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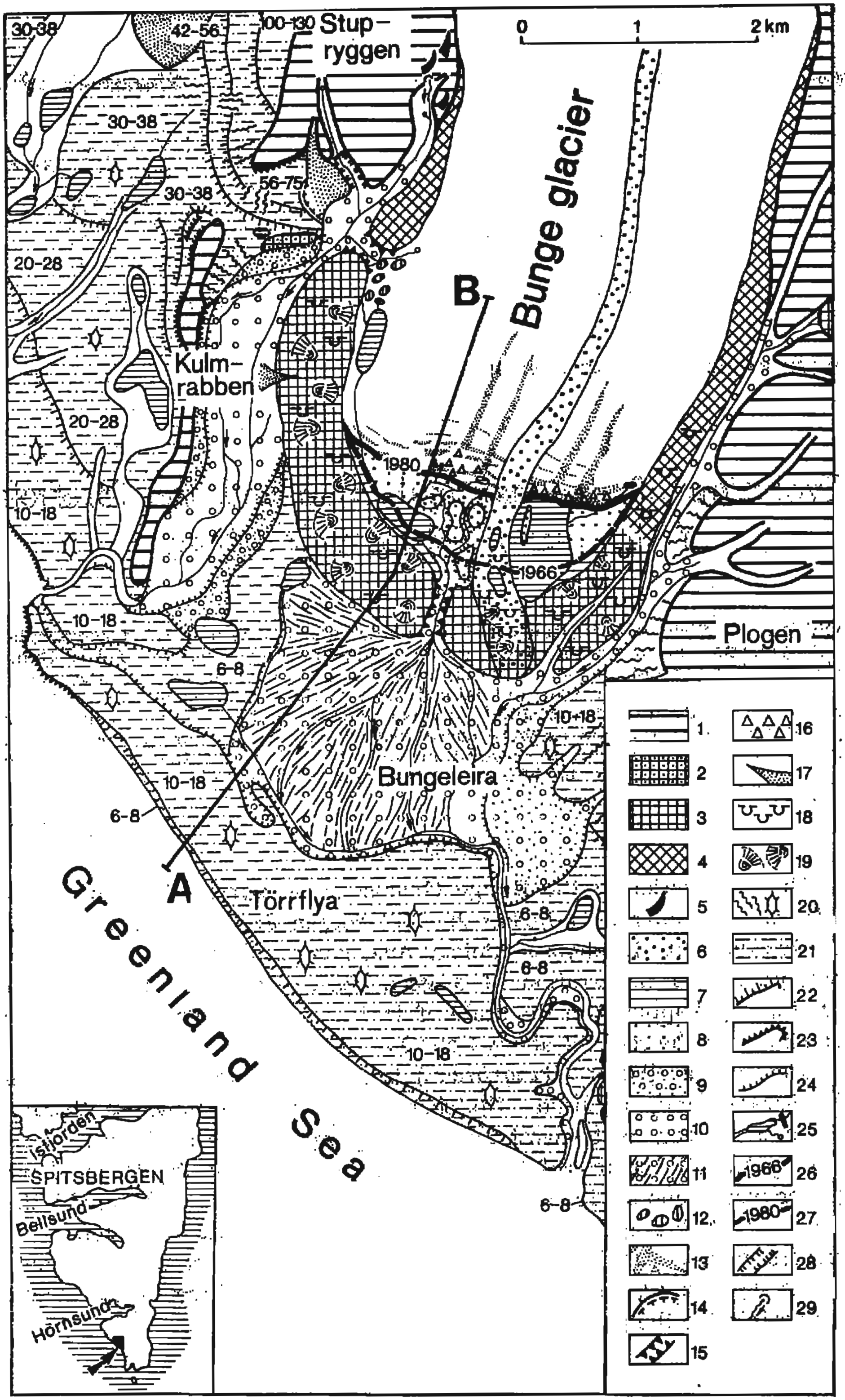
Evolution of the marginal zone and the forefield of the Bunge Glacier, Spitsbergen

ABSTRACT: Field investigations and air photo interpretation enabled geomorphologic-geologic recognition of the marginal zone and the forefield of the Bunge Glacier (*Bungebreen*) in Sörkappland, southern Spitsbergen. Among the glacial features the terminal, median and lateral ice-cored moraines as well as a system of intramarginal and extramarginal outwash plains are the most important. These glacial features and sediments were correlated with marine raised terraces. Besides, an attempt to reconstruct the evolution and the decline of the Bunge Glacier during the Würm and Holocene is presented.

INRTODUCTION

The fieldworks on the Bunge Glacier were carried through by the authors in summer 1980 during the Spitsbergen Expedition organized by the Institute of Geophysics, Polish Academy of Sciences. The authors took part in a preparation of a geomorphologic map for the north--western Sörkappland in the scale of 1:25 000, with a use of Norwegian air photos in the scale of about 1:50 000.

The Bunge Glacier (*Bungebreen*) is located in the western part of the Sörkappland, southern Spitsbergen. Its tongue flows southwards and it is framed in the west by the Stupryggen massif whereas in the east by the Plogen massif (Text-fig. 1). The first investigations of this glacier were done by Jewtuchowicz (1962, 1965) who studied the ablation processes at the glacier itself as well as in its marginal zone. The authors wish to supplement this description and to discuss some genetic problems; besides, they intend to present a chronology of the events responsible for the present relief of this area.


Stup-
ryggen
Bunge glacier
Kulm-
rabben
Plogen
Bungeleira
Törrflya
Greenland Sea
A
B
1980
1966
0 1 2 km
30-38
42-56
100-130
56-75
20-28
10-18
6-8
10-18
ISFJORDEN
SPITSBERGEN
Bellsund
Hornsund

MARGINAL ZONE OF THE BUNGE GLACIER

The marginal zone of the Bunge Glacier is formed by several types of features and sediments (Text-figs 1 and 3*A*—*B*) that, starting from the glacier snout, are arranged in the following way.

GLACIER SNOUT AND TRANSITION ZONE

A description of the surface of the Bunge Glacier was given by Jewtuchowicz (1962, 1965). But the marginal part of the glacier snout is expressed quite differently now due to a considerable retreat lately (Text-fig. 2).

At present, the glacier snout is located about 700—800 m from the terminal ice-cored moraine. It is separated from the intramarginal outwash plain by a several dozen metres wide zone with an ablation moraine and ice pyramids (Text-fig. 1 and Pl. 1, Figs 1—2). A distinctness of this border is underlined locally by a marginal stream that dissects also the intramarginal outwash plain (Text-fig. 4*A*). An accumulation of an ablation moraine and ice pyramids does not seem to result in another generation of ice-cored moraines. After melting of the ice substrate it is supposed to form a ground moraine.

INTRAMARGINAL OUTWASH PLAIN

The outwash plain occupies a significant area to the west of the median moraine and a smaller area at the eastern side of this moraine close to the terminal and lateral ice-cored moraines (Text-figs 1 and 3*B*). At the eastern side of the median moraine there is a vast ice-dammed reservoir. A similar lake, although much smaller one, is located also to the west of the terminal moraine.

The whole intramarginal outwash plain, composed of 4—5 morphologic levels (Text-fig. 3*B* and Pl. 2, Fig. 1), is deposited at the surface

Fig. 1. Geomorphologic sketch of the marginal zone and foreland of the Bunge Glacier; *A*—*B* denotes the line of geologic cross-section presented in Text-fig. 2

1 elevations of pre-Quaternary substrate, *2* older (Würm) moraine deposits, *3* terminal ice-cored moraines, *4* lateral ice-cored moraines, *5* roches moutonnées, *6* inner moraine, *7* surface of ablation moraine, *8* intramarginal outwash, *9* higher level of extramarginal outwash, *10* lower level of extramarginal outwash, *11* lower level of extramarginal outwash with supraglacial deposits, *12* morainic hills stretching throughout ice, *13* moraines within the glacier, *14* nival niches, *15* gorges, *16* ablation fans and supraglacial deposits, *17* alluvial fans, *18* thermokarst depressions (some filled with water), *19* solifluction niches and tongues, *20* structural soils, *21* marine terraces (height in m a.s.l.), *22* margins of marine terraces, *23* elevated marine cliffs, *24* erosion margins within outwash plains, *25* lakes, rivers, streams and waterfalls, *26* extent of glacier in 1966, *27* extent of glacier in 1980, *28* erosion ravines, *29* karst springs of a dead and stagnant glacier ice (Text-fig. 2). The higher outwash levels occur in fragments only, being smaller or greater islands and outliers (Text-fig. 3B). A presence of the ice inside and its varying melting, result in an uneven surface of the outwash. There are numerous kettle-like small depressions, usually filled with water (Pl. 2, Fig. 2). Seldom these kettles are arranged in a regular system, perpendicular to the glacier snout (Pl. 3, Fig. 1) and are located along the outflow, now dammed in many places by landslides coming from the edges of higher outwash levels. Some of them seem to have been connected with local icings (*cf.* Kozarski 1975).

The icing covers mainly the lowermost outwash level. It results in a great intensity of the processes that destruct the intramarginal outwash plain. Especially a marginal part of the icing has been subjected to quite a quick degradation and so, in a zone already ice-free and limited by the edge of the higher outwash level, an intensive meltwater outflow is noted (Pl. 3, Fig. 2 and Pl. 4, Fig. 1). An erosive and thermal action of these waters results in a further retreat of the edge and in an increase of its height.

The edges of the outwash levels, 2—3 m high, and slopes of thaw depressions show an inner structure of the intramarginal outwash plain. The outcrops in the edges prove that the ice substrate is overlain by a highly varying although generally coarse, sandy-gravel-stony sediment (Pl. 3, Fig. 2) with a common flat bedding.

ABLATION MORAINE

The intramarginal outwash plain is separated from the terminal ice-cored moraines by a narrow strip of an ablation moraine (Text-fig. 1). The latter is an effect of an intensive ablation at the proximal sides of the moraines where a slow melting of the ice core results in superficial flows of a morainic mud, stopped at the foot of the morainic hills. But it is not a final effect of a relief evolution in this zone. It should be taken into account that this accumulation occurs on an uncompletely melted glacier ice and not until its disappearance, a deposition of the muddy-stony sediments is possible.

ICE-CORED MORAINES

All the ice-cored moraines contain, under a relatively thin cover of a morainic deposit (0.5—1.5 m thick), a glacier ice core (Text-fig. 2, Pl. 5, Fig. 1). In the marginal zone of the Bunge Glacier there are median, terminal and lateral moraines (Text-fig. 1).

The moraine originates at the foot of the nunataks Sjdánovfjellet two parts: a larger western part and a considerably smaller eastern part (Text-fig. 1).

The median moraine is up to 50 m high and divides the glacier into (outside the described area). Jewtuchowicz (1962) noted a considerable degradation of this feature, numerous transversal fissures and its gradual levelling close to the glacier edge. The authors' observations support this opinion and suggest also that a varying melting of the ice core favors a formation of large depressions at the moraine (Pl. 5, Fig. 1).

The terminal moraine of the Bunge Glacier is up to 60 m high and does not form a uniform ridge but many more or less parallel elevations. Such a system is typical for ice-cored moraines and is generally considered for an effect of successive retreat phases of the glacier (Szupryczyński 1963). The mentioned terminal moraine is, similarly as the median moraine, intensively degraded. As opposed to a disintegration of the median moraine, the melting of the terminal moraine results in a flattening of its shape and in a formation of vast, flat ablation depressions filled with silty-sandy sediments. The accumulative processes of these features are presented by Jewtuchowicz (1962) and Kłysz (1982).

When describing the terminal moraine of the Bunge Glacier, Jewtuchowicz (1962) distinguished but the two mentioned above features, defined by him as the accumulative moraines, also the pushed moraines. The authors observations prove that an occurrence of such moraines in the terminal zone of the Bunge Glacier is impossible. The exposures that show an inner structure of terminal ice-cored moraines in the southern gorge of outwash streams crossing these

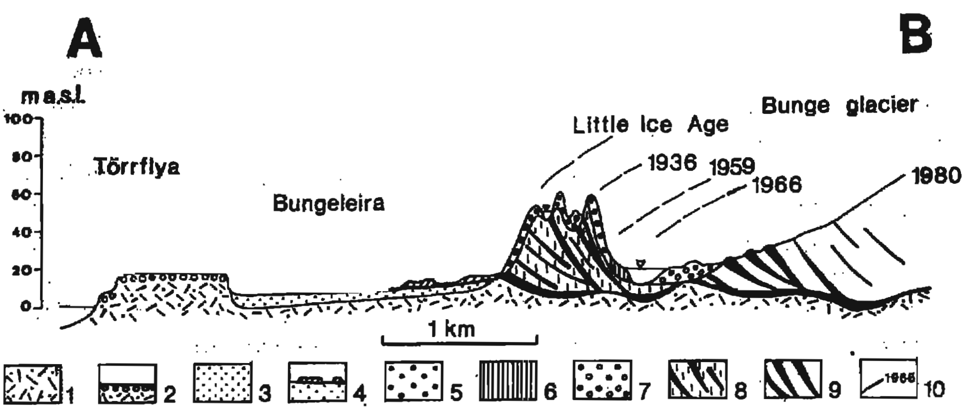


Fig. 2. Geologic cross-section (*A—B*) through the marginal zone and forefield of the Bunge Glacier (*cf.* Text-fig. 1)

1 bottom moraine, *2* marine gravels overlying bottom moraine, *3* gravels and sands of extramarginal outwash, *4* gravels and sands of extramarginal outwash with supraglacial deposits, *5* moraines overlying ice-morainic ridges, *6* ablation moraine, *7* gravels and sands of intramarginal outwash, *8* dead ice with morainic material, *9* active ice with morainic material, *10* extent of glacier in successive years moraines, prove the shears and dynamic deformations preserved there inside the ice to be the remnants of a primary structure of the glacier ice.

The lateral moraines occur at the eastern as well as at the western side of the Bunge Glacier (Text-fig. 1). At the western side of the glacier they are separated from the terminal moraine by the western meltwater gorge; instead, they are strictly connected with the terminal moraine in the east, without any distinct morphological border. But their position in relation to the glacier, these features can be distinguished on the ground of the following criteria: greater content of gravels and boulders, in opposite to a terminal moraine they increase their extent by an occurrence of longer features towards the firn field of the glacier as well as by their lateral accretion (Pl. 8, Fig. 1). In the first but also in the second case, the larger extent is caused mainly by melting in the marginal part of the glacier where a morainic sediment, transported along the glide planes, is deposited. In many places but especially close to the western gorge, gravels and sands of individual accretions of the lateral moraine at the glacier side, show a significant lithologic and grain size differentiation. In some places they form even something like gravel-boulder islands at the surface of the glacier margin (Text-figs 1 and 4*B*). A presence of an ice core and no bedding of a sediment, noted by the authors, do not allow to accept an opinion of Jewtuchowicz (1962) who found these features for a complex of kames and eskers.

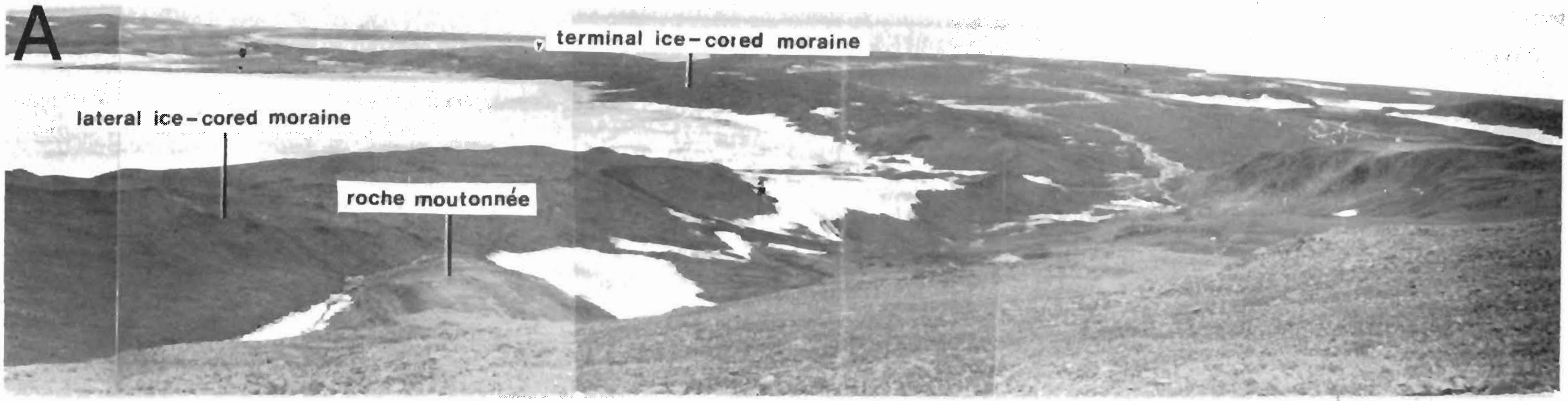
MELTWATER GORGES

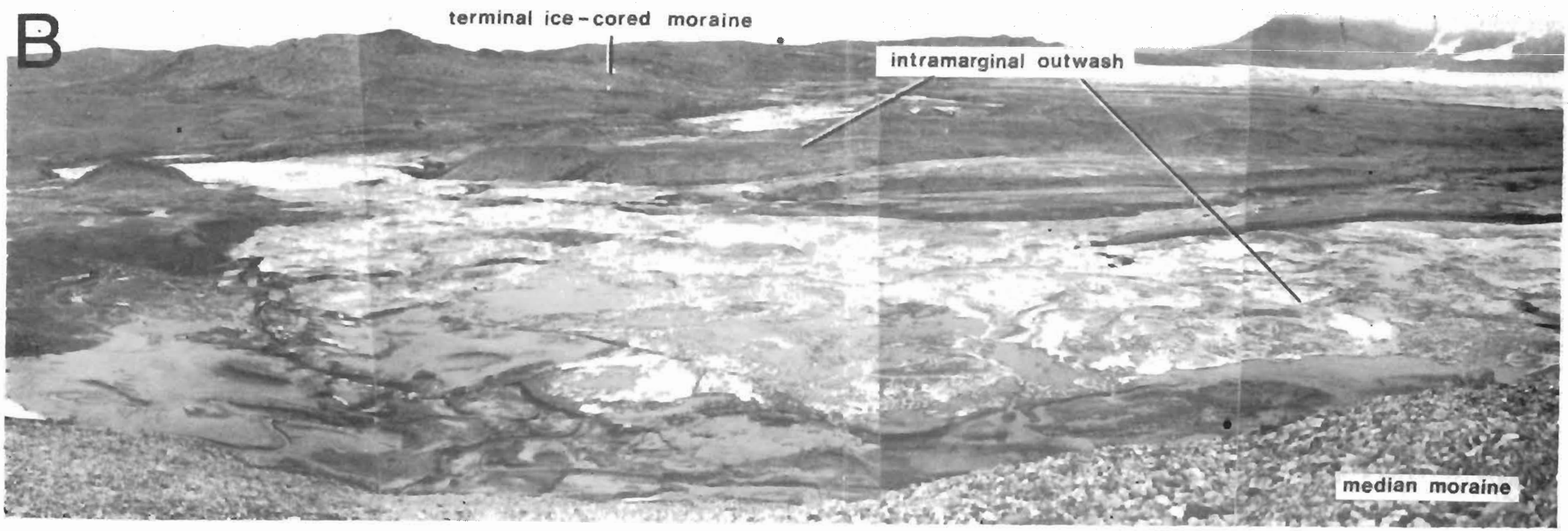
The marginal zone of the Bunge Glacier is drained through two gorges (western and southern) across the ice-cored moraines (Text-fig. 1). The western gorge (Pl. 6, Fig. 1) separates the lateral moraine from the terminal one and is used by a less than one third of the meltwaters whereas the southern gorge (Pl. 6, Fig. 2) passes across the most elevated part of the terminal moraine, to the west of its connection with the median moraine, and is used by the remaining quantity of water. Outside the southern gorge, the meltwaters form now a very extensive system of alluvial fans of the extramarginal outwash plain. In a distal part of the terminal moraine, this outwash is separated from it by a narrow (5—10 m wide) ledge of a transitional outwash fan.

EXTRAMARGINAL OUTWASH PLAIN

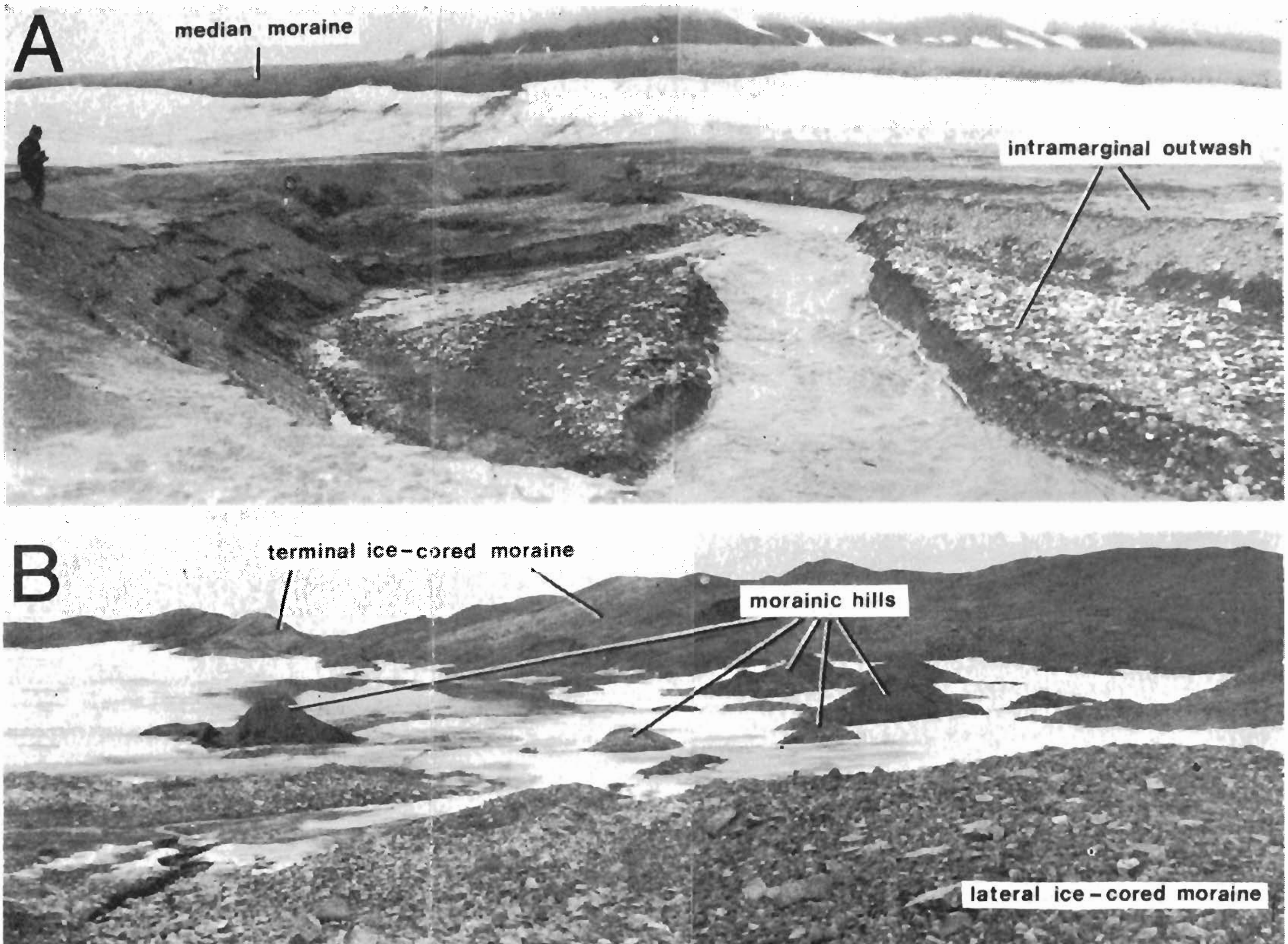
The surface of the extramarginal outwash plain was formed by meltwaters flowing away the Bunge Glacier and its marginal zone. In the forefield of this glacier there are two distinct outwash tracts, starting

Bunge Glacier: marginal zone and forefield seen from the west (A) and the western part of the intramarginal outwash (B)





Bunge Glacier: intramarginal outwash (A) and morainic hills rising throughout the ice (B)



at the outlets of the two mentioned gorges (Text-fig. 1). At the surface of the extramarginal outwash there are several levels corresponding with successive phases of the glacier retreat. The higher level extends at 10—6 m a.s.l. It forms ledges along the western outwash tract at the eastern side of the Kulmrabben elevation and in the marginal zones of the southern tract (Bungeleira region). The traces of this level are also well preserved further to the west where there is a distinct ledge, put into a dissected surface of marine terraces (Pl. 5, Fig. 2). The lower level, at 8—6 m a.s.l., is separated from the previous one by erosive edges (Pl. 7, Fig. 1). It occurs mainly within the limits of the western tract and suggests that there was a period when the outflow has been more active through the western gorge than it is nowadays. Both outwash levels compose of several separate steps. The actual meltwater outflow runs at the lowermost step of the lower level at 3—4 m a.s.l. Within the limits of the southern outwash tract (Bungeleira region) the lowest step was covered in summer 1980 by vast icings (Pl. 6, Fig. 2 and Pl. 7, Fig. 2) that disturbed the water runoff and infuenced much the morphogenetic processes at the accumulated outwash plain.

FOREFIELD OF THE MARGINAL ZONE OF THE BUNGE GLACIER

ROCHES MOUTONNÉES

In the vicinity of the Bunge Glacier there appear features that suggest a greater extent of the glacier in the past. Among the features there are, first of all, roches moutonnées and fragments of older morainic ridges (Text-fig. 1). The roches moutonnées occur commonly at the eastern slope of the Stupryggen massif (Pl. 9, Fig. 1). In some cases the surfaces of roches moutonnées are dissected by karst rills (Pl. 8, Fig. 2). A much greater extent of the glacier is also supported by a presence of a glacier-smoothed top surface at the rocky elevation Kulmrabben (Pl. 9, Fig. 2) as well as of other elevations within the massives of Stupryggen and Plogen. These surfaces form plateaux or ledges, frequently of structural predispositions. Stankowski (1981) suggests that some of them have been formed by an abrasion. However, it seems more probable that they were formed due to a glacier erosion during the Würm; the latter existed also in this area as proved by the investigations in the adjacent regions (Kłysz & Lindner 1981a, b, c).

OLDER MORAINIC RIDGES

In result of a photographic interpretation and the field investigations, several fragments of hills and flat agglomerations of morainic sediments have been noted outside the described ice-cored moraines. A single hill of this type is located at the eastern side of the pass that separates Kulmrabben from Stupryggen (Text-fig. 1). The hill is composed of clayey-rubble sediments and forms a fragment of an ancient lateral moraine, cut off in the east by an outwash tract. It delimits a greater extent of the Bunge Glacier, probably during the Late Würm. Concentrations of ancient morainic sediments, although less visible in morphology but quite distinct at air photos, were noted at the top surfaces of Kulmrabben (about 100—120 m a.s.l.) and at the south-eastern slopes of Stupryggen where they reach 300—350 m a.s.l., already outside the described area. Together with distinct traces of glacier cirques, they prove that these elevations were covered by the Würm glaciers.

MARINE RAISED TERRACES

In the forefield of the Bunge Glacier there is also a system of seven distinct marine terraces (*see* Text-fig. 1). The highest terrace, at 100—130 m a.s.l., forms a distinct abrasive ledge at the western slope of Stupryggen. The four lower terraces (56—75, 42—56, 30—38 and 20—28 m a.s.l.), included in the north-western Sörkappland into the middle terraces (Kłysz & Lindner 1981c), are conserved mainly to the west of Stupryggen and Kulmrabben as well as in the passes that possess a relatively thin cover of marine gravels, forming systems of storm ridges separated by lagoon-like depressions. In many places these ridges are cut by rock outcrops that emerge from terrace surfaces as rock cliffs, typical for a skerry coast.

Two lowest marine terraces (10—18 and 6—8 m a.s.l.) were included in the north-western part of Sörkappland into the low terraces (Kłysz & Lindner 1981c). In the forefield of the Bunge Glacier they form a vast Törflya plain (Text-figs 1—2). A considerable part of this plain is occupied by the terrace 10—18 m a.s.l. The marine series of this and of the lower terrace are underlain by a ground moraine of the ancient Bunge Glacier. In the exposure at the sea cliff that cuts these terraces to the south-west of Kulmrabben, this moraine composes (Pl. 10, Fig. 2) of several metres thick boulder-rubble layer, of a similar structure as the moraine that underlies the marine terraces of Kulmstranda (*cf.* Kłysz & Lindner 1981b). A bottom of this bed could not be studied in summer 1980 due to a cover of a shore ice and an ancient snow.

ADVANCE AND RETREAT OF THE BUNGE GLACIER

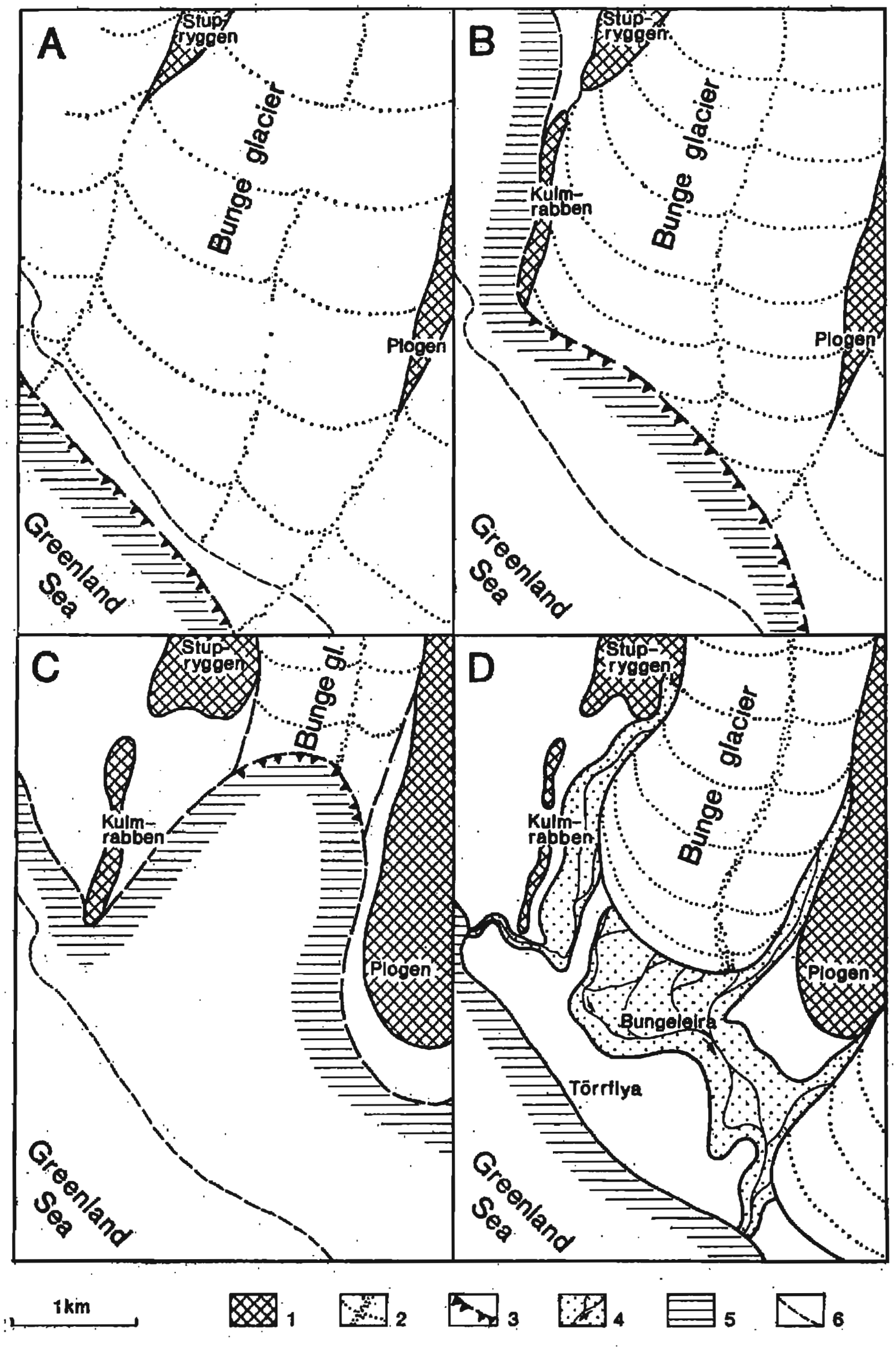
Geomorphologic and geologic observations in a marginal zone and in the forefield of the Bunge Glacier enabled to reconstruct an advance and a retreat of this glacier (Text-fig. 5). Similarly as in the adjacent area (*cf.* Kłysz & Lindner 1981a, b, c), the glaciers occupied during the Würm and the Early Holocene a vaster area than today in this region.

A greater extent of the Bunge Glacier is proved by roches moutonnées, smoothing of elevation summits, ancient morainic sediments that are noted up to 300—350 m a.s.l. and a ground moraine of this glacier, exposed in the present sea cliff i.e. about 1.5 km outside the extent of the present ice-cored moraines. These facts point out that such a far (towards the Greenland Sea) extent of the glacier and so highly noted traces of its erosive and accumulative activity, must have been connected with an almost entire cover of this part of Sörkappland by an ice cap, at least 300—350 m thick. Such an considerable thickness and such an intensive erosive action, could be typical for the glaciers during the maximum of the Würm Glaciation (Text-fig. 5*A*); the latter occurred at Spitsbergen about 45—50 thousand years ago (*after* Boulton 1979, and Salvigsen 1979) or about 46—42 thousand years ago (*after* Baranowski 1977). A similar conclusion was drawn by the authors during investigations carried through in the Slakli valley (Kłysz & Lindner 1981a) and in the Lisbet valley (Kłysz & Lindner 1981c).

The traces of the abrasive undercuts, developed at previously glacier smoothed western slopes of Kulmrabben, occur at the altitude corresponding with the surface of the highest marine terrace (100—130 m a.s.l.) and so, they prove a significant glacier retreat during a formation of the terrace. The published data (Feyling-Hanssen & Olssen 1959—60, Feyling-Hanssen 1965, Grosswald 1963, 1980, Troitsky & *al.* 1975, Baranowski 1977) and the authors' observations in the adjacent areas (Kłysz & Lindner 1981a, b, c), suggest that this moment (Text-fig. 5*B*) occurred about 33—25 thousand years ago. A deposition of ancient morainic sediments, preserved at higher parts of the Stupryggen slopes, should be also connected with this time interval.

A further melting of the Würm glaciers in this area is marked by a presence of an ancient morainic hill at the eastern side of the pass that separates Kulmrabben from Stupryggen (Text-fig. 1). The eastern and so, the proximal part of this feature marks probably a successive Early Würm standstill of the Bunge Glacier. This standstill occurred during a formation of the marine terrace 30—38 m a.s.l.

At the beginning of the Holocene a further retreat of the glaciers caused that the valley, occupied before by the Bunge Glacier, got partially ice-free and its lower part was flooded by the sea — the marine terrace 10—18 m a.s.l. was formed (Text-fig. 5*C*). Marine pebbles of this terrace can be found within the gravel-boulder sediments that cover the ice-cored moraines of the Bunge Glacier and amidst the outwash series of the same age. An incorporation of these pebbles into the typical glacial sediments is, but a geomorphologic criterion, the evidence for


A
B
C
D
Stup-ryggen
Bunge glacier
Bunge gl.
Kulm-rabben
Plogen
Greenland Sea
Bungeleira
Törrflya
1km
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the Late Holocene advance of the Bunge Glacier onto the marine sediments. This advance occurred most probably during the Little Ice Age, i.e. from 600 to 100 years ago (Baranowski 1976, Pękala 1980).

An extent of the Bunge Glacier during the Little Ice Age is marked mainly by the described ice-cored moraines (Text-figs 1—2). These moraines as well as a higher level of the extramarginal outwash at their distal sides, mark the maximum extent of the glacier and of the outwash tracts of that time (Text-fig. 5*D*).

The retreat of the Bunge Glacier, lasting until nowadays, has been already started at the end of the XIX*th* century. At first, it was expressed by a lowering of the glacier surface (mainly of its marginal parts), resulting in abundant meltwaters that formed numerous streams cutting the higher level of the extramarginal outwash plain. The retreat favoured also a considerable accumulation of the morainic sediment in the marginal part of the glacier. The last of the mentioned processes was a most intensive already at the beginning of this century (Koryakin 1975) and initiated a formation of the ice-cored moraines. The data of Koryakin (1975) prove also that the melting of the Sörkappland glaciers, with their snouts on the land, caused also a decrease of their area of 1.4% during the first 36 years of this century. The first more certain mapping data about the extent of the ice-cored moraines around these glaciers come from the Norwegian topographic maps in the scale of 1:100 000, published in 1936. They are the basis to fix an earlier retreat phase of the Bunge Glacier (Text-fig. 2).

The field observations collected by the authors in 1980 and their comparison with the Norwegian air photos of 1966 and with data of Jewtuchowicz taken in 1959 (*see* Jewtuchowicz 1962), enabled to recognize the younger retreat phases of the Bunge Glacier and especially; of the extent of its more and more flat snout (Text-fig. 2). A retreat of the glacier snout is still quicker and equals several hundred metres during the last 20 years. The retreat rate of the Bunge Glacier is similar as of Werenskiold (*cf.* Szupryczyński 1968) or of Hyrne (*cf.* Marks 1981) glaciers.

Marginal zones and forefields of some Spitsbergen glaciers, among others of Bunge, Werenskiold and Nann ones, show a certain regularity expressed by a presence of two distinct outwash tracts, connected with

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Fig. 5. Reconstructed extents of glaciers and seashore in the investigated part of western Sörkappland

A — Maximum extent of Würm (= Vistulian) Glaciation, about 45—40 000 years B.P.; **B** — Older stage of the retreat of Würm (Vistulian) glaciers, about 33—25 000 years B.P.; **C** — Younger stage of the retreat of Würm (Vistulian) glaciers, about 11—10 000 years B.P.; **D** — Maximum extent of glaciers during the Little Ice Age about 600—100 years B.P.

1 nunataks and exposures of pre-Quaternary substrate, *2* surface of glaciers, *3* ice cliffs, *4* outwash plains, *5* sea extent, *6* present-day seashore gorges within the ice-cored moraines of these glaciers. One gorge and the outwash initiated at its outlet can be defined as the western, whereas the other one as the southern. During the last dozens of years a trend is noted to abandon the western outwash tracts and to form the southern gorges. This trend seems to have been caused by a quicker melting of southern and south-eastern parts of these glaciers due to their greater insolation and, on the other hand, by a faster isostatic uplift of the central part of Spitsbergen, resulting from a quicker melting of the glaciers due to the warming by the Gulf Stream. These facts are also supported by the studies over the Holocene uplift of Spitsbergen (Punning & Troitsky 1980).

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P. KŁYSZ i L. LINDNER

ROZWÓJ STREFY MARGINALNEJ I PRZEDPOLA LODOWCA BUNGE NA SPITSBERGENIE

(Streszczenie)

Na podstawie badań terenowych w lecie 1980 r. oraz analizy norweskich zdjęć lotniczych dokonano charakterystyki geomorfologiczno-geologicznej strefy marginalnej i przedpola lodowca Bunge (*Bungebreen*) położonego w zachodniej części Sörkapplandu (południowy Spitsbergen), dla którego opracowano mapę geomorfologiczną *. Wśród form lodowcowych na pierwszy plan wysuwają się kilkudziesięciometrowej wysokości wały lodowo-morenowe tworzące zespół moren czołowych, środkowych i bocznych oraz system intramarginalnych i ekstramarginalnych powierzchni sandrowych (fig. 1—5 oraz pl. 1—10). Całość wyróżnionych form i osadów lodowcowych przedstawiono w korelacji z dobrze wykształconymi tutaj tarasami

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* Mapa ta została wykonana przez zespół w składzie: Mgr L. Andrzejewski, Dr P. Kłysz, Doc. dr hab. L. Lindner, Doc. dr hab. W. Stankowski w ramach problemu międzyresortowego *MR II 16 B* „Rozpoznanie i ochrona środowiska polarnego w dziedzinach nauk o Ziemi".

morskimi (*patrz* fig. 1 i 2 oraz pl. 10). Z przeprowadzonej próby odtworzenia historii rozwoju i zaniku lodowca Bunge (*patrz* fig. 5) wynika, że lodowiec ten w środkowym i młodszym würmie odznaczał się większym rozprzestrzenieniem niż obecnie. Nie znaleziono natomiast śladów staro- i środkowoholoceńskich transgresji tego lodowca. Klasycznie wykształcone wały lodowo-morenowe lodowca Bunge są pozostałością jego rozprzestrzenienia w czasie Małej Epoki Lodowej trwającej tutaj od 600 do 100 lat BP. Zanik tego lodowca został zapoczątkowany pod koniec ubiegłego wieku i w ostatnich czasach odbywa się z prędkością kilkuset metrów na 20 lat.

Wysunięto przypuszczenie, że obecnie rysująca się tendencja do lokowania się odpływów wód roztopowych wzdłuż bardziej południowych szlaków sandrowych, w większości kończących się na lądzie lodowców południowo-zachodniego Spitsbergenu, może być warunkowana większym tempem izostatycznych ruchów wznoszących centralnej części Spitsbergenu *.

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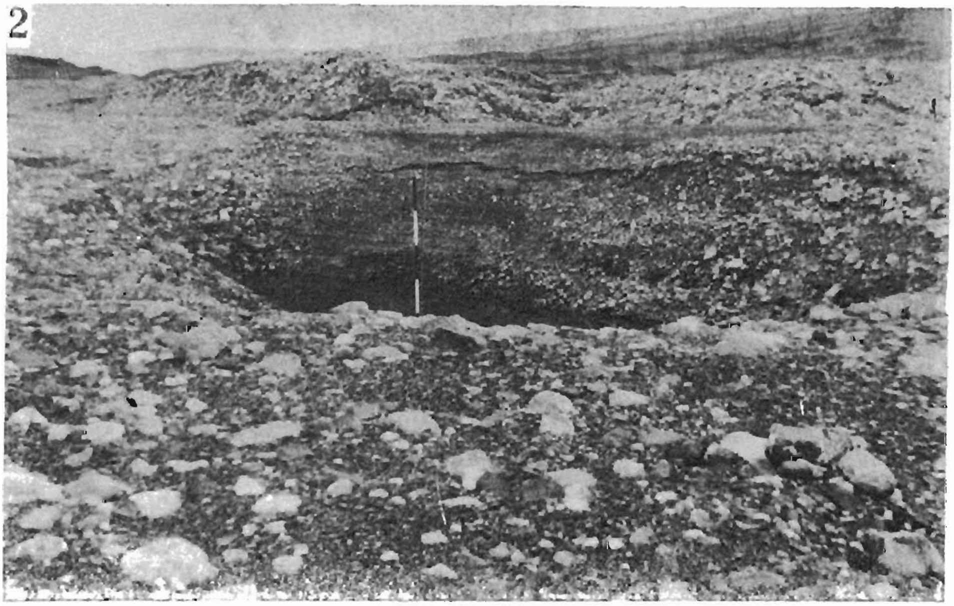
* Praca wykonana w ramach planów międzyresortowych *MR. II-16B* oraz *MR. I-29*.

1 — Ablation cover (upper part) on the Bunge Glacier
2 — Ablation cover (lower part) on the Bunge Glacier

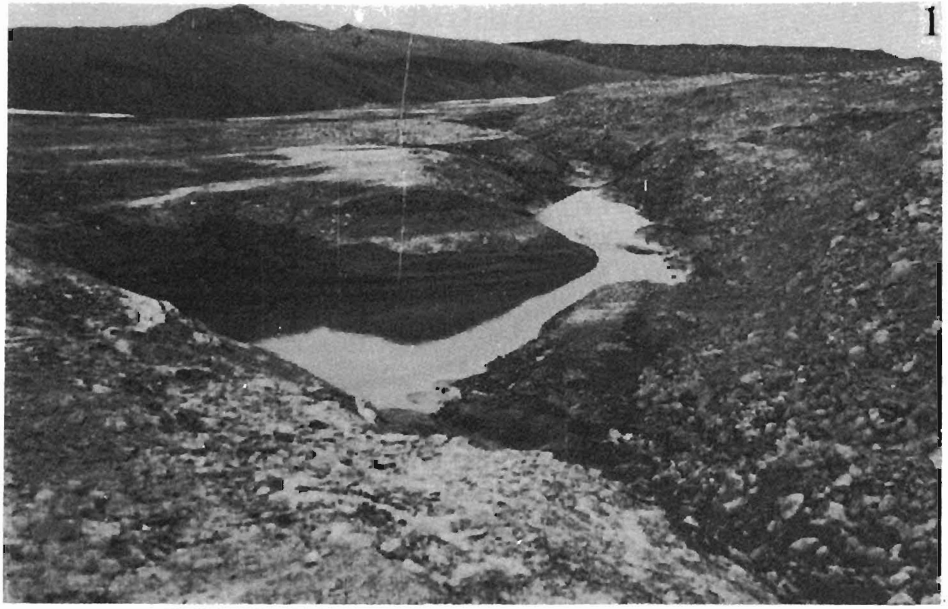
1

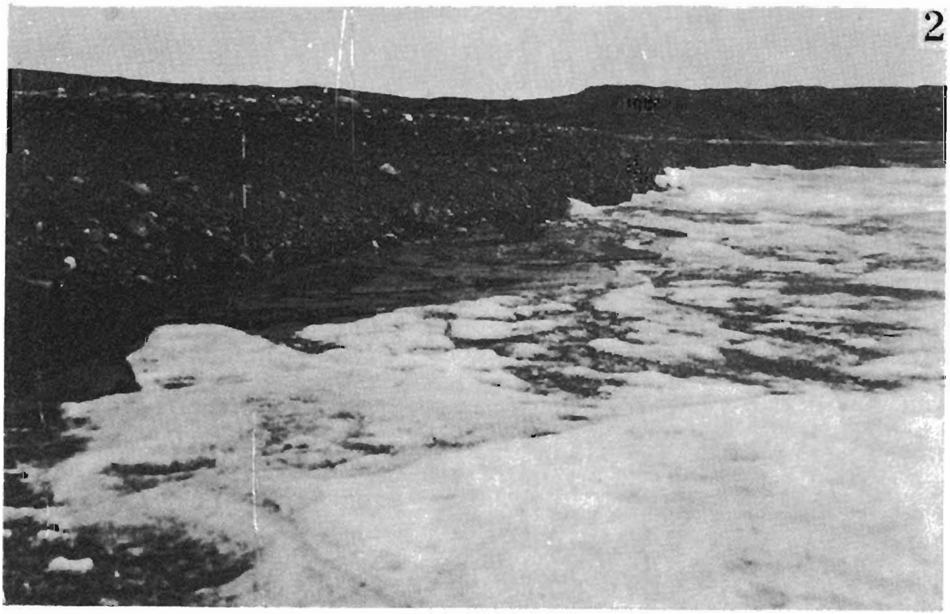
2



1 — Marginal zone of the Bunge Glacier: intramarginal outwash, taken from the median moraine

2 — Marginal zone of the Bunge Glacier: kettles on the intramarginal outwash



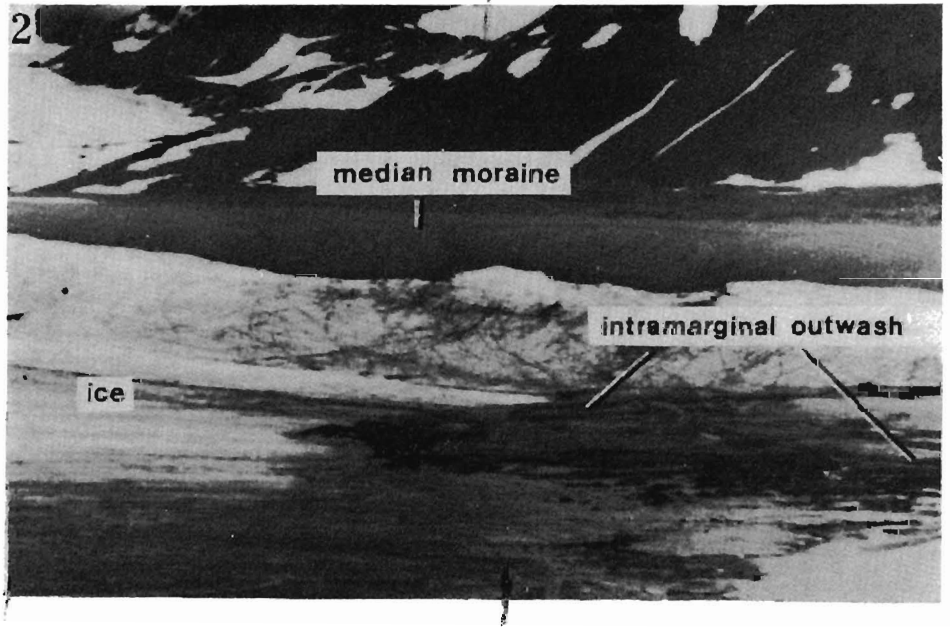


1 — Marginal zone of the Bunge Glacier: dead streams on the intramarginal outwash

2 — Marginal zone of the Bunge Glacier: braided stream between the glacier and the margin of intramarginal outwash plain

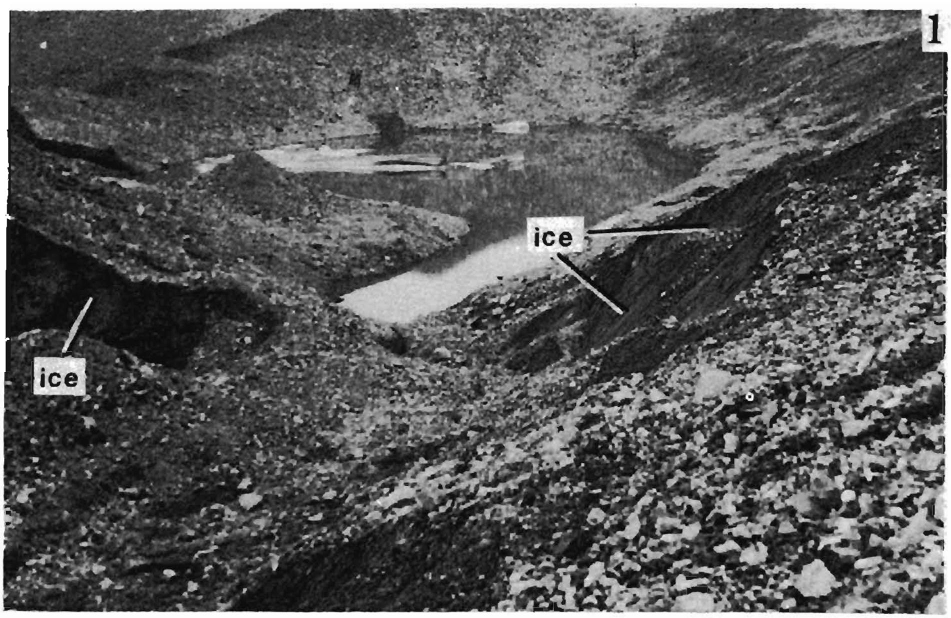
1

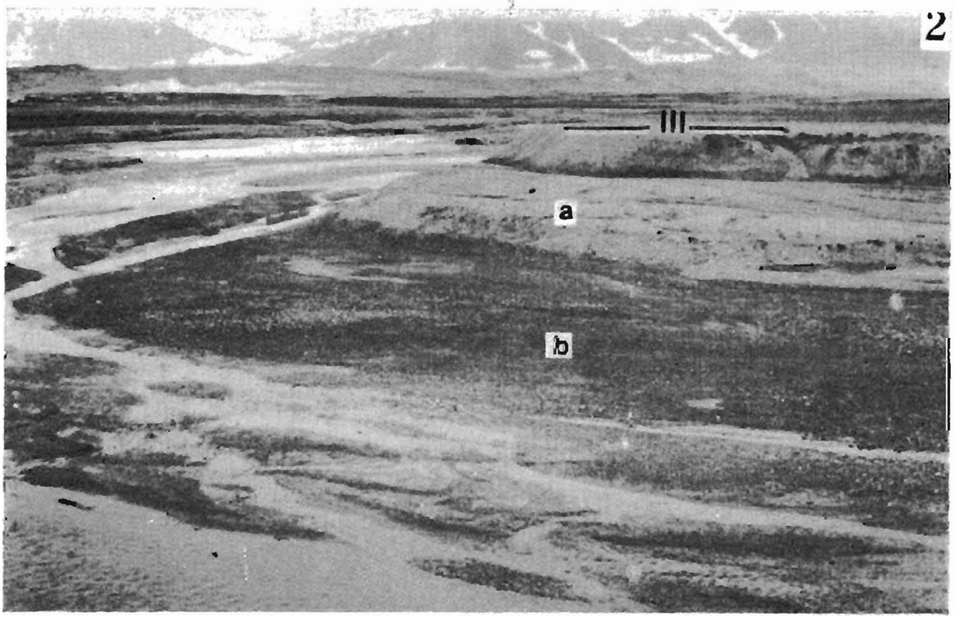
2



1 — Marginal zone of the Bunge Glacier: streams over the ice within the intramarginal outwash

2 — Bunge Glacier: contact of the glacier with the intramarginal outwash; at the background, a part of the ice-morainic ridge of the median moraine is visible



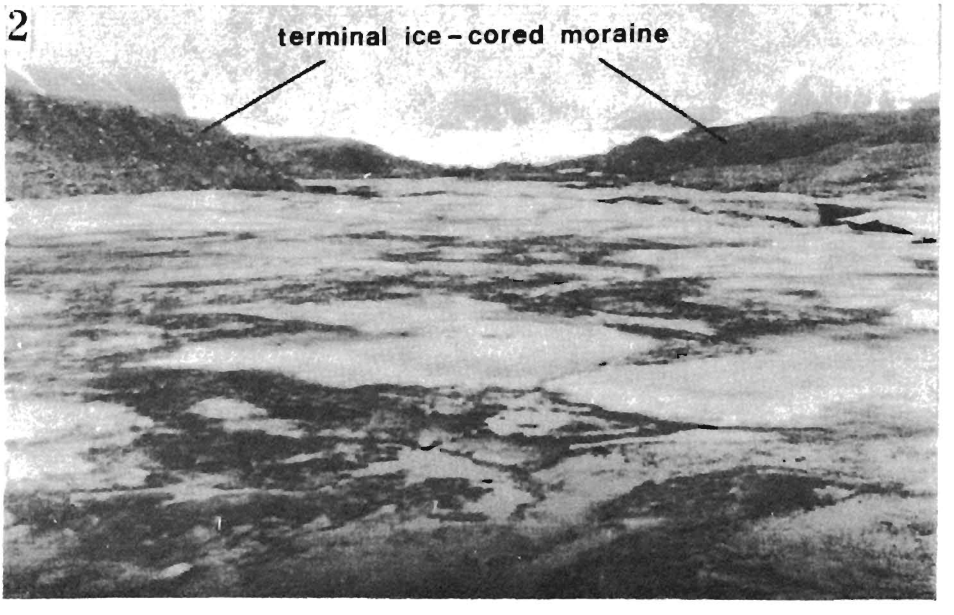


1 — Marginal zone of the Bunge Glacier: kettles in the southern part of the median moraine; at the foreground, the dead ice covered with a thin sheet of morainic material is visible

2 — Forefield of the Bunge Glacier: higher (*a*) and lower (*b*) level of the extra-marginal outwash inserted into the marine terrace *III*

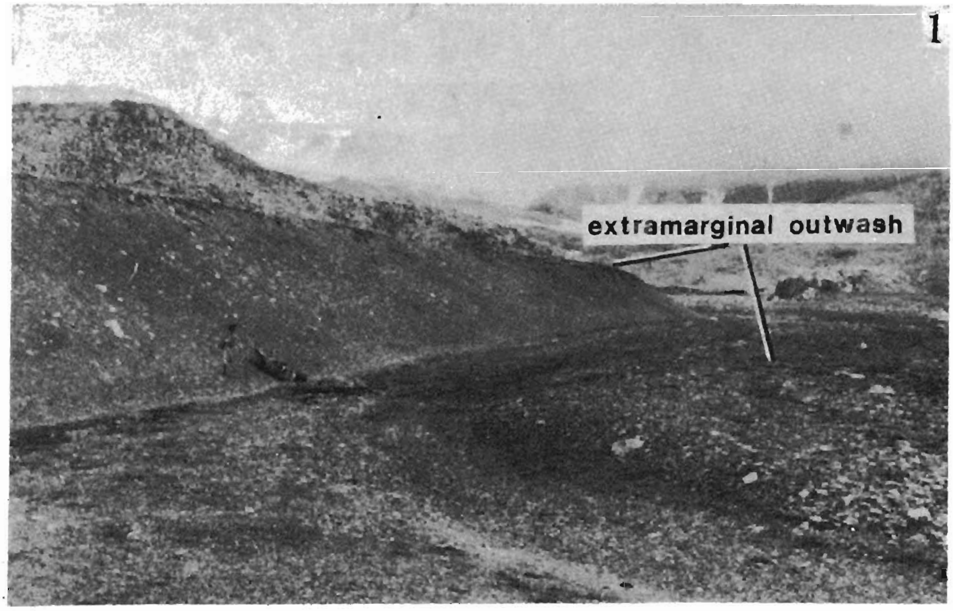
1

2



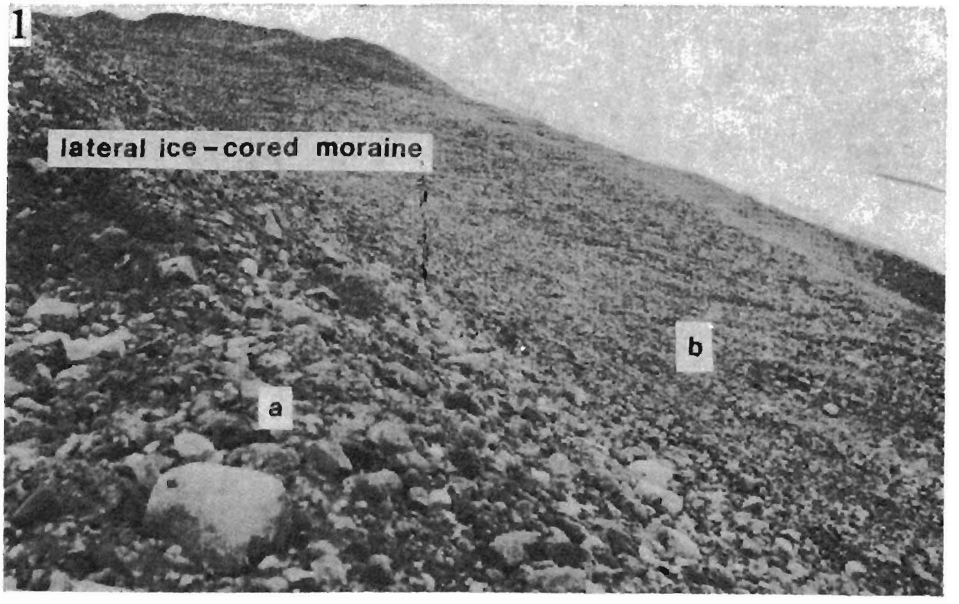
1 — Bunge Glacier: meltwater stream, flowing through the western gap

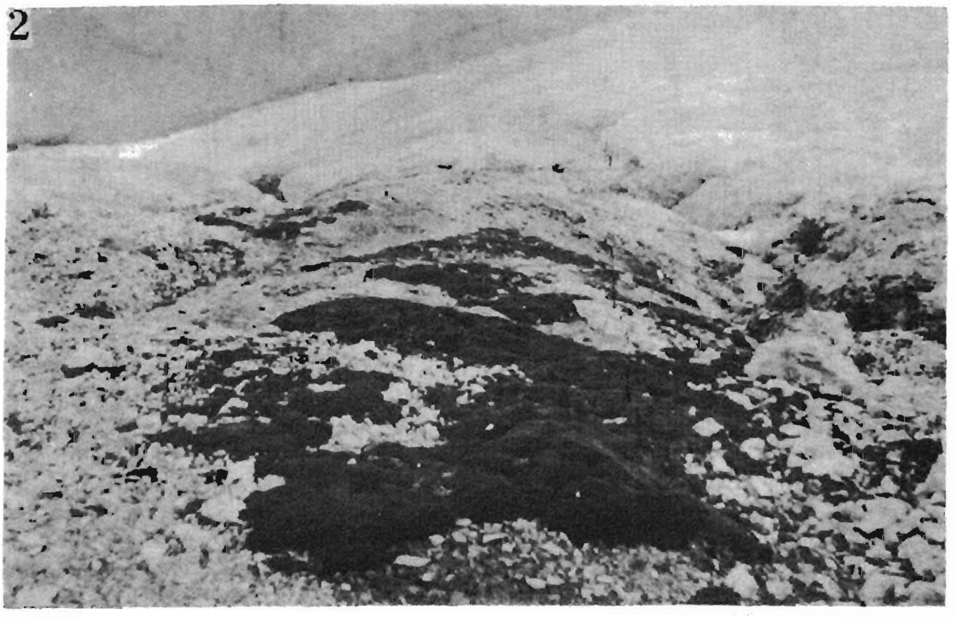
2 — Forefield of the Bunge Glacier: extramarginal outwash plain covered in places with ice; at the background, the southern gap through the terminal moraine is visible



1 — Forefield of the Bunge Glacier: erosion margins within the extramarginal outwash plain

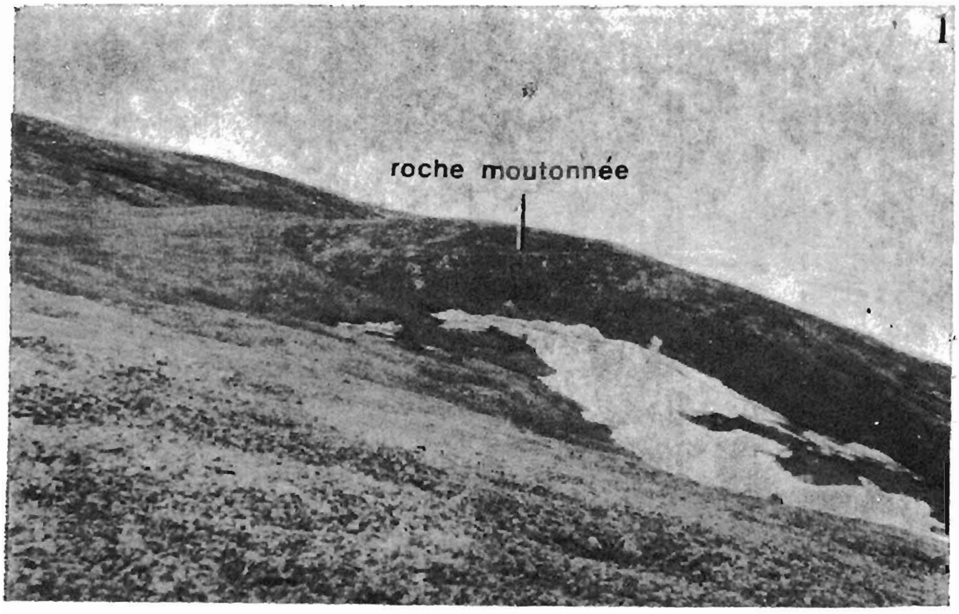
2 — Forefield of the Bunge Glacier: extramarginal outwash plain covered in places with ice

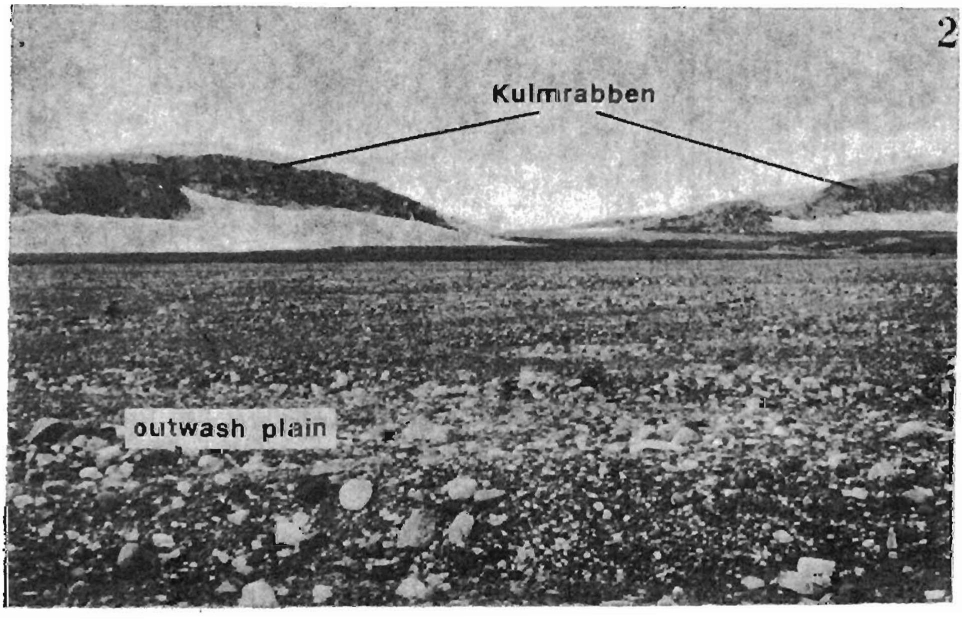




1 — Bunge Glacier: elder (*a*) and younger (*b*) parts of the western lateral ice-cored moraine

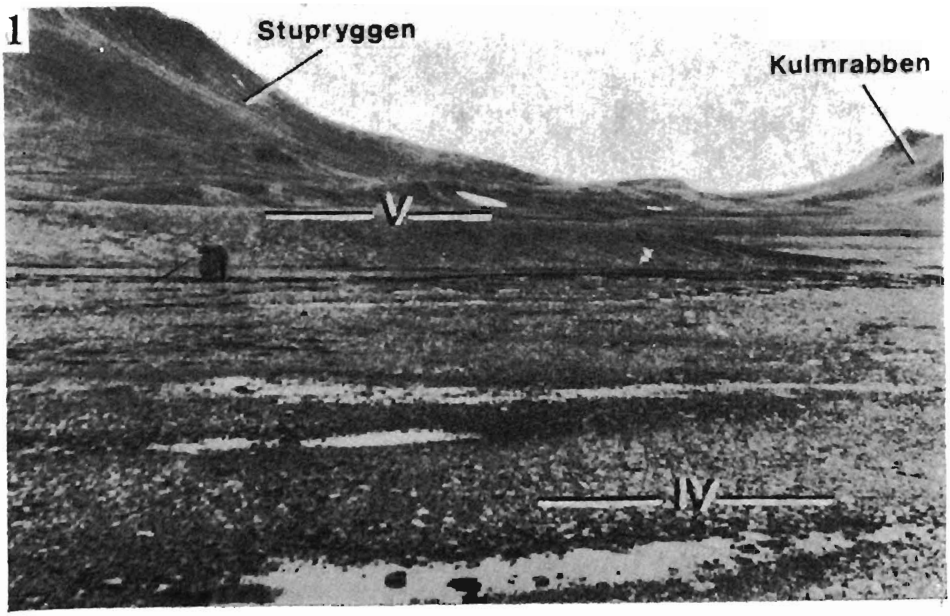
2 — Bunge Glacier: karst rills on the slope of a roche moutonnée

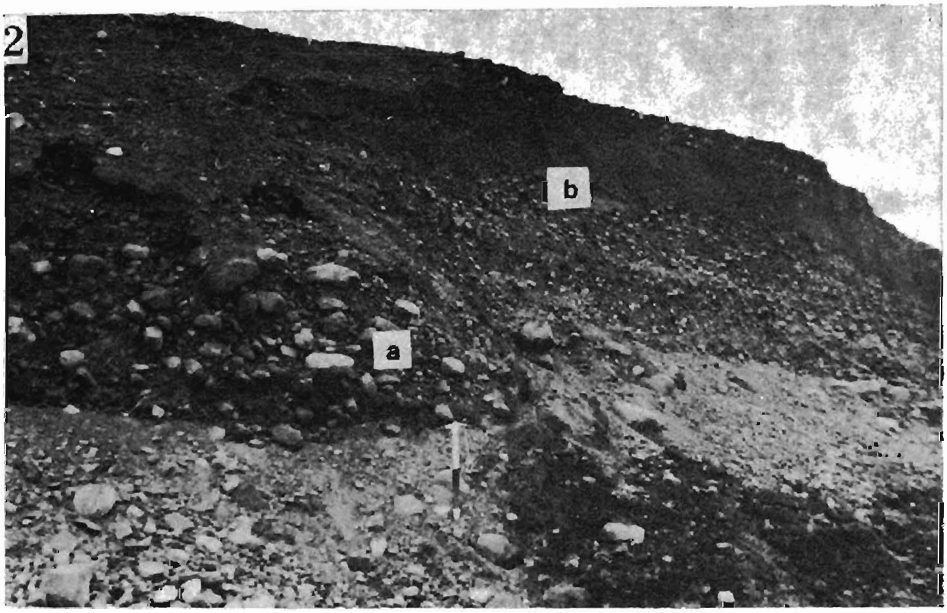




1 — Bunge Glacier: roche moutonnée at the western margin of the glacier

2 — Forefield of the Bunge Glacier: western outwash plain; at the background, the ridge of the Kulmrabben massif is visible





1 — Forefield of the Bunge Glacier: the pass between the Stupryggen and Kulmrabben massifs, behind the marine terraces *V* and *IV*

2 — Forefield of the Bunge Glacier, exposed along the seashore: bottom moraine (*a*) covered with marine gravels (*b*) of the terrace *III*