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Evolution of the Interlobal Zone of the Torell Glacier (Torellbreen), Spitsbergen

Ewolucja strefy interlobalnej lodowca Torella na Spitsbergenie

Эволюция интерлобальной зоны ледника Торелла на Шпицбергене

INTRODUCTION

The interlobal zone of the Torell Glacier (Torellbreen) in West Spitsbergen (Wedel Jarlsberg Land) forms an isolated, difficult of access, non-glaciated land fragment (Fig. 1, annexed map). It is surrounded from the North, East and South-East by lobes of the Torell Glacier (vestre Torellbreen and austre Torellbreen) as well as smaller glaciers: Profilbreen, Skoddebreen and Ratisen, flowing down the nunataks of Raudfjellet and Tanngerden (Fig. 2). In the southwest, this interlobal zone forms an indistinct bulge of a shoreline between the sea bays Skodde (Skoddebukta) and Isfjell (Isfjellbukta) of the Greenland Sea. About a kilometre far from the interlobal zone there is in a sea, as a natural continuation, the Island Insöya that forms the north western end of a small extended archipelago of the Isöyane (Fig. 2).

The interlobal zone is composed of two principal parts: the mountain massif with peaks of Raudfjellet (1014 m a.s.l.), Krakken (537 m a.s.l.), Högsoetet (802 m a.s.l.), Oksegga (910 m a.s.l.) and Glöersenfjellet (831 m a.s.l.) as well as the coastal plain of Torellkjegla that passes northeastwards towards the mountain massif, into the median moraine of Torellmorena (Fig. 2). Most probably, a difficult access of this area made it to have been devoid before 1980 of detailed and in the same time, complex geological and geomorphological investigations. The general geological map of South Spits-bergen in a scale of 1 : 500.000 (Flood, Nagy and Winsnes 1971) presents only that the mountain massif of the interlobal zone is composed of Proterozoic carbonate, pelitic rocks and green slates of the Middle Hecla Hoek formation. Carbonate rocks of the same age are also marked on nIsöya. The other papers dealing with this area are small contributions only. One of them informs of thermal springs at the margin of the austre Torellbreen and Raudfjellet (Migała and Sobik 1982) whereas the other presents the uncomplete extent of the Torell Glacier cliff (mainly of the austre Torell-

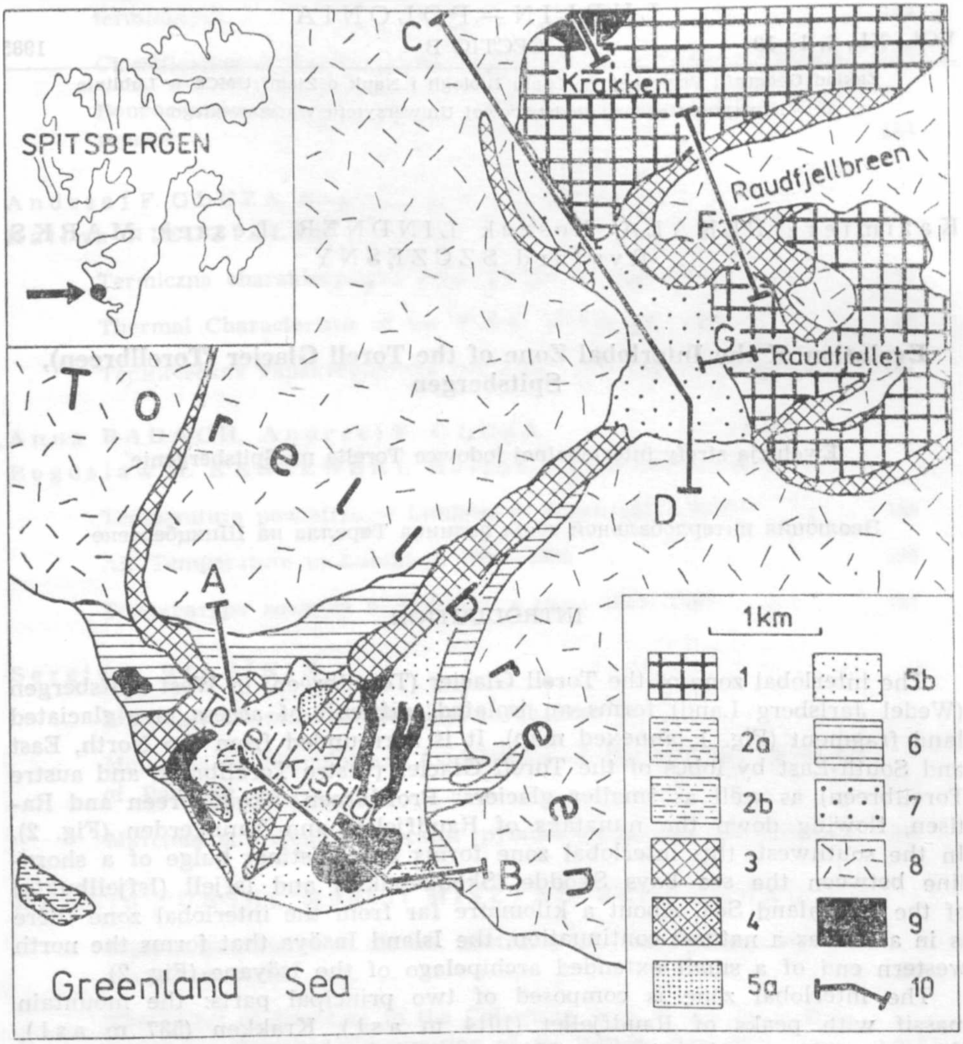

Fig. 1. Schematic geomorphologic-geologic sketch of the interlobal zone of the Torell Glacier: 1 — mountains; raised marine beaches: 2a — at 10—18 m a.s.l., 2b — at 5—6 m a.s.l.; 3 — ice-cored marines; 4 — push moraines; extramorainal outwash: 5a — older, 5b — younger; 6 — ablation till, 7 — ice-dam lake sediments; 8 — glaciers, 9 — lakes; 10 — geologic sections

Szkic geomorfologiczno-geologiczny strefy interlobalnej lodowca Torella: 1 — góry; podniesione terasy morskie: 2a — 10—18 m n.p.m., 2b — 5—6 m n.p.m; 3 — wały lodowo-morenowe; 4 — moreny spiętrzone; sandr ekstramarginalny: 5a — starszy, 5b — młodszy, 6 — glina zwałowa ablacyjna; 7 — osady jezior zaporowych; 8 — lodowce, 9 — jeziora; 10 — przekroje geologiczne breen) in 1982, based on terrestrial photogrammetric works (Jania and Kolondra 1982).

Fieldworks in the interlobal zone were carried through in August 1980 by K. Pękala. At that time the geomorphological features were mapped as well as samples of deposits of push moraines were collected for thermoluminescence datings. The latter were done by Dr. J. Butrym in the Thermoluminescence Laboratory of the Institute of the Earth Sciences, M. Curie-Skłodowska University of Lublin. The received data were used for the stratigraphy of the Middle Pleistocene sediments in the Hornsund region (Lindner, Marks and Pękala 1983, 1984).

Also the access to Norwegian air photos of this area in a scale of about 1 : 50.000 and done in 1960, owend by the Institute of Geophysics, Polish Academy of Sciences, and the Institute of Land-Surveying and Cartography, Head Office of Land-Surveying and Cartography, allowed to prepare the photogeologic map in the scale of 1 : 10.000 annexed to this volume (Szczęsny, Lindner, Marks and Pękala 1985). A preparation of the map was based on the previously presented method (Lindner, Marks, Ostaficzuk, Pękala and Szczęsny 1985 in press, 1986 in press) and continues a series of such maps prepared by the authors for West Spitsbergen (Ostaficzuk, Lindner and Marks 1982, 1986 in press, Ostaficzuk, Marks and Lindner 1980).

The works connected with a preparation of this paper and of the annexed map were partly supplied by the grant within the interdepartmental project MR-I.29 whereas the edition of this map was founded by the Institute of the Earth Sciences, M. Curie-Skłodowska University of Lublin.

This paper is the attempt of a complex description of the interlobal zone of the Torell Glacier with its morphogenesis, similarly as the previous authors' papers on the Hornsund region (Lindner, Marks and Ostaficzuk 1982, 1984, 1986 in press).

RELIEF AND QUATERNARY DEPOSITS

Fieldworks and the photogeologic analysis resulted in 31 geologic-geomorphologic distinguished units in the interlobal zone of the Torell Glacier. They are put into 4 main genetic groups (annexed map): slope landforms (symbols 1—5); glacial and nival landforms and sediments (symbols 6—21); marine terraces (symbols 22—24); lake landforms and sediments (symbols 25—31). Aeolian covers (symbol 32), gorges (symbol 33) are distinguished separately, as well as two topographic elements (symbols 34 and 35).

SLOPE LANDFORMS

The northeastern part of the area is occupied by the massifs of Krakken and Raudfjellet, composed of metamorphic rocks of the Hecla Hoek Formation. They are usually mantled with a waste cover (symbol 1) whereas mountain crests (symbol 2) and steep slopes are devoid of them. At the western slope of the Krakken massif there are rock outliers (symbol 3) within the landslide fans. They are also noted in the Torellkjegla area: at the extramorainal outwash (Phot. 8, 13) and within the floody-outwash zone with icings.

The photogeologic analysis of slopes of the Raudfjellet and Krakken massifs enabled to distinguish on them several immense systems of landslide fans (symbol 5) and chutes (symbol 4). The latter are the collectors of snowy--stony avalanches and of nival waters coming from melting snow patches. The landslide fans get down on lateral ice-cored moraines or are hanging

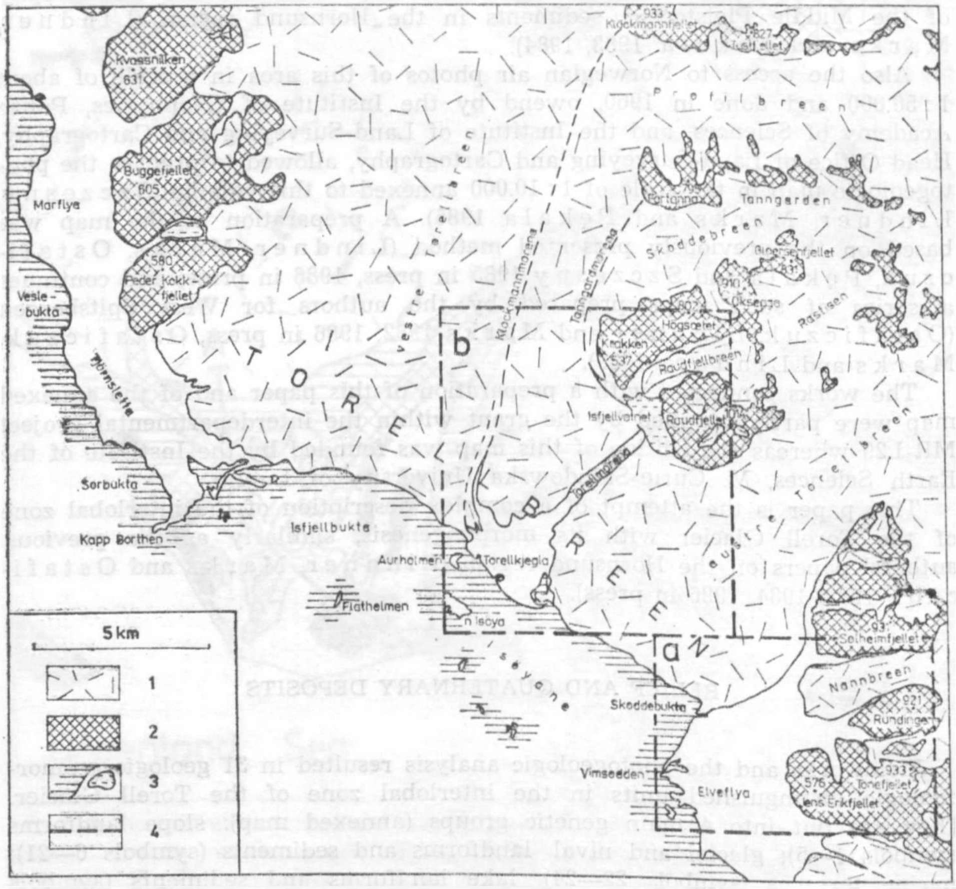

Fig. 2. Location of prepared photogeologic maps in the Torell Glacier area on the Norwegian topographic map in the scale of 1 : 100.000 (Norge, Topografisk Kart over Svalbard... 1953): 1 — glaciers (extents in 1936), 2 — mountains, 3 — shoreline and lakes in 1936, 4 — photogeological maps in the scale 1 : 10,000 prepared by the authors: a — Ostaficzuk, Marks and Lindner (1980), b — Szczęsny, Lindner, Marks and Pękala (1985)

Lokalizacja wykonanych map fotogeologicznych rejonu lodowca Torella na norweskiej mapie topograficznej w skali 1 : 100 000 (Norge Topografisk Kart 1953): 1 — lodowce (zasięg z 1936 r.), 2 — masywy górskie, 3 — linia brzegowa i jeziora w 1936 r., 4 — mapy fotogeologiczne w skali 1 :100 000 wykonane przez autorów: a — Ostaficzuk et al. (1980), b — Szczęsny et al. (1985)

in higher parts of slopes. A development of hanging fans depends either on outlier type of outcrops on the slope and deposition below weathering waste, or can result from a removal of the lower part of the fan by glaciers during their wider extent.

GLACIAL AND NIVAL LANDFORMS AND SEDIMENTS

Now most of the area is covered by glaciers whereas in the zone devoid of compact glacial ice, still glacial sediments and landforms predominate. A compact glacal ice (symbol 6) forms the snouts of glaciers that move down the mountains to the north of the massif Raudfjellet — Krakken (Fig. 2). Starting from the west there are the lobes of vestre Torell, Profil, Skodde and austre Torell glaciers. Besides, the pass between Krakken and Raudfjellet is occupied by the relic Raudfjell Glacier that goes down the southwestern

Table 1. TL datings of deposits from the Torellkjegla area

Datowania metodą termoluminescencji osadów w obszarze Torellkjegla

Dated deposits	Annual dose of radiction measured by			
	dosimetric method		spectrometric method	
	Laboratory dating No	Age (TL ka)	Laboratory dating No	Age (TL ka)
till	Lub — 228	73±9.5–209±27	———	———
till	Lub — 229	225± 30	———	———
marine clay	Lub — 230	413 ± 62	Lub – 906	383 ± 57
till	Lub — 231	313 ± 47	Lub – 907	284 ± 42
sand	Lub — 232	222 ± 40	Lub – 908	182 ± 27
gravel	Lub — 233	220 ± 33	Lub – 909	190 ± 28
till	Lub — 234	229 ± 34	Lub – 910	189 ± 28
aeolian sand	Lub — 235	8 ± 1.2	———	———

foot of the mountain massif. Relic glacial ice is also noted (partly under a snow) in hanging glacial cirques located on northern and southern slopes of Raudfjellet (Phot. 1). The snouts of the glaciers vestre Torell and austre Torell end with ice cliffs (up to 50 m high) in the Isfjell (Phot. 2) and Skodde (Phot. 3 and 4) bays, respectively.

A characteristic arrangement of crevasses in ice is worth mentioning: they are more common in marginal zones of every glacial lobe and besides, most of them are parallel to ice edges (annexed map and Phot. 4).

Push moraines (symbol 7 are the most out standing glacial features in the extraglacial zone. A particulary large push moraine, about 2 km long and to 30 m high, occurs in the central part of Torellkjegla (annexed map, Phot. 5, 6, 7, 8,). It forms a homogeneous feature, cut by a glacial stream in the north. Farther southwards there is an older, now dry and hanging, gorge (Phot. 7). This moraine is composed of glaciodislocated ancient marine clays (Fig. 3, Pho . 8), covered in the east by the ablation moraine (Fig. 3, Phot. 6). Two smaller push moraines are noted near the coastline of Torellkjegla, just in the forefield of the southern edge of the austre Torell Glacier that still stands on a land (annexed map). A cliff exposure of one of these moraines supplied with samples of sediments for thermoluminescence datings (Fig. 3, 4, Phot. 3, 9, Table 1). The core of this moraine is composed of glaciodislocated marine clays of the overturned fold. Probably these clays are of the same age as the ones noted in the mentioned previously ridge-like push moraine in the central part of Torellkjegla (Phot. 8, ryc. 3). The clays from the exposure were thermoluminescence (TL) dated in the grain size of 56—50 μ by two methods, based on different type of measurements of the annual radiation dose: by dosimetric method with a use of LIF dosimeters and by spectrometric method (B u t r y m 1981). The marine clays were dated by dosimetric method for 413 ± 62 ka and then, when larger samples were accessible, by spectrometric method for 383 ± 57 ka (Table 1, Fig. 4). Therefore, they

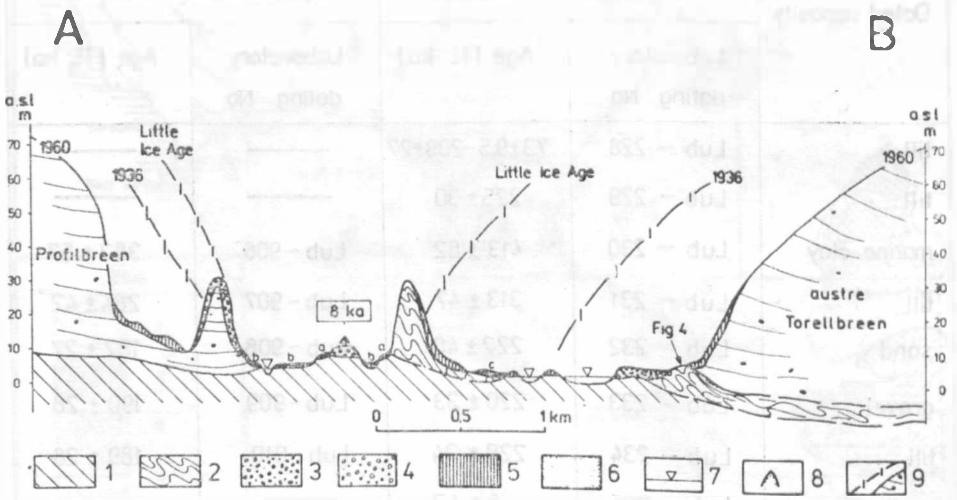

Fig. 3. Schematic geologic section of the Torellkjegla region: 1 — bedrock, 2 — glaciodislocated deposits, 3 — marine shingle, 4 — ice-cored morainic deposits, 5 — ablation till, 6 — gravels and sands of older (a) and younger (b) extramorainal outwash, and intramorainal outwash (c), 7 — present lagoon level, 8 — thermoluminescence dated aeolian sands, 9 — glacial extents and their probable age
Schematyczny przekrój geologiczny przez obszar Torellkjegla: 1 — podłoże skalne, 2 — osady zaburzone przez lodowiec, 3 — żwiry morskie, 4 — osady wałów lodowo-morenowych, 5 — glina zwałowa ablacyjna, 6 — żwiry i piaski starszego (a) i młodszego (b) sandru ekstramarginalnego oraz sandru intramarginalnego (c), 7 — obecny poziom wody w lagunach, 8 — piaski eoliczne datowane metodą termoluminescencji, 9 — zasięgi lodowców i ich przypuszczalny wiek

are the oldest Quaternary sediments noted up to now in this part of Spitsbergen. They represent the Torellkjegla Interglacial (Lindner, Marks and Pękala 1983, 1984). The marine clays are enveloped by a till, dated by dosimetric method for 313 ± 47 ka (by spectrometric method for 284 ± 42 ka) and then by sands dated for 222 ± 40 ka (182 ± 27 ka), gravels 220 ± 33 ka (190 ± 28 ka) and the other till, TL dated for 229 ± 43 ka and 225 ± 30 ka (189 ± 28 ka). The younger glaciodislocated sands and gravels were not dated (Fig. 4). These two tills and the separating sandy-gravel deposits represent two glacial advances during the Wedel Jarlsberg Land Glaciation (Lindner, Marks and Pękala 1983, 1984). All the described sediments are covered by a till (Fig. 4). Its TL dosimetric dating proved a large age interval from 73 ± 9.5 ka to 209 ± 27 ka (Table 1). It can result from incorporation of older tills by the austre Torell Glacier during the Sörkapp Land Glaciation (Lindner, Marks and Pękala 1983, 1984).

Median ice-cored moraines (symbol 8) are the other outstanding features of this area. They are subjected to intensive melting of buried glacial ice (annexed map). Such moraines separate the Profil Glacier from the other glaciers: austre Torell (Torellmorena), vestre Torell (Klockmannmorena) and Skodde (Tanngardmorena). Median ice-cored moraines are up to 40 m high Torellmorena — Phot. 1) but they are less and less distinct upglacier, passing in the end into flat strip-like concentrations of glacial drift on the ice surface.

Along the glacial margins there are usually terminal and lateral ice-cored moraines (symbol 9). The median ice-cored moraines generally contact with terminal ones. Both, terminal and lateral ice-cored moraines do not form continuous ridges along the glacial margins but are subjected to varying (in rate and scale) degradation caused by melting of ice cores. This phenomenon is particulary distinct at the terminus of the vestre Torell Glacier, the terminal moraine of which reaches the present coastline storm ridge and is very low (several metres) close to the sea (annexed map, Phot. 2, 10).

A most continuous system of terminal and lateral ice-cored moraines occurs around a small tongue of the Raudfjell Glacier and also, at the outlets of hanging glacial cirques on the Raudfjellet slopes (annexed map, Phot. 1). In the last case the terminal ice-cored moraines are already intensively transformed into moraine rock glaciers (Lindner and Marks 1985).

The confrontation of lateral ice-cored moraines of 1936 (Fig. 2) with air photos of 1960 suggests that the moraines at the foot of western and northern slope of Krakken are subjected to the specific inversion: they are quite quickly degraded and replaced by ice-dam lakes (Fig. 4), located in depressions formed due to glacier movement and increased ablation (caused by warmer rocks).

A degradation of the buried glacial ice results in formation of solifluction covers (symbol 10) on the median ice-cored moraine of the Torell Glacier (Torellmorena; annexed map, Phot. 1) as well as on its southwestern continuation of the push moraine (annexed map).

In the interlobal zone a considerable area is occupied by the ablation moraine. It occurs among others on rock outliers (symbol 11) in the floody-outwash zone between the austre Torell Glacier snout and the push moraine in the central part of Torellkjegla (annexed map). But firstly it covers a dead glacial ice (symbol 13) or its elevations (symbol 12), particularly in the fore-

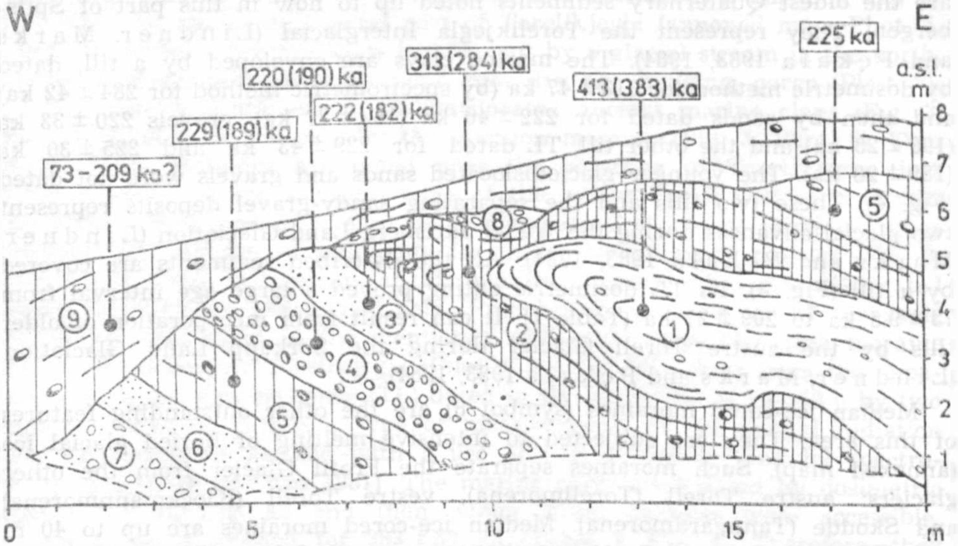

Fig. 4. Torellkjegla, an exposure with glaciodislocated deposits (Fig. 3). Sampling sites and TL datings of the sediments by dosimetric and spectrometric methods are shown (Table 1). Torellkjegla Interglacial: 1 — marine clays Wedel Jarlsberg Land Glaciation: 2 — till, 3 — fine-grained and medium-grained sands, 4 — gravels, 5 — till, 6 — stratified sands, 7 — stratified gravels and coarse-grained sands; Sörkapp Land Glaciation: 8 — gravels, 9 — till

Torellkjegla, odsłonięcie z osadami zaburzonymi glacitektonicznie (por. ryc. 3). Zaznaczono miejsca pobrania próbek i datowania TL osadów metodą dozymetryczną i radiometryczną (por. tab. 1). Interglacjał Torellkjegla: 1 — iły morskie zlodowacenia Wedel Jarlsberg Land, 2 — glina zwałowa 3 — piaski drobno- i średnioziarniste, 4 — żwiry, 5 — glina zwałowa, 6 — piaski warstwowane, 7 — warstwowane żwiry i piaski gruboziarniste: zlodowacenia Sörkapp Land, 8 — żwiry, 9 — glina zwałowa

field of the vestre Torell and Profil glaciers (annexed map, Fig. 3, Phot. 10, 11, 12) but also on the eastern slope of the central push moraine (Fig. 3, Phot. 6). The ablation moraine is also underlain by a compact glacial ice (symbol 14) at the margin of Profil, Skodde and austre Torell glaciers (annexed map, Phot. 1). It forms on the latter narrow strips that go up the glacier surface to about 90 m a.s.l. (annexed map). In the forefield of the Profil Glacier, the marginal part of the ablation moraine is cut by three gorges of the meltwater river system (annexed map, Phot. 13, 14, 15).

But the dead glacial ice noted in cores of ice-cored moraines, there are also its three small patches (symbol 15) in marginal zones of the Profil and austre Torell glaciers, at the contact and within the lake sediments (annexed map).

In the Torellkjegla area there are two levels of the extramorainal outwash and the intramorainal outwash (annexed map). The older extramorainal outwash (symbol 16) is preserved only in fragments at 8—12 m a.s.l., adjoining to the western slope of the central push moraine, relics of the raised marine beach 10—18 m a.s.l. and rock outliers (Fig. 3, Phot. 8, 13). It is locally covered with aeolian sands (symbol 32). The younger extramorainal outwash (symbol 17) forms a compact level at 4-9 m a.s.l., located between the central push moraine, ablation moraine of the Profil Glacier and terminal ice-cored moraine of the vestre Torell Glacier (Fig. 3, Phot. 8, 13, 14).

The occurrence of hanging fragments of both these outwash levels at the eastern side of the central push moraine, near the present dry gorge that passes across this moraine (Phot. 7) and a general southwestern sloping of both levels, together with their absence in the area between the central push moraine and the snout of the austre Torell Glacier (annexed map), prove that the extramorainal outwash was formed during a standstill of the austre Torell Glacier snout along the central push moraine.

The intramorainal outwash is noted only at the eastern side of the central push moraine (annexed map, Fig. 3), generally at 0—10 m a.s.l. The outwash surface is polygenic: it was formed due to erosion of the ablation moraine (symbol 18a) or deposition of sandy-gravel sediments — symbol 18b (Phot. 5, 7, 16). The surface of the intramorainal outwash is connected with the water flow from the north southwards, from the forefield of the Profil Glacier (Phot. 15) and along the Torellmorena Phot. 5).

On the surface of lake sediments at the foot of the southeastern slope of Raudfjellet and the southern slope of Krakken, there are outwash fans and trains (symbol 19), connected with periodical emptying of ice-dam lakes located at the foot of Krakken as well as with draining of the Raudfjell Glacier and the hanging glacieret in the southern slope of Raudfjellet (annexed map).

A considerable part of the area between the central push moraine and the edge of the austre Torell Glacier is occupied by the icings — symbol 20 (annexed map, Phot. 5, 7, 17, 18). It is the ephemeral phenomenon, probably connected with a periodical (yearly: in autumn and early winter) rapid outflow of waters from the ice-dam lake at the foot of Raudfjellet and Krakken, with possible outflow of thermal waters (Migała and Sobik 1982).

In the whole area presented on the map there are patches of perennial snow (symbol 21), collected in depressions on glaciers, glacial sediments and mountain slopes.

MARINE TERRACES

In the described area there are two distinct raised marine terraces (annexed map): 10—18 m a.s.l. (symbol 22) and 5—6 m a.s.l. (symbol 23), and the present storm ridge (symbol 24).

The marine terrace 10—18 m a.s.l. occurs in the Torellkjegla area (Phot. 8) and on the nIsöya Island (Phot. 16). It is composed of quite well rounded pebbles that overlie the bedrock. Their thickness is small as proved by many a time outcropping rock outliers. In the area between the Profil Glacier and the central push moraine this terrace forms three islands that stick up the surrounding outwash levels. This terrace is considerably covered by aeolian sediments, similary as the higher level of the extramorainal outwash. The bottom series of these aeolian sediments were TL dated for 8±1.2 ka (Fig. 3,

Table 1) whereas a fossil flora, buried by the recent aeolian sediment, was radiocarbon dated for 1830±60 BP (Gd—2075).

These datings as well as a palaeogeomorphologic analysis of the Torellkjegla area, suggest that the central part of this interlobal zone and the nIsöya Island were outside the glacier-occupied area not only during the Little Ice Age but also during the late part of the Sörkapp Land Glaciation (= Vistulian).

The terrace 5—6 m a.s.l. is preserved only at the southwestern part of the nIsöya Island (annexed map). During the photogeologic analysis it was found that linear phototones were visible from under the surface of the intramorainal outwash in the eastern part of Torellkjegla. Therefore, this outwash seems to have been partly deposited on a destructed raised marine beach.

The present storm ridge is the most distinct and, at the same time, the most widely expanded element of a marine relief in the described area. It forms a distinct and almost continuous ledge along the southwestern shore of Torellkjegla, closing numerous deep and vast lagoons (annexed map, Phot. 2, 3, 16). In the southeastern part of the Torellkjegla seashore it smooths the coastline but also forms several islands in the lagoon area (annexed map). With a strict relation to the sea level, this ridge is from several centimetres to about 2 m high.

LAKE LANDFORMS AND SEDIMENTS

In the southeastern part of the area, in the depression located between the massifs of Raudfjellet and Krakken and bordered in the south by the Torell Glacier while in the north by the marginal zone of the Raudfjell Glacier, there is an expanse covered by sediments of ancient ice-dam lakes (annexed map). These sediments are composed of at least several metre thick silty-sandy series that are most probably usually underlain by pre-Quaternary rocks but also by glacial deposits or dead glacial ice (ryc. 5). Due to the photogeological analysis they could be precisely demarcated and subdivided into four distinct devels (symbols 25—28), connected with various evolution phases of the lakes.

The highest lake level is located at 120—160 m a.s.l. (symbol 25). In the northeast it adjoins the slope of Krakken and the covering landslide fans whereas at the opposite side it contacts with the Skodde Glacier (annexed map, cf. Fig. 2). In the south the sediments of this level are delimited by the ice-cored moraine close to the slope of the Krakken massif. The morphology of the surface of lake sediments of this level and confrontation with 1936 (Fig. 2) suggest these sediments could have been deposited at the previous southernmost fragment of the mentioned lateral ice-cored moraine (Fig. 5). In a way, such palaeogeomorphologic situation resembles the ice-dam lake of 1960, existing at the northern side of the Krakken massif (annexed map, Fig. 5) in the place of the ice-cored moraine that still occurred there in 1936 (Fig. 2). Considering the fact that the loosing of waters by this lake resulted in erosion of ice-dam lake sediments at lower level (formed at the end of thirties), then the highest-level lake sediments were deposited at the end of forties (annexed map). The lower lake sediments (symbol 26) form the plain at 30—80 m a.s.l. and, as mentioned previously, were deposited at the end of

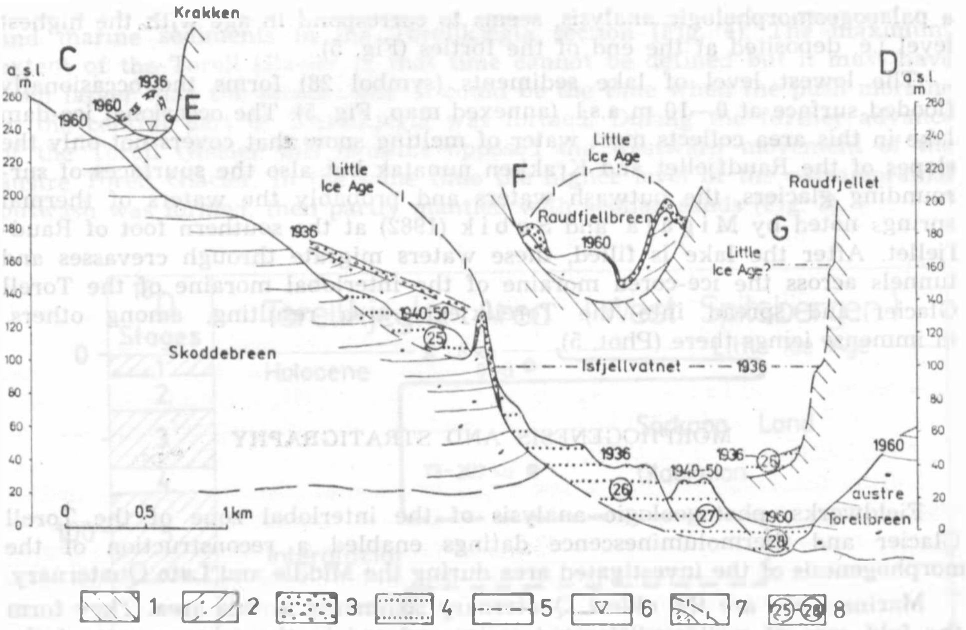

Fig. 5. Schematic geologic sections of the Raudfjellet-Krakken region: 1 — bedrock, 2 — glacial ice, 3 — ice-cored morainic deposits, 4 — lake sediments, 5 — ancient lake level, 6 — lake level in 1960, 7 — glacial extents and their probable age, 8 — numbers of symbols of lake sediments (see annexed map)

Schematyczny przekrój geologiczny przez rejon Raudfjellet — Krakken: 1 — podłoże skalne, 2 — lód lodowcowy, 3 — osady wałów lodowo-morenowych, 4 — osady jeziorne, 5 — dawny poziom jeziora, 6 — poziom jeziora w 1960 r., 7 — zasięgi lodowców i ich przypuszczalny wiek, 8 — symbole osadów jeziornych (por. zał. mapa)

the thirties (Fig. 5). They occupy a considerable area just in the forefield of the Raudfjell Glacier, the ice-cored moraine of which delimits them in the north (annexed map). Taking into account a distinct sloping of the surface of these sediments southwards, as well as traces of erosive trains and mantling of this surface by outwash sediments of the Raudfjell Glacier, the latter must have influenced considerably the lake series of this level. At the western slope of Raudfjellet the extent of the lake of this time is marked by the strandline at about 100 m a.s.l. (annexed map, Fig. 5). It proves that the lake was from over twenty metres in the north to about a hundred metres deep in the south.

Besides, the western slope of Raudfjellet possesses another abrasion strandline at about 160 m a.s.l. (annexed map, Fig. 5). The southernmost part of this strandline is covered by the ice-cored moraine of the rock glaciers from the cirque on the southern slope of Raudfjellet (annexed map, Phot. 1). This strandline was probably formed during the maximum extents of glaciers of the Little Ice Age or earlier.

Still a lower level of lake sediments (symbol 27) occurs at 10—30 m a.s.l. (annexed map, Fig. 5). It is younger than the previous one and, basing on a palaeogeomorphologic analysis, seems to correspond in age with the highest level i.e. deposited at the end of the forties (Fig. 5).

The lowest level of lake sediments (symbol 28) forms the occasionally flooded surface at 0—10 m a.s.l. (annexed map, Fig. 5). The occasional ice-dam lake in this area collects most water of melting snow that covers not only the slopes of the Raudfjellet and Krakken nunatak but also the suurfaces of surrounding glaciers, the outwash waters and probably the waters of thermal springs noted by Migała and Sobik (1982) at the southern foot of Raudfjellet. After the lake is filled, these waters migrate through crevasses and tunnels across the ice-cored moraine of the interlobal moraine of the Torell Glacier and spread into the Torellkjegla area resulting, among others, in immense icings there (Phot. 5).

MORPHOGENESIS AND STRATIGRAPHY

Fieldworks, photogeologic analysis of the interlobal zone of the Torell Glacier and thermoluminescence datings enabled a reconstruction of the morphogenesis of the investigated area during the Middle and Late Quaternary.

Marine clays are the oldest Quaternary sediments in this area. They form the fold core of a glaciodislocated series exposed in the eastern part of the Torellkjegla area. The origin and age of these sediments, dated for 413 (385) ka ascribed them to the warm interval, named the Torellkjegla Interglacial (Fig. 6; Lindner, Marks and Pękala 1983, 1984). This interglacial is to be correlated with the $^{18}0$ stage 11 of deep-sea sediments, dated by Shackleton and Opdyke (1973) for 440—367 ka. In Central Europe this period is named the Mazovian (Holstein, Likhvin) Interglacial.

During the following cooling, named the Wedel Jarlsberg Land Glaciation in this part of Spitsbergen (Lindner, Marks and Pękala 1983, 1984), the Torell Glacier advanced twice and each time it passed over the limit of its present extent (Fig. 6). These advances are proved by two tills, exposed in the Torellkjegla area (Fig. 4) and glaciodislocated together with older marine clays. The older till is dated for 313 (284) ka whereas the younger one for 225—229 (189) ka, respectively. These tills are separated from each other by sands and gravels dated for 222 (182) ka and 220 (190) ka.

A geologic structure and the mentioned dates prove that the older till was formed by the Torell Glacier during the older Wedel Jarlsberg Land Glaciation, corresponding probably with the beginning of a cooling recorded in deep-sea sediments as the $^{18}0$ stage 8 (cf. Shackleton and Opdyke 1973) and in Central Europe with the Saale I (Oder, Dnieper) Glaciation. The younger till correlates presumably with the Torell Glacier advance during the younger Wedel Jarlsberg Land Glaciation, recorded in deep-sea sediments by the $^{18}0$ stage 6 (cf. Shackleton and Opdyke 1973) and in Central Europe as the Saale II (Warta, Moskva) Glaciation.

The successive advance of the Torell Glacier was expressed by glaciodislocations of the mentioned sediments and occurred probably during the Sörkapp Land Glaciation, correlated with the Wisła (Weichselian, Würm) Glaciation (Lindner, Marks and Pękala 1983, 1984). It seems to be supported by the dates received for the till that overlies the deformed glacial and marine sediments in the Torellkjegla section (Fig. 4). The maximum extent of the Torell Glacier in that time cannot be defined but it must have been larger than the present one. It could be the time when the push moraine in the central part of Torellkjegla was formed. During the further advance of the Torell Glacier this moraine opposed the westward movement of the austre Torell Glacier. In the same time the higher level of the extramorainal outwash was formed, then partly mantled with aeolian sands (Fig. 3).

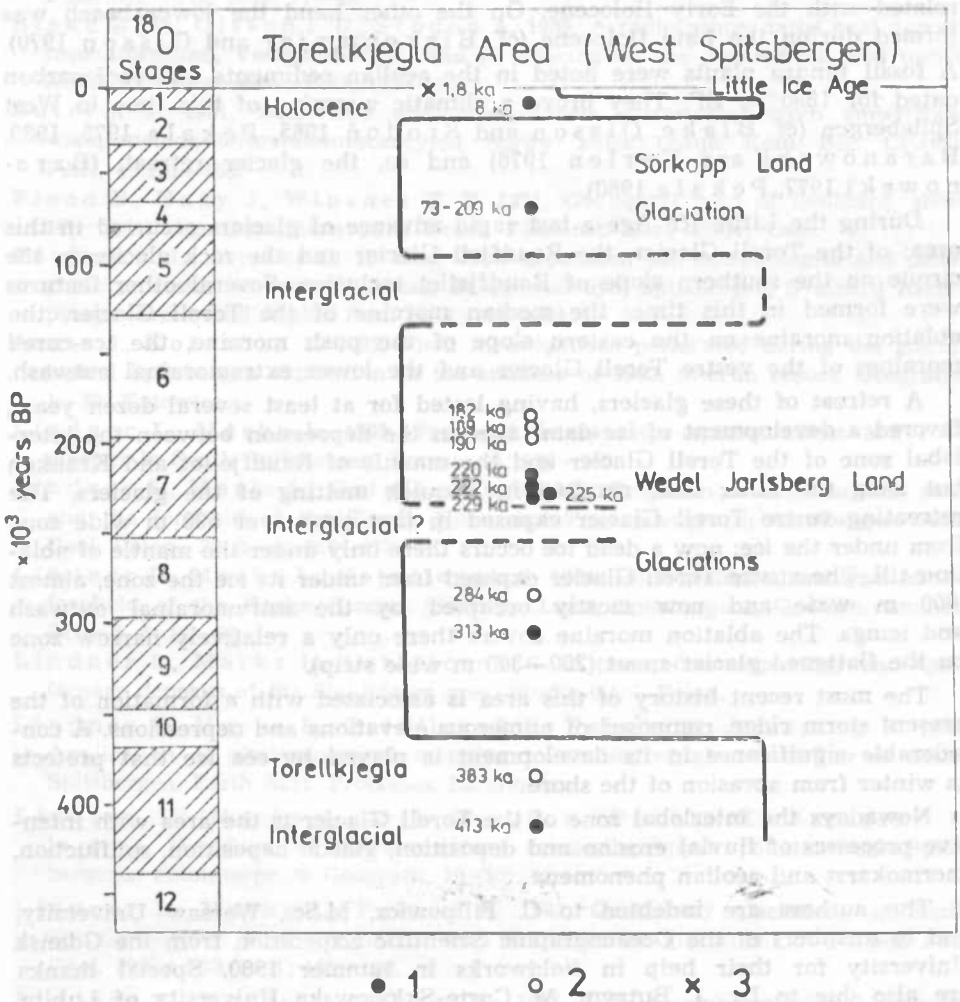

Fig. 6. Chronostratigraphic scheme of glociations in the Torellkjegla area. Oxygen[18] stages are taken from Shackleton and Opdyke (1973): 1 — TL datings by dosimetric method, 2 — TL datings by spectrometric method, 3 — radiocarbon dating

Schemat chronostratygraficzny zlodowaceń obszaru Torellkjegla. Stadia [18]O według Shackletona i Opdyke'a (1973): 1 — datowania TL metodą dozymetryczną, 2 — datowania TL metodą radiometryczną, 3 — datowanie metodą radiowęgla

The age of all the three distinguished Pleistocene glaciations of the Torellkjegla area corresponds roughly to three glacial episodes noted in northwestern Spitsbergen (cf. Miller 1982, Forman and Miller 1984).

The retreat of glaciers during the younger part of the Sörkapp Land Glaciation and at the turn of the Late Glacial and Holocene caused a considerable emergence of this area from under the ice, its partial flooding by a sea and formation of two raised marine beaches. The higher one (10—18 m a.s.l.) is covered by aeolian sands, dated for 8 ka, and so it can be correlated with the Early Holocene. On the other hand the lower beach was formed during the Late Holocene (cf. Birkenmajer and Olsson 1970). A fossil tundra plants were noted in the aeolian sediments and radiocarbon dated for 1830±60 BP. They prove a climatic warming of this time in West Spitsbergen (cf. Blake, Olsson and Środoń 1965, Pękala 1975, 1980, Baranowski and Karlen 1976) and so, the glacier retreat. (Baranowski 1977, Pękala 1980).

During the Little Ice Age a last rapid advance of glaciers occurred in this area: of the Torell Glacier, the Raudfjell Glacier and the rock glacier in the cirque on the southern slope of Raudfjellet inclusive. Several other features were formed in this time: the median moraine of the Torell Glacier, the ablation moraine on the eastern slope of the push moraine, the ice-cored moraines of the vestre Torell Glacier and the lower extramorainal outwash.

A retreat of these glaciers, having lasted for at least several dozen years, favored a development of ice-dam lakes in the depression between the interlobal zone of the Torell Glacier and the massifs of Raudfjellet and Krakken but from the other side, resulted in a quick melting of the glaciers. The retreating vestre Torell Glacier exposed in that time over 500 m wide zone from under the ice; now a dead ice occurs there only under the mantle of ablation till. The austre Torell Glacier exposed from under its ice the zone, almost 1000 m wide and now mostly occupied by the intramorainal outwash and icings. The ablation moraine covers there only a relatively narrow zone on the flattened glacier snout (200—300 m wide strip).

The most recent history of this area is associated with a formation of the present storm ridge, composed of numerous elevations and depressions. A considerable significance in its development is played by sea ice that protects in winter from abrasion of the shore.

Nowadays the interlobal zone of the Torell Glacier is the area with intensive processes of fluvial erosion and deposition, glacial deposition, solifluction, thermokarst and aeolian phenomena.

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EXPLANATION OF PHOTOGRAPHS

Phot. 1. Median ice-cored moraine of the Torell Glacier (Torellmorena). In the background the Raudfjellet massif with the Raudfjell Glacier and the cirque glacieret.

Phot. 2. Vestre Torell Glacier with its ice cliff to the left and ablation moraines to the right; in the foreground a small degraded terminal ice-cored moraine.

Phot. 3. Torellkjegla: push moraine (A, cf. Phot. 4, Fig. 9) and ice cliff of the austre Torell Glacier (B).

Phot. 4. Outlet of outwash waters in Skoddebukta; in the background an ice cliff of the austre Torell Glacier.

Phot. 5. Icings on the intramorainal outwash, in the background a push moraine.

Phot. 6. Push moraine (A) and adjoining ablation moraine (B) in the foreground a storm ridge and lagoon lakes.

Phot. 7. Intramorainal outwash with icings; in the background a gorge (A) between a push moraine (B) and ice-cored moraines (C); D — abandoned gorge.

Phot. 8. Push moraine from the west (a); in the forefield relics of a raised beach with a vegetation cover (b), older level of the extramorainal outwash (c) and younger out wash (d).

Phot. 9. Sediments of the push moraine exposed in a cliff close to the outwash mouth.

Phot. 10. Degraded ice-cored moraines in a morainal zone of the vestre Torell Glacier: a — ablation moraine, b — dead glacial ice, c — mudflow.

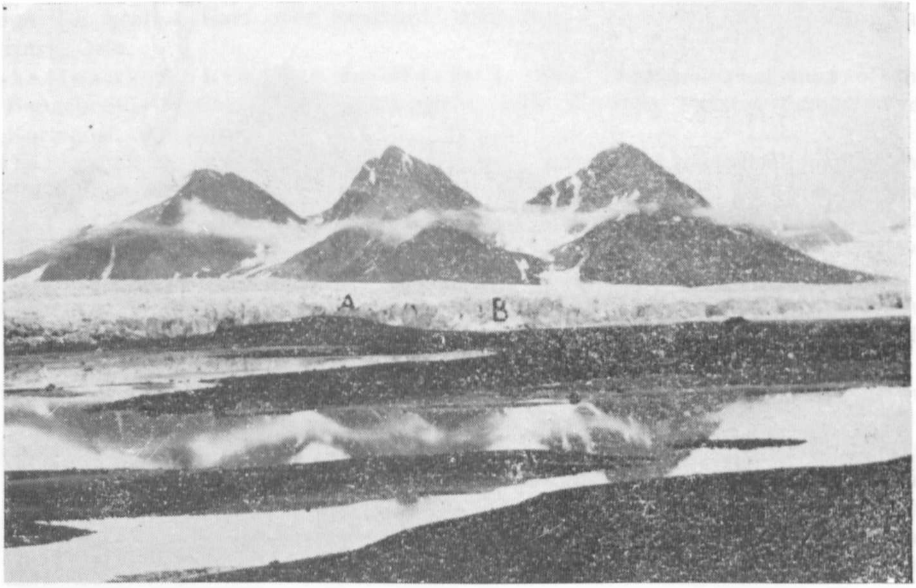
Phot. 11. Erratic in the ablation moraine (Torellmorena).

Phot. 12. Till with flow structures exposed in ablation moraine area.

Phot. 13. Eastern gorge (I) across the ablation moraine with the outwash cone

Fot. 1

Fot. 2



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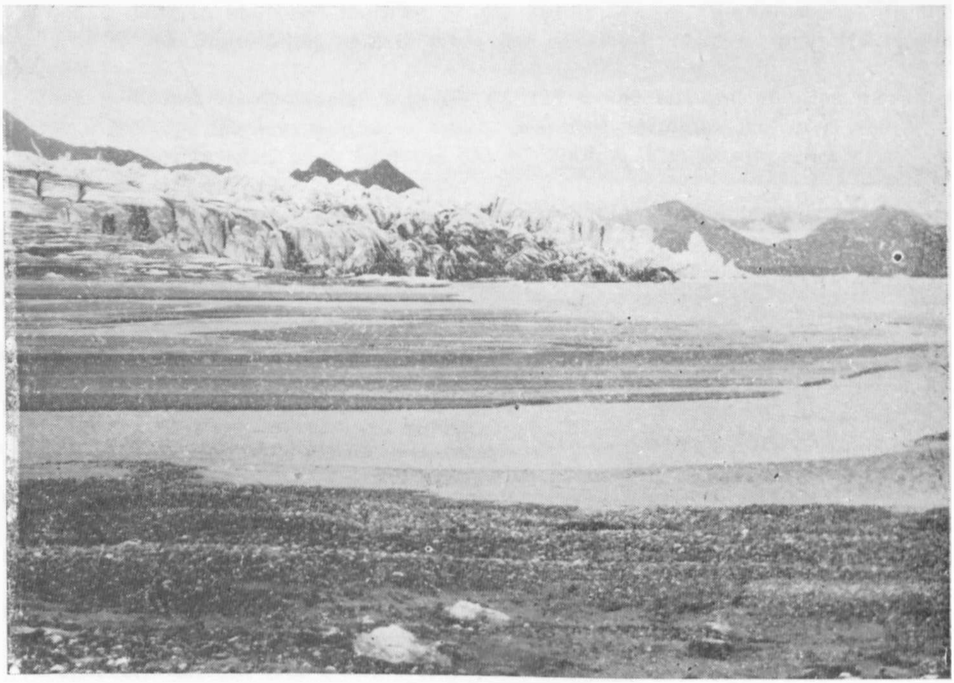

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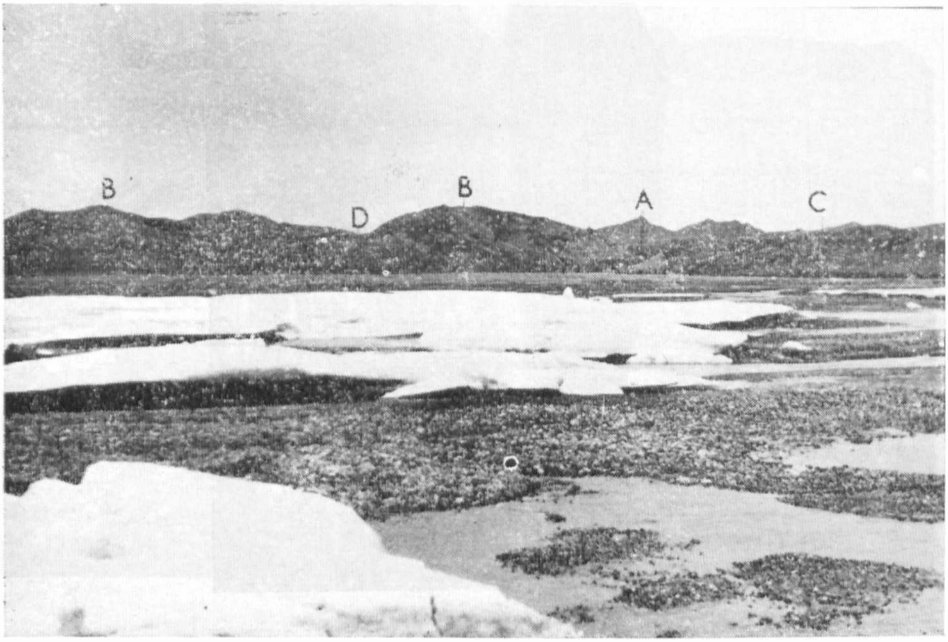

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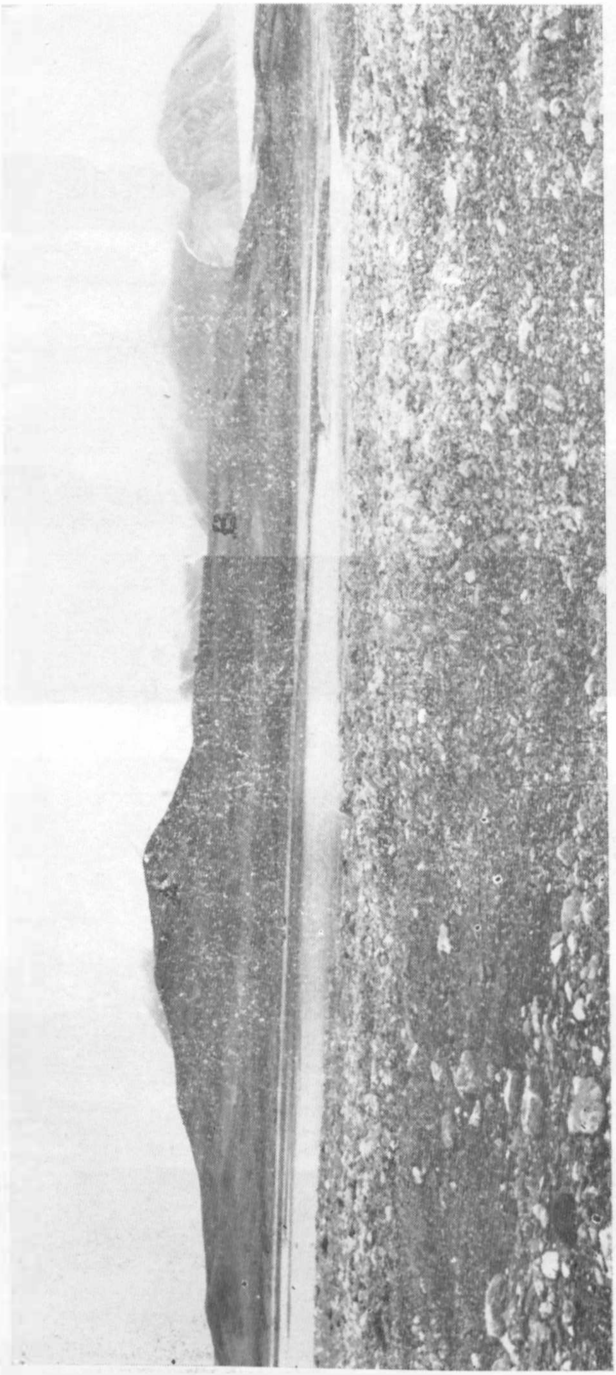

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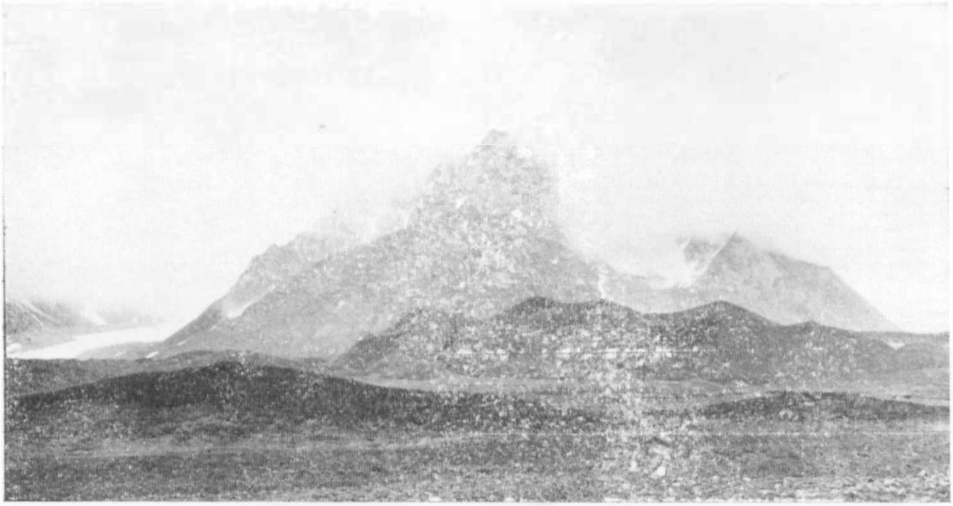

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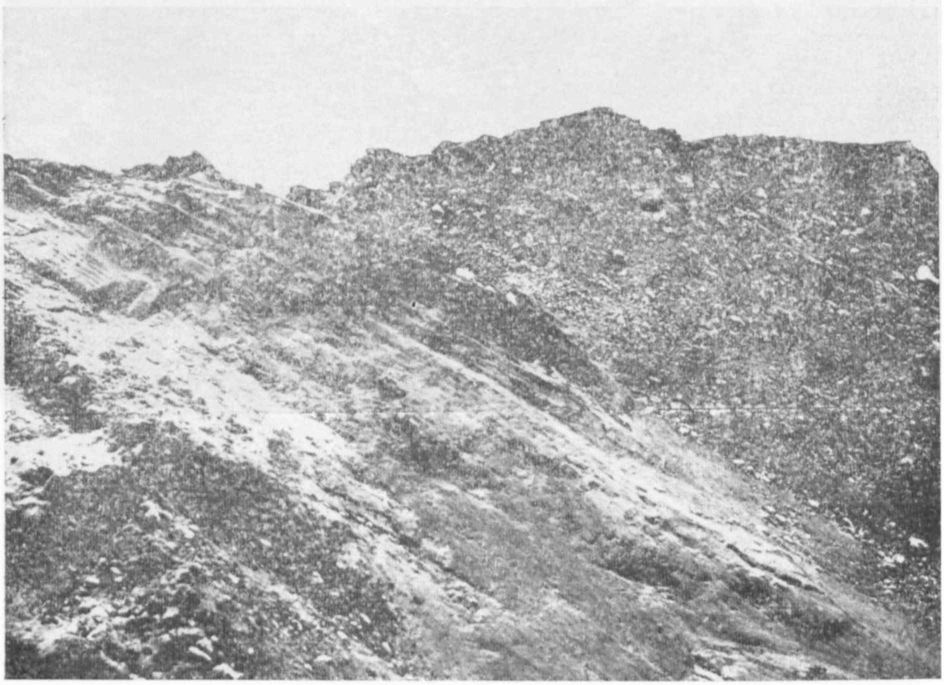

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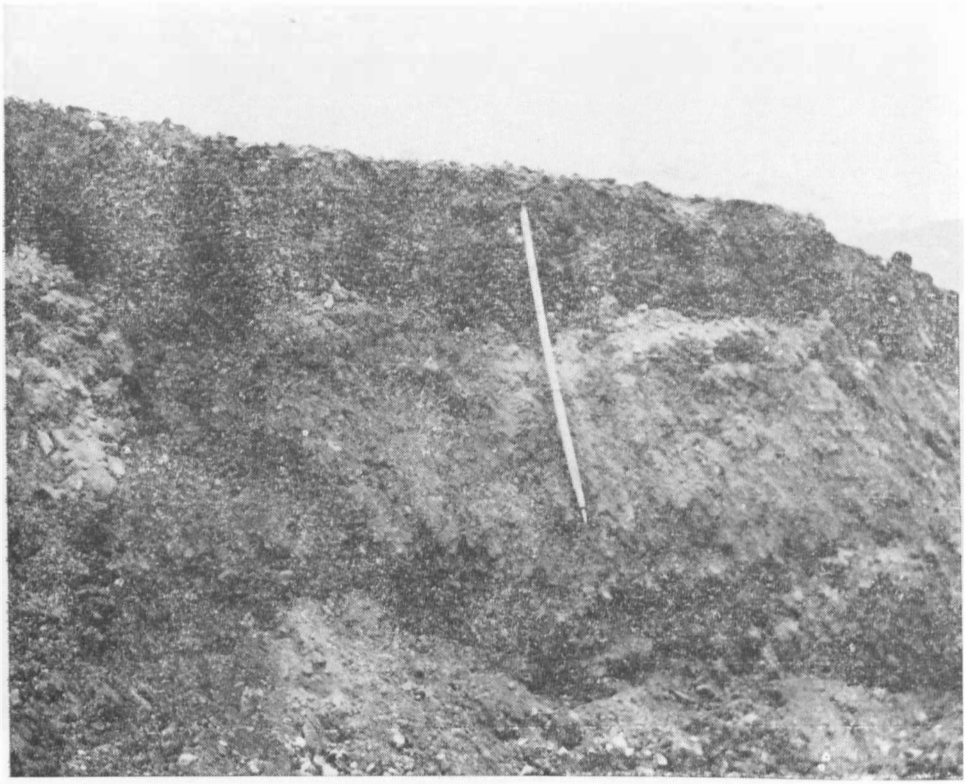

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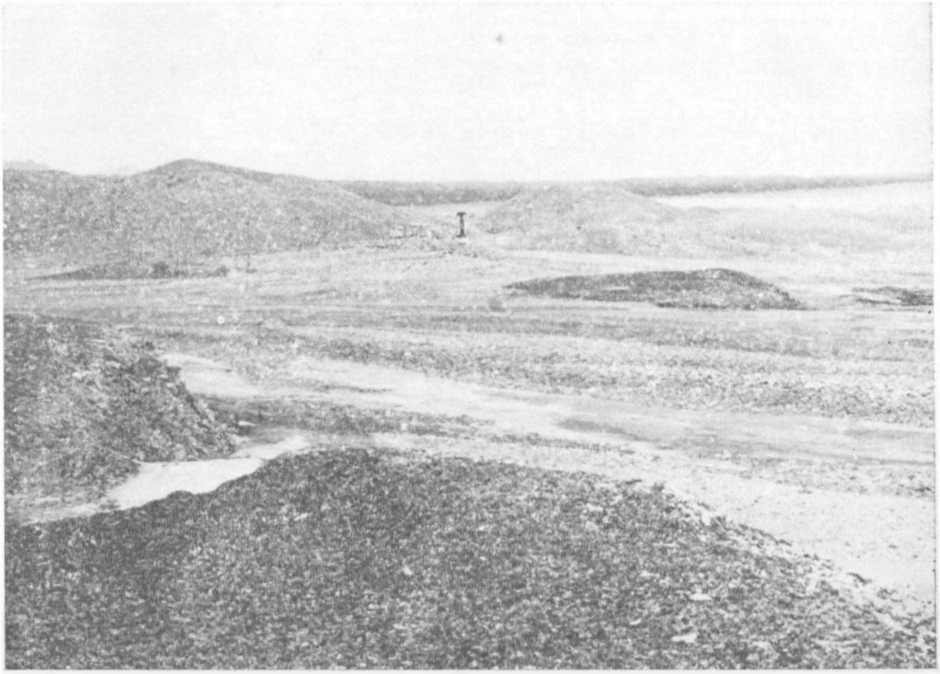

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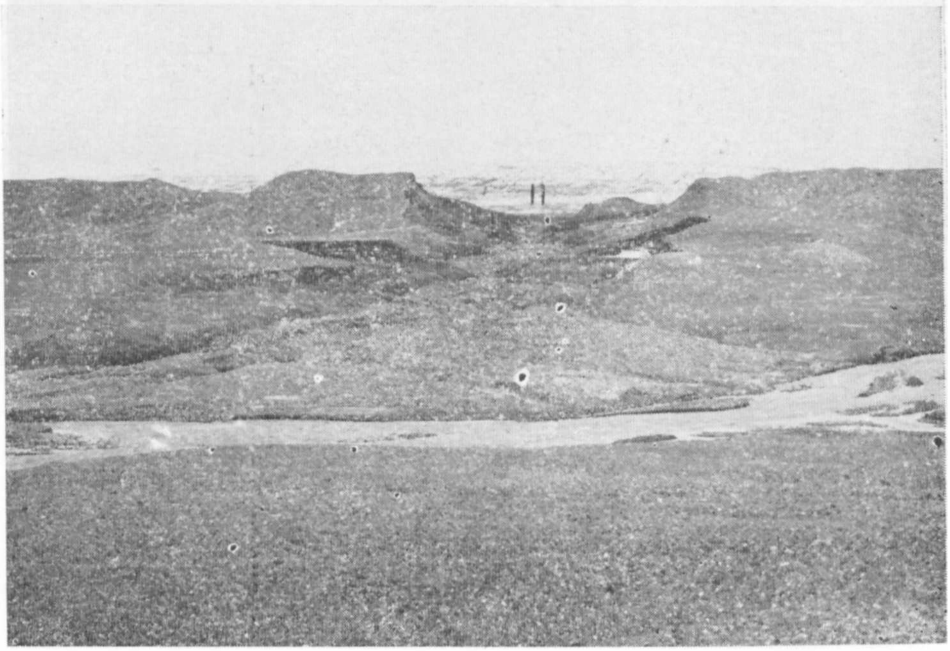

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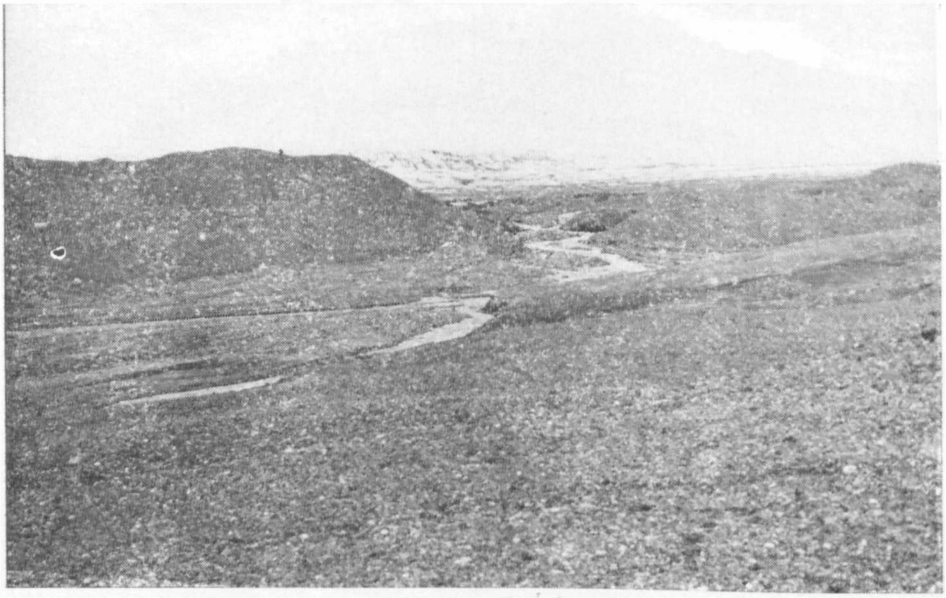

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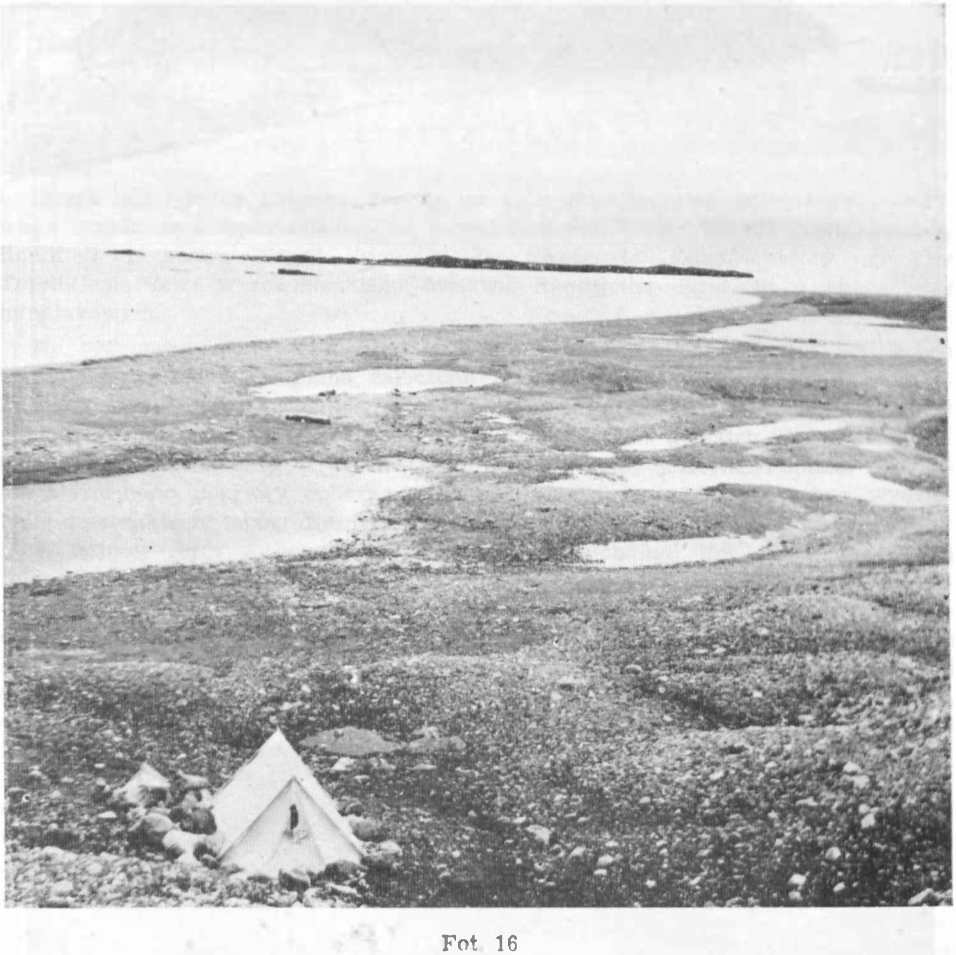

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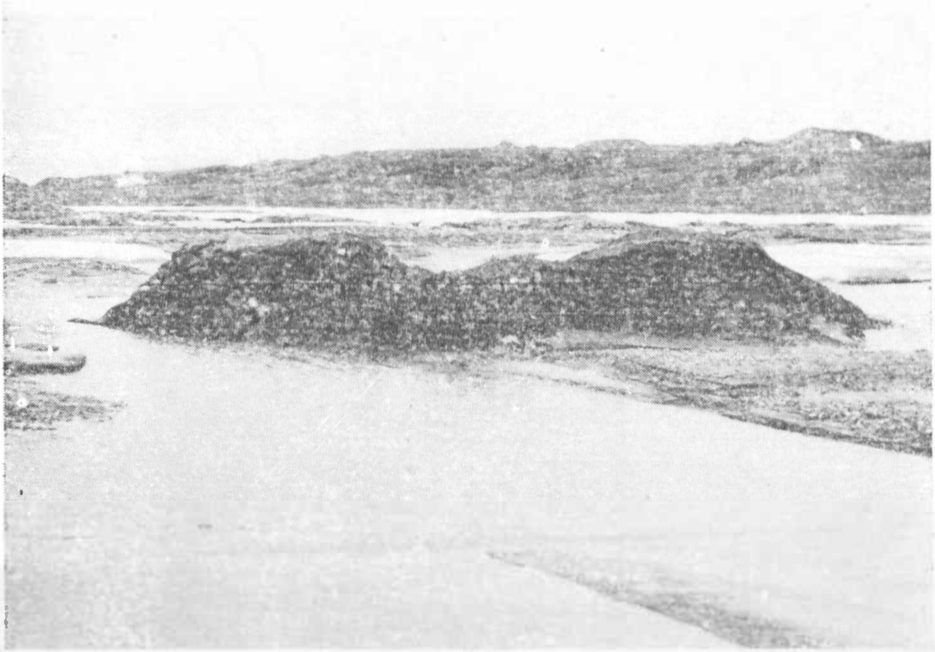

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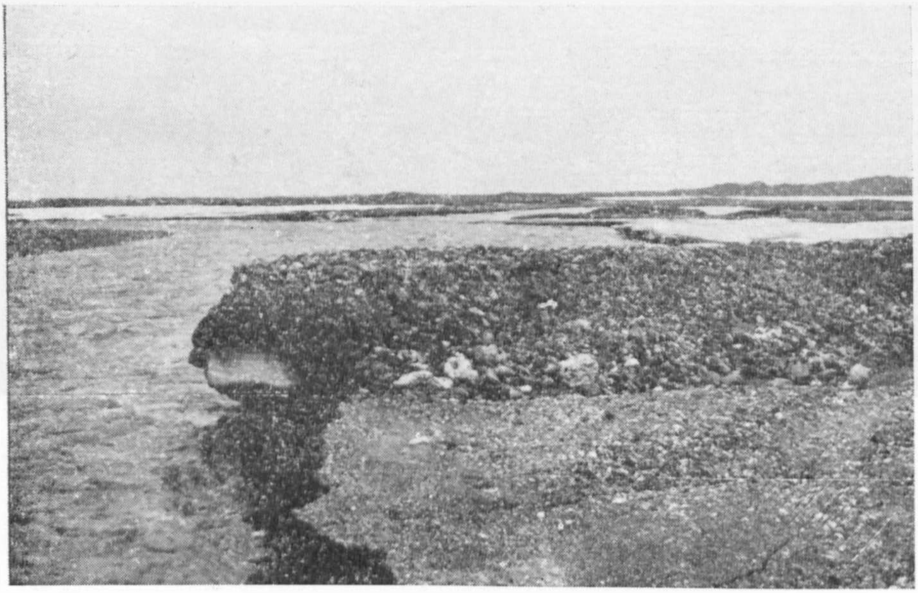

Fot. 18

at the outlet; Klockmannmorena in the background and rock outcrops more near, emerging in the extramorainal outwash.

Phot. 14. Gorge (II) in the central part of the ablation moraine area, located between Klockmannmorena and Torellmorena, with the outwash in the foreground.

Phot. 15. Gorge (III) in the eastern part of the ablation moraine area, acting in 1980; Profil Glacier in the background.

Phot. 16. View from the push moraine southwestwards onto the intramorainal outwash close to the ablation moraine, present beach and nIsöya Island.

Phot. 17. Icing mound covered by fluvial sands.

Phot. 18. Alluvial accumulation on icings within the intramorainal outwash.

STRESZCZENIE

Strefa interlobalna lodowca Torella na zachodnim Spitsbergenie stanowi izolowany obszar, w którym schodzą się loby lodowców: vestre Torell, Profil, Skodde, Raudfiell i austre Torell (ryc. 1, 2). Strefa ta składa się z równiny Torellkjegla oraz wysokogórskiego masywu Raudfjellet—Krakken o charakterze nunatakowym.

Na podstawie badań terenowych (1980) i analizy norweskich zdjęć lotniczych tego obszaru (1960) wykonano załączoną mapę fotogeologiczną w skali 1:10000. Zaznaczono na niej 31 wydzieleń geologiczno-geomorfologicznych, ujętych w cztery główne grupy genetyczne: formy i osady na zboczach górskich, formy i osady lodowcowe oraz niwalne, terasy morskie, formy i osady jeziorne. Ponadto oddzielnie wyróżniono pokrywy eoliczne, przełomy rzek i strumieni oraz dwa wydzielenia o charakterze topograficznym.

W zespole form występujących w strefie interlobalnej (fot. 1—18) szczególną rolę odgrywają moreny spiętrzone. Są one zbudowane z glacitektonicznie zdeformowanych osadów lodowcowych i morskich, które były datowane termoluminescencyjnie metodą dozymetryczną i spektrometryczną (ryc. 3, 4, tab. 1). Pozwoliło to na wyróżnienie kilku jednostek chronostratygraficznych czwartorzędu dla tej części Spitsbergenu (ryc. 6): interglacjału Torellkjegla (= Mazovian, Holstein, Likhvin), dwudzielnego zlodowacenia Wedel Jarlsberg Land (= Odra + Warta, Saale, Moskva) i zlodowacenia Sörkapp Land (= Wisła, Weichselian).

U podnóża południowo-zachodniego zbocza masywu Raudfjellet—Krakken stwierdzono występowanie różnowiekowych serii osadów jeziornych i linii abrazyjnych utworzonych prawdopodobnie po maksimum Małej Epoki Lodowej w ścisłym związku ze zmianami zasięgu sąsiadujących lobów lodowca Torella, często na miejscu uprzednio istniejących wałów lodowo-morenowych (załączona mapa i ryc. 5).

Przedstawiony obszar stanowi doskonały model dla zrozumienia rozwoju plejstoceńskiej rzeźby glacjalnej, fluwioglacjalnej i limnoglacjalnej obszarów górskich objętych zlodowaceniem. Wiele z zaobserwowanych prawidłowości można odnaleźć zwłaszcza przy odtwarzaniu przebiegu transgresji, maksymalnego zasięgu i zaniku lądolodów plejstoceńskich w starych masywach górskich Europy Środkowej, a zapewne również i na innych obszarach. Natomiast w porównaniu z innymi obszarami południowego Spitsbergenu, dla których uprzednio autorzy sporządzili mapy fotogeologiczne, strefa interlobalna lodowca Torella odznacza się stosunkowo małą liczbą form i osadów zboczowych. Wynika to niewątpliwie z faktu, że obszar ten dopiero niedawno został w istotnym stopniu pozbawiony zwartej pokrywy lodowej.

OBJAŚNIENIA FOTOGRAFII

Fot. 1. Środkowy wał lodowo-morenowy Torellmorene. W głębi masyw Raudfjellet z lodowcem Raudfjell i lodowcem cyrkowym.

Fot. 2. Lodowiec vestre Torell z klifem lodowym po lewej stronie i morenami ablacyjnymi po prawej. Na przednim planie niski, zdegradowany czołowy wał lodowo-morenowy.

Fot. 3. Torellkjegla. Widok na pagór moreny spiętrzonej (A — fot. 4, 9, ryc. 9) i klif lodowy lodowca austre Torell (B).

Fot. 4. Ujście wód sandrowych do Skoddebukty. Na dalszym planie klif lodowy austre Torell.

Fot. 5. Pokrywy naledzi na sandrze intramarginalnym, w głębi morena spiętrzona.

Fot. 6. Morena spiętrzona (A) i przylegająca do niej od wschodu morena ablacyjna (B). Na pierwszym planie wał burzowy i jeziorka lagunowe.

Fot. 7. Sandr wschodni z pokrywami naledzi. W głębi przełom (A) między moreną spiętrzoną (B) a wałami lodowo-morenowymi (C); D — przełom nieczynny.

Fot. 8. Morena spiętrzona widziana od strony zachodniej (a), ostańce terasy morskiej z pokrywą roślinną (b), starszy poziom sandru ekstramarginalnego (c) i młodszy sandr (d).

Fot. 9. Osady moreny spiętrzonej odsłonięte w klifie przy ujściu Isfjelelvy (fragment odsłonięcia na ryc. 3 — Lindner et al. 1983).

Fot. 10. Wały lodowo-morenowe degradowane w strefie marginalnej lodowca vestre Torell, a — morena ablacyjna, b — martwy lód lodowcowy, c — potok błotny.

Fot. 11. Głaz narzutowy w obrębie moreny ablacyjnej (Torellmorena).

Fot. 12. Glina zwałowa ze strukturami spływowymi w strefie moren ablacyjnych.

Fot. 13. Przełom (I) wschodni przez moreny ablacyjne ze stożkiem sandrowym u wylotu. W głębi Klockmannmorena, bliżej — wychodnie skalne wśród sandru ekstramarginalnego.

Fot. 14. Przełom (II) w środkowej części płata moren ablacyjnych położonego między Klockmannmorena a Torellmorena z przepływem sandrowym na pierwszym planie.

Fot. 15. Przełom (III) we wschodniej części moreny ablacyjnej aktywny w 1980 r.; w głębi lodowiec Profil.

Fot. 16. Widok z bazy na morenie spiętrzonej w kierunku SW na sandr intramarginalny przy morenie ablacyjnej, współczesną terasę morską z wałem burzowym i wyspą nIsöya.

Fot. 17. Kopiec z naledzi przykryty przez piaski fluwialne.

Fot. 18. Akumulacja aluwialna na pokrywach naledzi w obrębie sandru intramarginalnego.

РЕЗЮМЕ

Интерлобальная зона ледника Торелла на западном Шпицбергене является изолированным районом, на котором встречаются льды ледников: западного Торелла, Профила, Скодде, Раутфелл и восточный Торелл (фиг. 1, 2). Эта зона состоит из равнины Тореллкейгла и высокогорного массива Раудфейллег—Краккен нунатакового характера.

Опираясь на территориальные исследования из 1980 года и позднейший анализ норвегских авиационных снимков этого района из 1960 года изготовлено приложенную фотогеологическую карту масштабом 1:10 000. На этой карте отмечено 31 геологическо-геоморфологическое отведение, заключенное в четыре главные генетические группы: формы и осадки на горных склонах; формы и ледниковые осадки; нивные морские террасы и формы, и озерные осадки. Отдельно выделено эолические покровы, излом рек и ручьев, а также два отведения топографического характера.

В комплексе форм выступающих в интерлобальной зоне (фот. 1—18) особенную роль играют скопленные морены. Они построены из глацитектонически сдеформированных ледниковых и морских осадков, которые были датированы термолюминесценционно дозометрическим и спектрометрическим методами (фиг. 3, 4, табл. 1). Это дало возможность выделить несколько хроностратиграфических единиц четвертичного периода для этой части Шпицбергена (фиг. 6), т.е. для: интергляциала Тореллкейгла (Mazovian, Holstein, Likhvin), двусоставного оледенения Ярльсберга Веделя и оледенения Серкап Лонд.

У подножья юго-западного склона массива Раудфеллет—Краккен определено выступление разновозрастных серий озерных осадков и образионных линий созданных правдоподобно после максимума Малой ледниковой эпохи в тесной связи с изменениями диапазона соседних лбов ледника Торелла, очень часто на месте раньше выступающих ледянно-мореновых валов (предложена карта и фиг. 5).

Представленная зона является хорошей моделью для осознания плейстоценового развития глациального рельефа, флювиоглациальных и лимноглациальных горных районов обятых оледенением. Много замеченных закономерностей можно найти при восстановлении хода трансгресси, максимального диапазона и исчезновении плейстоценовых материковых ледников горных массивов Средней Европы, а наверно и в других районах. По сравнению с другими зонами южного Шпицбергена, для которых авторы создали фотогеологические карты, зона интерлобальная ледника Торелла отличается относительно небольшим числом форм и сточных осадков. Это вытекает несомненно из того факта, что зона эта недавно в существенной степени лишена плотного ледяного покрова.