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Andrzej Musiał, Jacek Drecki, Bogdan Horodyski,
Krzysztof Kossobudzki

QUATERNARY DEPOSITS OF ORUSTDALEN (WEST SPITSBERGEN)

Between Isfjorden, the Greenland Sea, Bellsund and Grönfjorden there lies the western part of Nordenskiöld Land strongly differentiated geologically and morphologically (A. Musiał 1983, 1984, 1985). In the relief of this area Orustdalen draws attention as the vastest valley form directed westwords. On the north it is limited by the massif of Systemafjellet (744 m a.s.l.), on the east by the ridge of Qvigstadfjellet (770 m a.s.l.) — Seipfjellet (720 m a.s.l.) and on the south — by the summits of Isnuten (585 m a.s.l.) and Kosterfjellet (825 m a.s.l.). Orustdalen has a complex run: its upper section runs from SE to NW while the lower part — from E to W. The valley is ca 2 km wide and its length down to the sea-shore plain does not exceed 9 km.

The highest fragments of Orustdalen are covered by the glacier Dahlfonna and its confluent glaccier Klaus. Within this catchment area there is also the small debris glaccier located on the NW slopes of Seipfjellet and a residual glacier on the slope of Kantlinuten.

West of the mountain ridges there spreads a flat, poorly drained surface of a sea-shore plain with groups of terraces reaching 74 m a.s.l. (J. Lacika, A. Musiał 1988).

On the sea-shore plain, not far from the Greenland Sea a series of coastal lakes occurs which are former lagoons. Present-day lagoons are Orustosen and Gravsjöen of which the greatest part changes into watts during low tide.

The geological structure of Nordenskiöld Land is characterized by a clearly streaked run of rock layers which differ in their Ethology, age and resistance to weathering. The width of the particular outcrops varies from 600 to 3,000 m (A. Musiał et al., in press).

The border line between strongly metamorphosed pre-Cambrian rocks of the Hecla Hoek formation and the Palaezoic sedimentary complex runs across the investigated area (B. Flood et al. 1971, A. Hjelle et al. 1986).

The deposits of the Hecla Hoek complex consist of: yellow-brown and steel-grey shales, limestones, pink and green marbles (Dahlofonna glacier region) and grey and black marbles (mouth of Jarndalen).

Besides, on the sea-shore plain there outcrop intrusions of green diabases (vicinity of Gravsjöen and Orustosen) as well as light grey quartz sandstones of the Lower Carboniferous (mouth of Loneelva).

Deposits of the Lower Carboniferous in the form of grey conglomerates lie discordantly directly on the Hecla Hoek rocks. Then they pass into light grey sandstones (very resistant to destruction, with well preserved remnants of flora and thin interbeddings of carbonic shales).

Sedimentary series of cherry and red fine-grain sandstones date from the Middle Carboniferous. Father eastward there occur outcrops of carbonate rocks of the upper Carboniferous as dark grey dolomites and marbles with interbeddings of gypsum or limestones and a rich fauna of Coelenterates.

Permian rocks occur as black siliceous limestones and grey limestones with a rich fauna of Brachiopoda (spiriferous horizons).

There are also, within Orustdalen, intrusions of grey-and green dolerites probably dating of the Cretaceous or the Jurassic.

Quaternary deposits are the produce of bedrock weathering and the result of activity of different morphogenetic processes. Block-and-rubble or rubble-and-clay slope covers lie on mountain ridges reaching the greatest thickness in the lower parts of slopes (Fig. 1).

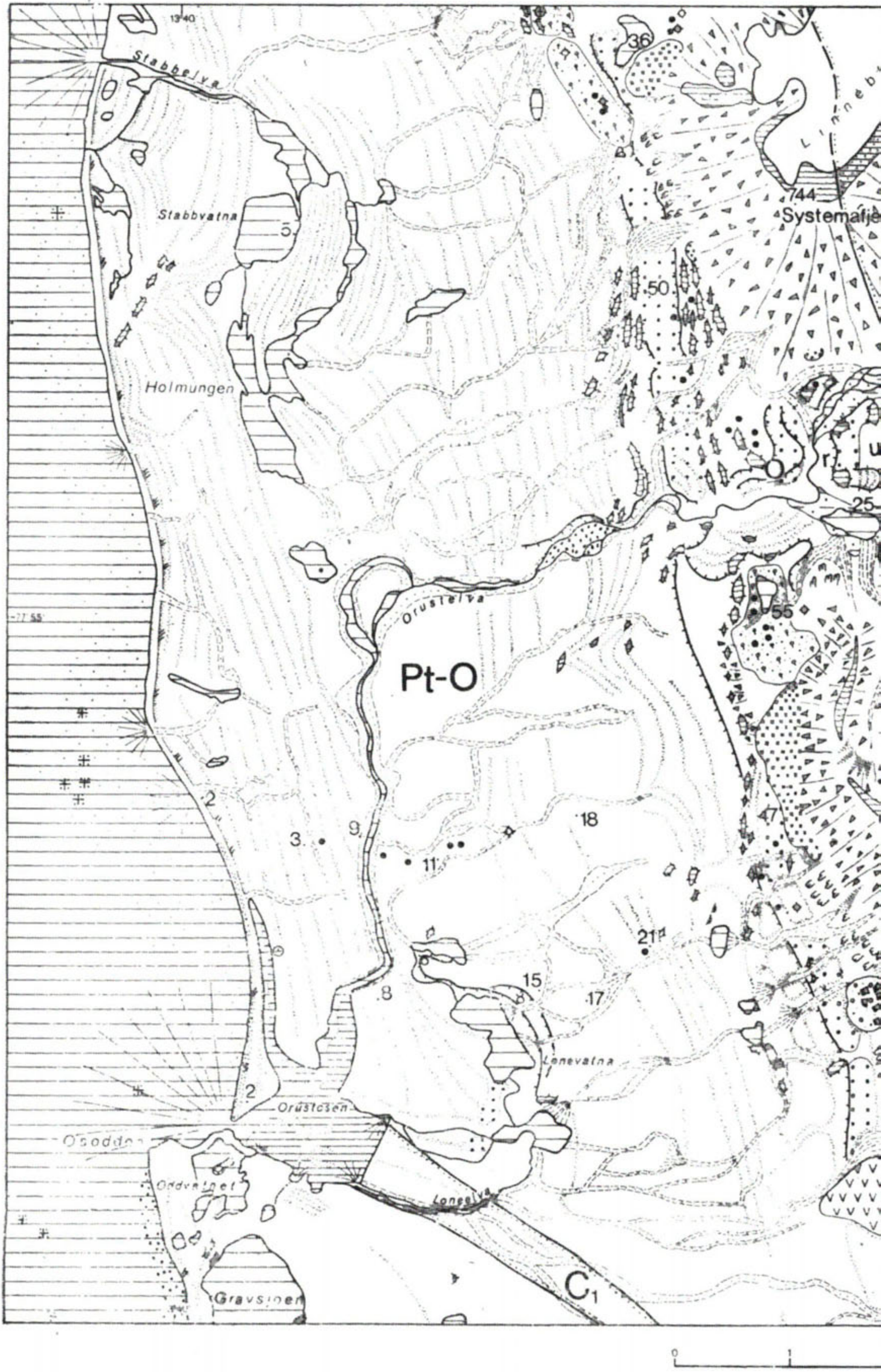
Klippen, towers, rock walls and faces outcrop near the summits frequently forming the faces of cuestas.

Convex forms built of light quartzite sandstones of the Lower Carboniferous often show traces of glacial abrasion. The waste cover is here decidedly less thick and its extent is limited.

At the base of the west slopes of Kosterfjellet (825 m a.s.l.) lies a vast block field from an enormous rock downfall. It consists of blocks of strongly metamorphosed shales of the Hecla Hoek formation, their size often exceeds 5—6 m of diameter.

Debris cones developed at the outlet of numerous gullies and under steep walls, their inclination reaches 35°. They are built of sharp-edged rock material of various sizes.

Present-day glacial deposits in this part of Nordenskiöld Land have a limited extent since the present glaciation is small. They consist mainly of various-size sharp edged rock fragments of ice-moraine ramparts which show distinct abrasion in the marginal zones of glaciers. Their thickness is usually small, maximum 1—1.5 m, but below glacier ice occurs. Within those forms of end and flank moraines great differences of petrographic composition can be observed. Ice-and-moraine ramparts



13°40
Stabbelva
Linnebr
744
Systemafjell
36
Stabbvatna
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50
Holmungen
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25
Orustelva
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77°55
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18
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9
11
21
15
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17
Lonevatna
2
Orustosen
Osodden
Oddvatnet
Loneelva
C1
Gravsjøen
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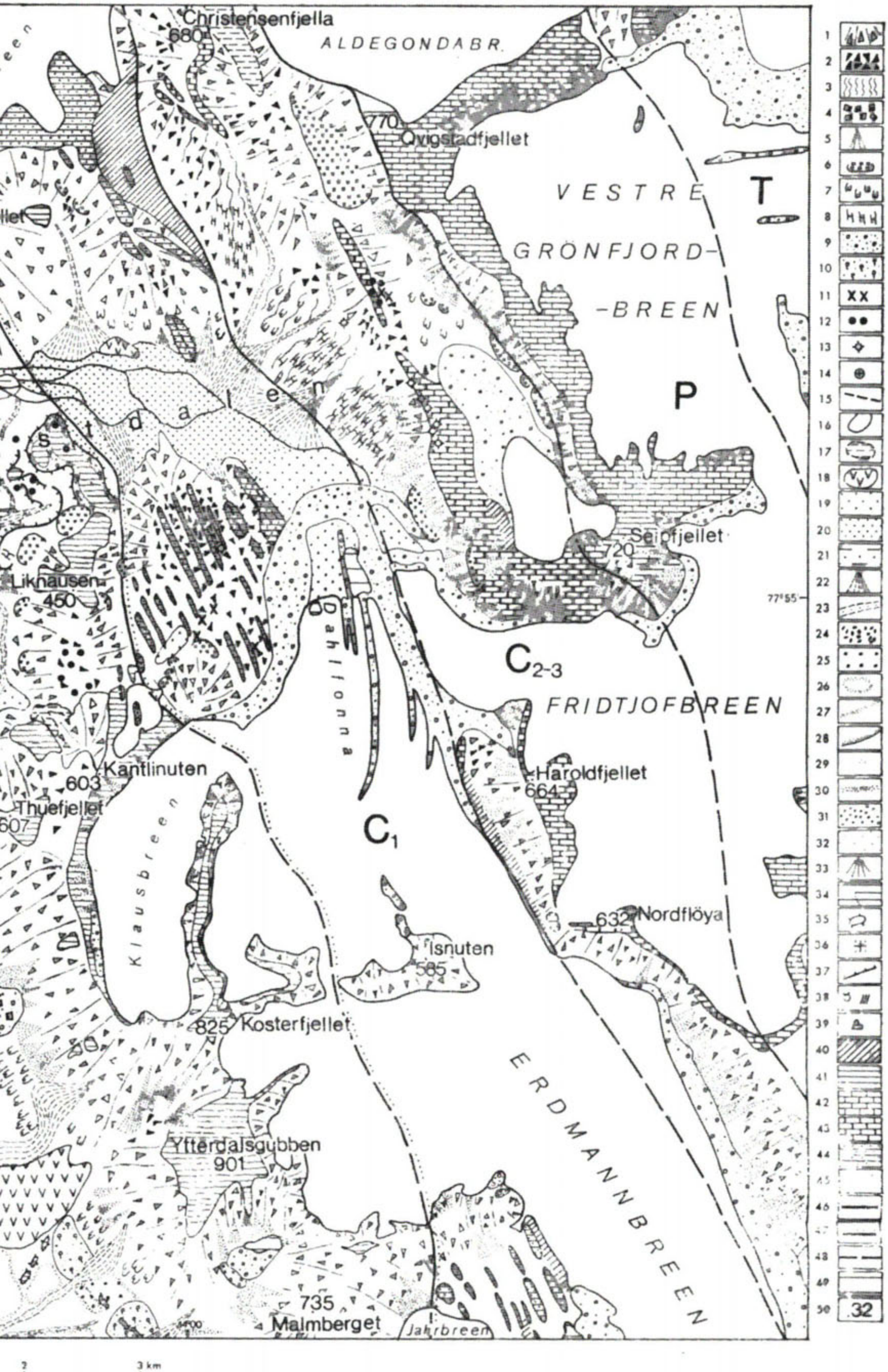

Christensenfjella
680
ALDEGONDABR.
770
Ovigstadfjellet
VESTRE
GRONFJORD-
-BREEN
T
P
Seipfjellet
720
77°55'
C2-3
FRIDTJOFBREEN
Likhausen
450
Dahlfonna
Haroldfjellet
664
Kantlinuten
603
Thuefjellet
607
C1
Klausbreen
632
Nordflöya
Isnuten
585
825
Kosterfjellet
ERDMANNBREEN
Ytterdalsgubben
901
735
Malmberget
Jahrbreen
2
3 km
1
2
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Fig. 1. Slope forms and deposits

1. Clayey block-and-debris slope covers, 2. block fields, 3. clayey waste mantles, 4. block
nival moraines, 7. rock boulders, debris, sands, loams and clays of soliflusion tongues,
debris, sands, silts, clays, loams of ice-moraine ramparts, 10. boulders, sands, silts, loams
in the form of pebbles of grey, cherry-coloured and red Carboniferous quartzite, 13. erratics
of rocks with glacier striae, furrows, undercuts and splinters, 16. glaciers, 17. many years
debris, pebbles, gravels of the base of outwash cones, 20. various-grain sands, silts of the
dammed lakes. Alluvial deposits and forms, 22. debris, gravels, sands, clays of alluvial
forms, 25. pebbles on the surface of marine terraces built of sand, 26. various-grain sands,
parts among lower marine terraces, 28. gravels and sands of present-day storm ramparts,
rions-grain sands, clays, on the abrasion platform, 33. sands and gravels of outdeltas,
emerging during low tides, 37. distinct edges of marine terraces, 38, whale bones and trunks
Cretaceous?), 41. T. fine-grain grey Griassic sandstones with dark streaks, 42. P. grey
43. C2-3 dark-grey dolomites, cherry-coloured sandstones, dolomites, gypsum and limestones
light-grey Lower Carboniferous sandstones with rhizomes of lepidodendrons and leaf im
of the Cambrian and the Ordovician, 46. stratigraphic limits, 47. lines of stratigraphic

fields of large rock falls, 5. debris and blocks of talus cones, 6. rock boulders, debris of
8. rock blocks, boulders, debris of boulder trains glacier forms and deposits, 9. boulders,
of old moraines, 1. erratics of pre-cambrian rocks of the Hecla Hock formation, 12. arratics
of Permian limestones blocks, 14. erratics of crystalline rocks (red granitoids), 15. outcrops
old snow patches, 18. naledi. Fluvioglacial and limnoglacial deposits and forms: 19. boulders,
latter parts of outwash cones, 21. various-grain sands, silts, locally clays of lakes and ice
cones, 23. pebbles, gravels, river bottom sands, 24. boulder fields. Marine deposits and
gravels, pebbles and boulders of marine terraces, 27. gravels and sands of old storm ram-
29. beach sands, 30. gravels in the beach zone, 31. gravels on the abrasion platform, 32. va-
34. watts, 35. rock abrasive monadnocks on higher marine terraces, 36. submarine rocks
of drifttrees, 39. mollusc shells on marine terraces, Basement rocks, 40. dolerites (Jurassic?
limestones and black siliceous Permian limestones with a rich fauna of brachiopods,
with a rich fauna of Coelenterata of the Middle and Upper Carboniferous, 44. C1 quartzite
pressions, 45. Pt. O shales, tillites, locally metamorphosed limestones: pink, green and grey
discontinuities, 48. tectonic lines, 49. surface waters, 50. spot heights.

of the Dahlfonna glacier show such differentiation. On the west side grey and steel-grey fragments of Hecla Hoek formation shales prevail reaching maximum sizes 80 × 85 × 90 cm. Cherry sandstones of the Middle Carboniferous or single block of light-grey quartzite sandstones of the Lower Carboniferous are seldom found in this part. In the sharp--edged material of this zone cobbles of light-grey quartzite sandstones of the Lower Carboniferous can often be found (the largest ones do not exceed 18 cm of diameter). Glacial till occurring here has a dark-grey colour. Instead, on the east side of the Dahlfonna, light-grey quartzite sandstone of the Lower Carboniferous and cherry-colour sandstones of the Middle Carboniferous prevail. Small fragments of conglomerates of the Lower Carboniferous can be found sporadically. Pink and yellow fragments of marbles of the Hecla Hoek formation are found rather frequently. Glacial till in this part of the glacier is more argillaceous and has a cherry colour.

The above-presented lithologic and facial differentation is strictly connected with the bedrock over which the glacier moved.

A more homogenous petrographic composition is observed in the supraglacial moraine covering the marginal part of the glacier which lies on the west side of Seipfjellet. It is wholy built of black siliceous Permian limestones and grey limestones from spiriferous horizons. The rock material is sharp-edged which shows its short transportation and the inclinations of the face part of the ice-moraine rampart reach 31°.

The analysis of glacial deposits distribution leads to palaeogeographic considerations concerning the dynamics of the development and shift directions of ancient glaciers. Between the ice-moraine ramparts and the present-day margin of the Dahlfonna glacier a lake forms periodically; limno-glacial deposits, mainly sands, silts and clays accumulate there.

Outwash takes up vast surfaces in front of the glacier; it is built of coarse-detritus and poorly rounded material at its base while in the peripheral parts-of sands, silts and clay.

Among Quaternary deposits of the investigated part of Nordenskiöld Land we notice deposits called "glacial-marine" by Soviet scientists (L. S. Troicki et al. 1975). They have been found at the outlet of Orustdalen and on the west side of Ytterdalsgubben (901 m a.s.l.) within a terraced sea-shore valley. Their occurrence can be observed starting at 52 m a.s.l. to which altitude the deposits of sea-shore terraces reach. Surfaces formed by those deposits consist of various grain sands, gravels and blocks of light quartzite Carboniferous sandstones with very poorly rounded edges, their maximum size not exceeding 1.3 m × 80 cm × 60 cm.

On many blocks glacial striae have been well preserved and their surface is covered by large colonies of lichen of the Rhizocarpon species.

A little above 52 m a.s.l. there runs a distinct morphologic border line which separates two sedimentary environments: the marine and the glacial, which is recorded in the morphology of the detritic rock material. The way of its rounding univocally shows marine abrasion but poor sorting and poor rounding prove short duration of abrasion.

Glacial deposits at the outlet of Orustdalen form a characteristic peninsula adhering by its base to the slopes of Thuefjellet (607 m a.s.l.) and directed northward. On the west and east side around it we can observe the successive terrace levels with beautiful marine pebbles of light-grey quartzite Carboniferous sandstones.

A small rocky uplift in the form of a rampart resembling in hight and run the above-described peninsula of glacial deposits lies on its east side within the outcrop of Hecla Hoek shales. Numerous striae and glacial polish can still be found here, among them lie blocks of light--grey quartzite sandstone with slightly rounded edges.

It is easy to observe erratic material in glacial deposits because of the narrow outcrops of roks differing in their petrography, age and resistance (A. Musiał 1983, 1984, 1985). The distribution of the erratic material shows the ancient directions of glacier transgression and it may by found in various morphological situations: in valley bottoms, on slopes, on mountain ridges and passes.

The most numerous group of erratics in this part of the archipelago is formed of quartzite sandstones of the Lower Carboniferous, light-grey, strongly resistant to exogenetic processes. In relation to the outcrop they have been carried away at a distance of 2—3 km in the SW direction and lie at present within the Hecla Hoek Shales. They have the form of blocks with poorly rounded edges (transversal hump in Orustdalen) of rounded blocks (outlet of Orustdalen and the gorge of Tjörnskardet), of small blocks, detritus and gravel (marine terraces up to 52 m a.s.l.).

Weathered blocks of Permian limestones form a less numerous group, they contain fauna of the so-called spiriferous horizons. Their greatest accumulation can be observed in the gorge of Tjörnskardet while single specimens have been found on the sea-shore plain.

Three such blocks of the size of 80 $\times$ 60 $\times$ 70 cm lie at 2.5 km to the west of the mountain slopes on a cuarino terrace, 16 m a.s.l. They have been "displaced" 7 km in straight line in relation to the outcrop.

Cherry-coloured, Middle Carboniferous sandstones, Lower Carboniferous conglomerates and Jurassic, Cretaceous? dolerites are scattered in the same way as that described above. They are much fewer and do not form distinct agglomerations but occur individually.

Another direction of glacial transportation has been recorded in the disposition of shales and marbles of the Hecla Hoek formation which form ice-moraine ramparts of the Dahlfonna glacier. The rock material has been moved from SW to NE and deposited within the outcrop of the Carboniferous.

An opposite movement of ice from NW to SE took place in the northern part of Orustdalen of which a proof are erratics of light-grey quartzite sandstones and conglomerates of the Lower Carboniferous. They were found at 100—120 m above the valley bottom on the slope and within the cuesta and the largest among them — a boulder with traces of glacial abrasion — is 3 × 2 × 1.5 m in size. It is stuck in waste on a slope built of Upper Carboniferous limestones. Over ten smaller boulders of that type lie in the edge zone of the cuesta and just behind it. In the erratic material particular attention should be paid to a red granitoid (30 × 10 × 20 cm) found at the altitude of 48—50 m a.s.l. at the outlet of Tjörnskardet onto the sea-shore plain.

A dozen or so similar pebbles of red granite were found on the beach between Gravsjöen and Stabbvatna. Their size ranged from several to over ten cm and the degree of abrasion — from good to poor.

The geological structure of Svalbard shows that the outcrops of those rocks are in the NE part of the archipelago (T. S. Winsnes 1988). The analysis of glacial deposits allows to state some regularities in their distribution. The greatest accumulation of morainic material occurs at the outlet of obsequent valleys directed towards the Greenland Sea (Orustdalen, the grge of Tjörnskardet). Instead, erratics occur individually on the sea-shore plain on marine terraces. The ways of glacier transgression reconstructed according to the arrangement of the rock material show the places where small ice streams merged and formed larger ones. This most frequently happened in the bottom of the main valley from which the principal tongue emerged.

The expansion of the ice cover was irregular and not simultaneous and thus its more dynamic parts obstructed the movement of those more stable. The result is that the extent of moraine covers and erratics in each valley is highly differentiated.

At the outlet of Orustdalen in its northern part there lies a group of abrasion monadnocks built by strongly weathered metamorphosed Hecla Hoek shales with white quartz veins. Here, too, on a terrace at 50 m a.s.l. we can frequently find boulders of light-grey quartzitic Lower Carboniferous sandstones with rounded edges. Small marine pebbles appear in this part of the valley as high as 57 m a.s.l.

Deposits of marine origin form vast morphologic horizons stretching along the west slopes of the Systemafjellet massif and the ridge Thuefjellet-Ytterdalssata (A. Musiał at al, in press). They can also be observed in the outlet section of Orustdalen. On its southern side they reach 52 m a.s.l. while on the northern side—up to 57 m a.s.l.; here small pebbles of light-grey quartzitic Lower Carboniferous sandstones occur; then show distinct features of marine abrasion.

At the outlet of Jarndalen small pebbles of 6 cm occur no higher than at the level of 76 m a.s.l.

In the described area higher levels of local extent have also been investigated; up to now, no marine deposits have been found there. Near Orustdalen the highest of them lying at 87 m a.s.l. is over ten metres wide and clayey waste outcrops on its surface; sharp-edged rock detritus is stuck in it. Solifluxion tongues enter here from the Systemafjellet massif.

Lower levels of 75 and 64 m a.s.l. have similar sizes and structure; there stick out monadnock Klippen of weathered Hecla Hoek shales with veins of white quartz. There occur blocks of morainic material, light-grey quartzite sandstones and conglomerates of the Lower Carboniferous cherry — coloured Middle Carboniferous sandstones and dolerites. The occurrence of Klippen causes a larger supply of wethered material which may completely conceal the hardly legible marine deposits.

In the light of available material the origin of those levels is not quite clear. They may have an abrasive character but at the same time their glacial foundation cannot be quite excluded.

The best developed group of marine accumulative terraces on the sea-shore plain stretches on the prolongation of the Jarn vallay. Their occurrence begins at 76 m a.s.l. Then follow those lying at 70, 65 and 59 m a.s.l.; they are built of fine gravels and variously grained sands among which occur cobbles reaching 35 cm of diameter.

The vastest level in this part of the archipelago is that at 56 m a.s.l. It is 200—250 m wide and is built of various grain sands with pebbles on the surface of which a "fine pavement" of 4—6 cm large pebbles occur. Within this terrace near the mouths of larger valleys boulders are found with poorly abraded edges overgrown by a rich cover of lichen.

The next accumulative marine terrace, 48 m a.s.l., is covered with very well-abraded pebbles of 3—4 cm in diameter. Single pebbles of over 22 cm in diameter can be found here. South of Tjörnskardet this level is built by sand-and-gravel deposits strongly cemented at the top. They outcrop in the incision of a stream where they can be observed along a section of 20 m. Under a thin cover of slope deposits there occurs a 30 cm thick series of sharp-edged gravels with traces of stratification, with detritus of Hecla Hoek shales and marbles. Below, down to 80 cm, fine gravel outcrops, it is stratified and contains single pebbles, and it dips to the NW. It changes then to thick gravel which is stratified, damp and has a dark-yellow colour.

Fine gravels with single pebbles occur at the depth of 1.1 m. The deposit is not cemented. It is easy to find small fragments of shells through out the outcrop. In the immediate neighbourhood of that wall, on the surface of a level at 48 m a.s.l. there lie very well-abraded marine pebbles of light-grey quartzitic Carboniforous sandstones of some scores of centimeters in diameter.

The terrace level at 39 m a.s.l. is built of fine pebbles mainly of light-grey quartzitic Carboniferous sandstones and it is worth noticing that it contains many sharp-edged fragments of highly metamorphosed Hecla Hoek limestones and shales. This level is completely overgrown with moss and grass as well as with polar willow. The accumulative terrace at 30 m a.s.l. has a similar character and is strongly marked in the morphology of the sea-shore plain.

Within the level of 28 m a.s.l. there occur single abrasive monadnocks of shales with quartz veins and Hecla Hoek limestones. Small pebbles of quartzitic sandstones also occur here, the largest reaching 15 cm in diameter. Strongly weathered bones of a whale have been found here. This surface is also overgrown by dense tundra vegetation.

On a terrace lying at 12—15 m a.s.l. shallow ponds can be seen, most of them dry up by the end of August. In such basins sharp-edged rock material outcrops-mainly Hecla Hoek shales, green- and grey diabases, and poorly rounded detritus of light-grey quartzitic Carboniferous sandstones with outcrops east of Orustdalen.

A distinct edge separates the described level from the next one at 7—9 m a.s.l. This terrace does not run parallelly to mountain ranges but is rather connected with depressions and lagoon lakes stretching along the Greenland Sea. Its edge has a complicated run and it is washed out in places.

On the lowest surfaces lying 2—3 m a.s.l. there occurs a whole group of abrasive monadnocks consisting of klippen of Hecla Hoek limestones, shales and conglomerates as well as of green-and-grey diabases.

On numerous terraces ancient storm banks have been preserved and they are strongly marked in the landscape.

Present-day storm banks are formed of various-grain sands and of pebbles the size of which sometimes exceeds 50 × 50 × 40 cm. Large amounts of drift wood agglomerate on them nowadays.

A flat sandy shore forming a beach occurs on the sand bar west of the outlet of Orustelva. In the various-grain beach sand there often occur very well-rounded marine pebbles consisting mainly of green-grey diabases. Stony beaches formed of pebbles of green diabases stretch on the west side of Gravsjöen. Ca thirty granitoid pebbles were found in the beach zone.

The abrasion platform modelled by the Greenland Sea is mildly inclined westwards. It contains numerous skerries. Strong westerly winds push sea water into sea-shore lakes and bays which results in the formation of backward deltas formed of sands and sluime (e.g. in the west part of Gravsjöen). During low tides Watts are exposed and form in Orustosen slimy beaches.

Sharp-edged blocks and rock rubble, sands, clays and locally on the surface — clays and silts form banks of nival moraines at the base of slopes. Those deposits cover the ice core which thows slowly. The petrographic composition of the material forming the banks first of all depends on the kind of neighbouring rocks.

The forms described above reach their greatest sizes on the side of the Greenland Sea at the foot of Thuefjellet, in the surroundings of the Qvigstadfjellet-Seipfjellet rigde and on the northern side of Liknansen (450 m a.s.l.). The influence of naledi on the formation of Quaternary deposits is limited because of their small expansion. They have developed west of Ytterdalsgubben (901 m a.s.l.) inside and outside the marginal zone of the Dahlfonna glacier and on the northern side of Orustdalen. The great hydration in their direct neibourhood favours washing and segregation of the rock material through sinking thick fragments.

In the summer of 1988 a small number of many years old snow patches were found; they remained in deep gullies and locally in nival recesses (northern slope of Thuefjellet 607 m a.s.l.). Thaw water from there, gradually freed during the whole ablation season transport rock material and thus cause its abrasion. Where snow has thawed nival pavament appears.

Seasonal thawing and freezing of the ground surface layer causes constant segregation of the detrital material. As a result of periglacial processes, networks of polygens, boulder trans, rings and circles have developed (Loneelva drainage basin, surroundings of Gravsjoen). The slight inclination of the slope (1—2°) causes an intensive development of solifluxion processes, which results in the formation of debris-and-mud tongues (western slope of Seipfjellet, surroundings of Systemafjellet).

In the bottom of upper sections of streams beginning on the coastal plain Hecla Hoek shales prevail among which single pebbles from marine terraces can be found. The farther from the mountain chain the higher is the degree of abrasion and segregation of deposits.

The width of numerous river channels is 2—3 m here and only in some places it reaches 4—5 m, the depth of their incision into the plain surface attainig 15—20 cm. At a distance of ca 1.5 km from sources, fine material prevails already in rivers; there are gravels and various--grain sands and only locally there occur bars of thicker material. The occurrence of a relatively large content of floatable parts has been stated in channel deposits.

The analysis of Quaternary deposits in the western part of Nordenskiöld Land has revealed their visible selection and specific distribution.

Deposits of glacial origin older than present-day ones have been preserved mainly at the outlet of valleys onto the coastal plain and they occur above 52 m a.s.l. Deposits of present-day glaciers fill the upper fragments of glaciated valleys and depressions. They are most frequently accompanied by glacifluvial and flacilimnetic deposits.

Farther from the mountains and with decreasing absolute altitude also the amount and fraction of the sea-abraded loose rock material decreases. The size of accumulative marine terraces changes, too. The distribution of erratics in the described part of the archipelago proves that the processes of their sedimentation and transportation are complicated.

The displacement of rock material as the result of the movement of old and present-day glaciers proceeded first in small variously directed valleys. When large valley glaciers were formed, ice masses moved from the East to the West.

Along the Western shores of the archipelago there took place, and is still going on the transportation of small quantities of rocks, mainly crystalline and metamorphosed, carried by the ice pack which is driven by sea currents.

The spatian situation of erratics shows also the uneven development of glaciers in the same valleys during the successive glacial epochs.

This leads to the conclusion on the unique character of dynamics of the particular glaciations.

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