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Present Morphogenetic Processes in a Periglacial Zone of Wedel-Jarlsberg Land, South-western Spitsbergen *

Współczesne procesy morfogenetyczne w strefie peryglacyjnej SW Spitsbergenu na przykładzie Ziemi Wedel Jarlsberga

Современные морфогенетические процессы в перигляциальной зоне ЮЗ Шпицбергена на примере Земли Ведель Ярльсберга

INTRODUCTION

South-western Spitsbergen has been explored for many years to know the course of periglacial processes and to define the present dynamics of a relief evolution. Many detailed papers have been written that approached a quantitative and qualitative study of present morphogenetic processes (Rapp 1957, 1960a, Czeppe 1960, 1966, Jahn 1960, 1961, 1967, 1976a, Klimaszewski 1960, Lavrushin 1969, Chandler 1972, 1973, Åkerman 1973, 1980, Martini 1975, Jania 1977, Pękala 1975, 1980a, Baranowski, Pękala 1982). A synthetic approach to periglacial processes was done by Rapp (1957, 1960b), Jahn (1961), Czeppe (1966) and Bibus, Nagel, Semmel (1976), being based on measurements done just in Spitsbergen. A denudation balance for the Arctic and Subarctic and a development of a periglacial slope were also evaluated (Jahn 1960, 1967, 1976b, Bird 1974, Caine 1974, Rapp 1974, Jahn, Siedlecki 1982). Różycki (1957) distinguished the zones in the arctic landscape of Spitsbergen, resulting from an increasing participation of glacial features with higher and higher altitudes. Zones of the various-age modelling of the relief by periglacial processes were also described. A great role

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of extremal phenomena in a modelling of the periglacial relief was underlined (Chandler 1972, Thiedig, Lehmann 1973, Rapp, Strömquist 1976, Rapp, Nyberg 1981, Larsson 1982). Studies over a chemical denudation, particularly in karst areas, have been carried through in the same time (Corbel 1956, 1957, 1959, Pulina 1974, 1977). A mechanism and dynamics of fluvial processes in glacier forefields (Szponar 1975, Cegła, Kozarski 1977, Karczewski, Wiśniewski 1977, Kozarski 1982, Karczewski 1982) and of glacial phenomena (Szupryczyński 1963, Baranowski 1977) have been also investigated. Most analytical data deal with the areas within a periglacial tundra below a firn line and within a zone influenced by a sea climate. The mountain areas above the firn line — in a nival stage, prove a slightly different rhythm and dynamics of geomorphologic processes. Geomorphologic investigations in this stage supplied with new data on present morphogentic processes and paleogeomorphology (Pękala 1975, 1980a, 1980b). In 1980 and 1983, after seven and ten years break, a set of measurements and observations was repeated for nival, subnival and tundra stages. The observations from numerous papers as well as the author's own data enabled to estimate a dynamics of morphogenetic processes that model now a morphology of three landscape stages i.e. of nival, subnival and tundra ones, in the mountain areas of the Hornsund region.

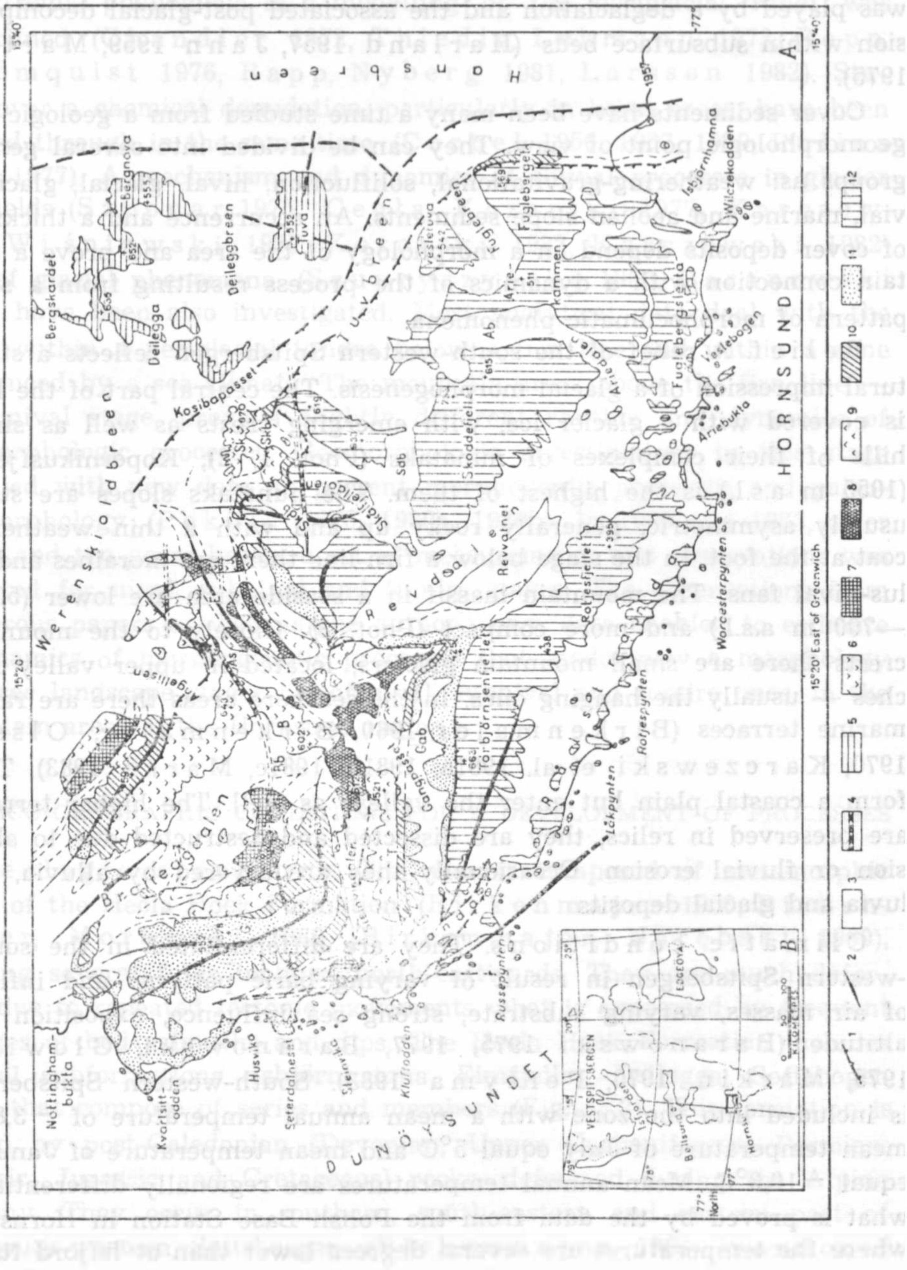
PHYSICO-GEOGRAPHIC CONDITIONS FOR A DEVELOPMENT OF PROCESSES

Geologic structure. The area is composed of metamorphic rocks of the Hecla Hoek Formation (Birkenmajer 1958, Birkenmajer, Morawski 1960, Birkenmajer, Narębski 1960), forming several folds inclined north-eastwards. They are much deformed due to repeated tectonic movements what is expressed by frequent changes of bed azimuths and dips. The Hecla Hoek Formation includes several subformations (Isbjörnhamna, Eimfjellet, Deilegga, Sofiebogen ones) that compose of series and members (Fig. 1, 2). This formation is coated by post-Caledonian (Devonian, Upper Carboniferous, Permian, Triassic, Jurassic and Cretaceous) rocks, deformed during the Alpine orogeny. They occur in southern, south-eastern and eastern part of the south-western Spitsbergen (Birkenmajer 1964, Wendorff 1983). The whole complex of metamorphic rocks, possessing varying physical properties (gneisses, amphibolites, shales, crystalline limestones), is highly tectonically fissured (Harland 1969, Smulikowski 1956, 1968) what particularly influences a denudation rate and a development of cover deposits. A certain part in a loosening of the rocks was played by a deglaciation and the associated post-glacial decompression within subsurface beds (Harland 1957, Jahn 1959, Martini 1975).

Cover sediments have been many a time studied from a geologic and geomorphologic point of view. They can be divided into several genetic groups as: weathering-gravitational, solifluction, nival, glacial, glacifluvial, marine and aeolian slope sediments. An occurrence and a thickness of cover deposits depend on a morphology of the area and prove a certain connection with a dynamics of the process resulting from a stage pattern of morphoclimatic phenomena.

Relief. A relief of the south-western Spitsbergen reflects a structural impression of a glacial morphogenesis. The central part of the land is covered with a glacier ice, with emerging crests as well as single hills of their complexes of nunataks (Phot. 1, 2); Kopernikusfjellet (1055 m a.s.l.) is the highest of them. The nunataks slopes are steep, usually asymmetric, generally rocky up and with a thin weathering coat at the foot. In the stage below a firn line there are moraines and talus-nival fans. The mountain massif in a seaside area are lower (500—700 m a.s.l.) and more compact (Phot. 3). Closely to the mountain crests there are small mountain glaciers, located in upper valley reaches — usually the hanging ones. In the seashore areas there are raised marine terraces (Birkenmajer 1960, Birkenmajer, Olsson 1970, Karczewski et al. 1981a, 1981b, 1981c, Marks 1983). They form a coastal plain but enter the valleys as well. The higher terraces are preserved in relics, they are dissected and destructed due to abrasion or fluvial erosion. Occasionally they are covered by alluvia, colluvia and glacial deposits.

Climatic conditions. They are differentiated in the south-western Spitsbergen in result of varying baric patterns and inflows of air masses, varying substrate, strong sea influence, exposition and altitude (Baranowski 1975, 1977, Baranowski, Głowicki 1975, Markin 1970, Pereyma 1983). South-western Spitsbergen is included into the zone with a mean annual temperature of $-3,8^{\circ}$C, mean temperature of July equal 5°C and mean temperature of January equal $-10,3^{\circ}$C. Mean annual temperatures are regionally differentiated what is proved by the data from the Polish Base Station in Hornsund where the temperatures are several degrees lower than at Isfjord Radio (Baranowski 1975, Szupryczyński 1980). The greatest contrasts in summer are noted between the glaciers and their margins. These contrasts disappear when a snow cover is present (Fig. 2). A precipitation is small and equal about 400 mm a year, with a maximum in winter. A mean snow accumulation at the Werenskiold Glacier in a firn



zone (380 m a.s.l.) for 1957—1974 equals 142 cm whereas at the ice plateau Amundsenisen (730 m a.s.l.) — 156 cm.

Climatic differences in particular stages are also reflected in maximum and minimum temperature values. The minimum temperatures below zero are noted at a seaside tundra in the second decade of September but the maxima are still above zero there. In the firn zone the maximum temperatures above zero finish in the second decade of September whereas the minimum temperatures below zero are noted since the beginning of August. In the nival stage the minimum temperatures below zero occur during the whole summer whereas the maximum temperatures below zero appear at a half of August (Baranowski 1977, Pereyma 1983). Temperature and precipitation as well as an inclination of a topographic surface create a specific system of the active permafrost layer but particularly, effect its thickness (Baranowski 1968, Jahn 1982). Thermic-precipitation conditions influence the local differentiated stage pattern of physico-geographic phenomena, among which a climatic firn line is a more important element that acts on the evolution of present relief-creative processes.

DESCRIPTION OF MORPHOGENETIC PROCESSES

PHYSICAL WEATHERING AND FALLING

A presence of immense stone fields at mountain slopes indicates a significant role of a physical weathering in the arctic areas. But opinions on a rate of a physical weathering in a periglacial environment are quite divergent (Büdel 1948, Rapp 1957, 1959). It made many authors undertake and explain this problem, basing on measurements in various regions of the Arctic (Jahn 1961, 1967, 1976a, Czeppe 1966, Rapp 1959, 1960b, Waters 1962, Washburn 1967, Bird 1974, Caine 1974, Pękala 1980a, 1980b). The physical weathering is difficult for direct measurements so, its rate is evaluated with an application of a gravitional processes as a falling. In the Hornsund re-

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Fig. 1. Geologic sketch (A) and location (B) of the area in southern Spitsbergen (after K. Birkenmajer, W. Narębski 1960); 1 — overthrusts, 2 — axes of anticlines, 3 — areas covered with snow, ice, water and Quaternary deposits, 4 — dolerite dikes, 5 — Deilegga formation (not subdivided), 6 — Brattegga amphibolites, 7 — Angellfjelet amphibolites, 8 — Gangpasset granitization zone, 9 — Torbjörnsenfjellet amphibolites, 10 — Steinvikskardet beds, 11 — Gulliksenfjellet series, 12 — Isbjörnhamna formation (not subdivided)

Szkic geologiczny (A) i położenie (B) terenu w południowej części Spitsbergenu (wg K. Birkenmajera, W. Narębskiego 1960); 1 — nasunięcia, 2 — osie antyklin, 3 — obszary pokryte lodem, śniegiem, wodą i osadami czwartorzędowymi, 4 — dajki dolerytowe, 5 — formacja Deilegga (nie rozdzielona), 6 — amfibolity Brattegga, 7 — amfibolity Angellfjellet, 8 — strefa granityzacji Gangpasset, 9 — amfibolity Torbjörnsenfjellet, 10 — warstwy Steinvikskardet Beds, 11 — seria Gulliksenfjellet, 12 — formacja Isbjörnhamna (nie rozdzielona)

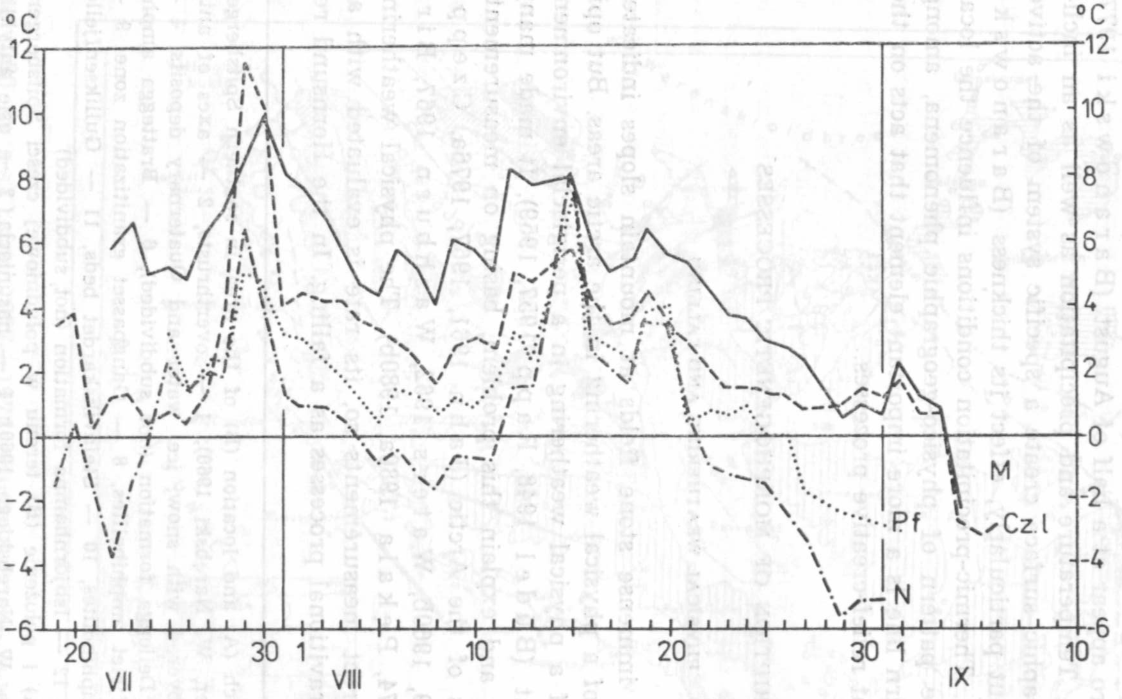


Fig. 2. Mean daily air temperature in summer 1970 at Werenskioldbreen (after S. Baranowski 1977); M — lower station in forefield of Werenskioldbreen (26 m a.s.l.), Cz. 1 — station at glacier snout (65 m a.s.l), P.f — station close to firn limit (380 m .a.s.l.), N — station at Glacjologerknausen (660 m a.s.l.) Przebieg średniej dobowej temperatury powietrza w ciągu lata na lodowcu Werenskiolda (wg S. Baranowskiego 1977); M — stacja dolna na przedpolu lodowca (26 m n.p.m.), Cz. 1 — stacja na czole lodowca (65 m .n.p.m.), P.f — stacja w pobliżu granicy firnu (380 m n.p.m.), N — stacja na Glacjologerknausen (660 m n.p.m.)

Tab. 1. Mean annual values of weathering and falling in Hornsund region (in g/m²)
Średnie roczne wartości pogodowe i opadowe w rejonie Hornsundu (w g/m²)

Rock	Landscape stage			
	tundra		subnival	nival
	seaside	slope		
Amphibolites	130	125	367	220
Gneisses /paragneisses/	340	290	480	400
Metamorphic shales	-	427	584	470
Limestones sandstones	342	175	335	380
Quartzites	27	15	-	-

gion this process was recorded by the author in three morphoclimatic areas: tundra, subnival and nival ones in 1973—1983. The received results (Table 1) supported a distinct vertical differentiation of a dynamics of physical weathering.

Mean annual values that represent the ten years' interval (1973—1983) prove a changeable rate of the physical weathering within particular morphoclimatic stages. It supported previous observations of Jahn (1961, 1976b), Rapp (1960a), Czeppe (1966) and Pękala (1980a). But a lithologic factor, a principal role is played by a water content and number of freezing cycles. From these reasons a coastal zone is distinguished, frequently sprinkled with a sea water, in which a certain influence is also played by a salt crystallization in pores and joint fissures of rocks (Martini 1975). A tundra stage is, together with the coastal strip, most differentiated if taking the rate of its rock weathering into account; it is connected with local conditions. The largest values were noted in a subnival stage, in which there is the greatest concentration of young blocky covers, at slopes as well as their bases, in talus fans (Phot. 3, 4; Fig. 3, 4). On the ground of a development of cryoplanation features (Phot. 5, Fig. 5) and an evaluation of the volume of talus fans, one can estimate a rate of rocky walls retreat during the last thousand years for 0.2—2.0 mm a year. Within a typical nival stage, at slopes above the firn fields, a physical weathering is smaller than below the firn line (400 m a.s.l.). This fact results presumably from less common freezy-thaw cycles. It should be underlined that a dynamics of the physical weathering in this stage depends on local conditions and particularly, on physical properties of rocks that form the slopes.

Chemical weathering in arctic areas is the active process and has been many a time described (Högbom 1912, Blanck et al. 1928, Hill, Tedrow 1961, Szerszeń 1965, 1974, Czeppe 1966). It is generally accepted that this process results from a dissolution of carbonates and to a limited degree, of silicates and from a liberation of iron, aluminium and manganese. Effects of this process can be noted as mineral precipitation, weathering crust and microrelief at surfaces weathered blocks (Dylik 1958, Czeppe 1966, Tedrow, Krug 1982).

During fields works a development of a weathering crust as well as of mirabilite efflorescences and sinters were noted within nival and subnival stages. Below the firn line there are common carbonate varnishes with specific mushroom-like sinters inside fissures and at a surface of rubble weathering wastes. In the tundra stage a chemical weathering is intensified due to a development of soil processes and physico-chemical processes within active permafrost layer (Jahn 1982). Thickness changes of the active permafrost layer, its content and the temperature result in a concentration of mineral components, particularly of iron compounds and carbonates. This process shows a local changeability and so, the outwashes and marine terraces with a development vegetation cover contain much iron in their soils. On the other hand the carbonates were noted within glacifluvial covers as concentrations and varnishes in the subsurface layer of sediments in the median morainic zone of Torellbreen, especially in sediments of push moraines. These sediments seem to have been intensively mineralized, thus a thickness of carbonate coats reaches 5 mm.

The chemical weathering is reflected by a magnitude of a chemical denudation defined with a use of physico-chemical methods for karstic as well as non-karstic areas (Corbel 1956, 1959, 1961; Pulina 1974, 1977, Krawczyk, Pulina 1979). The chemical denudation in the south-western Spitsbergen (Hornsund region) equals from 3 to 20 m^3 of a dissolved rock from the area of 1 km^2 every year, depending on a type of the bedrock (Pulina 1974, 1977).

Washing and suffosion are the processes that develop due to the action of meltwaters and rain waters. A degradation of slopes occurs then during spring and summer. Morphologic effects of surface and trough washing as well as of a suffosion result in a wash of rubble covers at steep slopes (over 15°), removal of a fine weathering waste from a rock surface but also in an enrichment and deposition of a fine sediment at the lower slope fragments and at their foot (Jahn 1961, Czeppe 1966). In the nival stage the sediment is transported along the slope by meltwaters and rain waters, then deposited in snow and on glaciers below the firn line. It is frequently washed into bergschrunds. A dynamics of these two processes is highly locally differentiated. It depends on many factors as: slope inclination, types of covers and bedrock, thickness of an active permafrost layer, thawing rate of a snow cover.

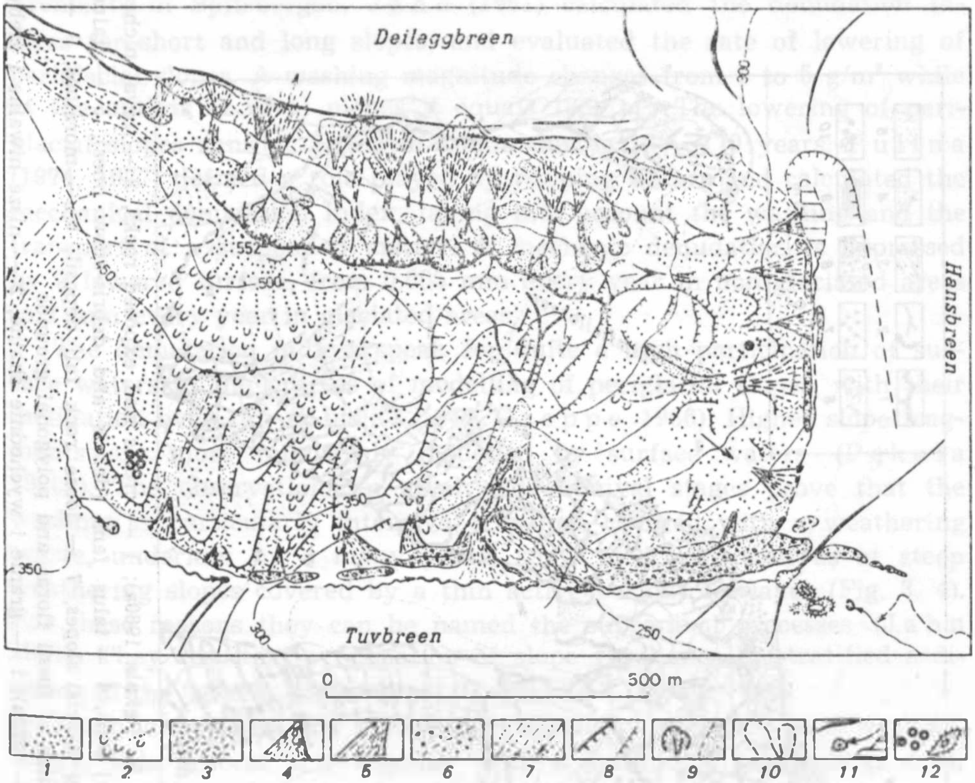


Fig. 3. Geomorphologic sketch of Tuva (552 m a.l.s.) — after K. Pękala 1980a; 1 — steep rubble slopes, 2 — rubble slope with solifluction stripes and lobes, 3 — talus slopes, 4 — talus-nival slopes, 5 — talus fans on ice with forms of thermokarst and erosion, 6 — moraines, 7 — ice-debris slopes modelled by avalanches and washing, 8 — rock edges walls, 9 — nival niches and patches of many year snow, 10 — denudation niches, 11 — glacial fissures and pits, periodical streams and lakes, 12 — sites of polygonal grounds, fossil floras, glacier tables

Szkic geomorfologiczny Tuvy (552 m n.p.m.); 1 — strome stoki rumowiskowe, 2 — stoki rumowiskowe z pasami i językami soliflukcyjnymi, 3 — stoki usypiskowe, 4 — stożki usypiskowo-niwalne, 5 — stożki usypiskowe na lodzie z formami termokrasu i erozji, 6 — moreny, 7 — stoki lodowo-gruzowe modelowanę przez lawiny i spłukiwanie, 8 — krawędzie skalne, 9 — nisze niwalne oraz płaty wieloletniego śniegu, 10 — niecki denudacyjne, 11 — szczeliny, studnie lodowcowe, potoki i jeziorka okresowe, 12 — stanowiska poligonów, flor kopalnych, stoły lodowe

magnitude and kind of precipitation. A certain role in suffosion is played by waters coming from a thawing ground ice, occurring within slope covers. A development mechanism of slope-creative processes in the Hornsund region under the influence of a running water was presented by Czeppe (1966) and Jahn (1961). Basing on several years' meas-

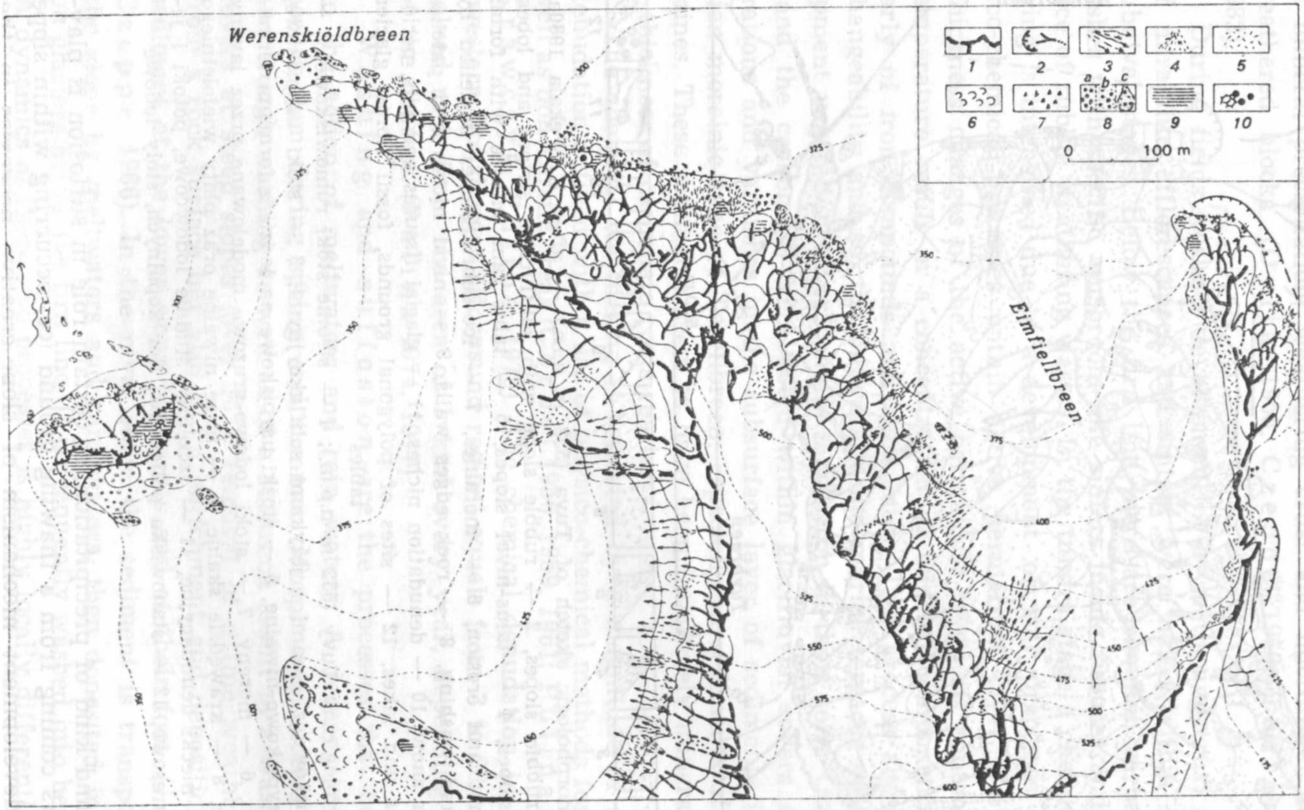


Fig. 4. Geomorphologic sketch of Eimfjellet (after K. Pękala 1980a); 1 — crests and exposed rocks, 2 — nival niches and corrasion, gullies, 3 — avalanche (debris-snow) fans, 4 — talus fans (debris and debris-snow ones), 5 — talus (rubble) slopes, 6 — solifluction (debris-clayey and debris) slopes, 7 — loose rock fall deposit, 8 — moraines, 9 — roche moutonnée, 10 — sites of fossil floras and polygonal grounds

Szkic geomorfologiczny Eimfjellet (wg K. Pękali — 1980a); 1 — granie i wychodnie skalne, 2 — nisze niwalne i żleby korazyjne, 3 — stożki lawinowe (śnieżno-gruzowe), 4 — stożki usypiskowe (gruzowe i gruzowo-śnieżne), 5 — stoki rumowiskowe, 6 — stoki soliflukcyjne, 7 — luźne bloki z obrywów skalnych, 8 — moreny, 9 — powierzchnie zmutonowane, 10 — stanowiska kopalnej tundry i grunty strukturalne urements in Spitsbergen, Jahn (1961) calculated the denudation indices for short and long slopes, and evaluated the rate of lowering of periglacial slopes. A washing magnitude changes from 1 to 5 g/m^2 while at the outlets of nival niches it equals 18 g/m^2. The lowering of periglacial slopes runs at a rate of 1 mm during 150—170 years. Pulina (1974, 1977) defined a role played by running waters and calculated the mechanical denudation index, taking into account the washing and the transport of a suspended matter. A mechanic denudation is expressed by a lowered surface, from 0.005 mm every year in non-glaciated areas to 1 mm every year in glaciated areas.

The denudation indices speak for quite a high participation of surface waters in the process of modelling of periglacial slopes, with their inclination over 15° (Büdel 1948, Czeppe 1966). Higher slope fragments are more intensively modelled by surface waters (Pękala 1980a). The observations in nival and subnival stages prove that the washing is particularly intensive at slopes covered with a weathering waste, underlain by a many years' snow or ice as well as at steep weathering slopes covered by a thin active permafrost layer (Fig. 3, 4). For these reasons they can be named the supranival processes (Jahn 1961). They result in a formation of slope rhythmically stratified sediments of the "grezés litées" type (Guillien 1951).

Marginal zones of the glaciers are especially subjected to a washing. There, this process acts together with a solifluction as well as with aeolian processes that develop during summer foehns. These winds are usually accompanied by heavy winds. A fine matter moved due to ablation is carried away by wind and after a deposition — it get to depressions, mainly to cave-in ones. The washing at ice-cored moraines is of a surface and trough type. Crevasses formed in result of drying up are widened and deepened and so, short-lasting erosive troughs are formed — they run into depressions of various magnitudes. Alluvial fans develop at the foot of morainic ridges as well as in lakes and depressions. Sometimes the depressions are filled with a clayey-sandy material.

During a spring snow thawing in the tundra, a washing acts sometimes violently. But a transport of a mineral material, there is also a destruction of a vegetation cover (Phot. 6). The tundra vegetation is sometimes torn away and therefore, the covers are exposed to the action of atmospheric factors.

Alluvial erosion and accumulation effect from a concentrated flow of permanent and episodic streams, originated from precipitation or glacier and ground ice ablation. For this reason they model a relief of a tundra stage, particularly seaside plains, slopes dissected by chutes or glacier forefields. Although fluvial processes have been

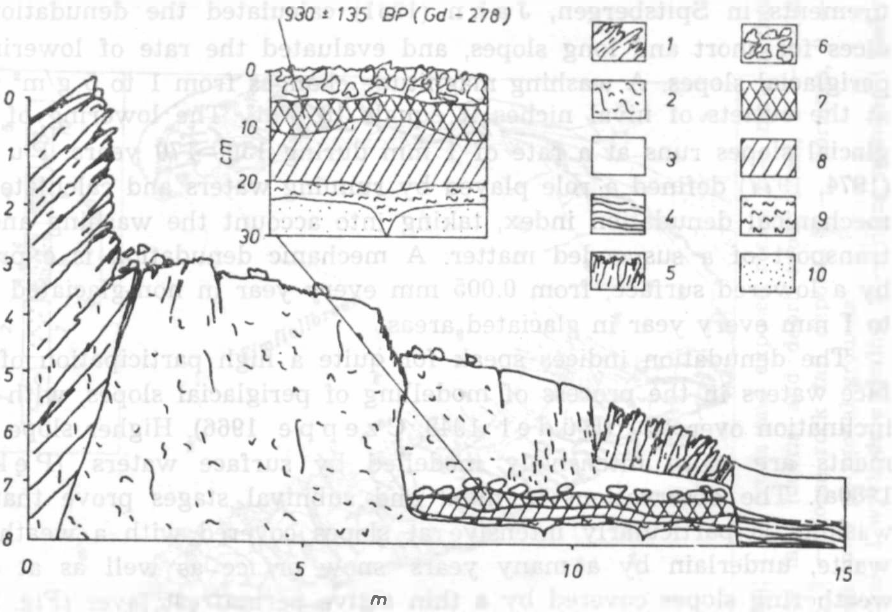


Fig. 5. Cryoplanation shelf with Viking-age fossil flora (after K. Pękala 1980a); 1 — schists, 2 — dolerites, 3 — snow and firn, 4 — ice, 5 — block weathering waste "in situ", 6 — waste debris, 7 — fossil floras, 8 — soil, 9 — weathering loam, 10 — mother rock (dolerite)

Stopień krioplanacyjny z florą kopalną wieku wikingowskiego (wg K. Pękali 1980a); 1 — łupki, 2 — doleryty, 3 — śnieg i firn, 4 — lód, 5 — zwietrzelina blokowa „in situ", 6 — gruz zwietrzelinowy, 7 — rośliny kopalne, 8 — gleba kopalna, 9 — glina zwietrzelinowa, 10 — skała (doleryty)

many a time described, no data are accessible on the rate of erosion. Basing on a depth an erosive incision of the dated lower marine terraces (Birkenmajer, Olsson 1970, Karczewski et al. 1981a, 1981c, Marks 1983), the rate of a linear erosion within the valleys can be estimated for about 1—1.5 mm a year. An erosive incision of the chutes is troublesome to be evaluated as their development results also from other processes as: corrasion, solifluction, washing, suffosion, mass movements.

Swelling and frost segregation are connected with water freezing and with thawing in the active permafrost layer, located within cover deposits that contain a considerable quantity of finer fractions. This process results in a water crystallization; the water is adhered capillarily towards the cooling plane and the soil increases its volume. During thawing the process results in a subsidence. In 1957—58 in the Hornsund region, the measurements of vertical soil movements were done that resulted from a frost action (Czeppe 1960, 1966;

Jahn 1968). The investigations were carried through at marine terraces as well as slopes with a different solifluction microrelief of a tundra stage. The vertical soil movements were found to cause a developments of patterned grounds (Högbom 1912, 1914). The carried through field experiments proved that the vertical movements are equal about 15 cm a year (Jahn 1961). This phenomenon is accompanied by moving the blocks and the rubble upwards whereas at the slopes the soil is displaced by a solifluction (Phot. 7, 8, Fig. 6).

In the nival stage the slopes are steep (over 25°) and generally covered by a weathering rubble. The snow occurs there for a long time whereas the active permafrost layer is thin (30—40, locally to 80 cm). Thus the conditions do not favour a development of the patterned grounds. Rare structures of that kind were noted at flat plains at 350—400 m a.s.l. (Fig. 7). Such forms are ancient ones and connected with a warm and moist climatic phase during the so-called Viking age (Pękala 1980a).

Solifluction has been many a time studied since the works started by Andersson (1906). It is the principal process of transformations and displacements of periglacial covers that develops in the active permafrost layer. A solifluction is expressed by a movement of wet sediments on an inclined surface (over 3°) under the influence of thaw-freeze action that initiates a gravitational movement (Jahn 1961). A displacement dynamics depends on many factors and particularly, on physical properties of deposits, thickness of an active permafrost layer, slope inclination and season of a year (Troll 1944, Büdel 1948, Klimaszewski 1960, Jahn 1961, Czeppe 1966, Chandler 1972, 1973, Rapp 1960, 1974 and others). A displacement rate is very irregular and equals on the average 2—10 cm a year in the tundra stage and 1—5 cm a year at nunataks i.e. in the subnival stage and partly in the nival stage (Jahn 1961, Czeppe 1966, Åkerman 1973, 1980, Pękala 1980a). The solifluction is expresed in various forms, starting from small terraces to large tongues and flows (Phot. 8, 9, Fig. 6, 7). In the glacier marginal zones, especially at ice-cored moraines the solifluction is expressed by landslides and locally, by immense mudflows (Phot. 10, 11). At gentle slopes (of a small inclination) it forms terraces whereas at steeper ones there are mainly tongues. Gentle slopes with a weathering cover containing fine fractions, are the areas that favour a solifluction. The active permafrost layer at such slopes is thick and wetter (Jahn 1982). At higher slope fragments there are snow patches; during their thawing in summer a moisture is provided and intensifies a solifluction. The latter develops mainly at slopes of tundra and subnival stages but plays also a significant part in the nival stage.

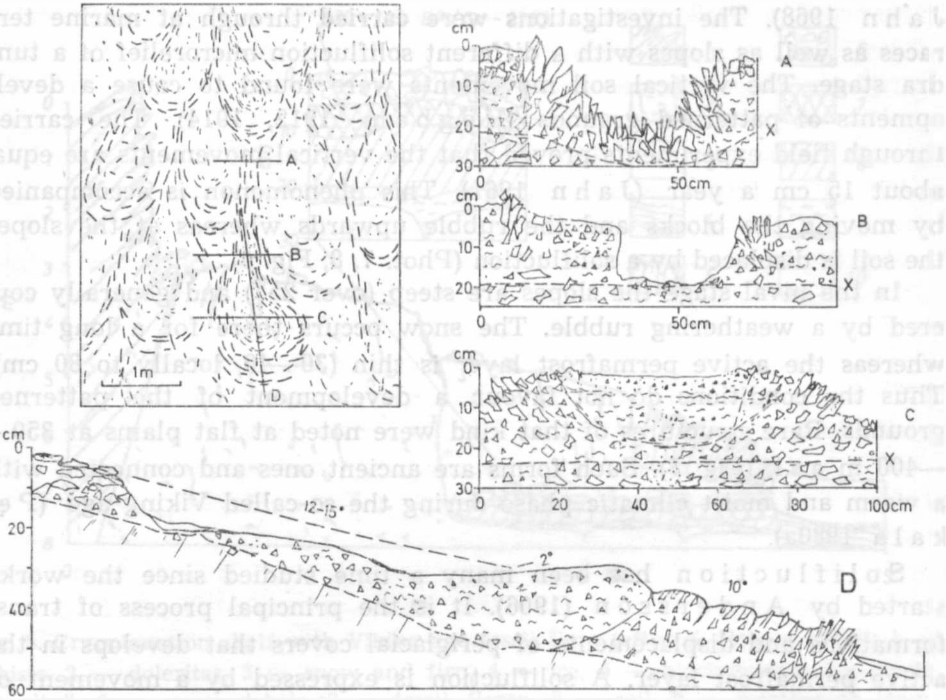


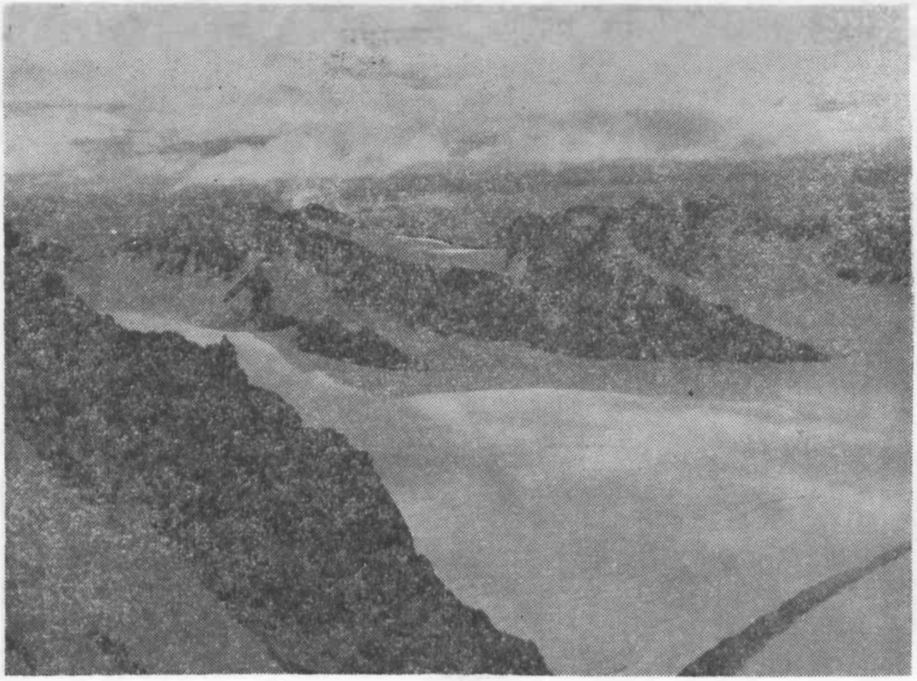
Fig. 6. Solifluction tongue at the south-western slope of Vesletuva A, B, C — sections, X — permafrost

Jęzor soliflukcyjny na SW stoku Vesletuvy. A, B, C — przekroje, X — zmarzlina

In every stage it cooperates with other processes as mass movements, washing, mechanical suffosion, nivation and creates a labile equilibrium. In extremal conditions — an excessive moistening of slope covers due to precipitation, can transform the solifluction into violent gravitational flows (Jahn 1967, 1976, Rapp 1974, Thiedig, Lehmann 1973, Larson 1982, Jania 1982).

Aeolian processes. A morphologic action of wind in the south-western Spitsbergen is expressed by corrasion, deflation and aeolian deposition. These processes are connected with summer and winter seasons when strong winds are blowing, mainly from the north-eastern, and eastern sectors (Czeppe 1966, Gerstmann 1981, Baranowski, Pękala 1982, Szczypek 1982). During winter (October-March) a mineral matter is transported and deposited together with snow. In result of ablation this process is expressed by accumulation at snow surface and on lee side of positive features. Strong winds are more rare in summer but due to vast alimentary areas they are very active, especially at seaside plains as well as outwashes and moraines

Fot. 1



Fot. 2

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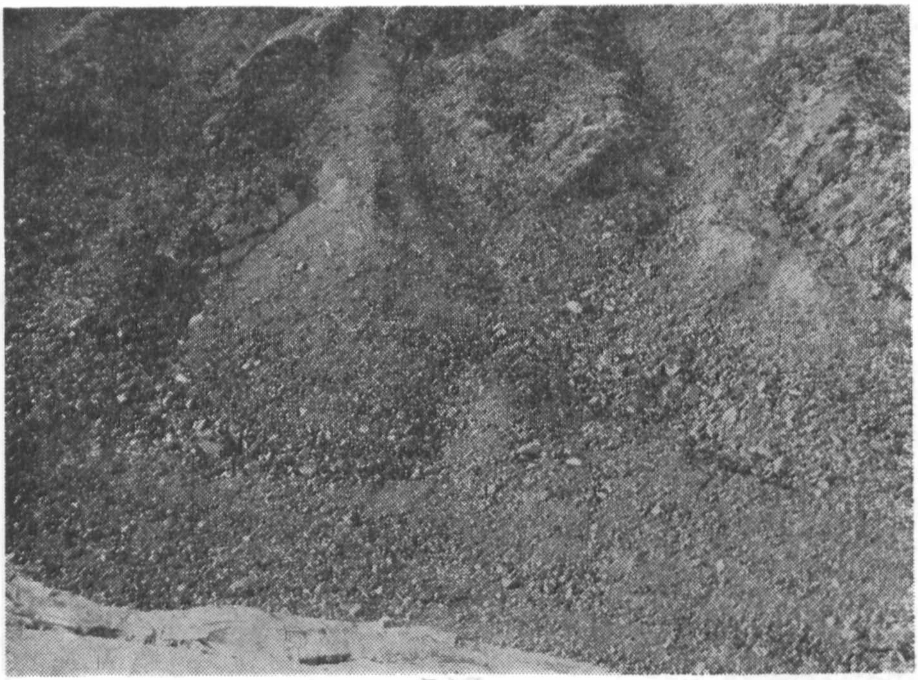

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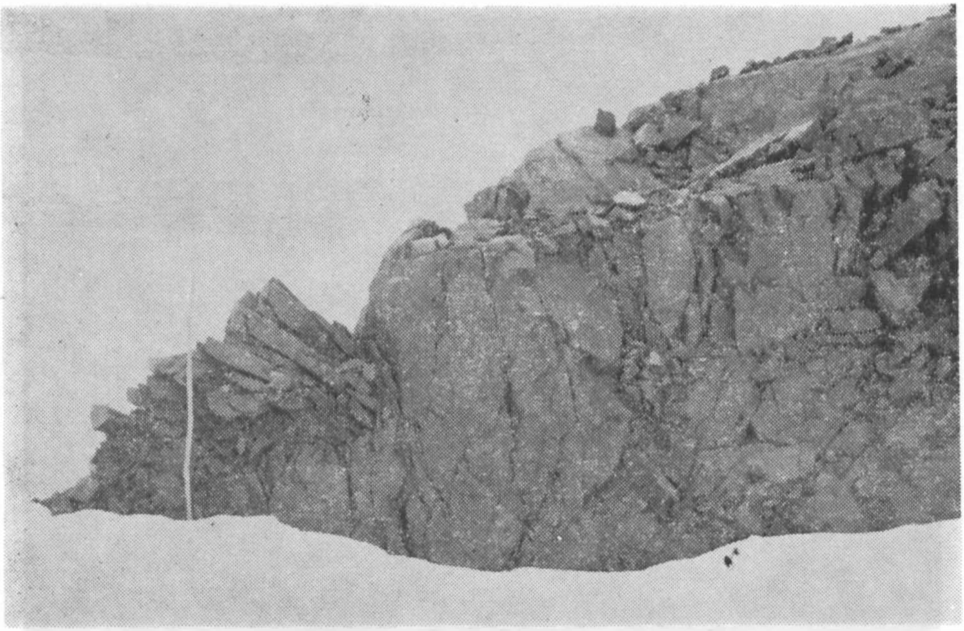

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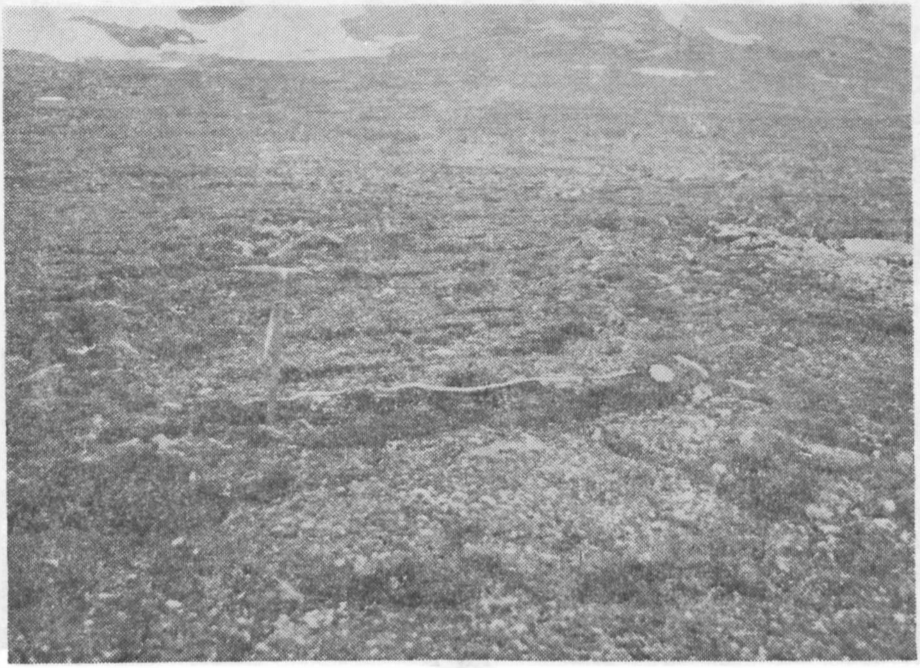

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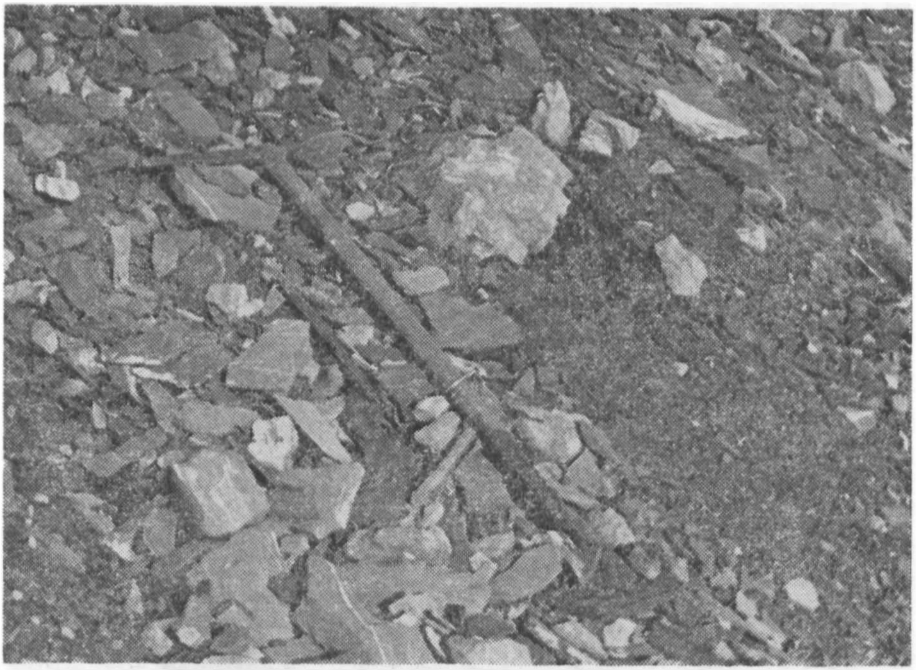

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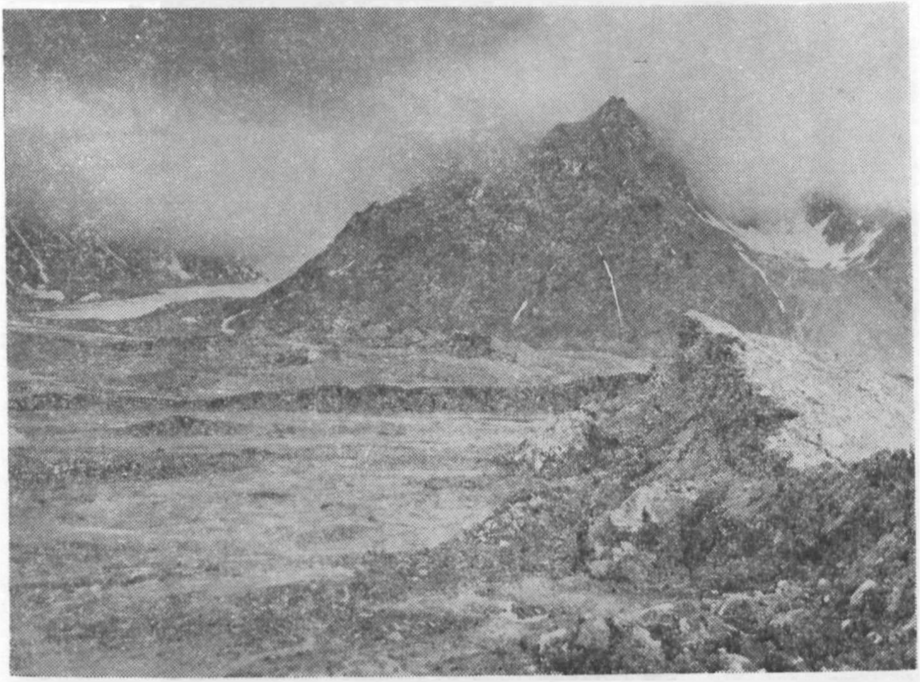

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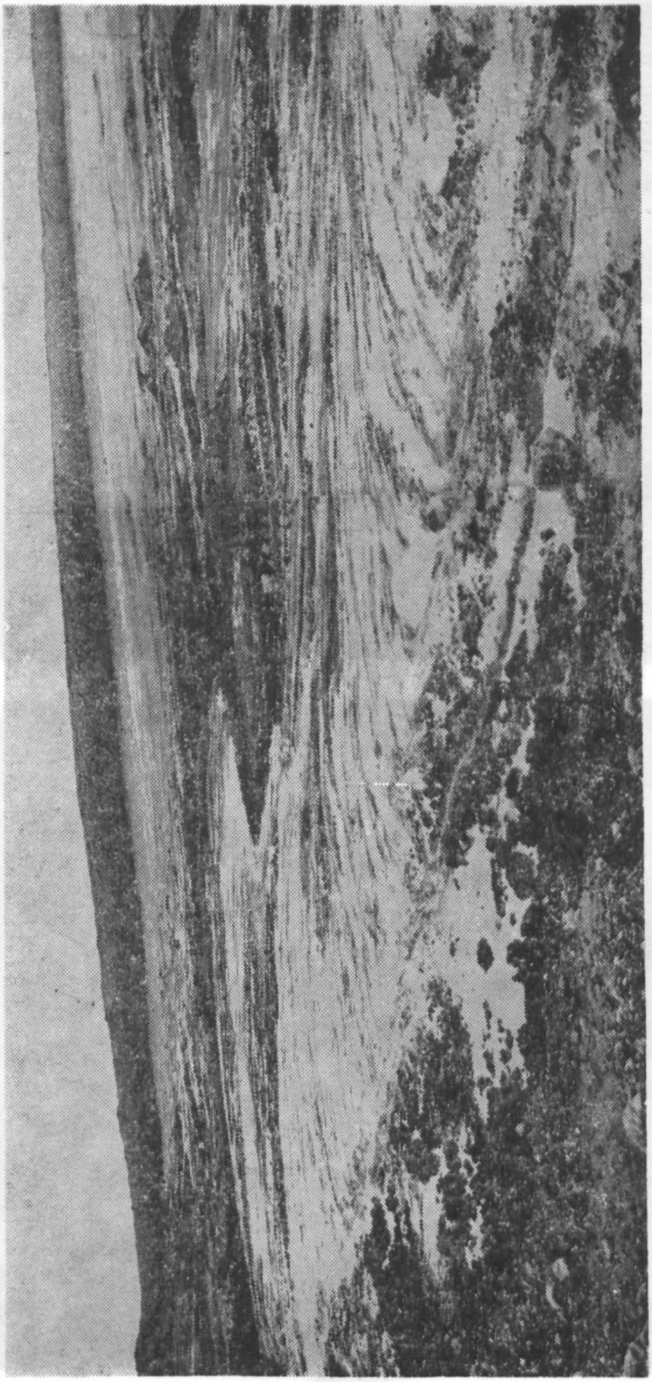

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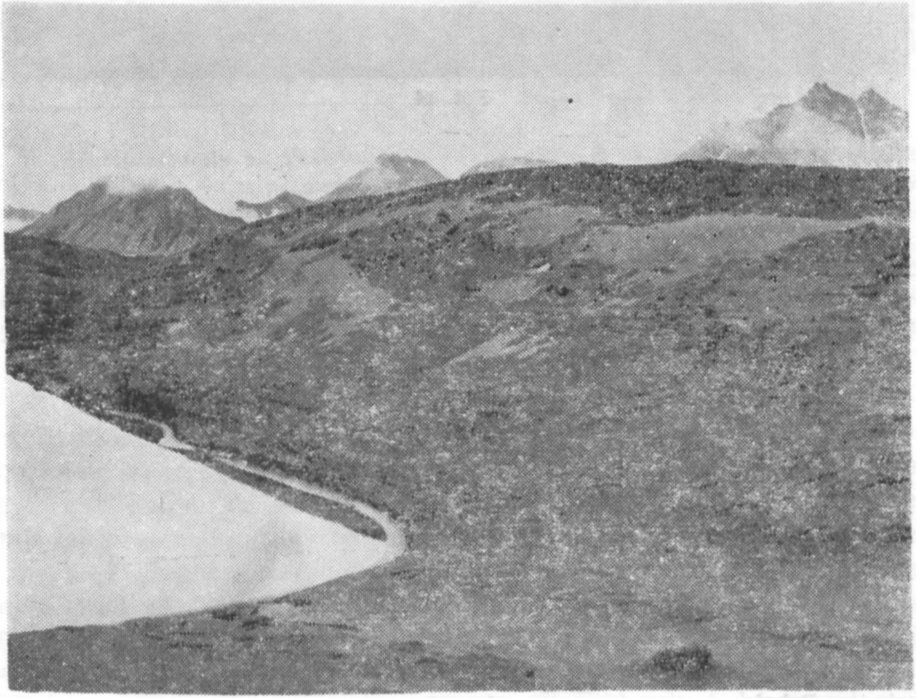

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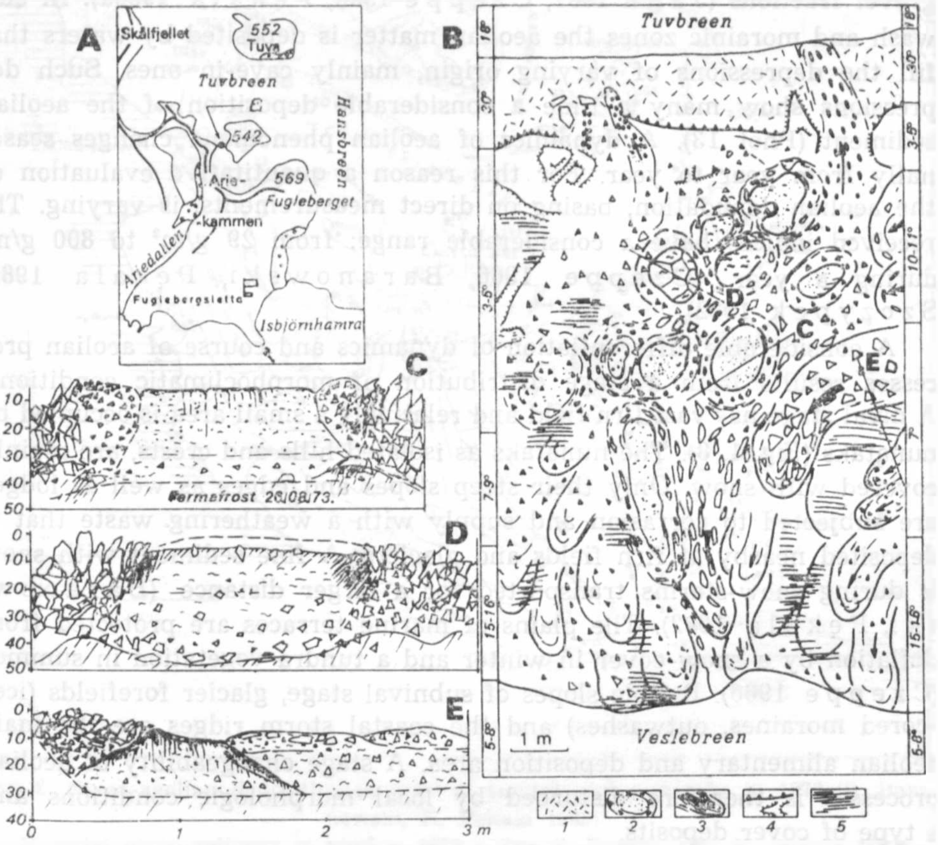

Fig. 7. Structural soils at Vesletuva; A — position, B — geomorphologic sketch, CDE — sections, 1 — talus slope, 2 — polygonal grounds, 3 — solifluction lobes and directions of movement along a slope, 4 — rock edges and walls, 5 — concentration of humus and of intensively destructed fossil vegetation

Grunty strukturalne na Vesletuvie; A — lokalizacja, B — szkic geomorfologiczny stoku, C, D, E — przekroje; 1 — stok usypiskowy, 2 — gleby poligonalne, 3 — języry soliflukcyjne i kierunki ruchu po stoku, 4 — krawędzie i ściany skalne, 5 — nagromadzenia humusu i roślinności fosylnej silnie zniszczonej

(Fig. 8, Phot. 12). Strong winds are accompanied by rain falls and for this reason, even large packets of a wet deposit (loosened by rain drops) are carried away. An intensity of aeolian processes is varying and depends on local morphologic conditions and type of the bedrock. A relief of the area rules a distribution of a snow cover. Positive relief features are exposed, to a corrasion of snow drift and supply with mineral and organic matter. During the transport, the rock particles get segregated and treated if the transport is sufficiently long. A fine matter is transported for a large distance so the sediment is predominated by sandy and gravel fractions (Jahn 1961, Czeppe 1966, Pękala 1980a). In outwash and morainic zones the aeolian matter is deposited by waters that fill the depressions of varying origin, mainly cave-in ones. Such depressions show many a time a considerable deposition of the aeolian sediment (Phot 13). A dynamics of aeolian phenomena changes seasonally from year to year. For this reason a quantitative evaluation of the aeolian denudation, basing on direct measurements, is varying. The received indices have a considerable range: from 29 g/m² to 800 g/m² during a year (Czeppe 1966, Baranowski, Pękala 1982, Szczypek 1982).

A considerable differentiation of dynamics and course of aeolian processes results from a stage distribution of morphoclimatic conditions. A nival stage has vast firn field and relatively a small area is occupied by nunataks (Fig. 1, 8). The nunataks as isolated hills and crests, are mainly covered with snow. Only their steep slopes and edges as well as lodges are subjected to corrasion and supply with a weathering waste that is deposited nearby at firn fields and glaciers. A fine sediment with snow is during snow-storms transported for a larger distance (Baranowski, Pękala 1982). The plains of marine terraces are protected from deflation by a snow cover in winter and a tundra vegetation in summer (Czeppe 1966). Rubble slopes of subnival stage, glacier forefields (ice-cored moraines, outwashes) and the coastal storm ridges are the main aeolian alimentary and deposition area. A stage changeability of aeolian processes is therefore disturbed by local morphologic conditions and a type of cover deposits.

Nivation processes. A snow plays a significant role in a morphological development of Arctic and in high-mountain areas but it can be evaluated indirectly only, basing on studies over landforms and deposits (Mc Cabe 1939, Levis 1939, Różycki 1957, Gardner 1969, St-Onge 1969, Kłysz 1980, Vincent, Lee 1982 and others). A snow acts directly on its substrate during sudden displacements (avalanches) as well as during a slow creep or only due to a long conservation on a slope. Such corrasive-denudational processes model a relief mainly above the firn line, particularly at steep slopes.

Snow avalanches commonly sculpture steep slopes within a nival stage whereas gentle slopes are usually covered with a thick bed of perennial snow (Phot. 14, Figs. 3—4). Due to corrasion the slope retreat, first of all inside glacial cirques and nival niches. A corrasive action of avalanches at slopes results frequently in a development of asymmetrical crests (Różycki 1957) what is noted for many nunataks.

In a subnival stage the avalanches are often composed of a very wet snow (slush avalanches), even at very gently slopes, and are usually

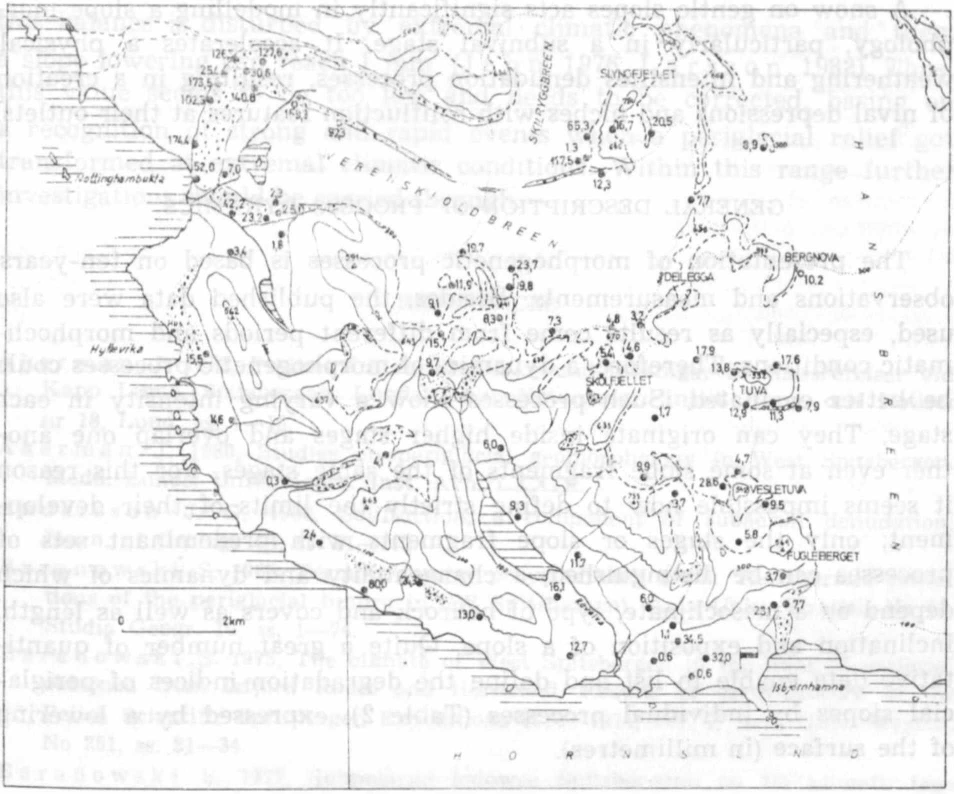

Fig. 8. Niveo-aeolian deposition in g/m² at tundra and nunataks in 1973 (S. Baranowski, K. Pękala 1982)

Materiał niveo-eoliczny w g/m² w 1973 r. (wg S. Baranowski, K. Pękala 1982)

moving in agreement with a slope morphology (corrasive chutes and niches). They transport immense amounts of a rock debris.

A slope degradation by snow and snow-debris avalanches is quick but quite poorly known. Measurements in a nival stage of the Hornsund region proved that indices of avalanche degradation equals 0.2—0.7 mm year and depend on a type of rocks. Beneath a firn line (subnival stage) the indices are higher (0.5—1.0 mm a year) but are restricted to corrasive niches and chutes, at the outlets of which nival taluses have been formed. Such pattern seams to be a correct one, as in the present tundra stage there are immense nival fans transformed into the so-called nival moraines and located below large nival chutes and niches, developed during the Early Holocene when a firn line occurred at lower altitudes (Czeppe 1966, Rapp 1960, Chandler 1973, Troitsky et al. 1975, Karczewski et al. 1981b, Birkenmajer 1982). Now these fans are the fossil landforms, being covered by talus covers.

A snow on gentle slopes acts significantly in modelling a slope morphology, particularly in a subnival stage. It accelerates a physical weathering and intensifies denudation processes, resulting in a creation of nival depressions and niches with solifluction features at their outlets.

GENERAL DESCRIPTION OF PROCESS DYNAMICS

The presentation of morphogenetic processes is based on ten-years observations and measurements. Besides, the published data were also used, especially as results come from different periods and morphoclimatic conditions. Therefore, a dynamics of morphogenetic processes could be better evaluated. Such processes show a varying intensity in each stage. They can originate inside higher stages and overlap one another even at some slope fragments of the same stages. For this reason it seems impossible now to define strictly the limits of their development; only the stages or slope fragments with predominant sets of processes can be distinguished, a changeability and dynamics of which depend on a mesoclimate, type of bedrock and covers as well as length, inclination and exposition of a slope. Quite a great number of quantitative data enable to list and define the degradation indices of periglacial slopes by individual processes (Table 2), expressed by a lowering of the surface (in millimetres).

Tab. 2. Degradation indices of mountain slopes in south-western Spitsbergen, Hornsund region

Wskaźniki degradacji zboczy górskich w południowo-zachodnim Spitsbergenie, rejon Hornsundu

Process	Lowering of a rock surface /in mm a year/
Physical weathering	0.2 - 2.0
Chemical weathering	0.003 - 0.02
Washing and suffosion	0.003 - 0.007
Erosion	1.0 - 1.5
Nival processes	0.2 - 1.0
Aeolian processes	0.0003 - 0.007
Solifluction	0.1 - 0.3

The indices cited in the Table 2 present the maximum and minimum values, and enable to define a mean slope degradation for a periglacial zone that is represented by south-western Spitsbergen. A mean degradation value for this zone equals about 3 mm a year and results from the action of main morphogenetic processes. It seems to be the value of the surface lowering in a dynamic balanced environment. Locally this balance is disturbed by extremal climatic phenomena and then, a slope lowering can reach 1 mm (Jahn 1976, Larsson 1982). Thus, this value seems to be too low and needs to be corrected, basing on a recognition of strong and rapid events when a periglacial relief got transformed at extremal climatic conditions. Within this range further investigations should be carried through.

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EXPLANATION OF PHOTOGRAPHS

Phot. 1. General view from Vesletuva to the central part of Torell-Wedel-Jarlsberg Land.

Phot. 2. View from Sylngfjellet to the south-western part of Wedel-Jarlsberg Land.

Phot. 3. Present talus fans at Vesletuva slopes.

Phot. 4. Ariedalen. Talus and nival fans at a margin of Ariebreen.

Phot. 5. Cryoplanation shelves cut in dolerites.

Phot. 6. Destructed and folded vegetation as an effect of washing.

Phot. 7. Stone rings in Revdalen.

Phot. 8. Solifluction terraces in Revdalen.

Phot. 9. Solifluction in a nival stage at southern slope of Kopernikusfjellet.

Phot. 10 and Phot. 11. Mudflows at ice-cored moraines of Torellbreen.

Phot. 12. Formation of a deflation pavement at Torellkjegla on 25th July 1980.

Phot. 13. Aeolian accumulation in cave-in depression and lake at the median moraine of Torellbreen.

Phot. 14. Snow avalnches at eastern slope of Lysefjellet.

STRESZCZENIE

Praca zawiera charakterystykę głównych procesów morfogenetycznych kształtujących rzeźbę obszarów peryglacjalnych SW Spitsbergenu w rejonie Hornsundu (ryc. 1, 3, 4). Oceny dynamiki poszczególnych procesów dokonano na tle budowy geologicznej rzeźby i klimatu, w oparciu o materiały pomiarowe z dziesięcioletniego cyklu obserwacyjnego. Zwrócono także uwagę na zróżnicowanie zespołów procesów wynikające z piętrowego układu zjawisk fizycznogeograficznych (tab. 1). Podano wskaźniki degradacji obszarów peryglacjalnych (tab. 2) pod wpływem działania głównych procesów morfogenetycznych w warunkach równowagi dynamicznej.

OBJAŚNIENIA FOTOGRAFII

Fot. 1. Widok ogólny z Vesletuvy na centralną część Ziemi Torella-Jarlsberga.

Fot. 2. Widok z Sylngfjellet na SW część Ziemi Wedel-Jarlsberga.

Fot. 3. Współczesne stożki usypiskowe na S stoku Vesletuvy.

Fot. 4. Ariedalen. Na obrzeżeniu lodowca Ariebreen stożki usypiskowe i niwalne.

Fot. 5. Stopnie krioplanacyjne wycięte w dolerytach.

Fot. 6. Zniszczona i sfałdowana roślinność w wyniku spłukiwania.

Fot. 7. Wieńce kamieniste w Revdalen.

Fot. 8. Terasy soliflukcyjne w Revdalen.

Fot. 9. Soliflukcja w piętrze niwalnym na S stoku Kopernikusfjellet.

Fot. 10 i Fot. 11. Potoki błotne na wałach lodowo-morenowych lodowca Torellbreen.

Fot. 12. Tworzenie się bruku deflacyjnego na Torellkjegli 25 VII 1980 r.

Fot. 13. Akumulacja eoliczna w zagłębieniu i jeziorze termokrasowym na morenie środkowej Torellbreen.

Fot. 14. Lawiny śnieżne na E stoku Lysefjellet.

РЕЗЮМЕ

В работе представлена характеристика основных морфогенетических процессов формирующих рельеф перигляциальных пространств юго-запада Шпицбергена в районе Горнсунда (рис. 1, 3, 4). Оценку динамики отдельных процессов проводилось на фоне геологического строения рельефа и климата, опираясь на измерительные материалы десятилетних наблюдений. Обращалось также внимание на различия отдельных групп процессов вытекающие из ярусности физикогеографических явлений (табл. 1). Даны показатели деградации перигляциальных пространств (табл. 2) под влиянием действия основных морфогенетических процессов в условиях динамического равновесия.