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DEVELOPMENT OF SURFACE RELIEF OF THE WESTERN PART OF NORDENSKIÖLD LAND (WEST SPITSBERGEN)

In the years 1980, 1985 and 1988 Academic Polar Expeditions, organized by the scholars and students of the Faculty of Geography and Regional Studies of the University of Warsaw, have been active in Nordenskiöld Land in Western Spitsbergen. The scientific programme of these expeditions envisaged performing of comprehensive studies of the natural environment in the polar regions. The most complete analyses performed to date concerned geology and geomorphology (see A.Musiał et al. 1990). The present paper constitutes the summary of results of studies related to surface relief of the central part of Svalbard archipelago against the background of foreign scientific literature.

The surface relief of Svalbard archipelago was formed due to the action of differentiated morphogenetic processes, both exogenous and endogenous ones. The activity of external processes related to polar climate is especially distinctly seen here. The degree of differentiation of the relief depends upon the level of activity of morphogentic factors, which is first of all influenced by its morphometric features. Geological structure has also high importance for the shaping of the surface of archipelago, with special emphasis on lithology, as well as activating influence of the earth crust movements, caused by neotectonic and glaciotectonic processes.

A number of geological units can be distinguished in the western part of Nordenskiöld Land. The oldest of them are constituted by the strongly folded and metamorphized rocks of Late Precambrian period, which were rejuvenated in the Neocene and in the Quaternary, the latter resulting in the emergence of young horst structures (B.Flood et al. 1971, A.Hjelle et al. 1986). Younger structural units, beginning with Palaeosoic down to Tertiary had not been metamorphized, but due to orogenic movements were inclined towards E under the angle of 70-60°.

The role and magnitude of neotectonic movements in the formation of the surface relief in the part of archipelago considered here is as yet not fully explained. According to D.V.Semevskii (1967) the whole of Svalbard is subject to uplifting due to neotectonic and glacioisostatic movements. On the basis of comparative analysis of the altitudes of marine terraces occurring around Bellsund fiord it was stated, though, that particular parts of the archipelago have been uplifted unevenly. Some authors deny the role of neotectonic processes in the formation of surface relief of Svalbard or assign only a secondary role to these processes (Salvigsen, Nydal, 1981, Landvik et al. 1987). According to these authors the primary importance should be attributed here to glacioisostatic movements occurring in Holocene, after the continental glaciers of Pleistocene recessed. At the present stage of studies it is difficult to determine unequivocally the role of neotectonic and glaciotectonic processes in the modelling of surface relief, of this land. It would be erroneous to treat them separately since they acted simultaneously. Glacioisostatic uplifting influenced the course of neotectonic movements due to which during the whole Holocene there occurred an uneven uplifting of the archipelago (Lindner et al., 1986). Presently the uplifting movements are becoming weaker (Salvigsen, 1984). In the surface relief of the western part of Nordenskiöld Land the symptoms of tectonic activity are presently well seen. A record of these proesses is constituted by a distinct fault stretching from Slettnesbukta in the NW direction (Musiał 1990, Musiał et al. 1990).

Intensive tectonical movements in Spitsbergen occurred after Palaeogene. Numerous splits and troughs were formed then, cutting through older and Palaeogenic structures. Along these tectonic lines the following inlets developed: Isfjorden, Van Mijenfjorden and Grönfjorden, as well as the valleys of Linne and Ytter (Lacika, Musiał 1988). These splits and troughs have been active during the whole of Quaternary. Similar phenomena were also noted in other parts of the archipelago. Due to the activity of tectonic processes a sharp geomorphological boundary emerged between the little diversified coastal lowland and the strongly dismembered mountain chains (Fig.1). These processes are still going on, this fact being reflected by the numerous earthquakes recorded within the area considered (Barentsburg).

An important influence upon the development of surface relief of Nordenskiöld Land was exerted by lithological conditions. There appears a rich composition of rocks, differing by their degree of resistance to weathering (quartzite sandstones, marbles, dolerites, limestones, conglomerates, gypsums, shists etc., see A.Musiał 1985). Resulting from the selective action of external processes there occurred skeletonization around the harder rocks due to destruction of the softer ones. It turned out that the most resistant to external factors were thick shelves of Lower Carbon quartzite sandstones. On the outcrops of yellow-grey spiriferous Permian limestones the steep rock walls were formed observed in Ytterdalsegga, Ingeborgfjellet, Voringen, Vardeborg, etc. ridges. Individual peaks, hummocks, structural breaks and walls are found in places where dolerites get uncovered. Several of such walls were cut through by rivers, forming deep gorges, like in Fold, Linne, Ytter etc. valleys.

During the whole of Quaternary the glacial and marine aquatic processes on Svalbard archipelago recurred many times (Kłysz et al. 1988, Lindner et al. 1983). The oldest glacial clays lying on the rock basis with the traces of exarational activity were identified within the territory in question between Isfjorden and Linnevatnet. O.A.Lavrushin (1969) assumes that they originated during Riss

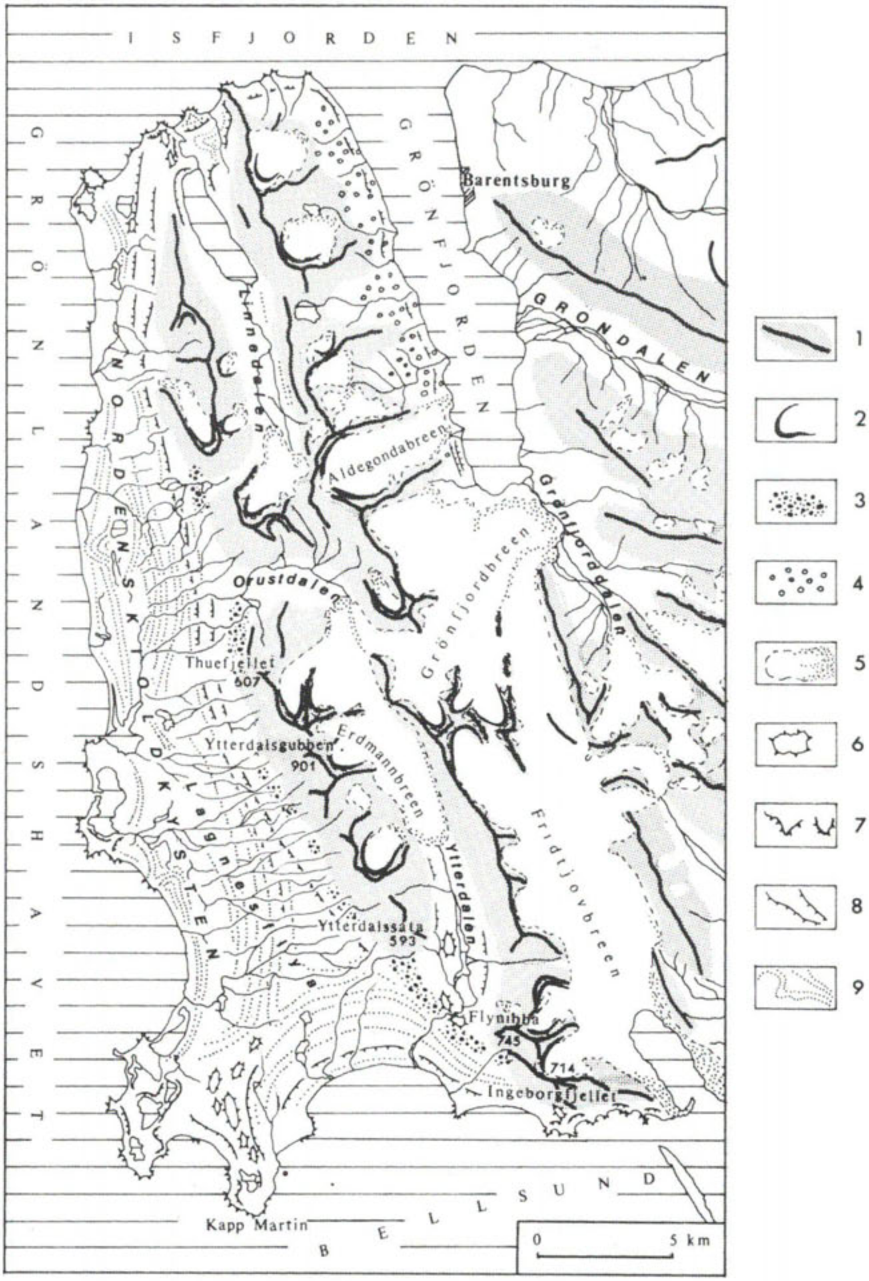

Fig.1. Geomorphological sketch of Nordenskiöld Land (Western Spitsbergen).

1 – mountain ridges with waste covers on slopes, 2 – glacial cirques, 3 – old terminal moraines, 4 – ground moraine, 5 – glaciers with walls of terminal, central and lateral moraines with ice core, 6 – abrasion nunatacs, 7 – abrasion spurs, 8 – distinct edges of marine terraces, 9 – storm walls on marine terraces.

glaciation (Wedel Jarlsberg Land). In the light of newer data these sediments could be much younger, though, and be related to Vistulian (Weichselian) glaciation (Salvigsen, Nydal 1981). Their roof is located a few meters above the sea level. It can therefore be presumed that in this period a strong overdeepening of valleys took place due to glacial erosion. The form of a great exarational tub was acquired then by the low which constitutes now the bowl of Linnaeus lake. Presently this form is a cryptodepression (max. depth of 59 meters). According to O.Salvigsen and R.Nydal (1981) in the Early Vistulian (Weichselian) glaciation period the whole of the archipelago was covered by growing glaciers. Thus, it is then that there existed adantageous conditions for accumulation of lower clays.

Then there occurred the marine transgression, during which the series of sand and silts with the rich mollusc and snail fauna of 10 meter of thickness was formed. According to O.Salvigsen and R.Nydal (1981) this could occur in Middle Vistulian period, when conditions corresponding to interstadial ones were prevailing. The sea was reaching at that time far into the present day valleys of Linne, Orust, Ytter and into the valley now filled by Fridtjov glacier. In this manner deep and narrow fiords with abrupt rocky walls were formed. During the same period coastal processes were developing intensively, cliffs were being formed, rock material was subject to abrasion and was being accumulated. Locally preserved from this period there are fragments of marine terraces which can be best observed in the western part of Western Spitsbergen. They are located at the altitude of more than 65 meters above sea level.

The subsequent glacial episode was connected with Late Vistulian. Glacial cover attained maximum dimensions at about 18,000 BP, and its centre was located on Kongs Karl Land (Salvigsen, Nydal 1981). It is from this period that the upper layer of clay with small boulders, of 1-1,5 meter thickness, uncovered at the mouth of Linnedalen towards Vardeborgslatta and Ytterdalen, could be formed. Judging upon the geographical distribution of glacial sediments the glaciers filled up the valleys and flowed up to the mountain forefield. In this manner the previous marine sediments were redeposited. Presently, the bigger marine boulders of light and cherry quartzite sandstones of Carbon can be found, for instance, on the peak of the hill of 187 meters above sea level in Linnedalen and on the structural flattenings in Ytterdalen (250 meters a.s.l.) — see A.Musiał (1985). Studies of the erratic material and of the Quaternary sediments make it possible to identify the dimensions and the character of the glacial cover in Late Vistulian within the considered part of Svalbard archipelago (Musiał et al. 1990). Ice covered during the maximum of glaciation the whole W part of Nordenskiöld Land. Over the surface of ice only nunatacs were rising formed out of the highest mountain ridges: Vardeborg – Quigstadfjellet – Flynibba and Griegfjellet – Ytterdalsgubben – Ytterdalssata. These ridges constituted parallel ice sheds of NNW - SSE orientation. The transfluences between them were located on passes and lower altitudes of the ridges, like in the vicinity of Kongress-vatnet, Seipfjellet, Folddalen etc.

Frontal moraines from that period have until now been recognized at the mouths and gorges entering into the coastal plain towards Greenland Sea (Musiał 1989). Their spatial situation, dimensions and petrographic characteristics demonstrate unequivocally that they were formed in the marginal zones of glaciers which flowed up to the mountain feet and ended with the abrupt glacial cliff in the sea. Marine terrace levels developed on these moraines at the altitude of 64 meters above sea level were identified as Late Vistulian (10,900-11,000 BP, see Landvik et al. 1987). In the same time Van Mijenfjorden was filled with a fiord glacier which left the glacial clay on the S rim of Bellsund.

The nature of glaciers located on the E side of the ice shed and flowing in the direction of Grönfjorden was different. They were longer and they covered vast land areas as well as the coastal zone of this fiord, as witnessed by erratics which are presently getting uncovered during low tides. No marine beaches with pebbles, located higher than 2-4 meters were observed. These facts together allow us to formulate the hypothesis that Grönfjorden was at that time entirely or to a large degree filled with glaciers (see Musiał, 1985). The Aldegonda glacier ended during the maximum reach in the Small Glaciation Age far in Grönfjorden. The paths of transgression of ice masses in that time between Isfjorden and Van Mijenfjorden, reconstructed on the basis of positions of rock material, indicate the locations of confluences of small ice "streams" and formation of the greater ones, like in Orustdalen. Growth of ice cover was uneven and not simultaneous, so that the more dynamically growing parts of this cover were blocking smaller glaciers.

Along the western coasts of the archipelago erratics were being transported, lifted by pack-ice which was moved over by marine currents.

According to J.Landvik and associates (1987), as well as J.Landvik and O.Salvigsen (1985) the development of surface relief of this area in Holocene took the following course. After the terrace of altitude of 64 m a.s.l. had been formed the sea level rapidly decreased by some 14 meters. The terrace of 52-50 m a.s.l. was formed at that time, quite vast and well seen in the relief, dated by some authors to 10,600-10,000 BP. In the same period the central part of Orustdalen was already free from ice. In the vicinity of Lagnesrabbane rocky islets appeared, which subsequently grew. During the following 2,000 years the sea level substantially lowered — by 40 meters — with the pace of 1.2 to 2.2 meters per 100 years.

Some 8,000 to 4,000 years BP there occurred marine transgression called holocene transgression. Around 7,600 years BP a recession took place of 3 to 5 meters, and the terraces of 12.1-10.8 meters of altitude a.s.l. were formed in this period. The maximum reach of transgression in Holocene took place approximately 6,000 years BP. Gradually, consecutive terraces appeared with well preserved storm ridges — 5-8 meters a.s.l. and 3-4 meters a.s.l., observed nowadays along the western coasts of Nordenskiöld Land. During formation of coastal plains glaciers expanded several times. There were three glacial episodes on Svalbard during Holocene: 8,000-9,000 BP, 2,000-3,000 BP and the Small

Glaciation period. Glaciers from these periods developed primarily in the upper fragments of valleys and were close to the present ones as far as their dimensions are concerned.

Presently a lot of water from melting snow gathers every year within the young coastal lowland, this lowland being glacioisostatically uplifted and weakly drained. This forms advantageous conditions for the development of cryogenic processes. Systems of structural soils of various forms and magnitudes are being shaped here out of a variety of rock material. On peat plains tuffurs and initial pingo hills developed. In the dry places of the 3-4 m a.s.l. terrace, deprived of vegetation cover, eolic processes take place and small dune forms are being created (maximum 60 cms of altitude). In coastal lakes and lagoons accumulation of material brought here by rivers goes on. High, rocky segments of the coast are being intensively destroyed by marine abrasion. On flat coasts abrasion is insignificant and accumulation gains much in importance. Then, on steep slopes gravitational processes get intensified, leading to appearance of stony belts and stripes and of mud-and-debris tongues. Fluvial and glaciofluvial processes are concentrated along riverbeds, while bigger surfaces are modelled by them along the borderline between the lowland and the mountains and at the forefront of glaciers, where system of alluvial and outwash taluses appear. Within the riverbeds of the western part of Nordenskiöld Land accumulation and lateral erosion dominate over depth erosion due to small gradient.

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