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Symptoms of aeolian accumulation in western Sörkapp Land, Spitsbergen

ABSTRACT: Landforms of aeolian origin from western Sörkapp Land, Spitsbergen, are described. Development of aeolian hillocks, sand banks and drifts as well as of aeolian covers on marine beaches and permafrost hillocks is discussed in connection with conditions of transport and deposition. Horizons of fossil organic matter found in some forms prove their persistence.

Key words: Arctic, Spitsbergen, aeolian accumulation

Introduction

Activity of aeolian processes in Spitsbergen have been already confirmed during geomorphological investigations of Czeppe (1966), Pękala (1980) and others. Deflation, aeolian transport and intensity of these processes were also studied in detail (Kida 1981, Baranowski and Pękala 1982, Bryant 1982, Szczypek 1982, Piotrowski 1983, Migała and Sobik 1985). However landforms of aeolian accumulation have been so far only seldom closely explored (Van Vliet-Lanöe and Hequette 1987).

Landforms of aeolian origin are not common in Spitsbergen owing to scantiness of areas in which air-borne sediment could be deposited. Most of Spitsbergen is covered by glaciers, that is why alimentary areas for aeolian processes are located nearby fiords and sea. Waste covers on mountain massifs, moraines, sandurs and marine beaches are the sources of aeolian material. Most of dust blown out from these terrains is therefore deposited in water. Only a small amount of dust and sand is deposited in the narrow strandflat zone. Width of strandflats, their relief, local

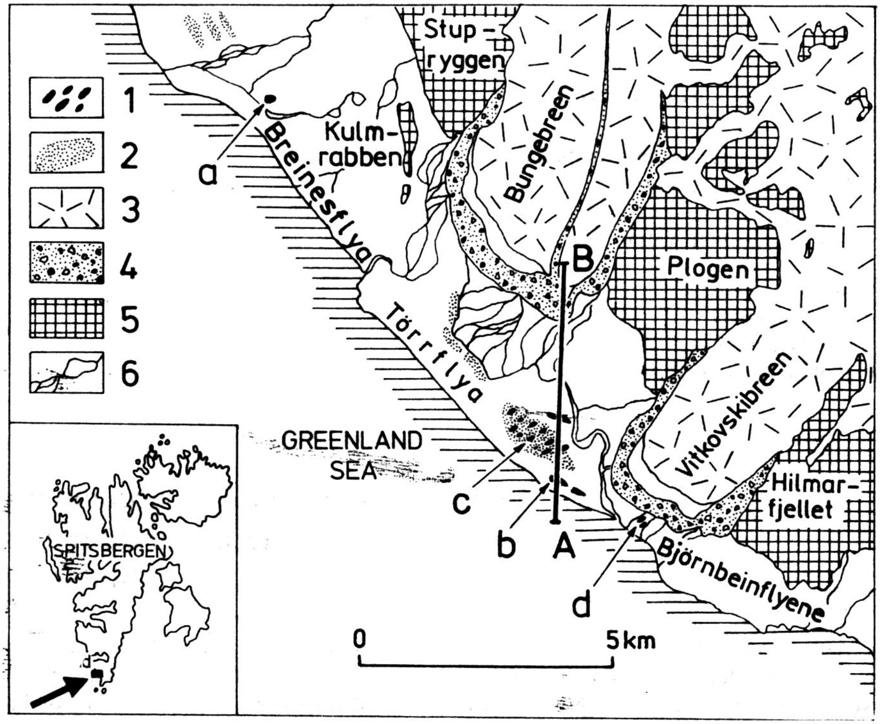

Fig. 1. Sketch of investigated area
1 aeolian landforms: a — covers on permafrost hillocks, b — sand drifts, c — hillocks, d — sand banks; 2 — patches of aeolian covers on raised marine beaches, 3 — glaciers, 4 — ice-cored moraines, 5 — mountains, 6 — streams and lakes

wind directions and lithology of bedrock influence intensity of deposition and shape of forms. Sand-dusty intercalations in a snow cover or thin layers on its surface form the most common evidence of aeolian accumulation (Czeppe 1966, Baranowski and Pękala 1982, Szczypek 1982). However these sediments do not create stable and distinct relief features, due to their removal by meltwaters.

Deposition of sand and dust behind different barriers was noted as well (Czeppe 1966, Bogacki 1970, Szczypek 1982, Van Vliet-Lanöe and Hequette 1987). Compact covers of aeolian deposits could be formed only in favorable conditions (Bryant 1982).

In this paper landforms from the western Sörkapp Land, on Törrflya and Björnbeinflyene are presented (Fig. 1).

Geologic setting and main aeolian processes

Research was carried through on Törrflya-Björnbeinflyene strandflats (Fig. 1; Pl. 1, Fig. 1) in forefields of the Bunge Glacier (Bungebreen) and the Vitkovski Glacier (Vitkovskibreen). These strandflats are composed of several raised marine beaches at altitudes of 5—8, 8—12, 15—18, 20—26 and 28—30 m a.s.l., containing numerous depressions as well as alluvial and sandur fans on their surfaces (Ostaficzuk, Lindner and Marks 1982; Szczęsny, Lindner and Marks 1987). The Little Ice Age terminal moraines of the Bunge Glacier and the Vitkovski Glacier occur on the highest marine beaches. Deglaciated intramorainal areas are occupied by ground moraines and intramorainal sandurs.

Glacier snouts fulfill valleys between mountain massifs of Stupryggen (638 m a.s.l.) and Plogen (691 m a.s.l.), and between Plogen and Hilmarfjellet (825 m a.s.l.). These depressions favor airflow and determine wind directions in this area. During the observation period winds from the northeast prevailed. Their speed during stormy winds reached 25 m/s. Similar weather conditions were noted in Hornsund. In 1982 the highest daily medium wind speed in Palffyodden was equal 17 m/s, with absolute maximum of 30 m/s during the northeastern gusts (Ziaja 1985). The same prevailing wind directions and wind speeds were noted at the Polish Polar Station on the northern coast of Hornsund (*cf.* Pereyma 1983).

Dust and sand transported by wind are delivered from waste covers formed by frost weathering on mountain slopes. Bedrock in this area is composed of Cambrian and Ordovician phyllites, limestones and quartzites, and of Triassic siltstones, shales and sandstones (Flood, Nagy and Winsnes 1971). Blocks, erratics, debris and gravel in terminal, lateral and ground moraines as well as in alluvial and sandur fans are composed of pieces of these rocks. Glacial and glaciofluvial deposits are the sources of dust

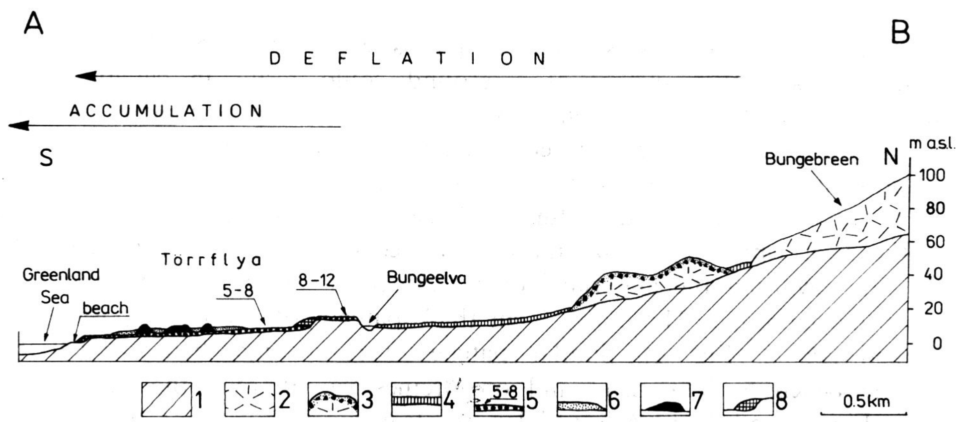

Fig. 2. Schematic geologic section across Törrflya (see location on Fig. 1)
1 — bedrock, 2 — glacier ice, 3 — ice-cored moraines, 4 — sandur fans 5 — marine beaches with aeolian pavement (altitude in meters a.s.l.), 6 — aeolian covers, 7 — aeolian hillocks, 8 — sand drifts

and sand blown by winds as well as marine beaches as indicated by aeolian pavement on their surfaces (Pl. 1, Fig. 2).

Suspension, saltation and rolling of grains are the ways of aeolian transport, depending on grain size and wind power. In Spitsbergen aeolian transport is the most intensive during strong fall winds or winds of foehn type, especially in summer and autumn when the area is not covered by snow. Material is usually set in motion by stormy gusts. Energy of wind is such to carry away large detritus of dimensions up to $5 \times 2.5 \times 1$ cm (Czeppe 1966). A considerably smaller energy is needed for keeping in motion just the same grains (*cf.* Gradziński *et al.* 1986). In this process water content in sediment is very important. Wet grains agglomerated by meltwater or capillar water are difficult to set them in motion. Therefore the most intensive transport is on permanent dry areas, or after sublimation of ice during autumn ground frosts when water-agglomerated material is transformed into a loose one (Migała and Sobik 1985).

A distance of transport depends on wind energy and grain size of material. Most dust is transported in suspension, and in West Spitsbergen is blown away to the Greenland Sea (Fig. 2). Accumulation forms are usually composed of coarser fractions, transported mainly by saltation. On wide and uneven terrces the possibilities of accumulation are great and they increase with winds blowing from areas with a lot of loose, fine and dry sediments.

Accumulation forms

Accumulation processes occur in places where transported material is being stopped. Wet surface of a ground could result in catching sand and dust. Capillary infiltration of water from thawing permafrost increase a water content of overlying sediments (*cf.* Cegła 1972) in the same way as presence of watertight rocks in a substrate.

In the forefield of the Bunge Glacier, western and southern banks of the river which drains sandur fans are covered by dusty sand (Fig. 1). On wet elevations the material blown away from sandur fans and moraines has been deposited. Therefore, 5 cm thick patches of aeolian deposits were formed (Pl. 2, Fig. 1). Similar patches were distinguished on Törrflya marine beach 5—8 m a.s.l., and on Breinesflya, all over the investigated area (Figs. 1 and 2). In Adventdalen, Central Spitsbergen, sources of aeolian material are richer than in the Sörkapp Land, so compact and thick aeolian covers could be formed (Bryant 1982).

Aeolian material could be also deposited on different wet elevations. In Breinesflya several permafrost hillocks have been distinguished (Fig. 1).

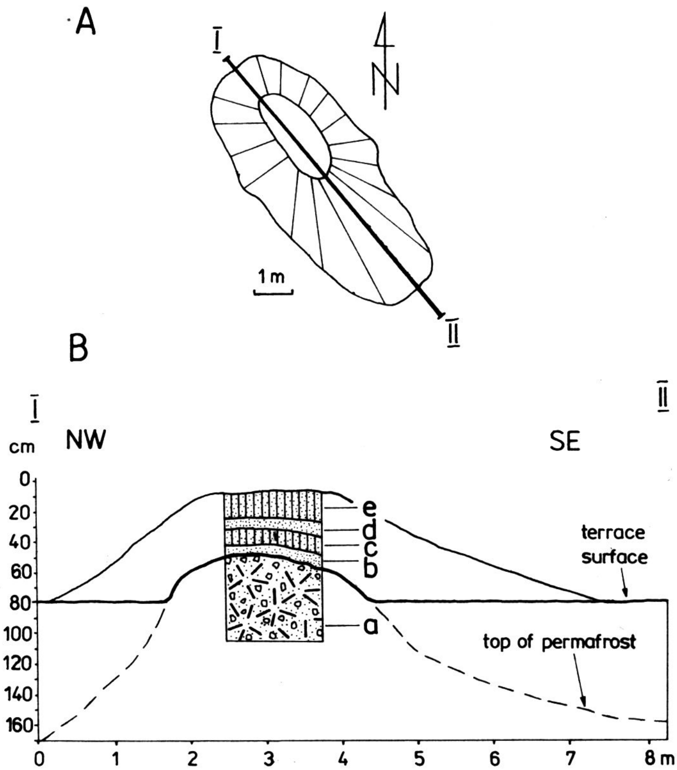

Fig. 3. Permafrost hillock with aeolian cover
A — plan of hillock with location of section, B — section across a permafrost hillock: a — frozen marine sand and shingle, b — fine yellowish-grey sand, c — fine brown sand with organic matter, d — fine and medium-grained sand with single phyllite blasts, e — fine and medium grained brownish-grey sand, rich with organic matter

Mud outflows comprise flatten hillocks 0.4—0.8 m high, 4—7 m long and 1.5—4 m wide. Most of them had ice cores covered by moss but hillocks with different structure were found too: frozen bedrock of marine sand and shingle with mollusc shells was covered by sediment of probable aeolian origin. The latter was composed of fine and medium — grained quartzic sand with single coarser grains, interbedded with a thin horizon enriched with organic matter (Fig. 3). This hillock was overgrown by moss. Convex ice core of the hillock while thawing, increased humidity of overlying sediments which became a good catch for wind transported sand. Presence of a humus horizon within sandy sediments indicates a stability of this form, second time overgrown by vegetation now. Presence of humic horizons within aeolian deposits deformed by thawing-freezing processes has been also noted in northwestern Spitsbergen by Van Vliet-Lanöe and Hequette (1987).

Barriers on marine terraces like ancient beach ridges, edges, driftwood

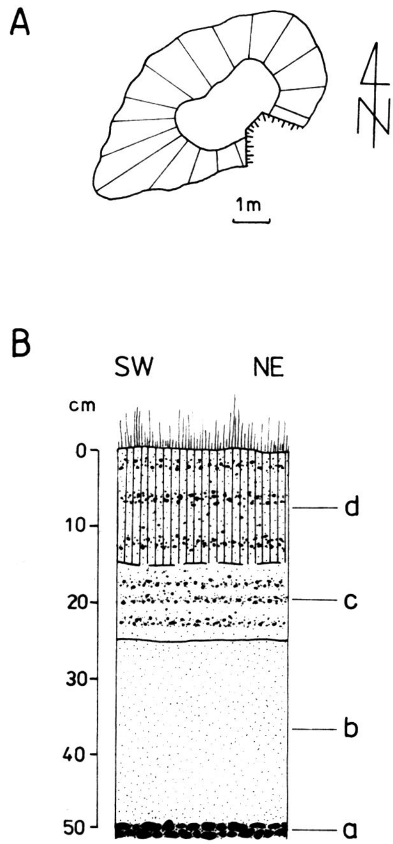

Fig. 4. Aeolian hillock on Törrflya
A — plan of hillock with profile location, B — profile of deposits in aeolian hillock: a — marine quartzitic and sandstone shingle and coarse-grained sand with mollusc shells, b — fine and medium-grained greenish-grey sand, c — fine lightgrey sand with gravel horizons, d — fine darkbrown sand with gravel interbeds, rich with organic matter

logs or erratics generate additional turbulences of air stream and occasionally favor deposition of fine aeolian material in their aerodynamic shadows (Czeppe 1966, Bogacki 1970, Van Vliet-Lanöe and Hequette 1987).

Sand drifts formed in this way have been distinguished on Törrflya down the edges of marine beaches 5—8 and 8—12 m a.s.l. (Figs. 1 and 2). Sediments of drifts 3 m long and 1 m thick are composed of fine bright-grey quartzic sand. Extension of sand drifts as well as wind ripples on their surface show that formation of such forms is due to northeastern winds carrying dust and sand from the forefield of the Vitkovski Glacier (Pl. 2, Fig. 2). Horizons enriched with organic matter were noted in a bottom of a drift.

On Törrflya, 1.5—2 km to the west from the outlet of the Bunge River (Bungeelva), another aeolian forms have been distinguished. On the marine beach 5—8 m a.s.l. small aeolian hillocks covered by sparse grass occurred (Pl. 3, Fig. 1). Hillocks have NE-SW directions which therefore correspond to predominant wind directions. They are 0.4—0.8 m high, about 4 m long and 1 m wide. Their northeastern slopes are short and steep while southwestern ones are long and flat. Hillocks are composed of lightgrey well-selected fine quartzic sand with single dark minerals. In the top the sand is interbedded with thin gravel horizons (Fig. 4). These deposits overlie marine medium and coarse-grained sand, and quartzitic-sandstone shingle.

Development of hillocks begun with accumulation of sand on wet ground behind erratics. Deposited sand became also wet, thus creating favorable conditions for vegetation development. Several initial forms have been found nearby. Grass catches dust and sand, making the hillock grow. Upper parts of sediments are enriched with organic matter.

Signs of deflation on hillock surfaces indicate that creative and destructive processes are synchronous. These forms seem to be of immediate but not of a year duration.

In the forefield of the Vitkovski Glacier several similar hillocks (banks)

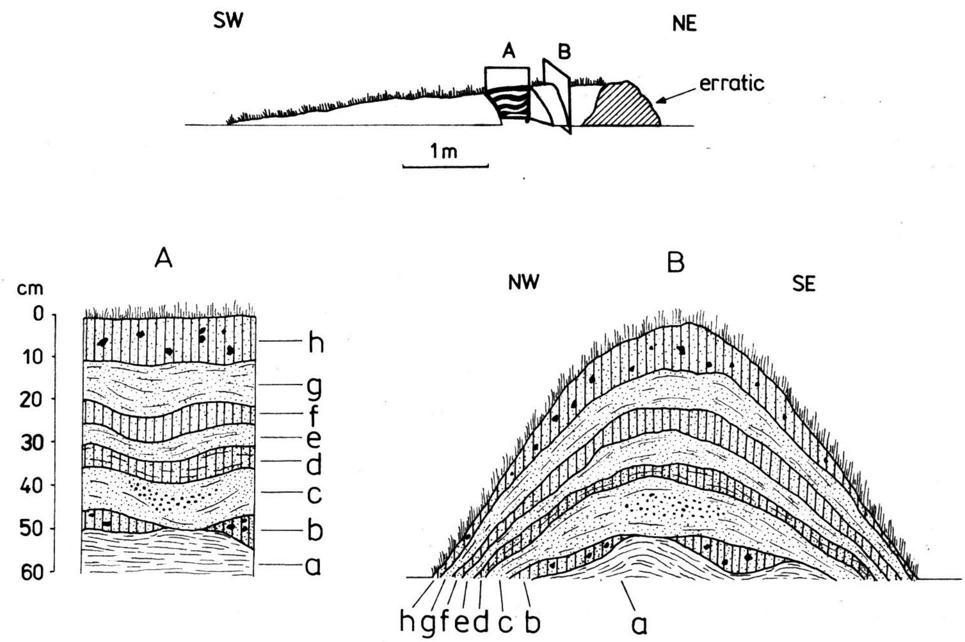

Fig. 5. Geologic sections across a sand bank in forefield of the Vitkovski Glacier
a — bluish-grey clay, b — medium-grained darkbrown sand with single coarse grains, rich with organic matter, c — greenish-grey fine silty sand with coarse grains, d — yellowish-brown fine-grained silty sand with organic matter, e — greenish-grey very fine silty sand, f — brownish-grey fine sand with organic matter, g — grey very fine silty sand, h — fine sand with numerous limestone detritus, rich with organic matter

have been distinguished (Fig. 1). Detailed studies show their diversified structure. On the marine beach 8—12 m a.s.l., about 200 m from the front of an ice-cored terminal moraine several sand banks of NNE-SSW direction were found. The biggest bank is 0.5 m high and about 5 m long (Pl. 3, Fig. 2). It was formed in shadow of a big erratic and is covered by thick grass. Inside, the same as in a permafrost hillock and in the bottom of aeolian drift, sandy horizons enriched with organic matter have been noted (Fig. 5, Pl. 4). Dusty sand, partly with coarse grains is interbedded with organic horizons. Substrate is composed of clay, deformed by thawing-freezing processes in the active layer of permafrost.

Such structure proves four periods of slow aeolian accumulation with milder climatic conditions. During these periods, like at present, flora overgrown a bank and horizons enriched with organic mater were formed. Bank was enlarged slowly by sand and dust catched by grass. Sandy interbeds within organic matter indicate more stormy conditions, more intensive delivering of material and fast form increment.

Presence of alternate horizons, with and without organic matter could not be connected with annual cycle. A lot of dust and sand could be deposited during short stormy episodes. Observations suggest that during 10 seconds, 105 g of sand and dust were deposited on 1 m^3 area (Szczypek 1982) while during a summer up to 1398 g of deposits could be deposited in such area (Piotrowski 1983). Medium annual thickness increment of aeolian deposits for arctic areas is calculated for 0.5—2 mm (Wojtanowicz 1976). Differences in deposition rate in the same area depend on prevailing weather conditions, mainly number of days with stormy winds and duration of a period without a snow cover.

Development of horizons with organic matter is much slower than deposition of mineral aeolian material. Therefore horizons with and without organic matter are not time equivalent.

Presence of coarse grains within the youngest horizon of organic matter (Fig. 5) seems to be connected with slow accumulation, whereas coarse grains indicate stormy conditions. At the same time lack of these fractions within ancient horizons can be explained in two ways. According to the first one the bank-forming material was delivered from marine beach and mainly from terminal moraine of the Vitkovski Glacier. First of all fine sand and dust forming an interior of the bank was blown out. Successively coarser grains were carried out, and that is why they occur only in youngest deposits.

The other interpretation is also possible. Material of the oldest horizons could be delivered from the different sources. The bank seems older than moraines from Little Ice Age. Moraines being formed in the neighborhood could therefore deliver coarser grains to the bank.

The preferable version cannot be selected at present as described forms keep growing. Undoubtedly the bank as well as other described forms are younger than marine beaches on which they occur. The ages of the terraces at 5—8 and 8—12 m a.s.l. were calculated for about 1500 and 8000 years respectively (*cf.* Birkenmajer and Olsson 1970).

Final remarks

In Spitsbergen periglacial climatic conditions favor intensive frost weathering of the bedrock. Products of weathering as well as loose glacial and glaciofluvial deposits become subjected to wind processes. Strong winds transported fine grains and some of them are accumulated on narrow strandflats. Several stable landforms as hillocks, sand banks, sand drifts, aeolian covers on marine beaches and permafrost hillocks are formed. Stability of these forms is different but horizons of fossil organic matter in some of them show their persistence. These forms are the most interesting, especially if comparing fossil horizons with the ones that form nowadays. Connections between accumulation conditions and climate are to be shown in this way. Dating of deposits using radiocarbon method and grain size analysis seem to support with new data on changes of a geologic environment in Spitsbergen during the Holocene.

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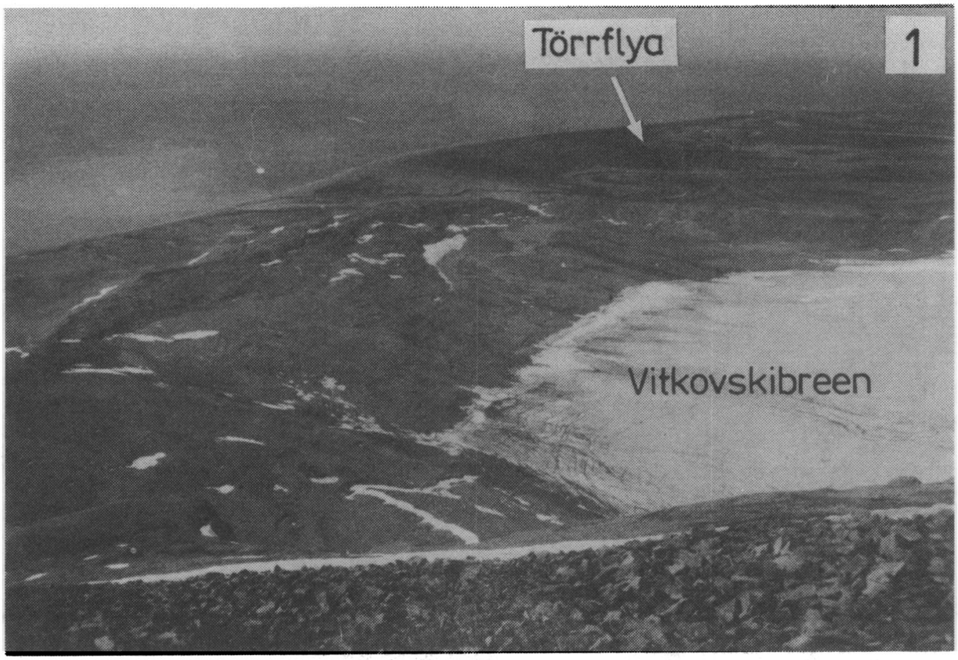
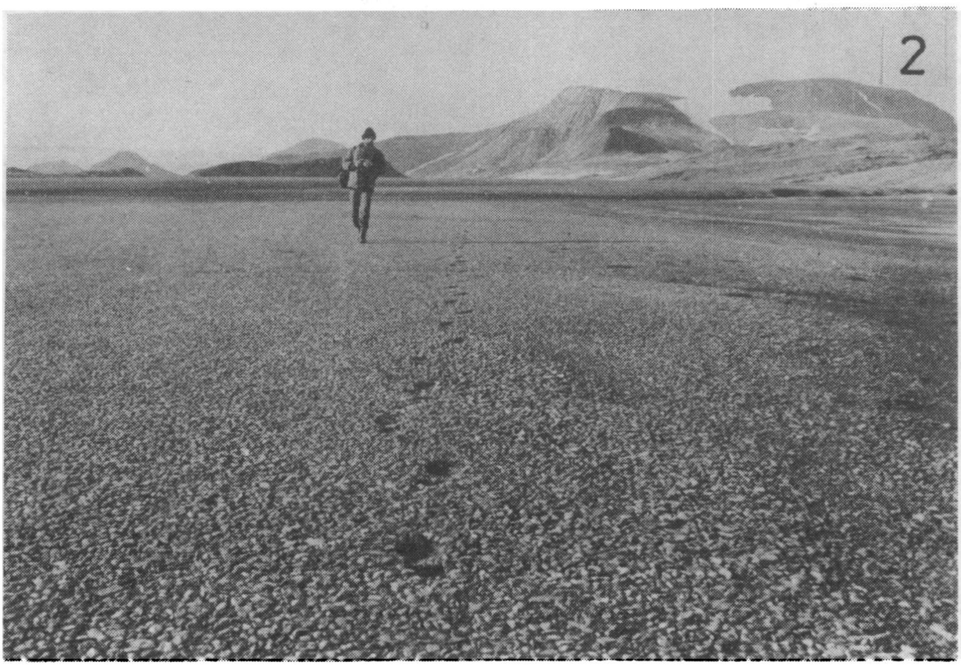
Streszczenie

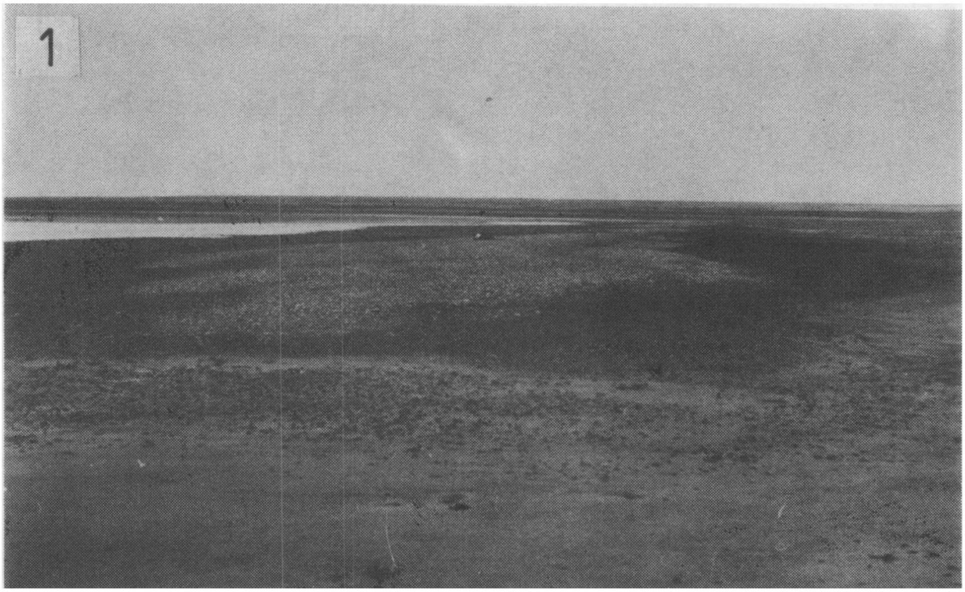
W artykule przedstawiono formy akumulacji eolicznej występujące w zachodniej części Sörkapplandu w rejonie Törrflya-Björnbeinflyene (fig. 1). Silne wiatry wiejące z NE transportują materiał pylasty i piaszczysty pochodzący z pokryw zwietrzeniowych na masywach górskich, osadów glacjalnych i fluwioglacjalnych. Większość materiału wywiewana jest do Morza Grenladzkiego, jednakże w sprzyjających warunkach piasek i pył może być akumulowany w wąskiej strefie równin nadbrzeżnych (fig. 2), tworząc różnego kształtu formy. Są to pokrywy eoliczne na tarasach morskich i pagórkach mrozowych (fig. 3) oraz piaszczyste pagórki, zaspy (fig. 4) i wały (fig. 5). Niektóre z tych form są trwałymi elementami krajobrazu, o czym świadczą obecne w ich wnętrzu kopalne poziomy wzbogacone w substancję organiczną.

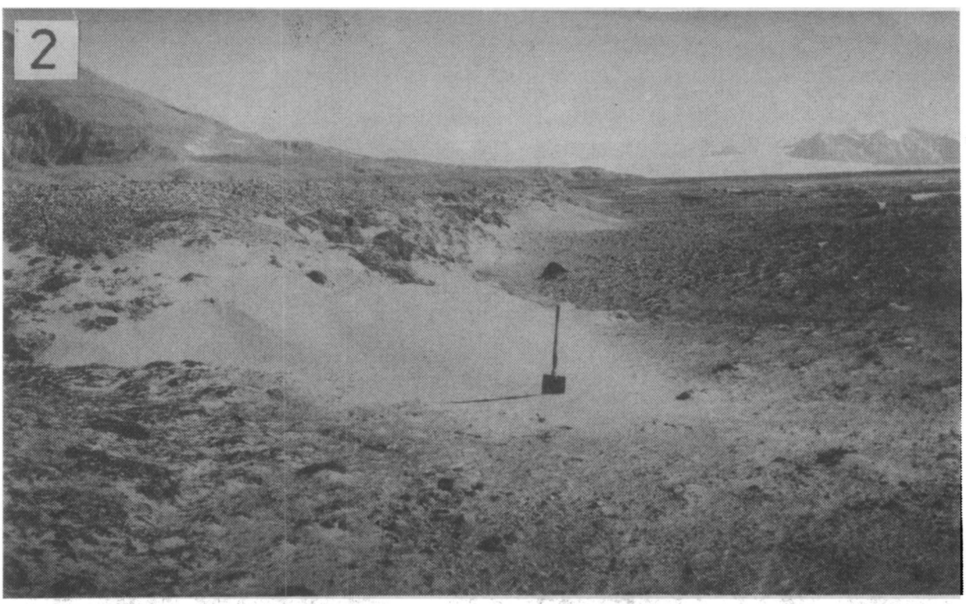
Praca została wykonana w ramach CPBP 03.03. B.7.



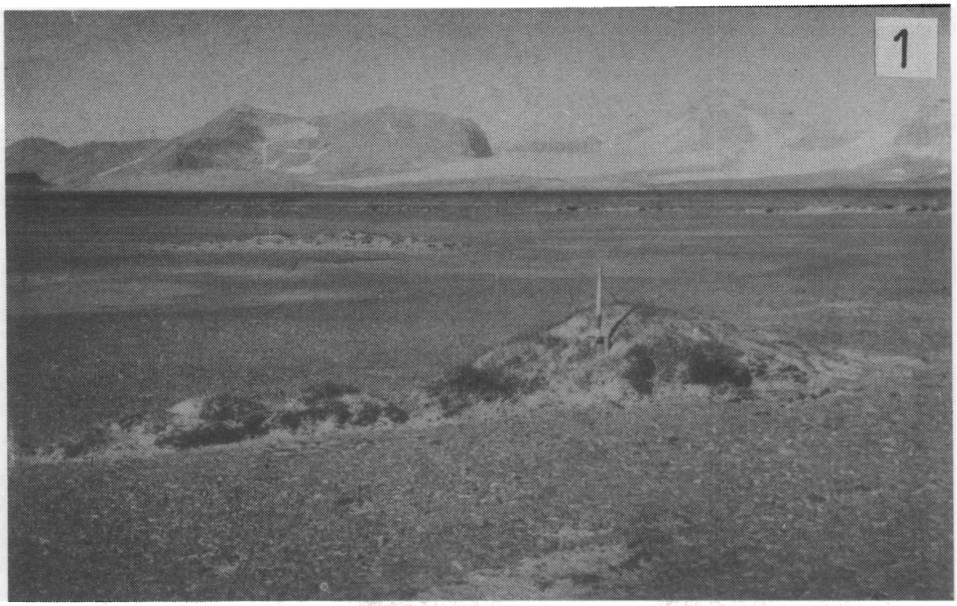


1. General view of investigated area (July 1985)
2. Aeolian pavement on the marine beach 8—12 m a.s.l. Törrflya (August 1985)

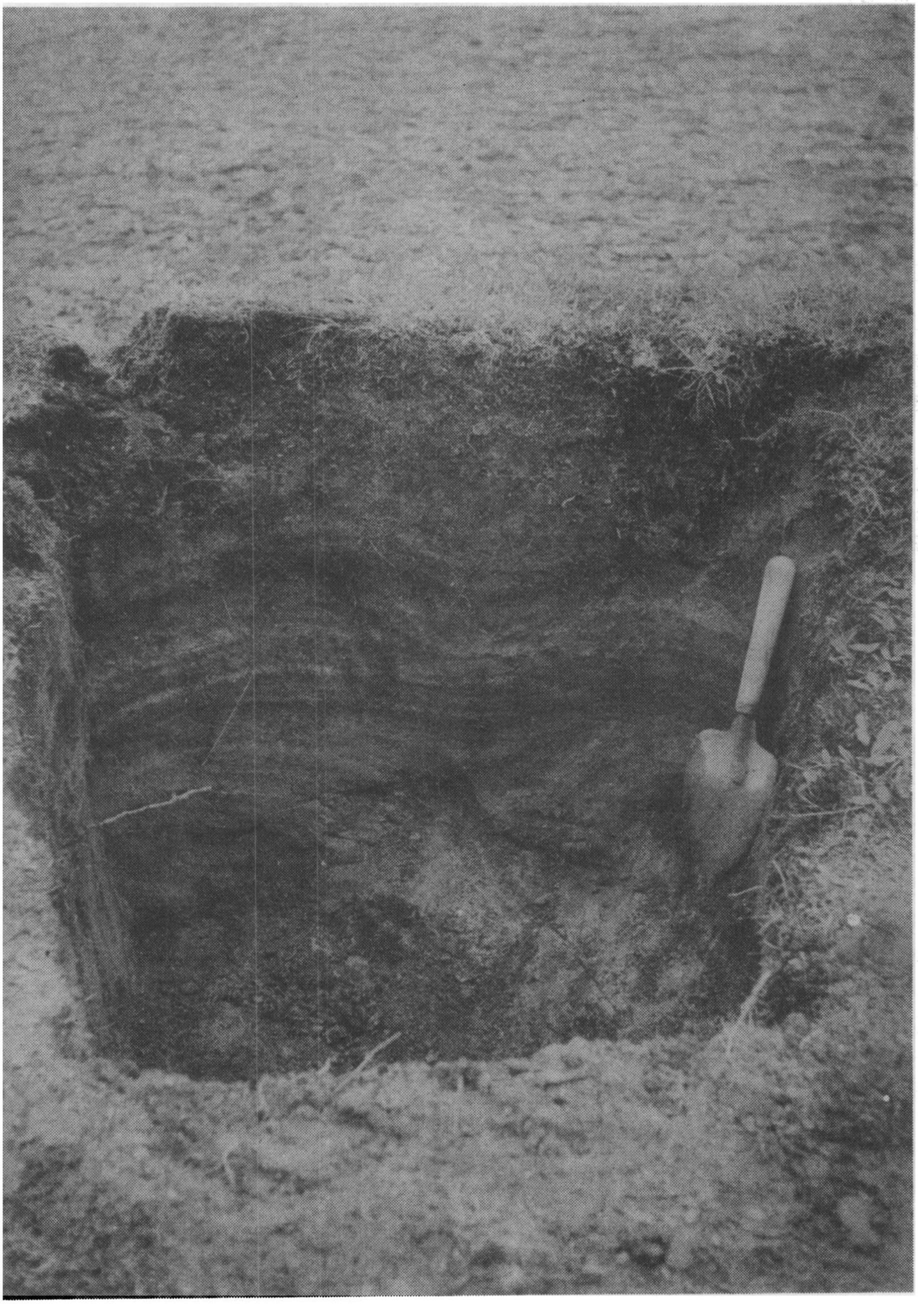




1. Aeolian covers on Törrflya (August 1985)
2. Sand drifts down a marine terrace on Törrflya (August 1985)



1. Aeolian hillocks on the marine beach 5—8 m a.s.l. on Törrflya (July 1985)
2. Aeolian bank in forefield of the Vitkovski Glacier (July 1985)



Profile of deposits in the aeolian bank (July 1985)