Baranowski (1977b), at the begining of the summer of 1970 the naled ice at Gåshamnøyra covered 2.5 km^2, i.e. 54 per cent of its area.

When the Goes Lake drained in the late winter or early spring of 1978, in August one could see in the extramarginal outwash a large fan-shaped naled field, strongly degreded by atmospheric factors and flowing water. The lake began to refill in the summer of 1979 and thus in the winter 1978–1979 the bed of the Goes Lake was empty. No naled ice was found in the forefield of the glacier. Because of the fact that the lake did not drain in the winter 1979/1980 and then not until July 1980, naled ice was not there, either.

The present authors belive that the facts presented above provide sufficient evidence that the winter-spring drainage of the Goes Lake cause naled ice to form in the forefield of the Gas Glacier (Gashamnoyra).

When the drainage mechanism of the lake is started, the lake water flowing through the glacier gate permeates the snow cover and fills the area of the internal marginal zone. The main break through the ice and moraine bank is blocked in winter by packed, blown snow, which in the first stage is a sufficient dam for the water flow from the glacier. The drainage from the glacier basin througt the breaks in ice and moraine banks was repeatedly found to be dammed, on many glacier (e.g. the Werenskiold or the Nann). When the snow dam is broken through, the water flows out to the snow-covered extramarginal outwash. In the first stage it spreads in a fan—shaped manner. In the second, in turn, beds are cut under temperature and abrasion in the permeated snow cover. Relatively soon the river beds covered by a layer of snow down to 3–3,5 m are restored, since these zones are most vulnerable to subsurface erosion. As the water flows farther from the break in the ice and moraine banks, the inclination and depth of the beds decrease. The water mass concentrated in the beds spreads again over the plain. Its flow to the sea is stopped by the storm bank with a superstructure of ice rubble formed in the course of autumn storms up to more than 1 m and 5–10 m wide. The whole is frozen and constitutes a hermatic barrier for the water. The hollow in front of this bank fills with inflowing water until it flow over the top. The back flow of the basin thus being formed per meates the increasingly wide part of the snow-covered outwash. The whole phenomenon occurs at negative air temperature. The water—per meated snow cover rapidly frezes. The water—filled hollows freeze to the bottom. This can be accompanied by the formation of the socalled ice burges. This process should explain the fact that in summer the naled ice is thickest in the coastal zone of the outwash. When the lake is drained the beds cut are quickly covered with snow, as a result of precipitation and primarlly because of its redeposition. When the drainage of the lake is accompanied by a snow storm, the damp surfaces trap then the redeposited snow causing an increase in the rate and the ultimate thickness of naled ice.

It sems necessary to point out the fact that the water-permeated and frozen snow is in its properties close to ice (0.75–0.85 g/cm^3) it therefore thaws much more slowly than the parts not covered by the winter—spring outflow and remains till late summer.

As the water flows farther from the breakthrough its energy decreases and the mineral material it carries accumulates. The amount of deposited sediments is not in direct proportion to the size of the flood, since erosin occurs in the frozen base. Despite this a number of ephemeral forms arise which resemble in their shape ozes and kems; naled patches are also preserved.

In view of the problems discussed above, one should also consider the forms outside of the moraine ridges in the area of the breakthrough. Their origin has been investigated by a number of scholars (Szupryczyński 1963, Wiśniewski and Karczewski 1976, Cegła and Kozarski 1977). The present authors think that their form should be related to the catastrophic of the lake when the glacier was in the line of the moraine ridges.

6. Summary

It is characterisric of the Goes Lake that for 81 years its area and depth conditions, despite a change in location, have barely changed. The sub and inglacial drainage of the lake occurs in the contact zone between the active and the passive part of the ice dam, both through the previously functioning and the newly formed channels. After a period of 6–7 months from the time when the lake bed is fully fielled, the lake begins to drain. The water has flowed out through the same places for a number of years. When the lake is drained its bed usually stays empty till the next summer season, which is caused by the fact the sublacial-inglacial drainage system continues to function. The lowering of the part of the ice dam floating in the lake does not occur until the winter season which precedes the filling of of the lake bed.

It should be stressed that all ice-dammed lakes have their own individual drainage system, even if they belong to the same type. The drainage system changes as the lake evolves; this evolution being strictly conditioned by changes the glacier.

Naled ice, with size exceeding the typical Spitsbergen dimensions, has repeatedly (but not annually) been found in the extramarginal outwash (Gåshamnøyra). It is not the effect of the freezing of the water flowing out of the glacier with a warm regime in the base. The naled ice of this type is a local phenomenon which occurs in a small part of the internal zone. The naled ice in the extramarginal outwash results from the winter drainage of the lake. Therefore it is observed in Gashamnøyra each year. The phenomenon occurs catastrophically and briefly (5–10 days). This naled ice is brought about by the permeation of layered water, as a result of the blowing of the snow cover with negative temperature. This gives layered ice 0.75–0.85 g/cm^3 thick which the authors have observed. It has repeatedly been observed that it disintegrates into single, vertical crystals up to some score cm long.

In viev of the above fact, does the naled ice belong in the definition of this kind of ice? It seems that the criteria for the emergence of naled ice not exact, since they should account for the mechanism of its formation and not only its structure.

7. Резюме

Гесватнет, это подпорное озеро, воды которого заграждает ледник Гас. Оно периодически подвержено субгляциальному-ингляциальному дренажу, обычно зимой. При максимальном заполнении глубина озера достигает 60 м, а поверхность 1кв. км. Проведена попытка объяснить механизм дренажа озера. Автор проследил изменения уровня и распространения озера в течение 81 года. Определены размеры и тип дегляциации краевой зоны ледника Гас. Установлена тесная связь между дренажем озера и наличием наледей на экстрамаргинальном зандре (Гасгамнойра).

8. Streszczenie

Goesvatnet jest jeziorem zaporowym, wody którego są piętrzone przez lodowiec Gas. Ulega ono periodycznym subglacjalnym spłynięciom; zwykle w okresie zimy. Przy maksymalnym wypełnieniu osiąga ono głębokość rzędu 60 m i powierzchnię około 1 km^2. Przeprowadzono próbę wyjaśnienia mechanizmu drenażu jeziora. Prześledzono zmiany położenia i zasięgu jeziora na przestrzeni 81 lat. Określono wielkość i charakter deglacjacji czołowej partii lodowca Gas. Stwierdzono ścisły związek pomiędzy spłynięciami jeziora a obecnością nalodzi na sandrze ekstremalnym (Gashamnøyra).

9. References

1. Aitkenhead N. 1960 — Observations on the drainage of glacier-dammed lake in Norway — J. Glaciol., 3: 607–609.
2. Aerial photo taken by Norsk Polarinstitutt — S 61, D 8, 1248..., 15 August 1960.
3. Baranowski S. 1977a — Subpolarne lodowce Spitsbergenu na tle klimatu regionu (Subpolar Spitsbergen glaciers seen against the climate of the region) — Wyd. Uniw. Wrocł. Studia Geograf., 31: 94–95.
4. Baranowski S. 1977b — Naled typ of ice front of some Spitsbergen glaciers — Acta Univ. Wratislaviensis, 387: 85–89.
5. Birkenmajer K. 1975 — Polarne drogi i bezdroża (Polar roads and pathless tracts) — Wyd. Geol., Warszawa: 108.
6. Cegła J., Kozarski S. 1977 — Sedimentary and geomorphological causequences of the occurrence of naled sheets on the outwash plain of the Gas Glacier, Sørkappland, Spitsbergen — Acta Univ. Wratislav. No 387, Spitsbergen Expeditions II, Wrocław: 61–84.
7. De Geer G. 1925 — Envirions de la Station Russe de l'hivernage, 1:50000. Missions scientifiques pour la measure d'un arc de meridian an Spitsberg — Mission Sne'doise, Bd. II, Topographie, Geologie, Stockholm.
8. Gilbert R. 1971 — Observations on ice-dammed Summit Lake, Britsh Columbia, Canada — J. Glaciol., 10: 351–356.
9. Golubev G. N. 1976 — Gidrologija lednikow — Leningrad: 216–233.
10. Jania J., Lentowicz Z., Szczypek T., Wach J. 1981 — Szkic geomorfologiczny rejonu Gåsdalen (południowy Spitsbergen) A draft geomorphological characterization of the Gåsdalen area, South Spitsbergen) — Proc. VII Polar Symposium, vol. 1, Sosnowiec: 119–128.
11. Liestøl O. 1955 — Glacier dammed lakes in Norway — Norsk Geogr. Tidsskr., 15: 122–149.
12. Maag H., 1969 — Ice dammed lakes and marginal glacier drainage on Axel Heiberg

Island — Axel Heiberg Island Research Reports, Mc Gill University, Montreal: 147.
13. Marcus M. G. 1960 — Periodic drainage of glacier dammed Pelsequah Lake — British Columbia, Geogr. Rev., 50: 89–106.
14. Mathews W. H. 1973 — The record of two jukulhlaps — Symposium on the hydrology of glaciers, LASH, Publ. N. 95: 99–110.
15. Pillewizer W. 1939 — Die Kartographischen und Gletscherkendlichen Ergebnise der Deutschen Spitzbergen Expedition 1938, Erganzungsheft Nr 238 zu "Petermans Mitteilungen" Gotha, Justus Perthes: 46.
16. Post A., Mayo L. R. 1971 — Glacier dammed lakes and outburst floods in Alaska — Hydrologic Investigations Atlas H A — 455, U. S. Geolog. Survey, Washington: 10.
17. Stenborg P. 1969 — Daley of runoff a glacier basin-Georg. Ann., 52, ser. A, N 1: 1–30.
18. Szupryczyński J. 1963 — Rzeźba strefy marginalnej i typy deglacjacji — lodowców południowego Spitsbergenu (The relief of the marginal zone and deglaciation types of the glaciers in South Spitsbergen) — Prace Geogr. 38: 46–53.
19. Thorainsson S. 1939 — The ice dammed lakes of Iceland, with particular reference to their values as indicators of glacier oscillations — Geogr. Ann., 21: 216–242.
20. Topografisk kart over Svalbord 1:100000, Blad C 13, Sökapp Norges Svalbard of Ishavs Untersokeler, 1948.
21. Wassiliew A. S. 1925 — Spitzberg, III, Fenille du Sud, 1:200000. Missions scientifiqnes pour la measure d'un arc de meridien au Spitzberg. — Miss. Russe, Publication de l'Academie des Sciences de Russie.
22. Whalley W. B. 1971 — Observations on the drainage of an ice dammed lake — Strupvatnet, Tromso, Norway — Norsk Geogr. Tidsskr., 25: 165–174.
23. Wiśniewski E., Karczewski A. 1976 — O rzeźbie sandrów utworzonych na lodzie (On the relief of the outwashes on ice), Przegląd Geograficzny, vol. 1, no. 2: 296–292.

Paper received 1982 Juni 02