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Morphogenetic features of talus cones in northwestern Wedel Jarlsberg Land, Spitsbergen

ABSTRACT: Studies over talus cones in nothwestern Wedel Jarlsberg Land enable to define main parameters of these forms, their morphogenetic features and longitudinal profiles. Three zones of occurrence of talus cones have been distinguished, dependent on microlimatic influence of glaciers. Zone A (below 150 m a.s.l.) is not influenced by glaciers. Zone B (from 150 to 350 m a.s.l.) is influenced by glacier snouts. Zone C (over 350 m a.s.l.) is under influence of firn fields. Most intensive development of talus cones in the studied area occurred during the Little Ice Age.

Key words: Arctic, Spitsbergen, geomorphology, talus cones

Introduction

Investigations of talus cones in northwestern Wedel Jarlsberg Land were carried out during the scientific expedition organized by the Maria Curie-Skłodowska University of Lublin, Poland. During fieldworks main parameters of cones as exposure, dimensions, inclination, longitudinal profile, petrographic composition and roundness of debris were observed.

On northwestern mountain slopes of Renardbreen as well as around Scottbreen and Blomlibreen, 62 talus cones were described in detail. Similar forms in other valleys were also observed.

Main parameters of talus cones

Area of northwestern Wedel Jarlsberg Land is composed of rocks of the Hecla Hoek Formation (metamorphized tillites interbedded with sandstones and phyllites). They form a syncline, the axis of which is slightly inclined northwards and runs across the western part of described area.

Such bedding favors irregular development of slope processes. On slopes parallel to dips of strata (eastern and southeastern surroundings of Scottbreen and Blomlibreen) talus cones are rare and incompletely developed, whereas on opposite slopes they are numerous and large. Exposure of slopes results in asymmetry of cone occurrence. On southwestern slopes frost weathering is more intensive due to insolation and causes a faster degradation of rock walls and so, larger supply and transport of rock debris. Northwestern slopes are however insolated for a shorter time and for this reason frost weathering and mass movements are limited (Fig. 1).

Most talus cones start in mouth of deep chutes, rock chimneys, joint fissures or tectonic loosen zones (Pl. 1, Fig. 1). Snow and rock debris

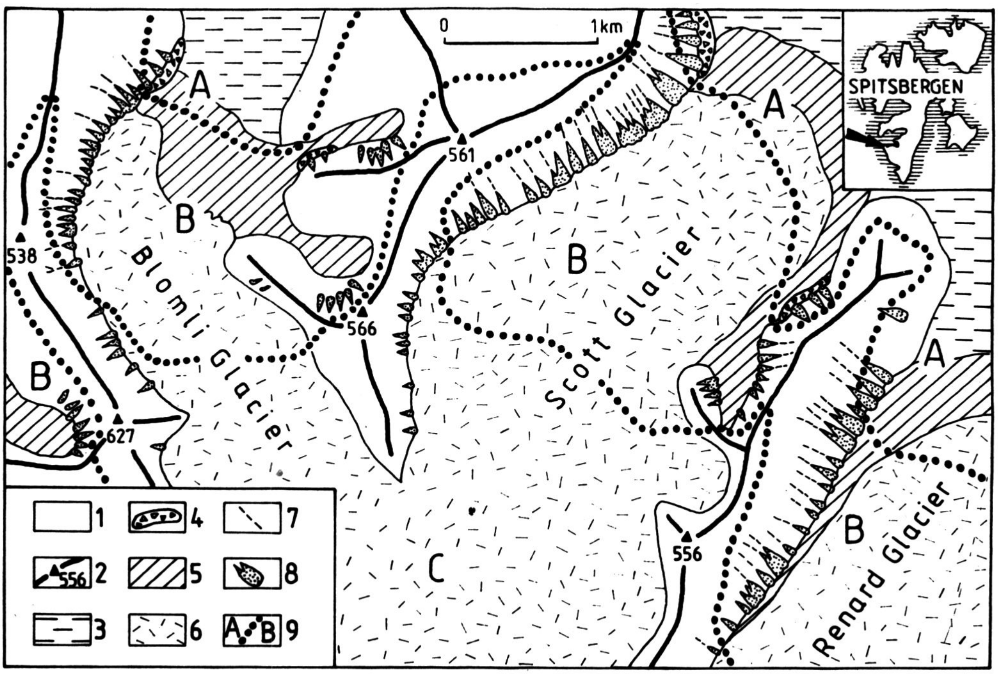

Fig. 1. Location of talus cones in northwestern Wedel Jarlsberg Land: 1 — mountain massifs, 2 — crests and peaks, 3 — marine terraces, 4 — nival moraines and subslope rock glaciers, 5 — terminal and lateral moraines, 6 — glaciers, 7 — chutes, 8 — talus cones, 9 — boundaries of morphoclimatic zones (A, B, C)

in chutes moves downwards after heavy rains or during warmer days, so mud and debris flows develop. Flow furrows are to 1.5 m deep and 3 m wide (Pl. 1, Fig. 2) and material deposited at furrow ends forms frequently digital bulges. Similar bulges arise after melting of snow mantled by debris and avalanches. Such forms create a characteristic microrelief of cones and make them grow.

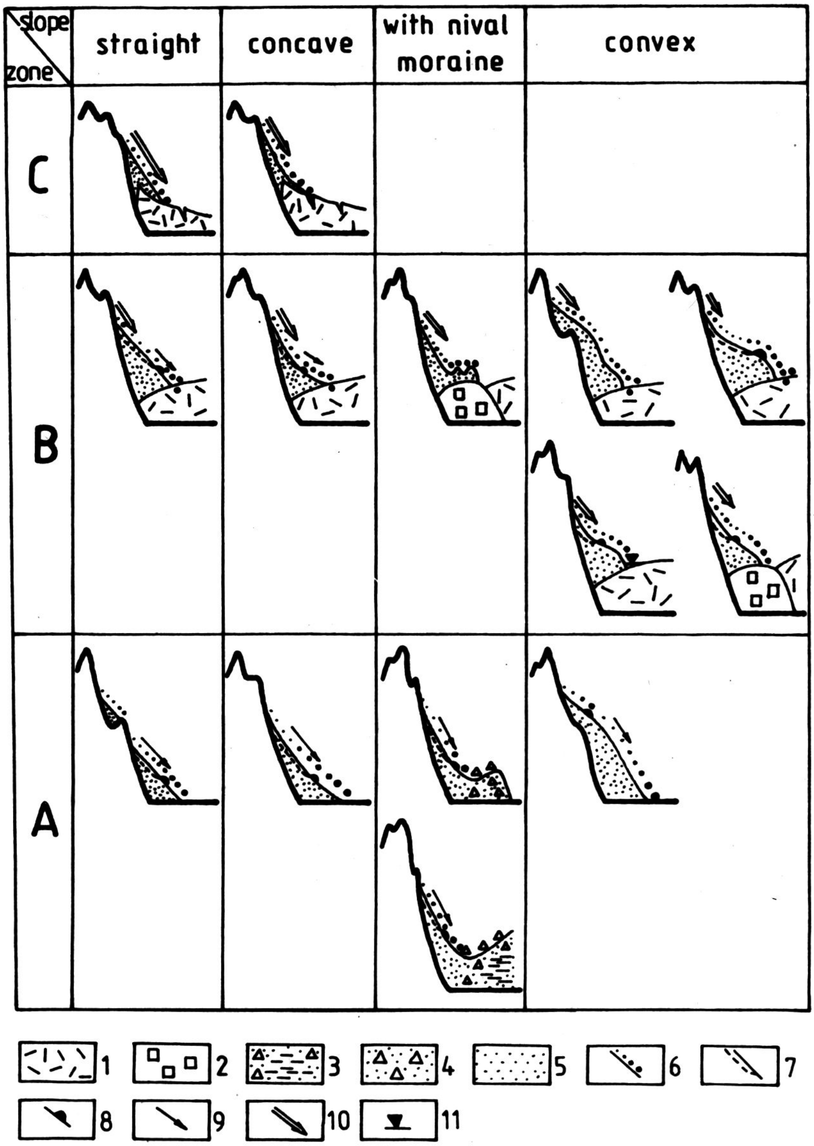

Fig. 2. Talus cones: typical profiles and slope processes dependent on morphoclimatic zones. A — zone outside a direct glacier influence (below 150 m a.s.l.), B — zone influenced by glacier snouts (150—350 m a.s.l.), C — zone influenced by firn fields (over 350 m a.s.l.), 1 — compact glacier ice, 2 — lateral moraines, 3 — rock glaciers, 4 — nival moraines, 5 — talus cones, 6 — fractional segregation of debris, 7 — furrows of debris-mud flows, 8 — bulges of mud-debris flows, 9 — solifluction, 10 — avalanches, 11 — glacial streams

Low active cones under microclimatic influence of glaciers are overgrown by vegetation which sets fine material. Such places are subjected to tonque solifluction and form sometimes solifluction terraces (Jahn 1970).

In northwestern Wedel Jarlsberg Land tops of talus cones occur at altitudes of 200 to 550 m a.s.l., whereas their feet at 130 to 500 m a.s.l. Largest forms are 250 m long and occur on northwestern slopes of Renardbreen. Their feet are 25—130 m, usually 55—60 m wide. Surfaces of talus cones are inclined at 25—42° (usually 32°). Such average is most common for talus cones with straight profiles, so the value of 32° is to be assumed as a natural slip angle for well segregated material on slopes composed of tillites. Individual talus cones have varying profiles what is a specific feature for polar areas (Klimaszewski 1981). A convex profile is the most common (over 50%). There are lots of cones connected with nival ramparts at their feet, being usually transformed into subslope rock glaciers (Pl. 3). Talus cones with straight profiles are also common contrary to concave cones which are rare (Fig. 2).

Shapes of longitudinal profiles of cones depend on local differentiation of their feet, glacier ice, melting snow patches, undercutting by meltwaters, bedrock structure and microclimatic conditions. The latter depend on altitude and distance from a glacier. Convex talus cones in northwestern surroundings of Renardbreen are due to undercutting by glacial streams and support by lateral moraines. In turn, convexity of forms on northwestern slopes of Scottdalen and Blomblidalen is caused by glacial erosion of lower parts of cones. Rock material buried in ice moves down-glacier and forms characteristic arch-like strips on ice surface or after melting of ice on mountain slopes (Pl. 4, Fig. 1). A convexity of cones on terraced slopes is due to rock thresholds (Pl. 4, Fig. 1). A convexity of slopes corresponds with inclination of rock strata exposed between talus cones; a similar phenomenon was observed by Musielewicz (1980) in the Polish Tatra Mts. Talus cones connected with a typical nival rampart (Pl. 4, Fig. 2), similar to the forms from the Tatra Mts. (Dzierżek *et al.* 1987), are rare.

In the investigated area most forms defined as double cones (Klimaszewski 1981) are the subslope rock glaciers accompanied by talus cones (*cf.* Lindner and Marks 1985, Dzierżek and Nitychoruk 1986). These glaciers were fed by material from slopes and as indicated by lichenometric studies (André 1986, Dzierżek and Nitychoruk 1987), their surface is to be dated for 3500—2000 years BP. Contemporary fronts of subslope rock glaciers are several dozen and sometimes several hundred meters away from feet of talus cones. Therefore the present supply with debris (which comes to rock glaciers across snow patches lying at feet of talus cones) is insignificant.

Inclinations of straight profile talus cones correspond with natural slip angles of rock debris and thus, a gravitation is the main transporting agent. Talus cones with concave profiles due to periodic washing of their lower parts (Musielewicz 1980, Klimaszewski 1981) are very rare in this area.

Morphologic and microclimatic variation of talus cones

Talus cones are usually presented in connection with climatic vertical zones in which different morphogenetic processes develop (Klimaszewski 1981, Rączkowski 1981, Kotarba 1984, Kotarba and Strömquist 1984).

During fieldworks main morphologic varieties of talus cones and of creative processes were distinguished. They depend on altitude and thus, on relations between talus cones and glacier snouts, firn fields or ice-free areas. A proposal of three microclimatic and morphologic zones with talus cones is presented (Figs. 1 and 2):

— zone A, outside a direct influence of glaciers (below 150 m a.s.l.),
— zone B, influenced by glacier snouts (150—350 m a.s.l.),
— zone C, influenced by firn fields (over 350 m a.s.l.).

In the zone A there are mainly mature, straight or seldom concave talus cones. They are seldom connected with subslope rock glaciers or nival moraines (Pl. 3). Cones are composed of well segregated waste debris. Solifluction tonques, terraces and ancient mudflow cuts form their microrelief (Jahn 1976). Debris falls from rock walls feed taluses. A rate of this process was estimated for 0.02—0.2 mm a year for limestones in Tempelfjorden (Rapp 1960) and for 0.11 to 0.7 mm a year for metamorphic rocks in northwestern Spitsbergen (André 1986). Slope processes in this zone were most active 3500—2000 years BP when subslope rock glaciers developed (André 1986, Dzierżek and Nitychoruk 1987).

Zone B is the area of most active present debris falls, mud flows, nival processes, deflation, solifluction and frost weathering. Especially good conditions for frost weathering (influence of glacier snout on temperature variations around 0° C) prepare rock material for transport by catastrophic processes. They are the main factor that models present cones. Debris-mud or mudflows and snow-debris avalanches are the most important processes. They are caused by heavy rains and snow melting (Rapp 1960, Kotarba 1976, Musielewicz 1980, Klimaszewski 1981, Rączkowski 1981, Ono and Watanabe 1986). André (1986) noted also stress relaxation within rock massifs whereas Jahn (1976) pointed out action of permafrost for debris movement down a cone. In this zone all types of longitudinal cone profiles occur. Talus cones are located at outlets of every chute and form interfingering fans on mountain slopes (Pl. 5, Fig. 1; Pl. 6, Fig. 1). Cones feet are undercut by glaciers. Debris of cones is poorly segregated and not weathered (Pl. 5, Fig. 2).

In the zone C talus cones are also absent (Fig. 1). They cannot develop on northern and northwestern slopes due to permanent snow cover (Pl. 6, Fig. 2). There are only initial forms on southern slopes and their material is collected in firn fields. If weather is favorable for deflation, frost weathering and debris falls occur. Snow-debris avalanches are also common in this zone.

Different intensity of debris transport on cones in described zones made authors locate several mark points and key sections. In the zones A and B on northwestern moutnain slopes around Scottbreen and Renardbreen four nets of 18, 20, 25 and 42 m^2 in area were installed. Lines and signs on cones were also pointed and several pickets were fixed. During fields works no debris transport was however noticed. Therefore, in spite of imperfect measuring methods, the turn of spring and summer seems to be the main development period for slope phenomena.

Conclusions

Observations and measurements of talus cones in northwestern Wedel Jarlsberg Land resulted in a description of their dimensions, exposition, microrelief and segregation of material as well as inclination, angle of natural slip and typical longitudinal profiles. They prove that were formed due to various morphogenetic processes in a polar environment. Reasons for asymetric location of cones were defined as well as differences in their development and creative processes dependent on contact of slopes with glaciers or ice-free areas. Relationship between development of talus cones as well as microclimatic and morphologic conditions allowed to distinguish 3 zones and to describe processes predominant in each zone. Geomorphologic observations and lichenometric datings from northwestern Spitsbergen permitted (André 1986) to distinguish 5 development stages of talus cones during the Holocene. Present shapes of talus cones were formed during the Little Ice Age. Their lower parts developed 500—300 years BP whereas the upper ones about 70 years BP (André 1986). Slope processes were also very active between 3500 and 2000 years BP when nival moraines, transformed later into subslope rock glaciers, were formed (André 1986, Dzierżek and Nitychoruk 1987). Most intensive present-day slope processes occur at contacts of slopes and glacier snouts.

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Streszczenie

Przedstawiono charakterystykę stożków usypiskowych na zboczach górskich w NW części Ziemi Wedel-Jarlsberga. Zdecydowana większość stożków rozwinęła się tam na zboczach o ekspozycji E i SE (fig. 1), u wylotu głębokich żlebów (pl. 1. fig. 1). Największe formy osiągają długość 250 m, a szerokość podstawy ponad 100 m. Średnie nachylenie ma wartość 32°. Zbudowane są z gruzu, głównie tillitów z domieszką piaskowców i fyllitów, który charakteryzuje się na ogół złą segregacją frakcjonalną w profilu podłużnym stożków. Powierzchnie stożków modelują rynny i wały spływów gruzowo-błotnych (pl. 1. fig. 2; pl. 2). Większość stożków ma profil podłużny prosto-wypukły lub wklęsło-wypukły (fig. 2). Powszechne są także stożki zakończone wałem podstokowego lodowca gruzowego (pl. 3) lub wałem niwalnym (pl. 4. fig. 2).

Zróżnicowanie cech stożków w zależności od wysokości bezwzględnej i kontaktu z lodowcem pozwoliło wydzielić trzy strefy morfoklimatyczne rozwoju zjawisk zboczowych:

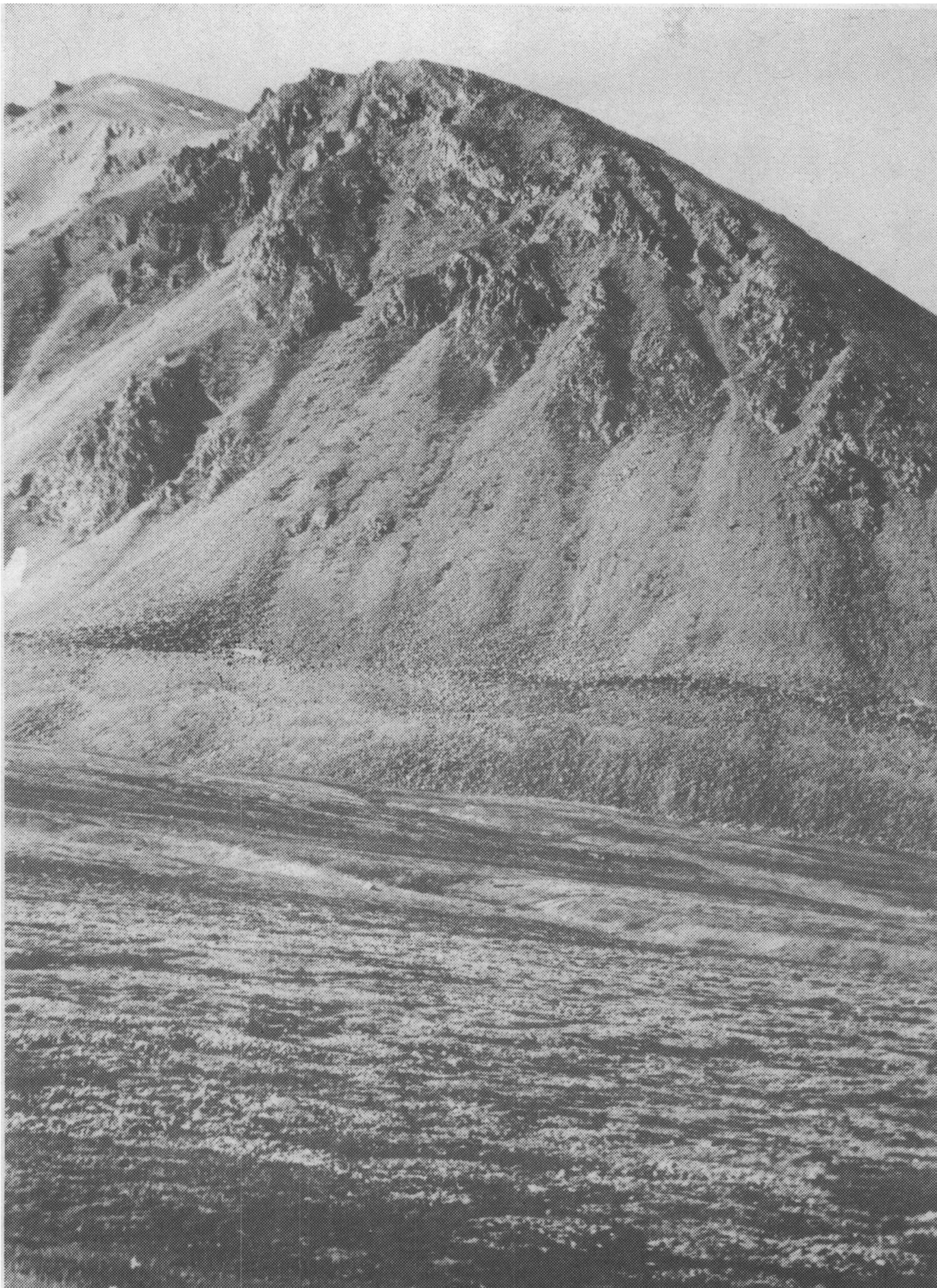
A — poza zasięgiem bezpośredniego wpływu lodowca (pl. 3).
B — oddziaływania jęzora lodowcowego (pl. 4, fig. 1; Pl. 5; pl. 6, fig. 1).
C — wpływu pola firnowego (pl. 6, fig. 2).

Najwyższe procesy zboczowe zachodzą obecnie w strefie B (fig. 1). Głównym etapem rozwoju stożków na omawianym terenie była Mała Epoka Lodowa.

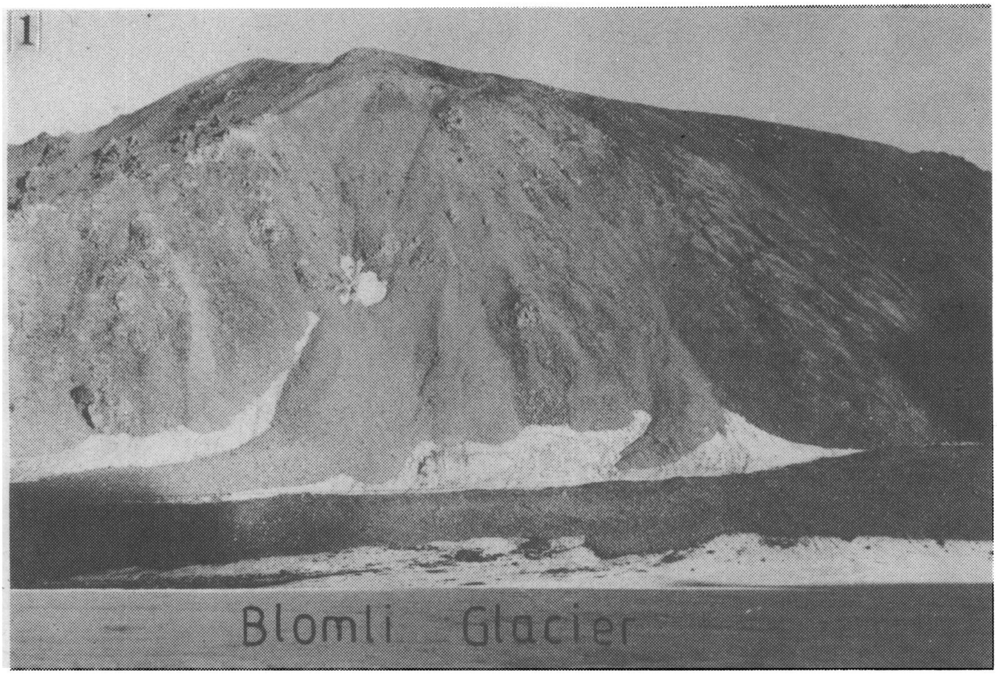
Praca została wykonana w ramach tematu CPBP 03.03.

1. Talus cones on a terraced slope in northwestern surroundings of Renardbreen
2. Furrow of mud-debris flow cutting a talus cone in northwestern surroundings of Renardbreen

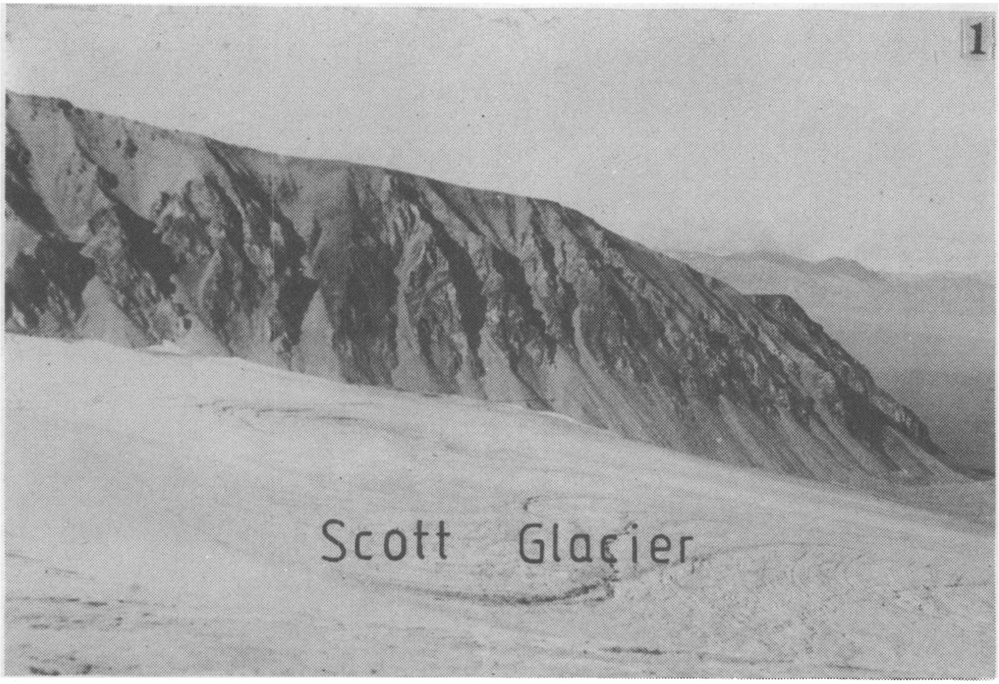
Debris bulges formed after melting of avalanche in northwestern surroundings of Renardbreen (arrowed)

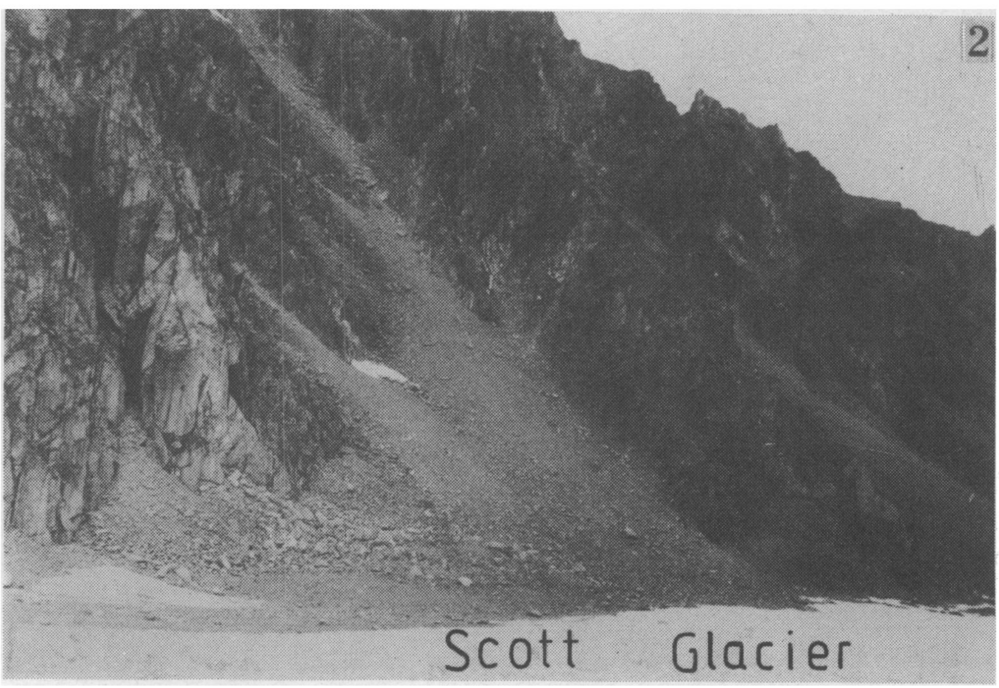


Subslope rock glacier at feet of talus cones, westwards from Scottbreen snout

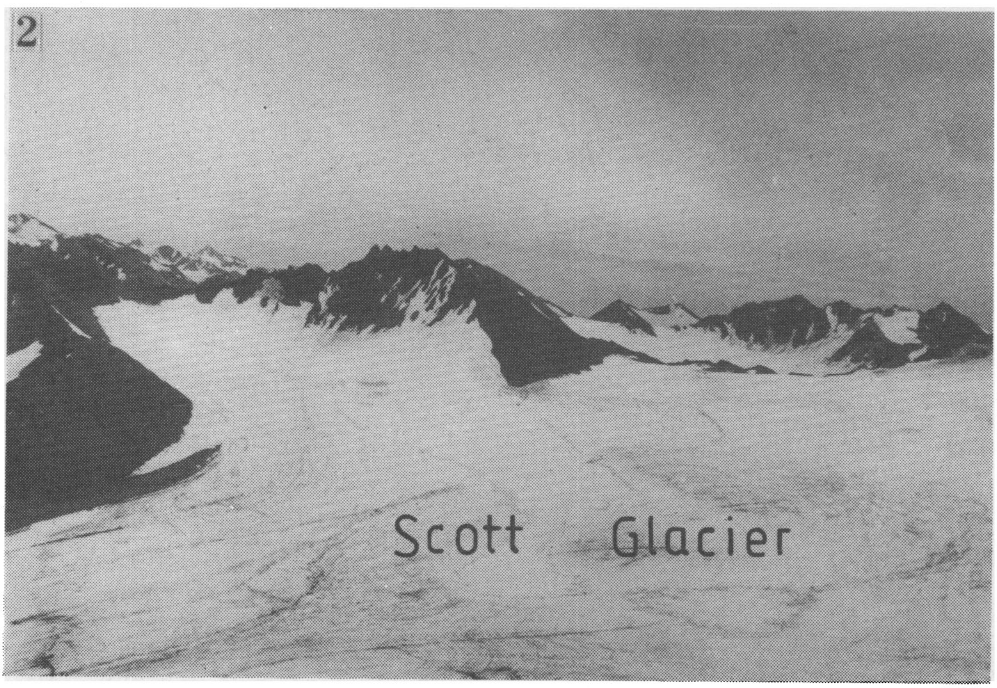


1. Feet of talus cones transformed by moving ice of Blomblibreen; below a present lateral moraine
2. Initial nival moraines (arrowed) on a lateral moraine of Renardbreen





1. Systems of coupled talus cones in northwestern surroundings of Scottbreen
2. Example of poor segregation of debris on talus cone in zone B in northwestern surroundings of Scottbreen



1. Well developed talus cones in zone B in northwestern surroundings of Scottbreen
2. Example of a limited development of slope processes in zone C on slopes around firn field of Scottbreen