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Antoni WÓJCIK[1] and Wiesław ZIAJA[2]

[1] Polish Geological Institute
Carpathian Branch
Skrzatów 1
31-560 Kraków, POLAND

[2] Institute of Geography
Jagiellonian University
Grodzka 64
31-044 Kraków, POLAND

Relief and Quaternary of the southern Sörkapp Land, Spitsbergen

ABSTRACT: Marine rock-accumulative terraces at 2-230 m a.s.l. in the southern Sörkapp Land are typical for glacioisostaticly uplifted areas. The Holocene terraces reach up to 19 m a.s.l. An outstanding coastal ridge at 9-10 m a.s.l. was radiocarbon-dated at 6580±160 years B.P. No marine transgression during the Holocene on higher and older terraces was noted, what is also confirmed by well preserved raised storm ridges. Any of glacial advances during the Holocene were more extensive than the one of the Little Ice Age. However the Pleistocene glaciations were more extensive. Among glacial landforms in the area there are: ice-cored frontal and lateral moraines up to 70 m high, plains of ground, ablation and fluted moraines, complexes of glacio-fluvial fans. The glaciers retreated 0.3-2 km since 1936 *i.e.* *ca* 10 m a year on the average. There are large consequent structural landslides on eastern slopes of Keilhaufjellet.

Key words: Arctic, Spitsbergen, Quaternary, landscape, marine terraces, glaciers.

Introduction

The paper was elaborated on the basis of field studies, carried out during expeditions of the Jagiellonian University in summers 1990 and 1991. The latter was financially supported by the Ministry of National Education.

The southern Sörkapp Land forms a southernmost part of Spitsbergen and is isolated from the rest of the island by the Olsok Glacier, the glacial plateau Sörkappfonna and the Vasiliev Glacier (Fig. 1). The isolation is accentuated by frequent occurrence of sea ice, delivered by a cold marine current which flows along the eastern coast to the south. Such ice occurs more often there than along

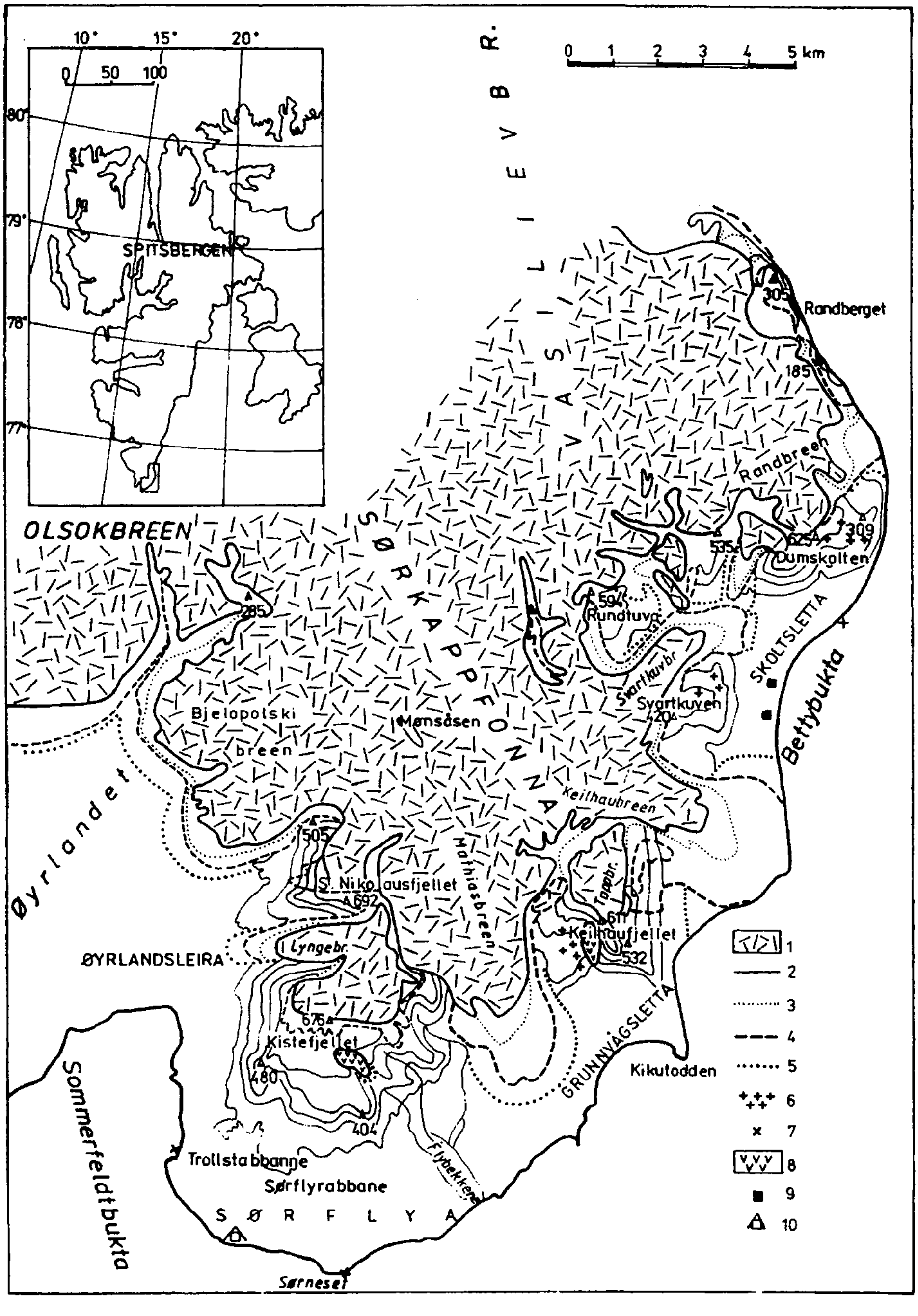


Fig. 1. Study area
1 - glaciers; glacial extents in: 2 - 1991, 3 - 1961, 4 - 1936; 5 - at maximum of the Little Ice Age; 6 - erratics of different origin, 7 - granite erratics, 8 - rock glaciers, 9 - recently discovered ruins of probable Pomor huts, 10 - Sörkapphytta

the western coast of Spitsbergen. Because of these unfavourable conditions, the area has been rather neglected by scientific expeditions, and no complex work on its landscape and the Quaternary has been done. Papers referring directly to the area are also rare (Werenskiold 1923, 1952-53, Lefauconnier and Hagen 1991, Winsnes *et al.* 1992).

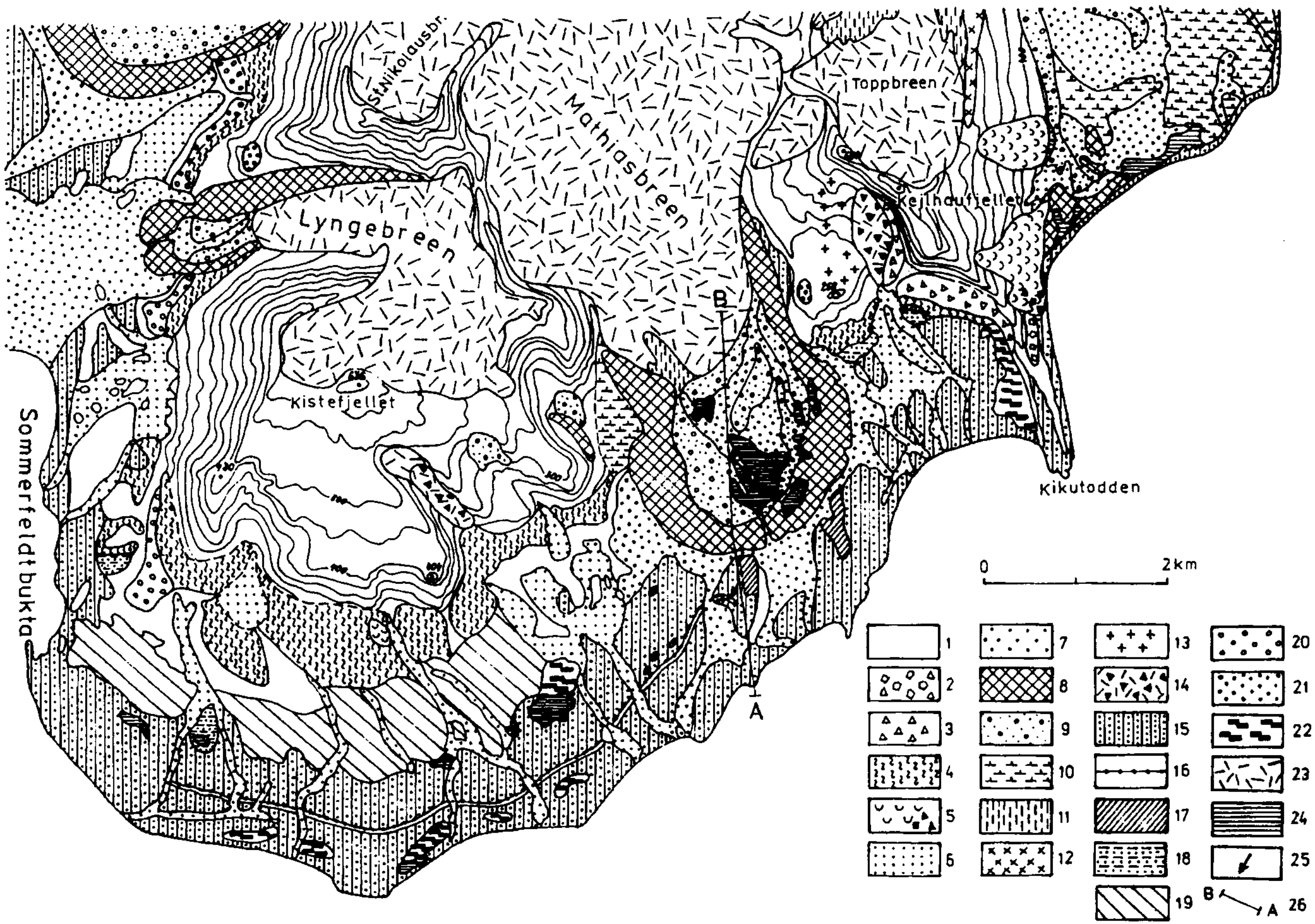
Field mapping of Quaternary deposits and landforms was carried out in scale of 1:25,000. The scale was a result of enlarging a topographic map 1:100,000 (Norge Topografisk kart), actual for 1936. Air photos of 1961 and 1990, received from the Norwegian Polar Institute, were also used. The map was not reliable in many places, because of progressive deglaciation that influenced glacier extents, new landforms and water outflow. During fieldworks, particular attention was paid to morainal zones and raised marine terraces. Maps of Quaternary sediments and changes in glacier extents result from this examination (Figs 1-3).

Bedrock and landscape

The bedrock is distinctly diversifed from west to east, in connection with occurrence of the main geological structures. Metamorphosed rocks of the Hecla Hoek Formation are located in mid-western part of the area. They comprise the Proterozoic and the Lower Palaeozoic schists, quartzites and metamorphosed carbonate rocks, and are outcropped in lower parts and at foot of Kistefjellet. Mantled with younger sedimentary rocks (quartzites, conglomerates, sandstones, mudstones and shales) of the Permian to the Tertiary age (Flood, Nagy and Winsnes 1971, Winsnes *et al.* 1992), they contain tectonic unconformities.

Small mountain massifs separated from one another by glaciers are the predominant feature. St. Nikolausfjellet (692 m a.s.l.) and Kistefjellet (676 m a.s.l.) that rise above coastal plains of Öyrlandsleira and Sörflya, are the highest ones in the western part of the area. To the east, Keilhaufjellet (611 m a.s.l.) is situated above Grunnvågsletta, whereas Svartkuven (420 m a.s.l.) and Dumskolten (625 m a.s.l.) above Skoltsletta. A narrow ridge of Randberget (305 m a.s.l.) occurs in the northeastern part of the area, north of the Rand Glacier, and its almost vertical eastern slopes fall directly to a sea. However, western slopes of this massif are more gentle and covered with the Quaternary marine sediments. The latter have been partly eroded and overlain with glaciofluvial or fluvial deposits.

Amongst typical landforms to the south there are also: a remodelled surface of the ancient marine terrace 100-130 m a.s.l. at foot of Kistefjellet, and two groups of old skerries, Trollstabbane and Sörflyrabbane (up to 100 m a.s.l.), set between Sörflya and its edges.



St.Nikolausbr.
Mathiasbreen
Toppbreen
Keilhaufjellet
Lyngebreen
Kistefjellet
Sommerfeldtbukta
Kikutodden
B
A
0
2km
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Quaternary marine landforms and sediments

The highest and the oldest fragments of rocky marine terraces with single marine gravels were noted at 220-230 m a.s.l. on slopes of St. Nikolausfjellet, Kistefjellet and Keilhaufjellet (Fig. 2). This fact is compatible with earlier descriptions of the area and the adjacent Hilmarfjellet (Werenskiold 1923, 1952-53, Ziaja 1989). Lack of data makes age determination of this terrace impossible.

The terraces 100-130 m a.s.l. are conserved at foot of Kistefjellet (Fig. 2; Pl. 1, Fig. 1) and are covered with marine sediments only locally. Most terraces are mantled with soliflucted deposits, enclosing incorporated marine gravels. TL-dating of this terrace on the northern coast of Hornsund points out to the Wedel Jarlsberg Land Glaciation (*cf.* Lindner *et al.* 1991) *i.e.* Saalian. Shells of marine molluscs in northwestern Spitsbergen at 80 m a.s.l. were radiocarbon-dated at 26-40 ka (Salvigsen 1979, Salvigsen and Österholm 1982), whereas at 85 m a.s.l. in central Spitsbergen - at *ca* 21 ka (Feyling-Hanssen 1965). Thus, the authors expect this terrace to have been formed during the Bogstranda (Eemian) Interglacial or the older part of the Sörkapp Land (Vistulian) Glaciation. The terrace is bordered by an outstanding cliff (Werenskiold 1952-53), falling down to 20-40 m a.s.l. This cliff is transformed locally into skerries that reach up to 100 m a.s.l. but occur also beneath the cliff. Location of skerries is determined by resistance and tectonics of the bedrock.

Fragments of the marine terraces 20-40 m a.s.l. occur between the skerries. Thin, usually to 2 m, gravel covers were noted in Trollstabbane (southwestern foot of Kistefjellet) on more extensive surfaces than in Sörflyrabbane to the east. There are two distinct terraces at *ca* 25 and above 30 m a.s.l. in the northeastern part of the area, at foot of Keilhaufjellet, Svartkuven and Dumskolten, however reshaped by denudation. Thickness of gravels in the terrace *ca* 25 m a.s.l. reached up to 5 m (foot of Keilhaufjellet and Svartkuven; Figs 2-3). The terrace 20-40 m a.s.l. could be formed at the turn of the Pleistocene and the Holocene when Svalbard was subjected to rapid glacioisostatic uplifting (Feyling-Hanssen and Olsson 1960, Feyling-Hanssen 1965, Boulton 1979, Péwé *et al.* 1982, Salvigsen and Österholm 1982, Landvik *et al.* 1987). Rare datings of these terraces are

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Fig. 2. Map of Quaternary deposits of the southern Sörkapp Land
1 - rock outcrops with thin local mantle of weathered material, 2 - block-covered slope, 3 - talus cones, 4 - soliflucted and deluvial sediments, 5 - landslide sediments, 6 - fluvial and outwash sediments, 7 - glaciofluvial sediments, 8 - ice-cored morainic ridges, 9 - ground and ablation moraines, 10 - fluted moraines, 11 - rocky surfaces with roches moutonnées, 12 - boulder moraines, 13 - erratics, 14 - rock glaciers, 15 - raised marine terraces 2-19 m a.s.l., 16 - raised storm ridge at 9-10 m a.s.l., 17 - rocky marine terraces 15-18 m a.s.l. with single gravels, 18 - raised marine terraces 20-40 m a.s.l., 19 - skerries up to 100 m a.s.l. with raised marine terraces up to 40 m a.s.l., 20 - raised marine terrace 100-130 m a.s.l., 21 - relics of raised marine terrace 220-230 m a.s.l., 22 - peat, 23 - glaciers, 24 - lakes, 25 - sampling site for radiocarbon dating, 26 - geological section A-B (*cf.* Fig. 4)

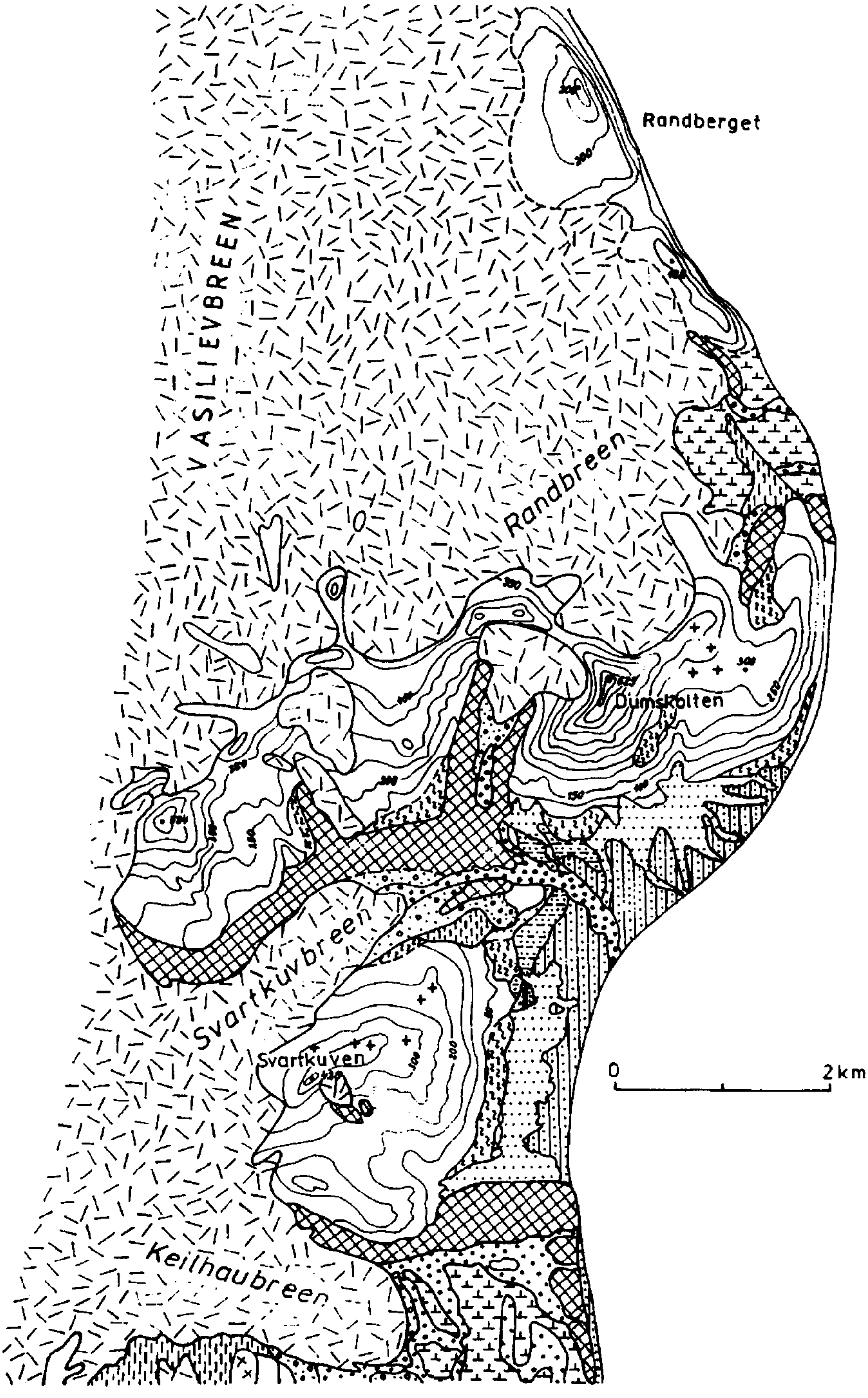

Fig. 3. Map of Quaternary sediments of the southeastern Sörkapp Land; for explanations *see* Fig. 2

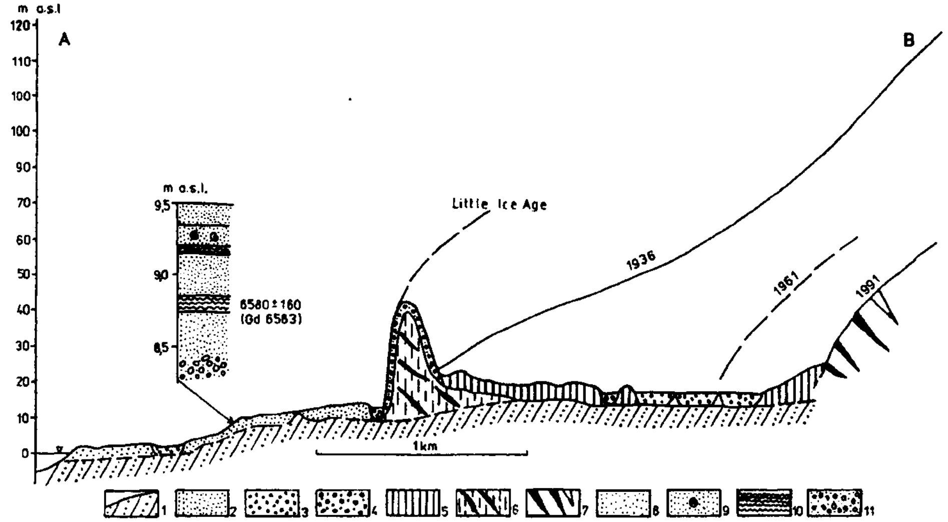

Fig. 4. Geological section A-B across a morainal zone and a forefield of the Mathias Glacier (*cf.* Fig. 2) 1 - bedrock, 2 - marine sediments, 3 - glaciofluvial sediments, 4 - ice-core mantled with till, 5 - ablation and ground moraines, 6 - dead ice with morainic material, 7 - glacier (its extent is indicated); excavation in a raised storm ridge: 8 - sand, 9 - sand with marine faunal remains, 10 - laminaria, 11 - gravel and sand

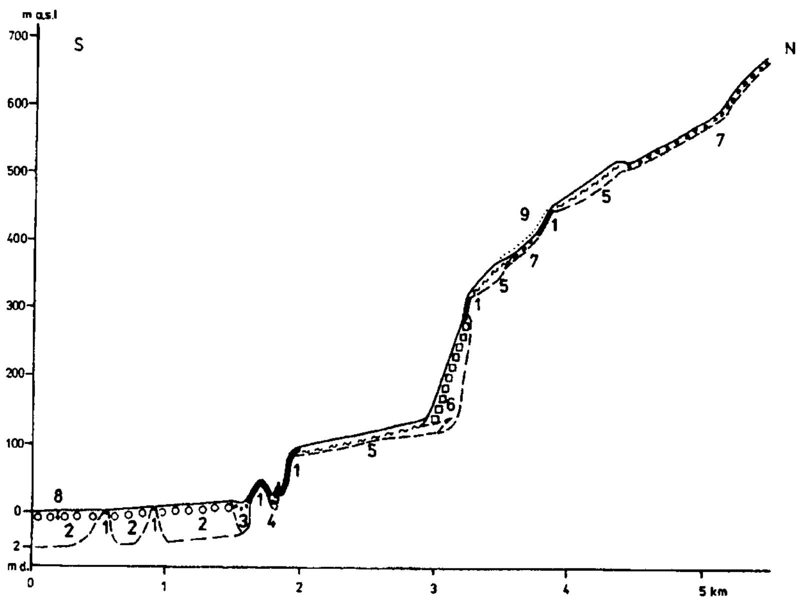

Fig. 5. Section from Sörkapphytta to Kistefjellet
1 - bedrock, 2 - marine sediments, 3 - fluvial sediments, 4 - peat and rubble, 5 - solifluction slope, 6 - talus slope, 7 - weathered waste, 8 - river, 9 - snow patch

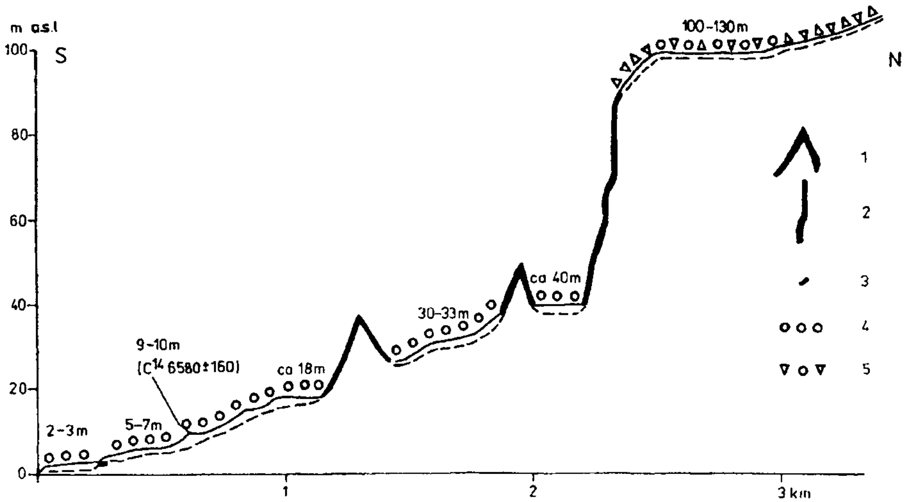

Fig. 6. Schematic section of raised marine terraces in the southern Sörkapp Land
1 - old skerries (Hecla Hoek rocks), 2 - rock edge (Hecla Hoek rocks), 3 - Triassic sandstones, 4 - marine sediments (to 2 m thick) on bedrock, 5 - marine gravels and weathering waste (0.5-1 m thick) on bedrock

from the area to the north of Hornsund but they cannot be referred to the southern Sörkapp Land which has been raised more rapidly.

The terraces up to 19 m a.s.l. (Figs 2-6; Pl. 1, Fig. 2; Pl. 2, Fig. 2) were formed during the Holocene as their superficial sediments above 11-12 m a.s.l. are older than 6.5 ka. There are several distinct abrasive-accumulative terraces (2-3, 4-8 and 9-11 m a.s.l., with particularly distinct coastal ridges at 9-10 and 14-18 m a.s.l.) to the west of the Mathias Glacier (Figs 2-6). It is difficult to distinguish these terraces to the east of the glacier because of monotonously rising altitudes of all the storm ridges up to 19 m a.s.l. (Fig. 2) and, especially on Skoltsletta, denudation of part of marine sediments.

Laminaria from the raised storm ridge below the Mathias Glacier at altitude of 9.5 m and depth of 0.7 m (Figs 4, 6), were radiocarbon-dated at 6580±160 B.P. (Gd-6583). Almost the same result was obtained from radiocarbon dating of a whalebone, collected by Eyles and Boulton on a coast of Bettybukta at similar altitude (Forman 1990). Some other datings of this altitude in western central Spitsbergen are very close (Péwé *et al.* 1982, Salvigsen 1984a, b, Landvik *et al.* 1987, Stankowski *et al.* 1989). However, the other datings from this altitude in western and northern Spitsbergen are 1-1.5 ka years older (Salvigsen and Österholm 1982, Salvigsen *et al.* 1990), and in the northern coast of Hornsund - 2-3 ka older (Birkenmajer and Olsson 1970). These data indicate that the Holocene uplifting was quicker in the southern Sörkapp Land than in the Hornsund Region and in northern Spitsbergen. It was also few times quicker than suggested by Boulton (1979) who located the southern Sörkapp Land beneath the isobase 2 m at 6.5 ka B.P. On the other hand, the uplifting rate was lower than in mid-eastern coast of Spitsbergen (Salvigsen and Mangerud 1991) and on islands of eastern Svalbard (Salvigsen 1978, 1981, Nagy 1984).

Distinct fragments of the terrace 5-7 m a.s.l., with substrate at 4-5 m a.s.l., are found further down *e.g.* at Sorneset. The lowest marine terrace is enlarged by marine deposition in bays, whereas headlands and peninsulas are wasted by abrasion. It seems possible to estimate deposition rate in Bettybukta, owing to discovered ruins of huts at distance of 100-130 m from a sea (Pl. 2). They are not older than the 17th century, if basing on historical data and degree of their preservation. Hence two big storm ridges with depressions from a land side and 100-120 m wide, were formed there during the last 300-400 years.

Glacial landforms and sediments

Retreat of glaciers was connected with decreasing thickness of glacial ice, both within tongues and firn fields. In result, the area occupied by glaciers has been reduced, being divided by outcropping roche moutonnées (Fig. 1). Deglaciation rate was estimated on the basis of fieldworks, analysis of a topographic map showing glacier extents in 1936 and air photos from 1961 and 1990. Maximum extent of glaciers of the Little Ice Age is indicated by frontal moraines and bigger agglomerations of erratics (Fig. 1). Glacier snouts have retreated significantly and different morainal zones were formed in indicated their forefields since 1936.

The lowest deglaciation rates are typical for the large Bjelopolski Glacier, almost stable before 1961. Only after this time, distinct retreat of the front (0.3 km) occurred. Thickness of melted ice can be estimated at 50 m there. Much larger values have been received for other glaciers (Fig. 1). The cirque Lynge Glacier has retreated *ca* 0.9 km since 1936. Total reduction of its thickness reached 50-60 m, or 1 m of ice a year. Similar rates are known for the southernmost glacier in Spitsbergen *i.e.* the Mathias Glacier. At present, its snout is *ca* 2 km from a maximum extent zone, demarcated by a frontal moraine; it occurred at distance of 1-1.1 km in 1936-1961, retreating the next 0.45-0.5 km during the last 30 years (Fig. 1). The glaciers Dumskolt and Svartkuv have retreated *ca* 1 km.

The Keilhau Glacier with a wide tidewater cliff in 1936, has diminished most. At present its front occurs *ca* 2 km from a sea. The glacier tongue, 20-50 m thick, has moved back 0.6-0.9 km in 1961-1991. The small Topp Glacier on northern slopes of Keilhaufjellet, was connected with the Keilhau Glacier in 1961. Now these glaciers are separated from each other by numerous roches moutonnées, 0.1-0.3 km wide. Single gravels and boulders, or a thin ablation moraine occur there locally. The Topp Glacier is a dead one probably. Similar disintegration of glaciers occurs to the west of Dumskolten (Fig. 1). Rocky outcrops appeared also in central part of the Bjelopolski Glacier. A relief of glacier bedrock influences such separation most.

In result of deglaciation the older relief is excavated *e.g.* structural rapids near the Topp Glacier or higher marine terraces near the Rand Glacier. All older deposits have been however removed. Glacial erosion is indicated in rocky rapids where glacial striae, to 5 m deep, were found. The glaciers seem to have remodelled the older relief insignificantly within their tongues. Glacial waters take much more important part in remodelling. In a morainal zone of the Rand Glacier, glacial rivers are cut into the Tertiary mudstones to *ca* 5 m.

Most glacial deposits in the described area come from the Little Ice Age. Ice-cored end and lateral moraines are the most clear and common. Almost all glaciers have the moraines apart from the Rand and the Keilhau glaciers, because they both ended in a sea still in 1936, being the surge glaciers (Leufaconnier and Hagen 1991).

There is an ice-cored semi-circular morainic ridge, 20-50 m high, in front of the Mathias Glacier (Fig. 3), composed of two-three secondary ridges. Between them, there are occasional water-filled depressions. Such end moraines are also in fronts of the Lynge and Dumskolt glaciers (Figs 2-3). They were formed during oscillations of the Little Ice Age. Ice-cored lateral moraines can be even higher and more extensive than the end moraines. The most outstanding lateral moraines, 50-70 m high, were formed by the Keilhau Glacier. They are composed of secondary ridges, the outer and central ones being the highest. These ridges are mantled with blocks and boulders, size and quantity of which decrease downwards. Similar lateral moraines are located at sides of the Dumskolt, Keilhau, Mathias, Lynge and Olsok glaciers (Figs 2-3).

Ice-cored ridges are covered with deposits, usually 0.5-2 m but maximum 5 m thick (Fig. 4). Gravels and blocks prevail on the surface, whereas content of clay and silts with single gravels and boulders, increases downwards. Ice cores are the thickest there. They consist of pure glacial ice, indicated in niches of small-debris mud landslides. Very thin sandy-clayey layers were observed in lower parts of lateral moraines of the Mathias and the Svartkuv glaciers only.

Particular ice-cored ridges are different from one another in their structure and lithology of bedrock. If the latter is composed of sandstones, there are many blocks and boulders in the morainic ridges. Material from Keilhaufjellet, delivered by the Topp Glacier, creates significant part of a lateral moraine of the Keilhau Glacier. If the bedrock is composed of non-resistant shales and mudstones, then clay prevails in morainic ridges, *e.g.* in moraines of the Bjelopolski and the Svartkuv glaciers, which are degraded due to melting of relic glacial ice and small debris-mud landslides. The end moraines of the Mathias and the Lynge glaciers are cut by short ravines of glacial rivers.

Thin patches of ground and ablation moraines occur directly on outcrops of older rocks between ice-cored moraines and glacier fronts. It seems difficult to distinguish a ground moraine from an ablation one, especially in forefields of the Olsok, Lynge and Mathias glaciers (Figs 2-3). These moraines consist of various clay-gravel deposits, up to 2 m thick, locally covered with glaciofluvial sediments. Significant part of glaciers has no ground moraine. The bedrock in forefields of the Mathias and the Keilhau glaciers is covered with very thin clay-gravel ground moraine, overlain with ablation one that forms boulder-gravel ridges.

Ice-worn rocky outcrops with a thin discontinuous fissured and fluted ablation moraine, are noted under melting ice. Vast areas of a fluted ablation moraine occur in forefields of the Keilhau (Pl. 3) and the Rand glaciers (Fig. 3). The recent geological map (Winsnes *et al.* 1991) indicates, probably by mistake, fluvial deposits instead of glacial ones in forefield of the Keilhau Glacier. Characteristic pattern of low ridges (up to 1 m high) built of gravel and sand, directly mantles rocky surfaces (Pl. 3, Fig. 2; Pl. 4, Fig. 1). They are arranged in narrow parallel belts, continued by fissures in glacier front and divided by depressions, locally with only single boulders and gravels on rocky outcrops. Morainic clays and silts, several centimetres thick, occur in forefield of the Keilhau Glacier in some depressions only. They are occasionally covered with glaciofluvial deposits (Figs 3-4) what results from frontal ablation of glaciers. Higher gravel-sandy ridges were formed inside longitudinal fissures of a glacier, and the lower ones - inside transversal fissures (Pl. 2, Fig. 3; Pl. 4, Fig. 1). Field investigations proved that higher ridges run almost perpendicularly from a glacier front to its forefield. They could be identified clearly in forefield of the Rand Glacier. There is obvious connection between such forms and linear relief of glacier fronts, confirming that the small ridges are traces of glacier superficial relief and indicate direction of glacier retreat (Lindner and Marks 1991a). Hence, such forms need not be only an indication of areal deglaciation as was suggested by Klimaszewski (1978).

Older glacial deposits in the southern Sörkapp Land were preserved as erratics. Their biggest accumulations occur on top flattenings and slopes of Dumskolten and Svartkuven up to 300-360 m a.s.l. Hence, the glaciers seem to have been much thicker in the past. Erratics were probably transported by glaciers during the Pleistocene Sörkapp Land (Vistulian) Glaciation (*cf.* Lindner and Marks 1991b) but they can be also older.

The raised marine terraces up to 30 m a.s.l., without any marine sedimentary cover, occur outside the morainic ridges. No glacial deposits were found on the terrace 100-130 m a.s.l. either. Hence, there are no traces of the Lower and Middle Holocene glacial advances beyond the extent of the Little Ice Age in the southern Sörkapp Land.

Rock glaciers

They occur on southern slopes of Keilhaufjellet and eastern ones of Kistefjellet. A small cirque glacier on Kistefjellet is buried with rock debris coming from the slopes. A typical rock glacier is located on southern slopes of Kistefjellet (Fig. 3).

Ancient extent of glacial ice, indicated by erratics, was much larger there. The glacier was mantled with rock debris, delivered from a steep slope. Debris accumulation gave occasion to plastic deformations of ice. The rock glacier is completely covered with debris, with ice subjected to plastic transformations and debris - to translocation, as evidenced by the glacier front (Pl. 4, Fig. 2); it is a debris-covered rock glacier according to classification of Lindner and Marks (1990).

Glaciofluvial and fluvial sediments

Glaciofluvial sediments form inner sandurs between glacier fronts and corresponding end moraines. They are very differentiated, from boulders and gravels to silt. Two sandur fans are in morainal zone of the Mathias Glacier (Fig. 3). Gravels and sands with single boulders, 3-4 m thick, occur in a river cutting of the older fan. The fan surface was still modified by glacial rivers in 1961. The second fan is formed at present. Glacial waters flow out a lake, dammed by the end moraine, through a short gorge. The extramorainal sandur is incised into older marine terraces downstream the gorge. There are numerous older glaciofluvial fans in the extraglacial zone. Older marine deposits were eroded and glacial rivers cut into a bedrock. Four zones of glaciofluvial fine-grained accumulation, indicating periodical stagnation of glacier front, can be distinguished in forefield of the Keilhau Glacier.

Fluvial fans are deposited at outlets of streams that drain snow patches and cut slopes. These fans are particularly extensive between a lateral moraine of the Keilhau Glacier and Dumskolten, and to the south of Keilhaufjellet. Fluvial deposits form wide and flat fans of different age on coastal plains, especially on Skoltsletta, Grunnvågsletta (Figs 2-3; Pl. 4, Fig. 2) and Öyrlandsleira. They consist of fine-grained sharp-edged gravel and of silt. Marine terraces are overlain by these fans.

Periglacial and slope deposits

Most of the described area is modelled by periglacial morphogenetic processes. They are active in marine, glacial, glaciofluvial, landslide and other deposits. In many places they create also new deposits. The latter are formed on solifluction slopes, especially on bedrock of the terrace 100-130 m a.s.l., and on extensive fragments of marine terraces which have been subjected to frost weathering and sorting, locally remodelling completely the older deposits. Thick accumulations at foot of Kistefjellet (Fig. 2) are modelled by solifluction, being replaced by frost sorting on flattenings. Solifluction deposits cover significantly smaller area at the foot of the mountains to the east (Fig. 3). Modelling of these deposits seems to have been mostly due to a sheetwash, as vegetation and typical solifluction microrelief are very scarce in this area.

Raised marine terraces are overlain with solifluction deposits, what could be observed on outcrops at foot of Dumskolten and Svartkuven, and at the western foot of Kistefjellet. Slope debris was noted at foot of Keilhaufjellet only, where it forms talus cones and screes, over 2 m thick (Fig. 2).

There are two big rocky consequent structural landslides on eastern slopes of Keilhaufjellet. The southern one consists of two parts, younger and older. The younger landslide has a thick block cover, falling down to a sea. Its structure and relief indicate rapid movement, resulting in disintegration of rock material. The older part is separated from a rock slope by a scarp and a trough, running from northeast to southwest and 5-8 m deep. The rock mass has been detached along the trough. There are bare rock layers along the front and cut by a sea. These fragments are rotated each to other what is indicated by different strike and dip of layers. The second landslide (to the north) has a niche in a rock wall, near the secondary ridge of Keilhaufjellet. There is a flattening with relics of ablation moraine within the landslide. Considerable differentiation of strike and dip of layers was noted in a few outcrops inside a lower part of the landslide. Marine gravels of the terrace 20 m a.s.l. occur under a landslide front. A small earthslide was noted on southern slopes of Kistefjellet.

Recapitulation

Sediments of raised marine terraces at different altitudes, locally with numerous ancient skerries, cover significant fragments of a non-glaciated area. Such terraces are typical for glacioisostaticly uplifted areas. Larger ones are connected with glacial retreats or advances. Extensive terraces from 12-13 to 19 m a.s.l. can be connected with a glacial advance of the Grönfjorden Stage (*cf.* Lindner and Marks 1990) during the Early Holocene. The following glacier retreat determined a glacioisostatic uplift of the area and development of the terraces up to 10 m a.s.l. They are well preserved, without any traces of marine abrasion. Beginning of this uplifting is indicated by the raised storm ridge at 9-10 m a.s.l., radiocarbon-dated at 6580±160 B.P. Traces of younger transgressions are unknown at present. Hence, a sequence of transgressions described by Chmal (1987, 1988) in the Hornsund Region, has no equivalent in the described area.

The Pleistocene glaciations were more extensive what is evidenced by erratics in mountain massifs. Erratics were not found, however, both on terraces up to 40 m a.s.l. (in forefields of contemporary glaciers) and on the terrace 100-130 m a.s.l. Hence extensive fragments of the southern Sörkapp Land must have been ice-free during the Vistulian Glaciation. The Holocene glaciations in the area were any more extensive than during the Little Ice Age, similarly as in some other areas of Spitsbergen. It seems also obvious from recent studies of vegetation evolution during the Holocene in Spitsbergen (*cf.* Birks 1991).

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Streszczenie

Objęty badaniami obszar południowego Sörkapp Land, jest oddzielony od pozostałej części wyspy lodowcami Vasiliev i Olsok oraz lodowym płaskowyżem Sörkappfonna (fig. 1). Występują tu fragmenty wysokich tarasów morskich 220-230 i 100-130 m n.p.m. (pl. 1, fig. 1). Ten ostatni opada wyraźnym klifem, przechodzącym miejscami w zespoły szkierów, między którymi zachowane są tarasy morskie 20-40 m n.p.m. (fig. 2). W północno-wschodniej części obszaru zachowały się fragmenty tarasów o wysokości ok. 25 m i ponad 30 m n.p.m. (fig. 3). Na podstawie niżej podanego datowania oraz literatury przedmiotu przyjęto, że są to osady z końca Vistulianu i początku holocenu, kiedy Spitsbergen podlegał stosunkowo szybkiemu wypiętrzaniu glaciizostatycznemu.

Holoceńskie tarasy sięgają do 19 m n.p.m. (fig. 2-6; pl. 1, fig. 2). Wyraźnie zachowany wał brzegowy o wysokości 9-10 m n.p.m. został wydatowany metodą radiowęgla na 6580±160 lat B.P. W Bettybukta odkryto ruiny chat, prawdopodobnie z XVII wieku, i na podstawie ich położenia stwierdzono, że od tego czasu utworzyły się dwa nowe wały brzegowe o łącznej szerokości 100-120 m (fig. 1, pl. 2).

Na podstawie badań terenowych, mapy topograficznej oraz norweskich zdjęć lotniczych z lat 1961 i 1990 ustalono wielkość deglacjacji (fig. 1). Najmniejszej recesji uległ lodowiec Bjelopolski (około 0,3 km). Najbardziej zmniejszona została powierzchnia lodowca Keilhau, występującego na wschodnim wybrzeżu. Obecnie jego czoło znajduje się 2 km od brzegu morza, podczas gdy w 1936 roku tworzyło ono klif lodowy. Oprócz topnienia jęzorów lodowcowych, stwierdzono również wytapianie lodu w polach firnowych, gdzie odsłaniają się zmutonizowane powierzchnie skalne.

Wśród form polodowcowych na pierwszy plan wysuwają się kilkudziesięciometrowej wysokości wały lodowo-morenowe tworzące zespoły moren czołowych i bocznych, systemy stożków fluwioglacjalnych oraz równiny moreny dennej i ablacyjnej żłobkowej (fig. 2-4). Szczegółowo scharakteryzowano je na przedpolu lodowców Mathias i Keilhau (pl. 3; pl. 4, fig. 1), gdzie materiał morenowy leży bezpośrednio na wychodniach skalnych. Starsze osady glacjalne zachowały się w postaci eratyków na wysokościach 300-360 m n.p.m. Stwierdzono, że zlodowacenia holoceńskie nie przekroczyły zasięgu wałów morenowych z Małej Epoki Lodowej. Osadów lodowcowych nie odnaleziono ani na tarasach do 40 m n.p.m. (na przedpolach współczesnych lodowców), ani na tarasie 100-130 m n.p.m. Świadczy to o tym, że duże fragmenty południowego Sörkapp Land nie były zlodowacone w Vistulianie.

Na południowych stokach Keilhaufjellet oraz wschodnich stokach Kistefjellet występują lodowce gruzowe (fig. 2). Lód lodowcowy został zasypany gruzem skalnym dostarczonym ze stromych sto-

ków. W wyniku akumulacji rumoszu lód lodowcowy podlega deformacjom plastycznym, a gruz jest przemieszczany, na co wskazuje wyraźnie ukształtowane czoło lodowca gruzowego na południowych stokach Keilhaufjellet (pl. 4, fig. 2). Natomiast na wschodnich stokach tego masywu występują dwa duże osuwiska strukturalne.

Obszar południowego Sörkapp Land posiada system skalno-akumulacyjnych tarasów morskich, charakterystycznych dla obszarów podnoszonych izostatycznie. Nie stwierdzono, śladów transgresji morskich na wyższe i starsze poziomy tarasowe, o czym świadczą dobrze zachowane wały sztormowe, z których jeden - datowany na środkowy holocen - opisano powyżej.

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1. Trollstabbane: raised marine terraces up to 40 m a.s.l. and 100-130 m a.s.l. July 1991
2. Skoltsletta: sea coast and marine sediments on the bedrock. July 1991

1. Bettybukta: ruins of a Pomor hut from the 17th century and two storm ridges, 100-120 m wide. July 1991
2. Bettybukta: storm ridges, marine terraces, fluvial plains, moraines of the Dumskolt Glacier; view from a coast. July 1991

1. Keilhau Glacier: morainal zone deglaciated after 1936; view from the south. August 1991
2. Keilhau Glacier: morainal zone, fluted moraine. August 1991

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1. Keilhau Glacier: morainal zone, fluted moraine. August 1991
2. Grunnvågsletta and Keilhaufjellet: raised marine terraces, fluted plain and cones, rock glacier in the centre, talus and rocky slopes above. August 1991