POLISH POLAR RESEARCH (POL. POLAR RES.) POLSKIE BADANIA POLARNE	6	4	497—513	1985

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Traces of the glaciations in the northwest part of Nordenskiöld Land (West Spitsbergen)

ABSTRACT: The present paper contains the results of geomorphological investigations carried out by the author during the IInd Polar Expedition of the Scientific Society of the Students of the Department of Geography and Regional Studies, Warsaw University, to the northwest part of Nordenskiöld Land (West Spitsbergen) in the summer of 1980. The present elaboration discusses the glacial forms and deposits which arose during previous stays of the glacier on this area. Particular attention was paid to the disposition of erratics, which permitted the determination of the directions of the transgression of the young Quaternary glaciations.

KEY WORDS: Geomorphology, glaciation, erratics, Nordenskjöld Land, Spitsbergen.

1. Geomorphology of the terrain and investigations carried out

The part of Nordenskiöld Land is an extensive peninsula, situated in the central part of the island of West Spitsbergen, among Isfjorden, Grönfjorden, Orustdalen and Sea of Greenland (Fig. 1). Here there is a strip, parallel system of the major forms of relief in the orientation NNW-SSE, reflecting the tectonic structures. The morphological axes of this region is Linnédalen, which is surrounded by steep mountain ranges. From the west there is the Linnéfjella ridge with the peaks: Griegaksla (473 m above sea level), Griegfjellet (778 m above sea level), Aagaardtoppen (732 m above sea level), Systemafjellet (774 m above sea level). From the east, Linnédalen closses the range with the peaks: Starostinaksla (231 m above sea level), Vardeborg (588 m above sea level), Sokolovtoppen (541 m above sea level), Voringen (675 m above sea level), Flintkammen

(570 m above sea level), Christensenfjella (680 m above sea level) and Quigstadfjellet (770 m above sea level). From it, the crests and hummocks branch off, descending towards Grönfjorden: Freboldrygen, Bodylevskyhögda (448 m above sea level), Heftyefjellet (425 m above sea level), Braganzantoppen (380 m above sea level), Productustoppen (523 m above sea level) and Strandlinuten (507 m above sea level). Among the particular heights, there stretch the depressions: Blendadalen. Kongressdalen. Stenbrohultdalen and the valleys now filled up with Tertiary deposits in the core. Thus, the distribution and differentiation of mountain ranges is marked by distinct asymmetry. All the ridges branching off the Starostinaksla-Quigstadfjellet range are on its eastern side. This brings about a considerable articulation of the terrain of this area, where both the longer axes of convex and concave forms are orientated in a similar way and are directed NE–SW.

In the lower section of Linnédalen, there is situated the elongated Linnévatnet with the area of 4.5 km^2. In the area discussed, there also occur other natural permanent water reservoirs; resembling in their outline to a circle — Kongressvatnet, Stemmevatnet and the numerous small lakes in Isfjordflya and Vardeborgsletta. The main water artery of the northwest part of Nordenskiöld Land is Linnéelva, originating from Linnébreen. The largest glacier in the area analysed, Vestre Grönfjordbreen, is in the southeast and descends to Grönfjorden. Over high passes it links with the second largest Aldegondabreen. Vardebreen, Voringbreen and Heftyebreen, extending east of the Starostinaksla-Quigstadfjellet range, have the form of small ice domes. A different type is represented by the valley glaciers: Solfonna and Linne. There are also a few small glacial cirques on the east slopes of Linnéfjella and at the foot of Productustoppen. In addition, a small suspended glacier flows from under a peak 668 m over the sea level in the Systemafjellet massif towards Tjörnskardet.

The northwest part of Nordenskiöld Land lies at the edge of a tectonic trough extending southeast of Isfjorden, with Tertiary deposits in the core (B. Flood, J. Nagy, T. S. Winsnes 1971). Along the east slopes of Linnéfjella there is the contact of the Hecla Hoek formation and paleozoic young formations (Fig. 2). The outcrops of the other deposit series: paleozoic, mezozoic and kenozoic, are arranged parallel to this line (H. E. Kellog 1975, D. Worsley, A. Mørk 1980). The upper group of the Hecla Hoek complex in the wicinity of Isfjorden is composed of Cambrian and Ordovician rocks, mainly limestones, dolomites, tillites and green and black slates. Veins of pink, grey and green marbles are quite frequent here. On the rocks of the Hecla Hoek formation, to the east, with disconformity, there lie grey Carboniferous conglomerates, dropping towards Grönfjorden at an angle of 70°, Further on, there appear monoclinically inclined grey quartzite Carboniferous sandstones with abundant flora (root-

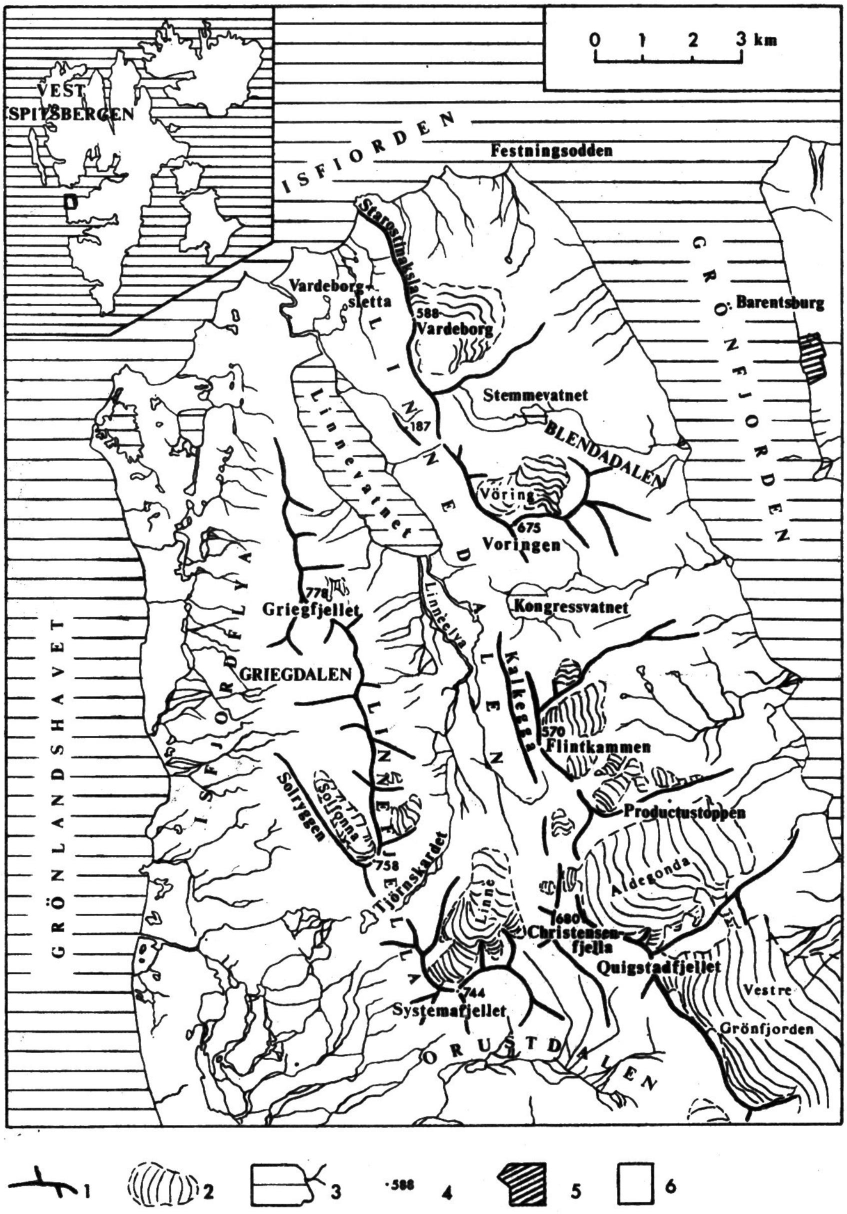

Fig. 1. A situation map of the northwest•part of Nordenskiöld Land. 1 — mountain ridges, 2 — glaciers, 3 — surface waters, 4 — altitude points, 5 — settlement, 6 — study area

-stocks of lepidodendrons), in which hard coal inserts occur. The upper Carboniferous system has the shape of grey limestones with well-preserved coral fauna. At the contact of quartzite sandstones and Carboniferous limestones there are Cretaceous and Jurassic intrusions of green and grey dolerites. The paleozoic deposits end with pulpy series of grey limestones forming successive spiroferous horizons (30° decline to the east). There is here a rich complex of fauna, mainly brachiopodic (Pleurohorridonia carbonaria, Productaceosemircticulatus, Productacea productus etc.). Further on, there lie the outcrops of grey and yellow Triassic sandstones and then strongly perturbed black Jurassic mudstones containing siderite concretions. The west coast of Grönfjorden is prepared in light Cretaceous sandstones and mudstones. From the mouth of Blendadalen to Festningsodden sandstones of the Older Tertiary system can be traced. In the northwest part of Nordenskiöld Land well legible marine-glacial deposits, building terraces, are visible up to 150 m above sea level. Above this height, denudation-alluvial covers of local material dominate (L. S. Troitski, E. M. Zinger, V. S. Koriakin ... 1975).

The lithological differentiation of rocks in the region studied is fully reflected in the present relief. Highly erosion-resistant quartzite sandstones and dolerites constitute threshold-making layers successfully opposing the processes of destruction. Distinct hillocks and ridges can be seen e.g. in the upper and central sections of the subsequent Linnédalen. Slope faults also formed at the particular spiryfer horizons.

Analysis of the relief of the part of Nordenskiöld Land studied draws attention to the presence of wide depressions in the main mountain ridges, undercuts in the slopes, "roundings" of crests and hypsometric level at the passes. The greatest depression is in the Starostinaksla--Quigstadfjellet range near Kongressvatnet (Fig. 3). It is prepared in the Kalkegga ridge and is as much as 2.5 km in width. The ridge section discussed, with its smooth, flat highly eroded surface, rises to about 100–110 m above sea level. It includes two lower depresions more than 200 m wide; one of which is now intersected by a stream flowing from Voringen. From the direction of Linnédalen, in the Kalkegga ridge, about 75 m above sea level, there are sequences of dolerite outcrops forming distinct structural thresholds. Where the two depressions mentioned

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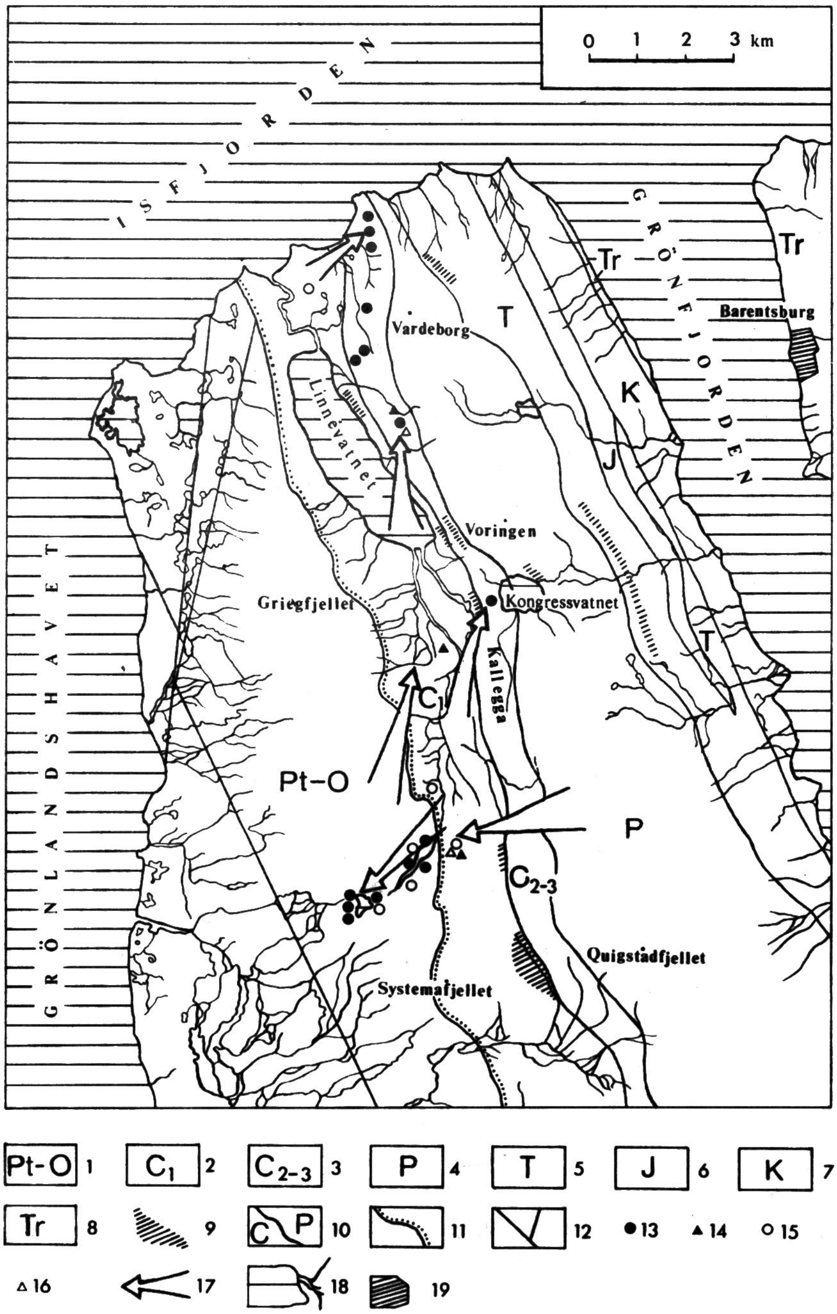
Fig. 2. Open geological map of the northwest part of Nordenskiöld Land, acc. to G. A. Kowalowa and A. Musiał. 1 — limestones, dolomites, tillites, green and black Cambrian and Ordovician slates, 2 — grey pudding stones, quartzite sandstones with Lower Carboniferous hard coal inserts, 3 — dark red quartzite sandstones, grey limestones, dolomites, marl slates, silica lime slates from Middle and Upper Carbonifereous, 4 — grey limestones, Permian silica limestones, 5 — Triassic sandstones, 6 — black mudstones with siderite Jurassic concretions, 7 — Cretaceous sandstones and mudstones, 8 — paleogenic sandstones, 9 — Jurassic?, Cretaceous ? green and grey dolerites, 10 — stratigraphic boundaries, 11 — stratigraphic discontinuity lines, 12 — tectonic lines, 13 — erratic rocks from Lower Carboniferous, 14 — erratic rocks from Middle and Upper Carboniferous, 15 — erratic Permian rocks, 16 — dolerite erratics, 17 — directions of old glacier transgressions, 18 — surface waters, 19 — settlement


0 1 2 3 km
ISFJORDEN
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Voringen
Kongressvatnet
Griegfjellet
C1
Kallegga
Pt–O
P
C2-3
Quigstadfjellet
Systemafjellet
Pt-O 1
C1 2
C2-3 3
P 4
T 5
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K 7
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Fig. 2

above occur, these thresholds are "moved back" to the east by about 150 m. This indicates a strong development of erosion processes in these sections. In the case presented, one should exclude river erosion as a direct factor which has caused niches within the threshold, because these forms are not linear in nature. The present V-shaped cuts under Voringen have a quite different appearance.

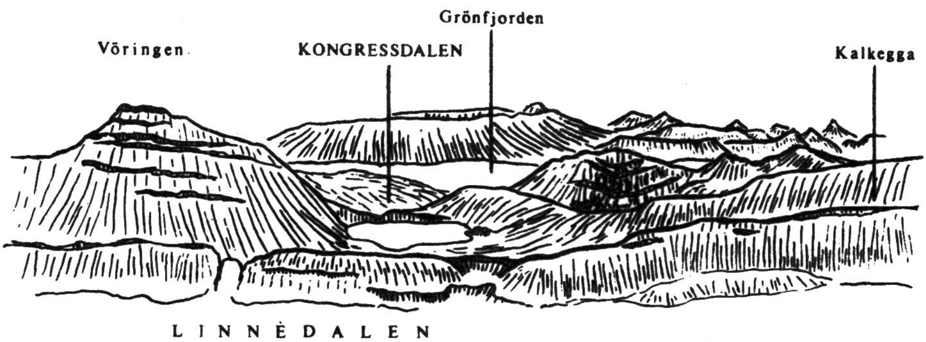

Fig. 3. Field sketch with a view of the depression on the Starostinaksla-Quigstadfjellet near Kongressvatnet

To the south the Kalkegga ridge rises gradually, and increasingly higher flattenings and successive faults occur. The first level is seen at a level of about 150 m above sea level, the successive ones are as high as 200, 250 m above sea level; the highest reaches 350 m above sea level. According to Soviet researches (L. S. Troitski, E. M. Zinger, V. S. Koriakin ... 1975), the well preserved sea terraces around Grönfjorden can be observed as high as 120–135 m above sea level. They formed as abrasion and abrasion-accumulation levels on the surface, built of pebbles, under which dark grey glacial clays lie. Thus, the flattenings in the Kalkegga ridge lie much higher than the sea terraces and it is wrong to relate their origin to the sea action.

In the course of field research carried in July and August 1980 * on the west slope of Kalkegga 150 m above sea level (with altitudes measured by an altimeter) erratic boulders were found (Fig. 2). They are single pebbles stuck among sharpedged pieces of local rocks; the largest of them was twentyodd cm large. Here, there dominated well and well

*) The research was carried out in the framework of the IInd Students' Polar Expedition "Spitsbergen 80", organized by the Scientific Society of Geography Students of Warsaw University.

rounded pieces of grey quartzite sandstones from the Lower Carboniferous period, outcrops of which are found at the bottom of Linnédalen; i.e. about 50–80 m below the place where they occur at present. A much richer set of pebbles was found at the culmination of an elevation 187 m over the sea level, situated on the east shore of Linnévatnet between Vardasen and Sokolovtoppen. The largest of the specimens found here exceeded 40 cm in diameter. This time. in addition to grey quartzite sandstones, pebbles of dark red quartzite sandstones were also found, probably from the Middle Carboniferous, outcrops of which were identified about 1 km south of Linnévatnet, at the foot of Kalkegga and east of Linnébreen. Besides, single rounded dolerite pieces were identified here. In the case discussed pebbles lie about 140 m above the parent rocks. Their dimensions, the height at which they can be found at present and the distance by which they were displaced, all seem to exclude sea transport. In the situation presented, one should, however, consider the possibility of the transportation of rounded mineral material in the geological past by e.g. ice float. A closer analysis of the phenomenon excludes such a process, since it would be difficult to conceive that the pebbles lying on the bottom ow the basin could. after freezing into ice, have "raised" as high as 140 m.

In the light of the facts presented, it is interesting to consider the situation and origin of Kongressvatnet, which is circular in outline. This lake lies on the east side of the Kalkegga ridge, at its lowest depression, with the levels described: 150, 200, 250 and 350 m above sea level. From the side of Grönfjorden it is closed by a 10 m threshold and an elevation 200 m above sea level with a small lake at the top. The convex form discussed has smoth slopes; in the east, where outcrops of Permian limestones occur, legible traces of slickensides have been preserved. In view of the situation and the surrounding forms, the depression of Kongressvatnet seems to correspond to the conditions in which potholes and bowls of a glacial overdeepening occur M. Klimaszewski, L. Starkel 1972).

Thus, there are sufficient premisses to recognize the depression in the Kalkegga ridge and also the Kongressvatnet bowl as forms of glacial origin. In view of that at present, in the direct vicinity of Kongressdalen there are no larger glaciers, these glacial forms should be related to the exaration activity of the earlier glaciations. The presence of quartzite sandstone boulders on the slopes of Kalkegga and on the ridge 187 m above sea level indicates that the glaciers (glacier?) existing at that time could have been flowing towards Grönfjorden or north, to Isfjorden. These presumptions seem to be confirmed by the hypsometric situation, since the present water divide running here only slightly exceeds 100 m above sea level. So far no erratic boulders have been found to indicate that the ice masses displaced east. In addition, the distribution of erratic material, in particular dark red (Middle) Carboniferous quartzite sandstones, clearly determines the path of the glaciers — from south to north, i.e. according to the morphological axis of Linnédalen.

The remainder of an earlier glacial epoch in this part of Spitsbergen are the preserved brown-red glacial clays running along the slopes of Kalkegga and Griegaksla. They occur in the upper section of Linnédalen on a level of 150 m above sea level (measured by an altimeter), forming slight flattenings. In turn, on Vardeborgsletta they can be found 26–28 m above sea level. Here are also erratic boulders with poorly rounded edges, at times exceeding 2 m in diameter. They are stuck in clay or only partly immersed in it. Probably, the glacial deposits described here or the boulders on the ridge 187 m above sea level come from the same glaciation.

The traces of old glaciers in Linnédalen are indisputable, and, therefore, one should expect older glacial forms in its closest vicinity. Today, they are hardly legible, since they were erased by later morphological processes; they were mainly covered by slope deposits.

The earlier glacial activity can also be evidenced by the presence of a large number of Carboniferous grey quartzite sandstone erratic boulders. They are clustered in Linnédalen along Vardasen, Vardeborg and Starostinaksla. At present this material, in the form of pebbles, up to 40 cm in diameter, builds sea terraces 53, 58 and 65 m above sea level. The deposits mentioned lie on limestones, dolomites, marl slates and sillicate limestone slates from the Middle Carboniferous period (D. J. Gobbett 1963). It seems that such a large concentration of rock material could only have occurred as a result of glacial transport.

The traces of the exaration of pre-Holocene glaciers are also seen in the depressions and passes between Flintkammen and Quigstadfjellet. Among others, the pase between Flintkammen and Hermod Pettersenfjellet (Fig. 4) indicates glacial remodelling. The rock ridge here lowers distinctly and over more than 0.5 km it is "rounded" and smooth. Here begins a small valley going into Linnédalen, whose width is disproportionately large to length. On the slopes enclosing it at about 350–400 m over the sea level, flattenings with slickensides are visible. They lie high over ice-moraine banks determining the maximum range of the present glaciers. Thus, also in the case discussed, the noted effects of glacial exaration should be ascribed to older glaciations.

The depression between Hermod Pettersenfjellet and Christensenfjellet is characterized by larger dimensions (more than 1 km long) and similar morphology. Also, one can see here a "retreat", to the east by nearly 1 km, of a structural threshold developed on outcrops of limestones forming a spiryfer horizon.

The range of the present glaciers can indicate that in the past ice masses flowed over the depression between Hermod Pattersenfjellet and Christensenfjella. As late as the 30's of our century, Aldegondabreen

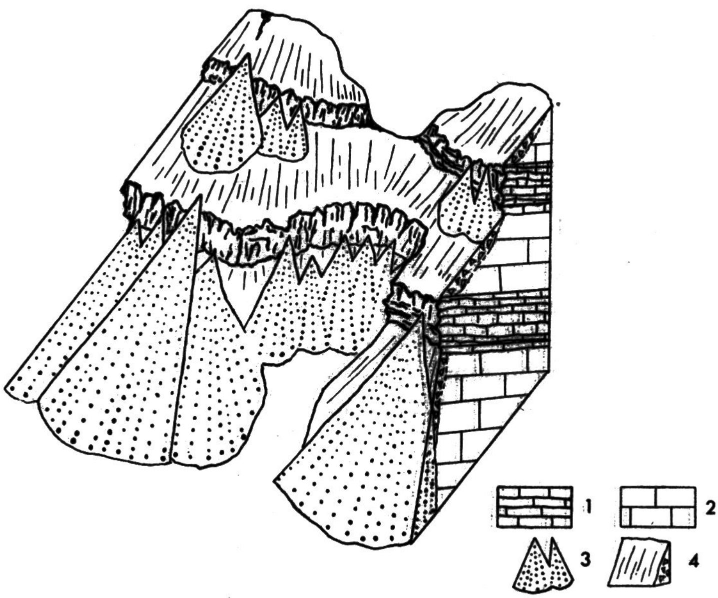

Fig. 4. Block diagram representing the situation of detersion niches cut under passes at structural thresholds.
1 — layers more resistant to destruction, 2 — layer less resistant to destruction, 3 — tali, 4 — erosion covers on slopes

transflowed to the west of Linnedalen and joined with Linnebreen (Topografisk kart over Svalbard 1948). Over the recent 40 years, ice also receded from the ridge closing Linnébreen from the west and the lower parts of nunatakas sticking out from Vardeborgbreen and Vestre Grönfjordbreen (Topografisk kart over Svalbard 1955).

In the light of the documented data, it is commonly accepted that the present glaciation of Svalbard has reached small dimensions compared with the older glaciers (K. Birkenmajer 1959, A. Jahn 1959 a, b, O. A. Lavrushin 1969, J. Szupryczyński 1963, 1966, 1968, M. Klimaszewski 1960). Thus, it should be expected that the previous glaciers (glacier) transflowed freely over passes to the other side of the main ridges of the northwest part of Nordenskiöld Land. In view of this, depressions in the mountain ranges, within which flattenings and faults can clearly be distinguished, arose as a result of detersive activity of earlier glaciers and constitute their old shoulders and glacial undercuts in slopes.

A trace of the earlier glaciations in this part of Spitsbergen is also a distinct glacial cirque, situated on the south slope of Systemafjellet. Its diameter exceeds 1 km, and on the flat bottom, numerous roches moutonnes with clear glacial features can be seen. This cirque is suspended about 200 m over Orustdalen (i.e. 250 m over the sea level). This fact indicates a distinct support from the south, which could have been a glacier filling up this valley. Analysis of the relief surrounding Orustdalen draws attention to the flattenings occurring here up the slopes. They extend here 250–300 m above sea level, i.e. at a level to which the glacial cirque described earlier is related. This coincidence suggests a distinct genetic and temporal relation between these forms. At similar heights, there extend flattenings in Tjörnskardet and in Griegdalen, within Freboldrygen, Bodylevskyhögda etc.

The facts cited so far and the relief forms described do not provide sufficient basis for establishing the origin of levels found in the part of Svalbard Archipelago studied. According to W. Stankowski (1981), the oldest morphological level conditioned by the sea activity, in the surroundings of Lisbet Valley (Sörkapp) occur up to 535–560 m over the sea level. This is the highest altitude of sea abrasion surfaces noted so far by researchers in Spitsbergen. In view of this, the surfaces 250–300 m above sea level described, found in the area among Grönfjorden, Sea of Greenland and Isfjorden, should, according to the opinion of W. Stankowski, be ascribed to the sea activity.

Geomorphological mapping of the northwest part of Nordenskiöld Land gave evidence permitting a different interpretation of the origin of such forms. Namely, the ridge enclosing Linnébreen from the west was found to be very distinctly muttonized (A. Musiał 1981, E. Ryżyk 1981). A table survey of the marginal zone of this glacier permitted exact determination of the height up to which traces of glacial detersion and detraction occur on the ridge (Map of the marginal zone of Linnebreen (1981)). According to cartometric measurements carried out, the glaciers (glacier?) exceeded here 270 m above sea level. In addition to well preserved glacial features indicating the transgression direction of ice masses northwest and west, on the smooth ridge an enormous erratic block of quartz its sandstone was found (Fig. 5). Its dimensions are 3 × 4 × 3 m. The unrounded sharp edges indicate a short path of transport. Rock block which are very similar in terms of external and lithological properties, lie at present on the east ice-moraine banks and on the surface of Linnébreen. In view of this, it is possible to determine exactly where these blocks came from. They are fragments of a small side ridge close to the peak 630 m over the sea level in the Systemafjellet massif, i.e. on the east side of Linnébreen.

The spatial situation of the smooth west ridge with the enormous boulder with respect to the present ice-moraine banks indicates a distinct difference in time between these forms. The ice-moraine banks found now in Spitsbergen define the maximum range of the Holocene glaciation, the so-called "Little Ice Epoch" (A. Jahn 1959 b, M. Klimaszewski 1960,

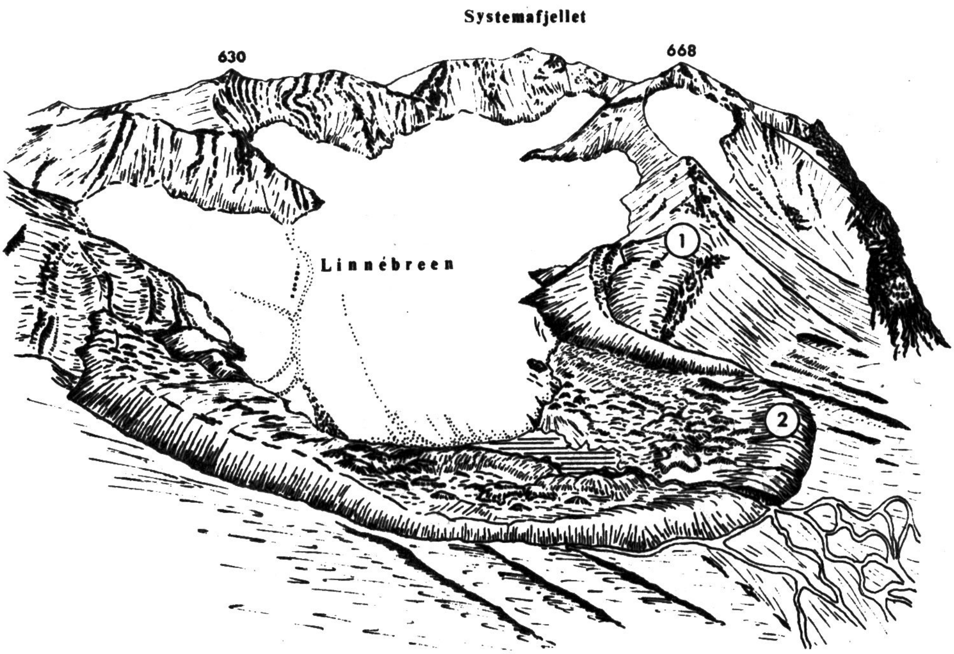

Fig. 5. Linne Glacier in the Systemafjellet massif.
1 — erratic quartzite sandstone boulder, 3 × 4 × 3 m, on a muttonized ridge, 2 — ice-moraine banks

A. Kosiba 1958, O. A. Lavrushin 1969, J. Szupryczyński 1963, 1968, S. Z. Różycki 1957, L. S. Troitski, E. M. Zinger, V. S. Koriakin ... 1975). In the case of Linnébreen, between the slickenside and the ice-moraine bank there extends a deep marginal valley. Thus, the glacier described did not manage to the previously muttonized ridge, barring his way west towards the Sea of Greenland. Therefore, the preserved traces of glacial activity come from earlier glaciations (glaciation?). It is interesting to note the distinct coincidence in height between the flattenings in the northwest part of Nordenskiöld Land (250–300 m above sea level) and the slickenside in the west ridge enclosing Linnébreen (270 m above sea level). This suggests that they constitute a genetic whole, owing their formation to the activity of earlier glaciers (glacier?).

The routes of the older glacier transgressions in the area among the Sea of Greenland, Isfjorden and Grönfjorden are determined by numerous erratic boulders. Their identification is made easier by the strip-like course of outcrops of the underlying rocks, distinctly differentiated in age and lithology. The wind of particular rock series is small — up to 2 km, at most. This makes it possible to reconstruct even small material displacements.

Detailed investigations of erratic boulders were carried out in the vicinity of the marginal zone of Linnébreen. A distinct shift of erratic material from the east to the west was found (Fig. 2). The longest distance was covered by pieces of Permian limestones and dolomites, making up the so-called spiryfer horizons. The distance between the outcropped rocks and the last erratic boulder is almost 4 km. They are scattered along the depression of Tjörnskardet, lying on Carboniferous quartzite sandstones and slates of the Hecla Hoek formation. The largest of the erratic boulders reach the dimensions 1 × 1.5 × 2, and they were found on the east side of Linnéfjella within Ordovician and Cambrian rocks. Grey Carboniferous quartzite sandstones were transported over a shorter distance (over 2 km). They occur in the form of sea pebbles and are clearly visible among the brown and black slates of Hecla Hoek. At the mouth of Tjörnskardet, towards the Sea of Greenland, they build sea terraces about 65 and 53 m above sea level. Grey Carboniferous quartzite sandstone pebbles reach here almost 80 cm in diameter. It is particularly interesting to note the fact that their propagation over the plain on the sea is distinctly limited. They can be encountered exclusively at the mouth of Tjörnskardet; in turn there are no such pebbles at the feet of Solryggen and Systemafjellet, nor farther on towards the west on Isfjordflya. The surface area covered by these terraces is about 300 m wide and almost a kilometer long. It was observed here that the largest pebbles occur on the edges.

Considerations of the manner of the transport of the erratic material described should above all take into account the glacial factor. Sea waves could not have managed to carry such amounts of rock pieces over such a long distance. Only ice masses could have transported blocks 1 × 1.5 × 2 m large.

In Tjörnskardet 245 m above sea level there are distinct flattenings, where the highest localisations of grey quartzite sandstone pebbles were found. Directly over these surfaces there rise vertical rock faces, which turn into the uniformly inclined slopes of Solryggen and Systemafjellet. The forms presented correspond to the glacial shoulders and undercuts described in the literature.

As can be seen, the effect of the previous glaciers on the shaping of the relief of the northwest part of Nordenskiöld Land is distinct, in turn the origin and situation of the sea pebbles commonly occurring here requires explanation. It seems that in the case of interest, there has been a change in the original nature of the moraine material as a result of workings in the sea environment.

The development of these processes was possible at the following moments, when:

1. The old glaciers (glacier?) flowed over Tjörnskardet towards the Sea of Greenland to the west side of Linnéfjella and frontal moraines formed on land (in a way similar to the present Linnébreen, Erdmannbreen etc.). Subsequently, as a result of a raise in the sea level, the moraine deposits were rounded.

2. The old glaciers (glacier?) flowed over Tjörnskardet towards the Sea of Greenland to the west side of Linnéfjella and entered the bay directly (just as the present Fridtjovbreen, Grönfjordbreen etc.). The melting moraine deposits got immediately into the sea environment and underwent working.

The chronology of events proposed refers to the history of the relief development in the Pleistocene and Holocene accepted at present for Svalbard Archipelago (O. A. Lavrushin, 1969; L. S. Troitski, E. M. Zinger, V. S. Koriakin ... 1975). However, it is difficult to establish how many times and in what conditions the erosion-resistant Carboniferous quartzite sandstones were redeposed. Single sea pebbles (?) were found, e.g., in the formations building the slit forms of the marginal zone of Linnébreen. Therefore, the conclusion can be drawn that the deposits of the sea environment were carried by glaciers (glacier?) and deposited at various places in the form of a ground moraine, e.g. at the flattenings on the slopes. Therefore, the finding of a sea pebble on some surface does not, in the author's opinion, prove deciding evidence of its marine origin.

Spatial analysis of the distribution of erratic boulders permitted in addition the reconstruction of the directions in which ice masses displaced in the past. The old glaciers exceeding in size the present ones flowed from the side of Grönfjorden to the west (Fig. 2). Such movement was facilitated by valleys and depressions running east-west, e.g. Blendadalen, Kongressdalen, etc. A convenient route in this respect was the valley occupied now by Aldegondabreen, subsequently, the depression between Hermod Petersenfjellet and Christensenfjella and Tjörnskardet. Probably, ice masses transgressing in this way led to the muttonization of the ridge shutting off Linnébreen from the west. This process was most complicated in the case of the lower part of Linnédalen. A high barrier on the path of the glaciers was the massif of Linnéfjella with Griegfjellet 778 m above sea level. Here, the ice streams flowing over Grönfjorden through Kongressdalen were stopped, and hence they flowed north over the hill 187 m above sea level on Vardeborgsletta. Also, at that time, through smaller passes and depressions, ice masses flowed west. Further research is required to explain the question whether the glaciers did not cross the Linnéfjella ridge at the moment of their maximum development.

For a few small Carboniferous quartzite (?) sandstone pebbles were found on its west side, and, therefore, already at Griegdalen. The directions in the movement of ice masses established seem to confirm the results of studies by G. de Geer (1900) and J. Büdel (1960) (see J. Szupryczyński (1963)).

Traces of pre-Holocene glacial relief can (?) also be found on the west shores of Grönfjorden. Distinct glacial slickensides with glacial features, situated over the present ice-moraine banks, were observed on the extension of the Productustoppen ridge. Muttonized rocks occur here up to more than 200 m over the sea level. The most legible flattenings on the slopes in this part of the research region were found at a level of about 250 m above sea level.

2. Final conclusions

Geomorphological investigations in the northwest part of Nordenskiöld Land (West Spitsbergen) indicated the presence of a set of glacial forms and deposits related to earlier glaciations. They are mainly:

2.1. muttonized pieces of the ridge, occurring over the present ice-moraine banks.

2.2. glacial undercuts of rock faces, mainly at passes,

2.3. surfaces of glacial shoulders,

2.4. cirques,

2.5. detersion niches cut in the structural thresholds,

2.6. bowls and drums of glacial overdeepening,

2.7. glacial levels and flattenings,

2.8. brown-red glacial days,

2.9. erratic boulders.

In view of the repeating transgressions of sea and glaciers, the deposits occurring here show traces of working in these environments and could repeatedly have been redeposited.

Some flattenings on the slopes, which have so far been identified as old obrasion surfaces, are glacially founded. They were recognized at 100 (?), 150, 200, 250 and 300 m above sea level.

The orientation of the old forms and the distribution of glacial deposits indicate the direction of displacement in the past of the ice masses from the east to the west.

4. Резюме

Северо-западния часть Земли Норденшельда представляет собой в границах острова Западный Шпицберген крупный полуостров, расположенный между Исфьорден, Грен-

фьорден, Орустдален и Гренладским морем. Морфологической осью изученной территории является Линнедален, которую окружают горные хребты, тянущиеся с Северо-запада на Юго-восток. Самый крупный ледник этой террирории, Гренфьордбреен, соединяется через перевалы с Альдегондабреен, Вардебреен, Ворингбреен и Хефтьебреен представляют собой крупные ледниковые бассейны. Ледники Сольфонна и Линне принадлежат к долинному типу. Вдоль восточных склонов Линнефьелла проходит контакт пород формации Хекля Хёк с палеозойскими породами, которые дальше к востоку переходят в мезозойские и кайнозойские породы. Литологические еазличия пород ясно отражаются в современном рельефе. Устойчивые кварцитовые песчаники и долериты образуют пороги, а понижения расположены на выходах глинистых юрских сланцев, известняков и меловых алевритов.

Структурный рельеф архипелага подвергался неоднократно воздействию очередных оледенений (A. Jahn, 1959, J. Szupryczyński 1963, 1966, Л. С. Троицкий, Е. М. Зингер, В. С. Корякин 1975). Геоморфологические исследования в СЗ части Земли Норденшельда выявили наличие комплекса гляциальных форм и отложений древних ледниковий. Были обнаружены между прочим: широкие понижения в главных горных хребтах со следами мутонизации, расположенные над современными ледово-моренными валами, подрезанные воздействием ледника скальные обрывы, главным образом на перевалах, выравненные ледником на склонах, висячие ледниковые кары, ниши ледникового шлифования в структурных ригелях, чаши и ледниковые котлы, гляциальные уровни и выравненные площадки, краснобурые ледниковые глины. Установлено повсеместное распространение валунов до высоты свыше 200 м н.у.м. Направление переноса валунов указывает на движение в прошлом масс льда с востока на запад (J. Büdel 1960).

Полученные результаты подтверждают цикличность морских трансгрессий и ледниковий (J. Szupryczyński 1966, 1968, Ю. А. Лаврушин 1969, Л. С. Троицкий, Е. М. Зингер, В. С. Корякин и др. 1975). Отложения в этой части острова обнаруживают следы обработки в морской и гляциальной среде. Кроме того они многократно подвергались переотложению. Выравненные на склонах площадки некоторые исследователи считали до настоящего времени образионными поверхностями (W. Stankowski 1981). В свете собранных материалов установлено, что эти площадки, на которых были найдены валуны и ледниковая штриховка, являются формами гляциального происхождения. Они обнаружены на высоте 100?, 150, 200, 250, 300, и 350 м нум.

4. Streszczenie

NW część Ziemi Nordenskiölda stanowi rozległy półwysep w obrębie wyspy Spitsbergen Zachodni, rozciągający się pomiędzy: Isfjorden, Grönfjorden, Orustdalen i Morzem Grenlandzkim. Oś morfologiczną opracowywanego obszaru stanowi Linnèdalen, którą otaczają strome pasma górskie o układzie NW–SE. Największym lodowcem na tym terenie jest Grönfjordbreen, który poprzez przełęcze łączy się z Aldegondabreen. Formę niewielkich czasz lodowych mają: Vardebreen, Voringbreen oraz Heftyebreen; typ dolinny reprezentują lodowce: Solfonna i Linnè. Wzdłuż wschodnich stoków Linnèfjella przebiega kontakt skał formacji Hecla Hoek i paleozoicznych, które dalej ku wschodowi przechodzą w osady mezozoiczne i kenozoiczne. Zróżnicowanie litologiczne skał znajduje pełne odzwierciedlenie w dzisiejszej rzeźbie. Odporne na wietrzenie piaskowce kwarcytyczne oraz doleryty tworzą warstwy progotwórcze, natomiast obniżenia założone są na wychodniach ilastych łupków jurajskich, wapieniach oraz mułowcach kredy.

Rzeźba strukturalna archipelagu była kilkakrotnie modelowana przez kolejne zlodowacenia (A. Jahn 1959, a, b, J. Szupryczyński 1963, 1966, L. S. Troicki, E. M. Zinger, W. S. Koriąkin 1975). Badania geomorfologiczne w NW części Ziemi Nordenskiölda wykazały obecność zespołu form i osadów glacjalnych wcześniejszych epok lodowcowych. Rozpoznano między innymi: szerokie obniżenia w głównych grzbietach ze śladami mutonizacji rozciągające się powyżej dzisiejszych wałów lodowo-morenowych, podcięcia lodowcowe ścian skalnych — głównie w przełęczach, powierzchnie barków lodowcowych, zawieszone kary lodowcowe, niższe detersyjne wycięte w progach strukturalnych, misy i kotły przegłębienia lodowcowego, poziomy i spłaszczenia glacjalne, brunatnoczerwone gliny lodowcowe. Stwierdzono ponadto powszechne występowanie eratyków, które identyfikowano do wysokości ponad 200 m npm. Kierunek przewieszenia materiału eratycznego wskazuje na ruch mas lodowych w przeszłości ze wschodu na zachód (J. Büdel 1960).

Uzyskane wyniki potwierdziły cykliczność transgresji morskich i lodowców (J. Szupryczyński 1966, 1968, O. A. Ławruszyn 1969, L. S. Troicki, E. M. Zinger, W. S. Koriakin ... 1975). Występujące zatem w tej części wyspy osady wykazują ślady obróbki zarówno w środowisku morskim jak i glacjalnym a ponadto były wielokrotnie redeponowane. W świetle zgromadzonego materiału stwierdzono, że spłaszczenia na stokach identyfikowane dotychczas przez pewnych badaczy jako dawne powierzchnie abrazyjne (W. Stankowski 1981) z występującymi w ich obrębie eratykami i rysami lodowcowymi mają założenia glacjalne. Rozpoznano je na wysokościach: 100?, 150, 200, 250, 300 i 350 m npm.

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Paper received 1982 September 24