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Evolution of the marginal zone and the forefield of the Torell, Nann and Tone glaciers in Spitsbergen

ABSTRACT: The studies over sediments and features in the marginal zone and the forefield of the Torell, Nann and Tone glaciers (Wedel-Jarlsberg Land) in Spitsbergen enable a critical approach to the origin of inner ice-cored moraines of the Torell Glacier, considering them for the outliers of a glacier ice, enriched in a morainic material. They allow also to present a morphological evolution of this area during the Late Würm (= Vistulian) and the Early Holocene but first of all, since the beginning of the Little Ice Age.

INTRODUCTION

The marginal zone and the forefield of the Torell, Nann and Tone glaciers (Wedel-Jarlsberg Land) in Spitsbergen have hitherto been described from geomorphologic point of view (Szupryczyński 1963; Karczewski & Wiśniewski 1975, 1977; Wiśniewski & Karczewski 1978; Karczewski & *al.* 1981b), and the first description of glacial sediments was presented by Szupryczyński (1963), whereas Karczewski & Wiśniewski (1975, 1977) reconstructed morphologic evolution of the morainal zone of the Torell Glacier and confronted the present-day and Würm outwash landforms, among others basing on a morainal zone of the Torell Glacier (Wiśniewski & Karczewski 1978).

The authors used the Norwegian topographic map in the scale of 1:100 000 or its enlargements for mapping the area. Due to accession of the Norwegian air photos of 1966, the first photogeologic map of this area in the scale of

1:10 000 was prepared (Ostaficzuk & al. 1980). The nature and range of the distinguished structures have been verified during the fieldworks carried through in Spitsbergen by P. Kłysz and L. Lindner in summer 1980.

MARGINAL ZONE OF THE NANN GLACIER

The Nann Glacier is located between the mountain massifs of Rundingen and Solheimfjellet. It is now about 4 km long with its width from about 1.5 km at the snout to about 1 km at the margin of a firn field. In the morainal zone of this glacier there are several types of landforms and sediments (Text-fig. 1).

GLACIER SNOUT

The snout is more flatteneed than in 1960 (*see* Szupryczyński 1963) and is covered by several vast patches of an ablation moraine, forming the streaks of a clayey-rubble deposit parallel to one another and perpendicular to the glacier snout (Text-fig. 2*A* and 3*A*), similarly as the debris bands in the northern part of the glacier (*cf.* Text-fig. 1).

INTRAMORAINAL OUTWASH AND ICE-DAM LAKE

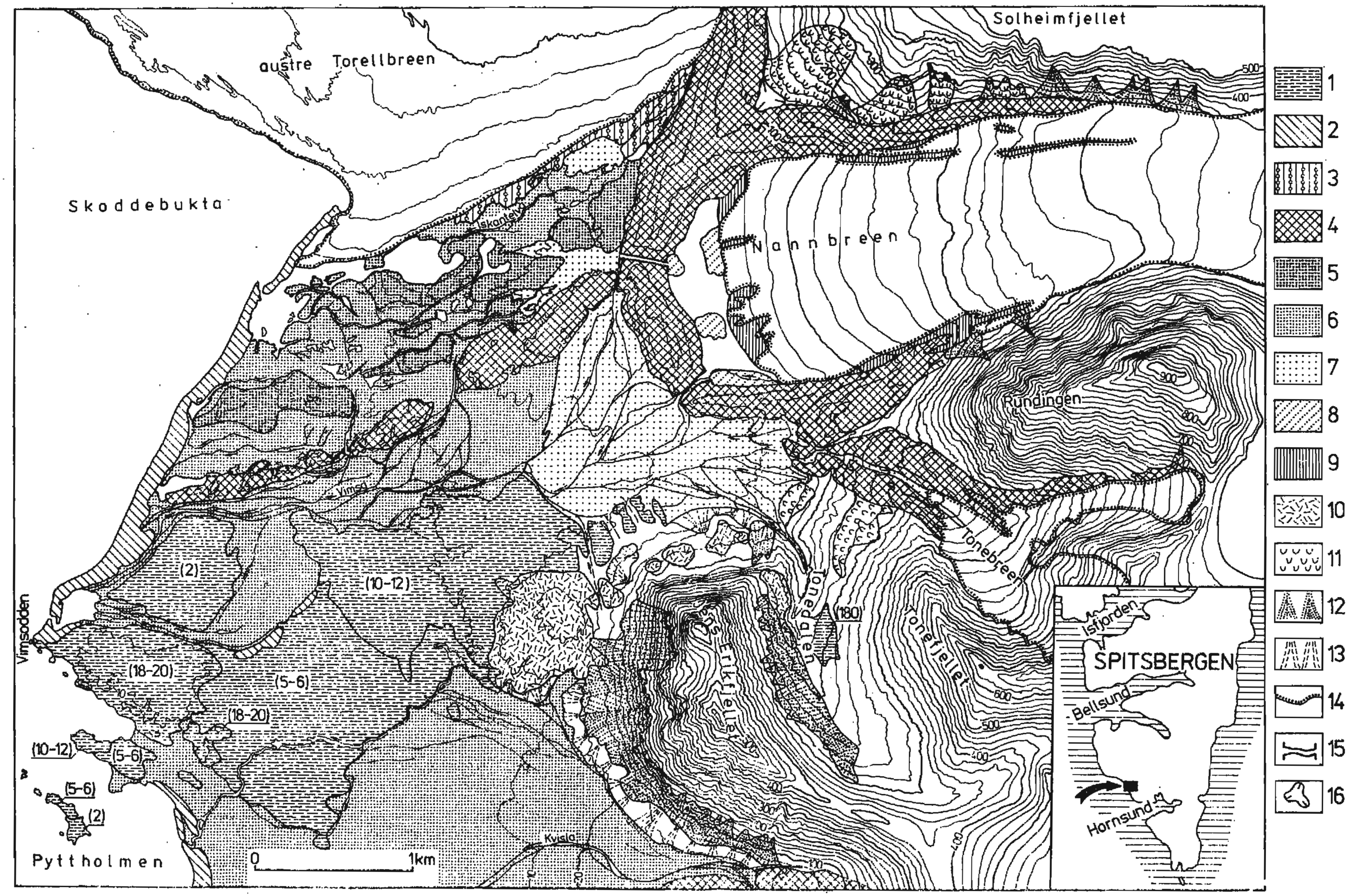
The outwash is composed of a gravel-rubble sediment: in the northern part of the zone it contacts with the glacier and the vast dead-ice patch (*cf.* Text-fig. 1), whereas in other sites it forms islands and peninsulas within the lake (Text-figs 2*A* and 3*A*); the latter occupies a considerable part of the glacier morainal part. In the southern fragment of the zone the outwash forms a terrace, contacting with the inner slope of the southern ice-cored moraine whereas in the west a similar terrace occurs at the meltwater outlet within a terminal moraine.

ICE-CORED MORAINES

The ice-cored moraines are composed of a glacier ice socle, covered by a thin (0.5—1.5 m) series of the morainic material. In the morainal zone of the Nann Glacier there are terminal and lateral moraines (*cf.* Text-fig. 1). At the inner side, the lower fragments of these moraines are covered with relatively narrow (10—50 m) solifluction mantles. The observations of 1980 support the previous reports (Szupryczyński 1963) that within the terminal moraine there are four morainic rows: the outer (western) ones are covered with a more fine-grained material than the inner (eastern) rows. This moraine is up to 40—50 m high and its highest parts are over 70 m a.s.l. (Text-fig. 3*D*). The depressions between the rows and the morainic surface contain small ponds, several metres in diameter.

The terminal ice-cored moraine of the Nann Glacier is dissected by two gorges. The southern gorge is used by the Vimsa River (Text-fig. 3*D*) that drains

Geomorphologic-geologic sketch of the forefield and the morainal zones of the Torell, Nann and Tone glaciers (based on the photogeologic map by Ostaficzuk & *al.* 1980)



1 raised marine terraces (altitudes in metres a.s.l.), *2* storm ridges, *3* ground moraine, *4* ice-cored moraines, *5* glacier ice outliers with morainic cover, *6* extra-morainal outwash, *7* outwash fans, *8* intramorainal outwash, *9* ablation moraine and debris bands, *10* nival moraines, *11* solifluction covers, *12* talus cones, *13* diluvial covers, *14* glaciers, *15* gorges, *16* intramorainal depressions the meltwaters from the ice-dam lake. The gorge bottom is located at its outlet slightly above 20 m a.s.l. and its width does not exceed 10 m. The northern gorge cuts the middle part of the moraine (Text-fig. 3B). Its bottom occurs at the outlet at over 25 m a.s.l. In summer 1980 this gorge was inactive probably since a longer time as results from the previous observations (Szupryczyński 1963), and its bottom was covered with boulders up to 3 m in diameter.

The terminal ice-cored moraine of the Nann Glacier passes directly into lateral ice-cored moraines and in the north-west it is connected with the outermost ice-cored moraine of the Torell Glacier (*cf.* Text-fig. 1). The rock debris that covers the southern fragment of the lateral moraine of the Nann Glacier, comes mainly from the Rundingen slopes. It is from several centimetres to several metres thick and overlies a relic ice. The northern fragment of the lateral moraine is fed in many places by a rock material coming from the Solheimfjellet slopes. Closely to the lateral moraine of the Nann Glacier there is a vast drainage-less depression, being the intermorainic depression with a loamy-silty bottom.

The lateral ice-cored moraines are up to 30 m high. Their relic ice cores show traces of slide plains and the fissures typical of a glacier ice. Within the morainal zone no crevasses (noted by Szupryczyński 1963) were found. If present formerly, they could disappear during formation of the intramorainal outwash plain, nowadays considerably covered by the ice-dam lake.

MARGINAL ZONE OF THE TORELL GLACIER

The Torell Glacier (Austre Torellbreen) ends with an immense ice cliff that enters the sea (Text-fig. 1). In the west it is limited by by a median moraine, starting from the Raudfjellet massif (outside the described area) whereas in the east it is bound by the Solheimfjellet massif. Independently of a frontal retreat the glacier shrinks also transversally (Text-figs 4—5).

The glacial structures formed in the morainal zone of the eastern part of the Torell Glacier have been mapped for the first time by Birkenmajer (1959), and their preliminary description was given by Szupryczyński (1963). A more detailed description was presented by Karczewski & Wiśniewski (1975, 1977) who criticized the previous data; among others, they found the systems of ice-cored moraines to be the terminal moraines whereas some of them would be considered as the so-called overpassed moraines.

The last field observations and a photogeologic analysis enable to distinguish the below described types and structures.

GLACIER SNOUT

The "inland" snout of the Torell Glacier, accessible to field observations, is relatively compact at a distance of slightly over 2 km and runs from south-west to north-east (Text-fig. 2C). Towards the morainal zone it slopes down at an angle of several degrees. At the ice surface there appear numerous fissures and inserts of a morainic deposit, concentrated mainly along the well pronounced slide plains. At a distance of about a kilometre from the terminus, the glacier surface is not accessible for field observations for its numerous fissures that, in turn, favour an intensive calving of the glacier snout at its contact with the sea.

GROUND MORAINE

The ground moraine occupies a relatively narrow (50—100 m) and elongated (about 1200 m) strip along the eastern "inland" reach of the Torell Glacier snout. Easternmostly it occupies the whole area between the snout and the outer ice-cored moraine of this glacier (*cf.* Text-fig. 1). The moraine is composed of a clayey debris with local inserts of a silty matter. It overlies a dead glacier ice, similarly as most sediments of the morainal zone.

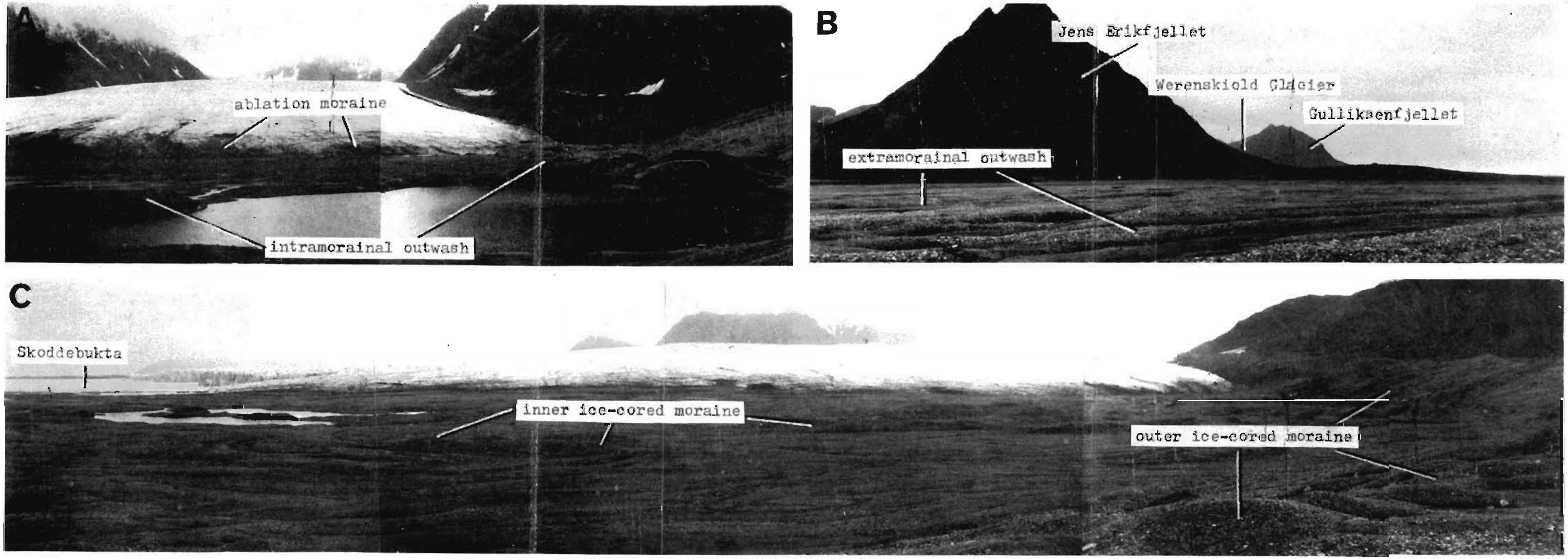
ICE-DAM AND MELT-OUT LAKES

In the forefield of the eastern part of the Torell Glacier snout, amidst the rows of inner ice-cored moraines as well as within the outwash surface in the morainal zone of the glacier, there are dispersed ice-dam and melt-out ponds (Text-figs 2*C*, 3*E* and 3*F*). An existence of these lakes results from the buried dead glacier ice and, on the other hand, from numerous inflows of proglacial and extraglacial waters, Iskantelva included. These lakes show permanently changing extents and depths, dependant on deglaciation of the area and an ablation rate at the surrounding glaciers.

GLACIER ICE OUTLIERS (INNER ICE-CORED MORAINES)

These features form at least three distinct rows, being more or less parallel to the outer complex of ice-cored moraines of the Torell Glacier and the present position of the "inland" extent of the glacier (Text-figs 1, 2C and 3*F*). The observations of 1980 prove that the cores of these moraines are composed of a dead glacier ice with traces of its primary structure (among others with slide plains, accentuated by concentrations of the morainic material). A possible occurrence of a relic ice inside was already suggested by Karczewski & Wiśniewski (1975). The moraines are covered by a morainic material, composed of a loamy-debris ablation sediment of varying thickness (0.5—2 m). In most cases the slopes and the feet of the moraines are covered by outwash sediments. These landforms are 5—20 m high, several hundred metres long and 50—300 m wide. The proximal slopes are less inclined than the distal ones and their shapes are usually oval Text-fig. 4).

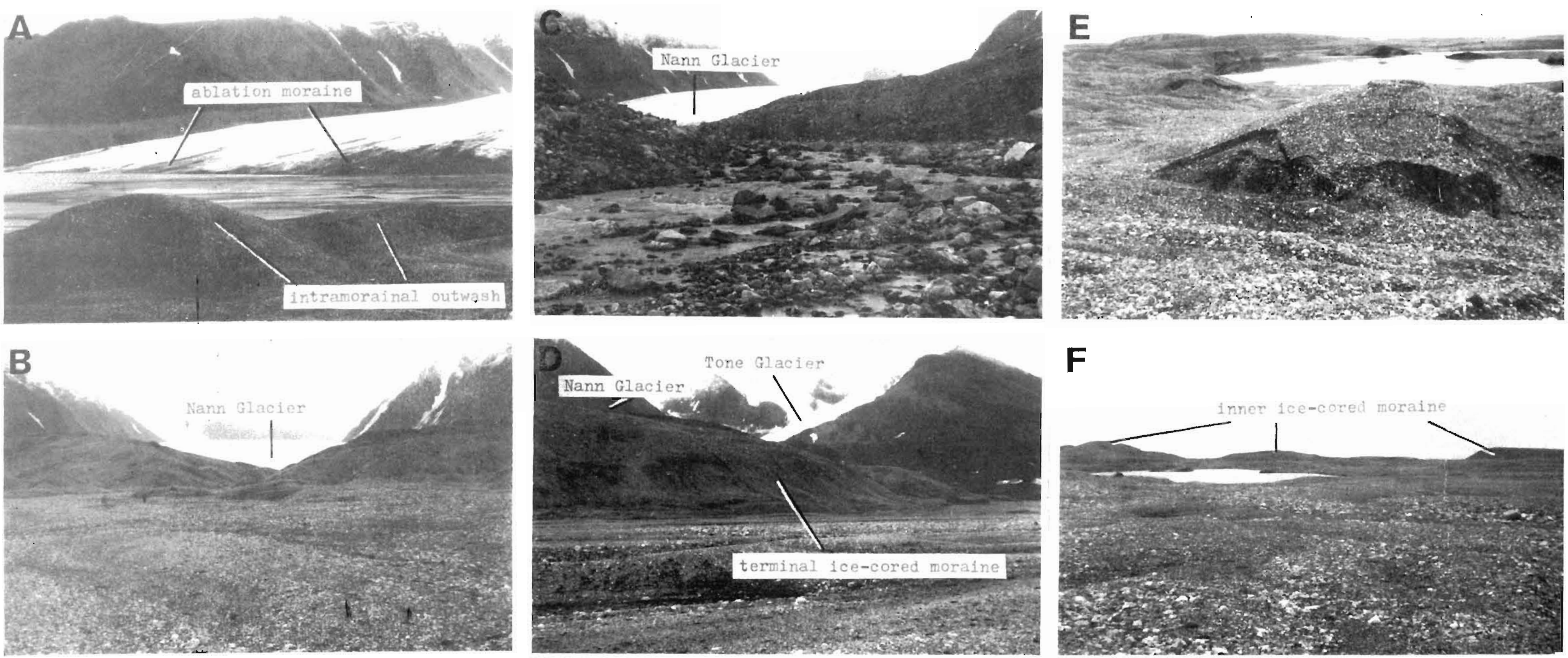
Szupryczyński (1963) considered these hills as the so-called inner lateral moraine of the Torell Glacier, whereas Karczewski & Wiśniewski (1975, 1977) called them as the overpassed ice-cored moraines i.e. the terminal moraines formed during the glacier advance, moutonnéed during its further southward movement; according to these authors, the maximum extent of the glacier of that time is marked by the outer ice-cored moraine.



A — Morainal zone of the Nann Glacier: at the background a glacier snout with streaks of an ablation moraine; in the foreground an ice-dam lake and fragments of an intramorainal outwash; August 1980

B — Forefield of the Nann Glacier: an outlook of an extramorainal outwash; at the background the Jens Erikfjellet massif with a nival moraine at its foot (the moraine overlies the marine terrace 10—12 m a.s.l.); in the distance the valley occupied by the Werenskiold Glacier and the Gulliksenfjellet massif; August 1980

C — Morainal zone of the Torell Glacier: to the right the fragments of an outer ice-cored moraine, in the distance to the left — Skodde bukta; in the centre the outwash plain with buried glacier ice outliers (inner ice-cored moraines) and lakes; at the background the "inland" snout of the Torell Glacier; August 1980



A — Snout of the Nann Glacier covered with patches of an ablation moraine; in the foreground an ice-dam lake and fragments of erosive outliers of an intramorainal outwash; August 1980

B — Forefield of the Nann Glacier: the northern gorge in a terminal ice-cored moraine; August 1980

C — Forefield of the Nann Glacier: the southern gorge in a terminal ice-cored moraine, used by the Vimsa River; August 1980

D — Forefield of the Nann Glacier: a distal side of a terminal ice-cored moraine; in the foreground the extramorainal outwash plain; August 1980

E — Morainal zone of the Torell Glacier: the outwash sediments overlying a melting dead glacier ice; in the distance the kettle ponds; August 1980

F — Morainal zone of the Torell Glacier: in the foreground an outwash plain with a pond, at the background the outliers of a glacier ice (inner ice-cored moraines); August 1980

Fieldworks and the photographic interpretation forced to a critical approach to the later opinion. The inner ice-cored moraines of the Torell Glacier seem to be the relic of a primary glacier ice structure. In agreement with the model, presented for Spitsbergen glaciers by Boulton (1972), during an areal deglaciation more or less isolated and parallel to one another glacier ice outliers are formed; they are enriched in a morainic debris and so, overlain by a mantle of a rock sediment, melted out at the surface (Text-fig. 4 *A—C*). The depressions amidst the outliers art filled with a stratified outwash sediment, deposited by proglacial waters of the Torell Glacier (and thus, being the intramorainal one) and by proglacial waters of the Nann Glacier (and thus, the extramorainal one).

A complete similarity of this situation was noted in a complex of fluvioglacial landforms, created at the end of the Vistulian Glaciation in the northern Poland, at a proximal side of the terminal moraines of the Gardno Lobe (*cf.* Petelski 1978).

OUTWASH PLAIN IN THE MORAINAL ZONE

For a simplification of a cartographic image (Tet-fig. 1), as the etramorainal outwash for a distinct predominance of meltwaters of the Nann Glacier in the outwash formation. Karczewski & Wiśniewski (1975) found four levels within these plain; the two uppermost that contact with the outer ice-cored moraine as well as the lowest one, developed close to the Torell Glacier, have been thought to form by meltwaters of this glacier. Instead, the other level was created mainly by the proglacial waters of the Nann Glacier, running there through the northern gorge within the terminal ice-cored moraine of this glacier. The fieldworks prove that these levels can be noted only in the eastern part of the area. Towards the sea, the boundaries between them are less and less distinct and finally disappears, resulting in a uniform outwash plain.

These levels are composed of gravel-sandy sediments, and they still overne a non-melted glacier ice. Consequently, they locally collapse and form the melted--out ponds (Text-fig. 4C and Pl. 1, Fig. 2) as well as hills (Pl. 1, Fig. 1), with their shapes similar to those of eskers, kames or dead-ice moraines (*cf.* Szupryczyński 1963).

OUTER ICE-CORED MORAINE

The moraine is up to 40—50 m high and forms an arch, corresponding with the inner moraines as well as the "inland" terminus of the Torell Glacier. The arch is over 3 km long whereas its width is from 100—150 m in the west to 700 m in the east. Its eastward increasing width agrees with an increased content of a rock material that covers the moraine; it results from its passing into an interlobal feature or a median moraine between the Torell and the Nann glaciers. During fieldworks of 1980 no relic ice was found within the moraine. But there are erosive rills at its surface; as they start in deep niches they suggest a probable occurrence of buried ice masses. The numerous ponds that develop at the surface and at the slopes of the moraine, seem to speak for a presence of a dead glacier ice inside.

EXTRAGLACIAL ZONE OF THE TORELL AND NANN GLACIERS

Outside a terminal ice-cored moraine of the Nann Glacier and at the southern side of the outer ice-cored moraine of the Torell Glacier, there is a system of vast plains of extraglacial outwashes (Text-figs 2*B* and 4*B*), five raised marine terraces, ice-cored moraines of the Tone Glacier and numerous nival-slope features, among which the so-called nival moraines and talus cones predominate (Text-fig. 1).

EXTRAGLACIAL OUTWASH PLAINS

These plains form two distinct levels. The higher one originated in result of the meltwater runoff, during the maximum extents of the Torell and Nann glaciers as well as during the first phases of their retreat. The outwash forms a distinct rubble-gravel plain outside the western and central parts of the outer ice-cored moraine of the Torell Glacier and fill the erosive incisions close to the sea, amidst the fragments of marine terraces. In many cases, especially at places of numerous gorges in the outer moraine of the Torell Glacier, this outwash plain passes into higher outwash levels, distinguished by Karczewski & Wiśniewski (1975, 1977). The lower outwash plain (Text-fig. 2*B*) is separated from the higher one by low erosive edges (1—2 m high) and forms a system of alluvial fans; some of them start in the southern gorge in the terminal ice-cored moraine of the Nann Glacier whereas the others at the ice-cored moraines of the Tone Glacier and at the outlet of the Tone Valley (Tonedalen).

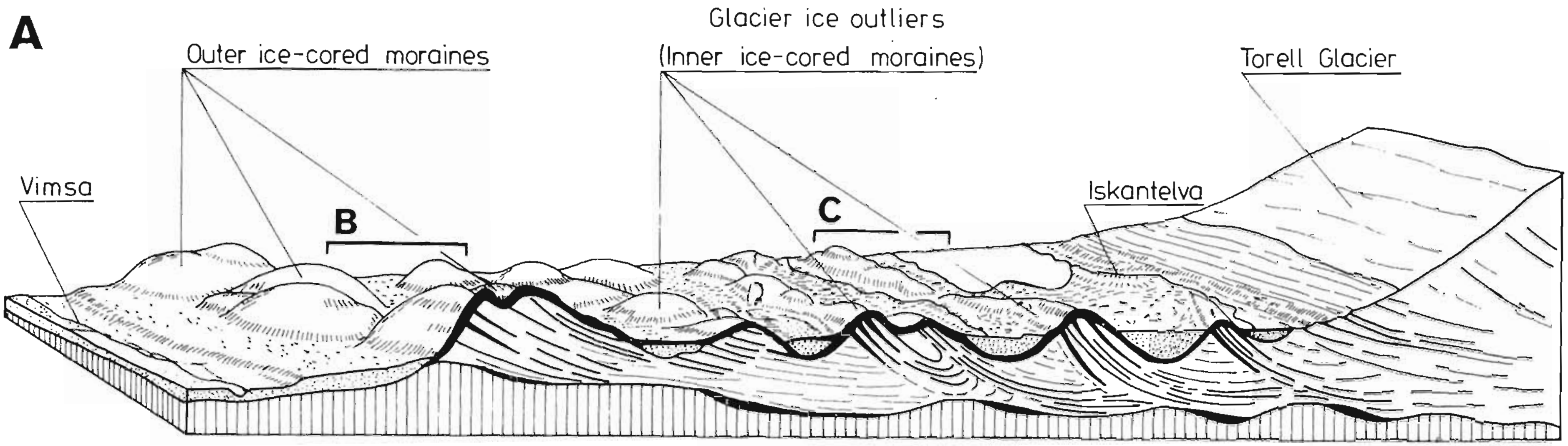
ICE-CORED MORAINES OF THE TONE GLACIER

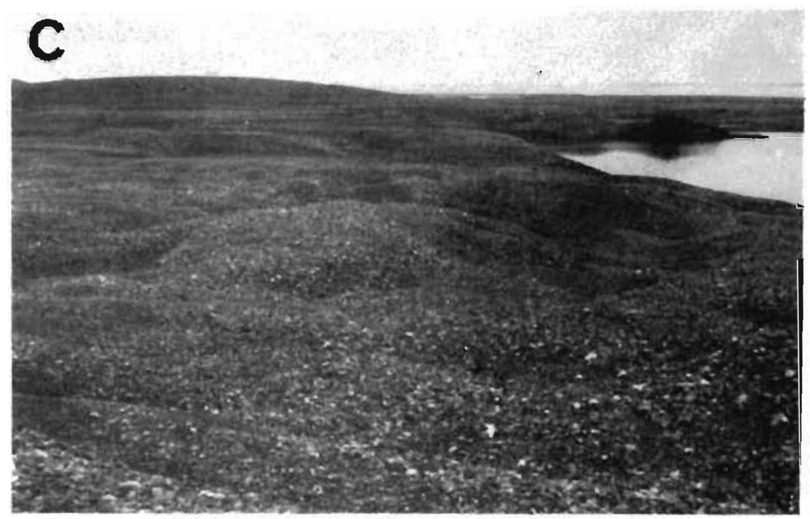
The Tone Glacier occupies an area between the mountain massifs of the Tonefjellet and Rundingen. It is composed of three branches that connect with one another in a terminal part, creating an uniform ice mass. The glacier terminus occurs at about 200 m a.s.l.

The terminal ice-cored moraine is dessected in its central part by a deep meltwater valley. The moraine does not form a distinct ridge and its top surface gradually gets down north-westwards and then, beneath a hanging rock threshold of the glacial valley, it becomes a deformed (due to the sliding of morainic deposits along a steep bedrock slope) tongue at 50—120 m a.s.l.

The lateral ice-cored moraines are asymetrical: at the foot of the Tonefjellet the moraine is short and reaches up to 260 m a.s.l., whereas at the foot of the Rundingen it is much longer and reaches up to 460 m a.s.l. One of its fragments even occurs still higher up, contacting with a firn field and starts in a gully at a mountain slope at over 600 m a.s.l.

The Tone Glacier possesses also a distinct median ice-cored moraine that starts at a terminal ice-cored moraine close to a meltwater valley and spreads up-glacier, to about 280 m a.s.l. It partly separates the ice masses running from two separate firn fields.





A — Blockdiagram of the morainal zone and the forefield of the Torell Glacier, based on the melting model of Spitsbergen glaciers presented by Boulton (1972), and two examples (*B* and *C*) to illustrate this model

B — Forefield of the Torell Glacier: erosive cuts of the outer ice-cored moraine; in the foreground the sediments of an extramorainal outwash plain; August 1980

C — Morainal zone of the Torell Glacier: the outwash plain with kettles filled with meltwaters; August 1980

RAISED MARINE TERRACES

Between the extramorainal outwash plain of the Werenskiold Glacier (south of the area) and the extramorainal outwash plain of the Nann Glacier there is a west-east strip of raised marine terraces that contact with the foot of the Jens Erikfjellet massif in the east, and the seashore in the west. These terraces have been intensively undercut by meltwaters of the Nann and Torell glaciers whereas close to the sea they have been greatly dissected and destroyed.

The marine terrace 2 m a.s.l. is noted only close to Vimsodden where it forms quite a compact plain within the outwash sediments. It rises only slightly above the surrounding outwash plains but possesses a decidedly different system of structural features (storm ridges and separating depressions), approximately parallel to the recent coastline.

The marine terrace 5—6 m a.s.l. occurs to the south-east of Vimsodden where it connects two higher marine terraces. At its surface there are numerous ponds that formed due to melting of the permafrost. In the north-western section there stretches an exceptionaly well conserved storm ridge. Instead, the south-eastern part of the terrace has been undoubtedly subjected to the intensive erosion by meltwaters of the Werenskiold Glacier; for that reason, small fragments of the terrace are isolated and surrounded by outwash sediments.

The marine terrace 10—12 m a.s.l. occurs between the terrace 5—6 m a.s.l. in the south-west and the slope of Jens Erikfjellet in the east. It rises in this direction and locally, at the mountain foot occurs over 20 m a.s.l. what results partly from a cover of slope sediments, among others of an immense nival moraine. The terrace surface has been considerably dissected in the north by the meltwaters of the Nann Glacier whereas in the north-east — by nival streams running down from a slope of Jens Erikfjellet. A fragment of this terrace occurs also at the peninsula, south of Vimsodden.

The marine terrace 18—20 m a.s.l. forms the base and the Vimsodden peninsula. It is relatively compact and separates the bays of Skoddebukta and Nottinghambukta.

The marine terrace 180 m a.s.l. is noted in the Tonedalen that separates the mountain massifs of Jens Erikfjellet and Tonefjellet. It forms a distinct flattening within the valley bottom (Ostaficzuk & *al.* 1980) which due to field observations appeared to have been confined to the sea abrasion.

RECENT STORM RIDGE

The storm ridge runs along the present seashore, from Vimsodden to the Torell Glacier. It really consists of several separate storm ridges what is proved by longitudinal structural lines as well as by a considerable width (generally over 100 m). The complex ridge cuts locally the sea lagoons or dams the outwash streams and thus favors the formation of ponds. A similar storm ridge runs south of Vimsodden, already within the Nottinghambukta.

NIVAL-SLOPE FEATURES

Nival moraines occur at the foot of the western, northern and eastern slopes of the Jens Erikfjellet massif; in the latter case they enter the outlet reach of Tonedalen (*cf.* Birkenmajer 1959; Szupryczyński 1963, 1968; Karczewski & *al.* 1981a).

The feature at the marine terrace 10—12 m a.s.l. occupies an area of 800 by 700 m and reaches the altitude of over 40 m a.s.l. that is 20—30 m above the terrace surface. At the same time, there are great rock vacancies at the mountain slope of Jens Erikfjellet, above the nival moraine. Probably, the rock blocks sliding down covered the outcrops that lie in continuation of the mountain chain westwards. At the top flattening there are structural lines that suggest a more intensive transport within two zones, and perpendicularly to Jens Erikfjellet. A ridge-like nival moraine occurs at the northern slope of Jens Erikfjellet and at the outlet of Tonedalen in fragments. The ridge base is located at 80—120 m a.s.l. whereas its height does not exceed 20 m.

The talus cones are abundant at the slopes of Jens Erikfjellet, in Tonedalen and in the surroundings of the firn fields of the Tone Glacier. They form several superimposed sets, particularly at the western slope of Jens Erikfjellet. In the outlet part of Tonedalen they pass into a top surface of the nival moraine. Single talus cones were also found at mountain slopes of Solheimfjellet and Rundingen, contacting with the Nann Glacier.

Dilluvial covers are composed of fine-grained sands, saturated with water. They form 0.5—1.5 m thick series at the foot of Jens Erikfjellet. A great water content favors a development of a thick moss layer at the surface. The sands have been deposited by numerous nival streams flowing down the mountain slopes and transporting the finest particles of a weathering waste. The subslope dilluvial covers occur mainly at a margin of the extramorainal outwash plains of the Werenskiold Glacier and the Nann Glacier. They occupy also small areas at the foot of a nival moraine.

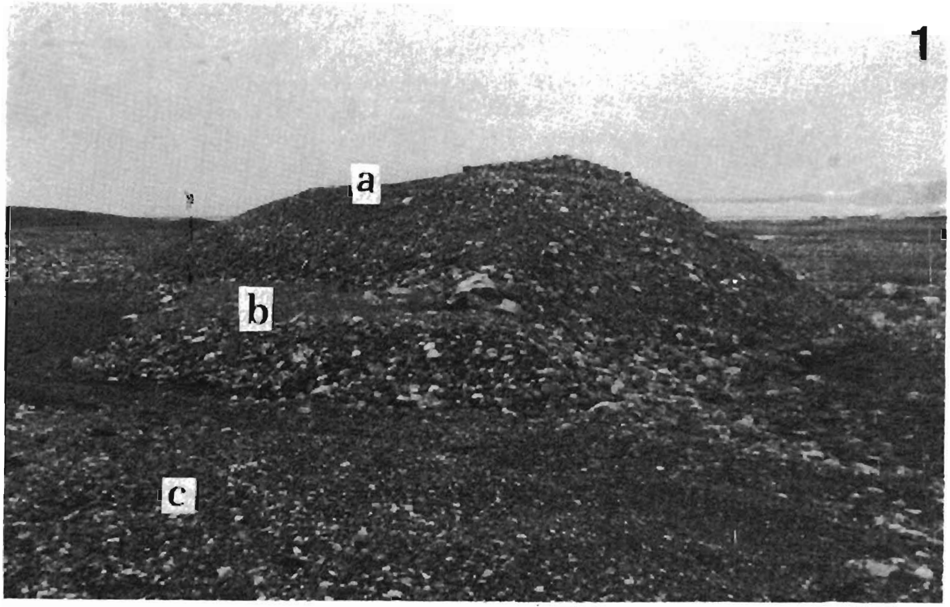
Besides, the zones with an intensive solifluction were noted at the mountain slopes, strictly connected with landslide niches: they occur within the sediment coming from the niches. They were found only at the southern slopes of Solheimfjellet. The cryoplanation terraces occur at the outlet of Tonedalen, at 50—70 m and 160—180 m a.s.l. The snow-debris fans are relatively common at slopes of Solheimfjellet and Rundingen. They get down into the upper part of the Nann Glacier (over 200 m a.s.l.), and they have been formed in result of landslides running down the slopes, and composed of a weathering waste mixed with snow masses.

EVOLUTION OF THE TORELL, NANN AND TONE GLACIERS

A photogeologic analysis and fieldworks in the morainal zone and the forefield of the Torell, Nann and Tone glaciers enable to reconstruct an advance and a retreat of the glaciers in connection with the recognized marine terraces.

The highest marine terrace (180 m a.s.l) proves a transgression of the Greenland Sea into the western Spitsbergen shores, probably during the Early Würm when the glacier occupied a much smaller area than in the Late Würm or nowadays (cf. Boulton 1979), Kłysz & Lindner 1981).

The next, lower marine terrace (18—20 m a.s.l.) forms in this area a small outlier only at the Vimsodden peninsula. It was formed due to a sea abrasion of pre-Quaternary rocks and their overlying by a thin



1 — Morainal zone of the Torell Glacier: three-levelled (**a**, **b**, **c**) erosive outlier in the outwash plain; August 1980

2 — Morainal zone of the Torell Glacier: dry drainage-less depressions (the largest one arrowed) in the outwash plain; August 1980

cover of marine gravels. Its present position results from the Early Würm glacier movements that got down along the valleys towards the seashore; these valleys are now occupied by the Werenskiold, Nann and Torell glaciers. Considering the possible altitude, age connections of this terrace with marine gravels at Prins Karl Forland, north-west Spitsbergen, noted at 20 m a.s.l. and radiocarbon datings for 12 590 years B. P. (Salvigsen 1977), one can expect this terrace and the surrounding glaciers of that time to be of the Late Würm glacier retreat interval in Spitsbergen.

Probably at the beginning of the Holecene, the valleys now occupied by the glaciers were mostly ice-free. During the Middle Holocene the sea entered the valleys and formed still lower and lower marine terraces (10—12 and 5—6 m a.s.l.), now recognizible only west of the Jens Erikfjellet massif (*see* Text-fig. 1). Marine pebbles of these terraces are dispersed nowadays within the gravels that cover the outer ice-cored moraine of the Torell Glacier and within the outwash sediments of its forefield. The presence of these pebbles in glacial sediments proves the Late Holocene glacier advance in this area (Text-fig. 5), which probably is to be dated as the Magdalenefjorden Stage, *i.e.* about 2 500—2 400 years ago (*cf.* Szupryczyński 1968).

An extent of the Torell, Nann and Tone glaciers during the Little Ice Age, lasting from 600 to 100 years ago (Baranowski 1977, Pękala 1980), is marked mainly by ice-cored moraines (*cf.* Text-fig. 1). These moraines as well as the extramorainal outwash at their distal sides, delimit the maximum extent of these glaciers at this century turn, and of the outwash tracts at that time (Text-fig. 5).

The retreat of the glaciers was primarily expressed by a lowering of the glacier surfaces (mainly of the marginal fragments of their tongues) that resulted in considerable concentration of morainic sediments at the glacier snouts. A maximum of this process was reached at the beginning of this century (Troitsky & *al.* 1975). The first cartographic data on the extents of ice-cored moraines around these glaciers come from the Norwegian topographic map (*Norge, Topografisk Kart over Svalbard*, 1953) that really presents the situation observed in 1936.

The last fieldworks and their confrontation with the Norwegian air photos of 1966 as well as with observations of J. Szupryczyński undertaken in 1959 and 1960 (Szupryczyński 1963), and with later works (Karczewski & Wiśniewski 1975, 1977), enable to reconstruct the later deglaciation phases of these glaciers, particularly the extents of their more and more flattened snouts (Text-fig. 5).

In the case of the morainal zone of the Nann Glacier there is also a regularity, typical of the glaciers of West Spitsbergen, and expressed by the presence of two gorges within an ice-cored moraine. The data

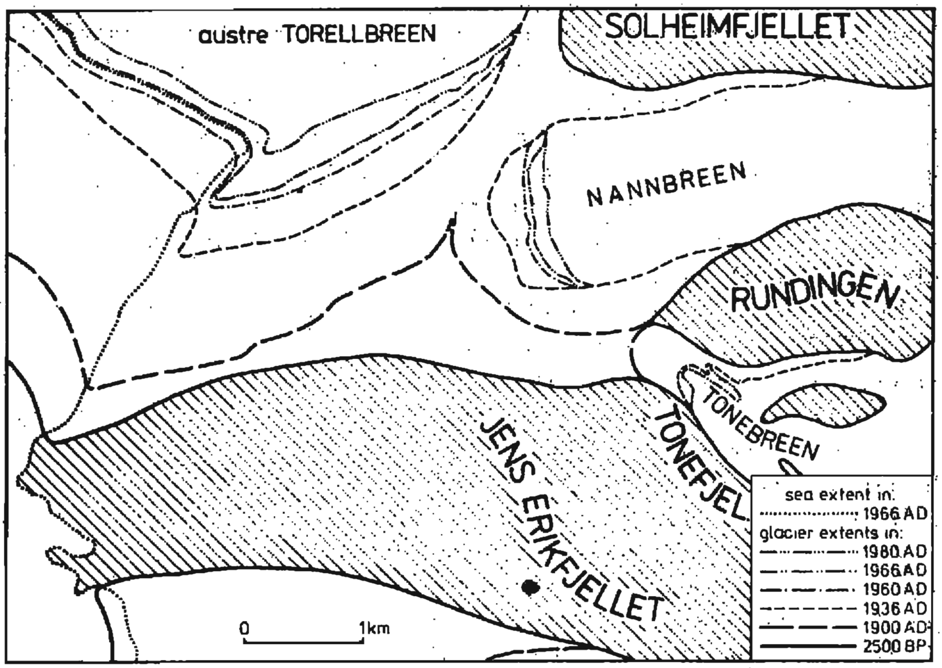


Fig. 5. Advance and retreat phases of the glaciers in the studied area; the extraglacial area is hachured

from literature, maps and field observations suggest that during the last dozens of years a trend is noted to concentrate the meltwater outflow in the southern gorges. According to Kłysz & Lindner (1982) this trend results from a continued melting of the southern and south-eastern parts of the glaciers due to more intensive insolation and from a quicker glaci-isostatic uplift of the central part of Spitsbergen, resulting from a quicker deglaciation caused by the Gulf Stream. The first process decided also about gradual areal deglaciation in the marginal part of the Torell Glacier; the snout of the latter, while retreating northwards, exposed a system of glacier ice outliers, being covered by morainic material and considered previously (Karczewski & Wiśniewski 1975) as the so-called ice-cored moraines.

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[NORGE, TOPOGRAFISK KART OVER SVALBARD 1 : 100 000, Blad B12 Torellbreen. *Norsk Polarinst.*; Oslo, 1953.]

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ROZWÓJ STREFY MARGINALNEJ I PRZEDPOLA LODOWCÓW TORELLA, NANNA I TONE NA SPITSBERGENIE

(Streszczenie)

W oparciu o wyniki badań terenowych przeprowadzonych w latach 1979—80 oraz interpretację norweskich zdjęć lotniczych opracowano mapę fotogeologiczną w skali 1 : 10 000 obejmującą strefę marginalną oraz przedpole lodowców Torella, Nanna i Tone (Ziemia Wedel Jarlsberga) na Spitsbergenie *. Na obszarze tym rozpoznano m.in. (patrz fig. 1—4 oraz pl. 1) wały lodowo-morenowe, sandr intramarginalny, oraz jeziora zaporowe w strefie marginalnej lodowca Nanna, a ponadto wały lodowo-morenowe, powierzchnię sandrową, jeziora zaporowe i wytopiskowe strefy marginalnej lodowca Torella. Opisano również położone na przedpolu lodowców Torella i Nanna sandry ekstramarginalne, wały lodowo-morenowe lodowca Tone, tarasy morskie oraz formy niwalno-zboczowe. Krytycznie ustosunkowano się do dawniejszych poglądów o zmutonizowanym charakterze wewnętrznych wałów lodowo-morenowych lodowca Torella, uznając je za ostańce lodu lodowcowego przykryte przez materiał morenowy. W nawiązaniu do rozprzestrzenienia i wysokości tarasów morskich przedstawiono ewolucję lodowców badanego obszaru w Würmie oraz w holocenie (patrz fig. 5).

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* Praca wykonana w ramach planów międzyresortowych *MR. II—16B* oraz *MR. I—29*.