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# Moraines forms and deposits of Antarctic ice-sheet at the contact with Bunger Hills *)

ABSTRACT: Ice-cored moraines are the only accumulation forms of Antarctic ice-sheet in the contact zone with Bunger Hills. Their longiness ranges from 3.5 km to 250 m, they are from 300 m to 30 m wide and their elevation oscillates between 10 and 5 m. A thickness of morainic cover which lags the ice-core is changeable in the limit of 1 m. A process of decay of ice-cores, leading to deformations of their moraines, plays a small part up to now. It is caused a dry climate, probably, which was not favorable for the release and the work of melted waters in a large scale. The weak separation of ice-cored moraines results from a small amount of morainic material transported to the front of ice-sheet, probably as the ice-sheet is almost motionless.
The granulometric analysis of morainic sediments shows their bad segregation.

Key words: Antarctic, Bunger Hills, glacial geomorphology

## 1. Geographical situation of Bunger Hills

The Bunger Hills (oasis) is one of the bigger area free from ice on Antarctic continent. They lie in Eastern Antarctic near the margin of ice--sheet, on the border between Land of Queen Mary and Wilkes's Land near the Knox Bank (latitude: from 66°20′ to 65°58′ S, longitude: from 101°20′ to 100°28′ E). The largest land part of Bunger Hills, in the central part of which occurs the Polish Antarctic Station named after A. B. Dobrowolski, has almost 500 km² of surface (Fig. 1).

The Bunger Hills are surrounded by ice from the every side. The front of Antarctic ice-sheet contacts with the Bunger Hills from the east, the Apfel Glacier abounds the oasis from the south, the Adisto Glacier does it from the west. The flowing-down Ramenhus Glacier closes this area from the north, together with the shelf-type Shackleton Glacier and with the many,

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many years old sea-ice. The distance about 70 km separates the Bunger Hills from the open ocean.

This free from an ice area presents itself the complex of rocky hills builded by precambrian metamorphic rocks, granato-biotite gneises are most common between them. This complex is cut by doleritic dikes (sills) furthermore. Depressions of oasis, which have a tectonic character, are filled up by numerous lakes: the Figurnoe Lake is largest among them. It is 18 km long, 1 to 0.1 km wide and it has the bigest depth 137 m.

The hipsometric relations of the Bunger Hills are very differentiated. The highest rocky lifts with abrupt slopes are situated in its eastern part. They reach the absolute altitude more than 140 m a.s.l. and 100 m of relative heights. But the highest hill called Piramidal (172 m a.s.l.) is situated 3 km apart of the Polish Station in the SW direction. The central, western and southern parts of oasis are characterized by more gentle relief, considerably. These area are hilly also, but absolute altitudes of elevations exceed seldom 100 m and its relative heights are no more than 70 m. The front of ice-sheet, which fits close the oasis from the east lifts quickly, becouse it reaches 300 m a.s.l. in the distance 1.5 to 1 km from the Bunger Hills and in the distance 7 km has the altitude 500 m a.s.l., already. The inclination of the head is small at first with the values 4°–3° and it increases itself up to 8°–6° nearby oasis (Fig. 2).

The different hipsometric relations were observed between southern part of Bunger Hills and the Apfel Glacier, which closes the oasis from this side and flows down from the ice-sheet. The surface of this glacier in the S direction from Dalekoe Lake is situated higher than the oasis initially, but it lowers itself in the W direction quickly to the altitude of 80 to 50 m a.s.l., this means it is situated underneath the Bunger Hills. The Adisto Glacier, which swims round the oasis from the west has the altitude between 25–15 m a.s.l. and the shelf Shackleton Glacier, together with the many, many years old sea ice (surrounding this area from the north in the immediate proximity) has the altitude 10 to 2 m a.s.l. only. This icy surrounding of the Bunger Hills lies considerably below regard to it.

## 2. Morphometrical and geomorphological characteristic of ice-cored moraines

The marginal zone of the ice-sheet, 17 km long, between Dalekoe Lake on the south and Leonov Bay on the north (Fig. 3) was the main object of author's study in the Bunger Hills. The coastal line of the ice-sheet in its general coarse is relatively straight and it has the azimuth N 15°. The uncovering itself, rocky basement. which has very differentiated relief — has an influence on the character of the contact between the ice-sheet and the oasis. This contact is formed as cliffs in the places, where the coastal line of the ice-sheet crosses the depressions of the ground, filled by lakes of different sizes. The entrance on the head of the ice-sheet is facilitated by many years old snow drifts often, in the less differentiated area. Such drifts continue along the coastal line and terminate as cliff form sometimes.

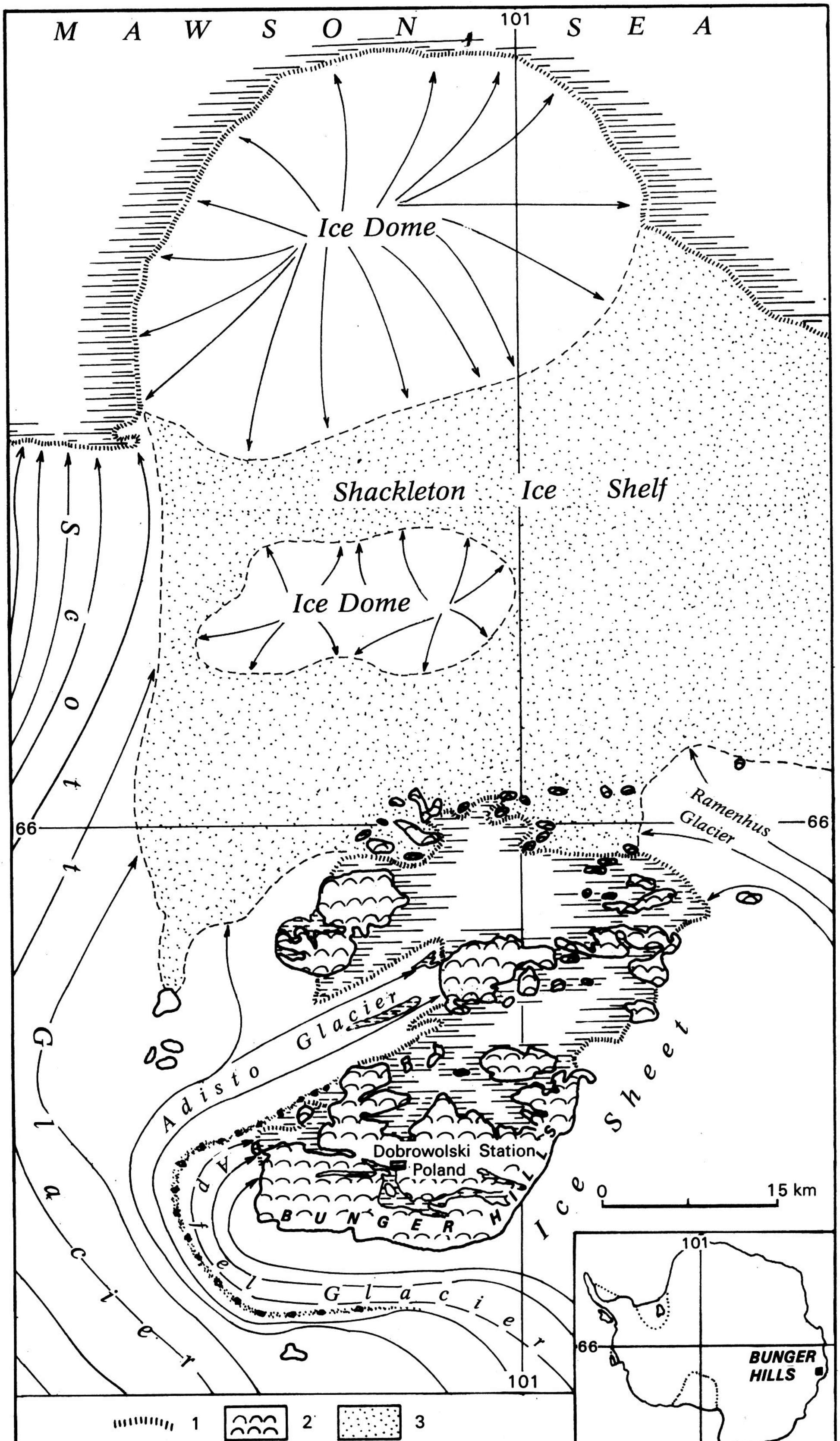


Fig. 1. Geographical situation of Bunger Hills
1 — icy cliffs, 2 — hilly-undulating area, 3 — ice-shelf

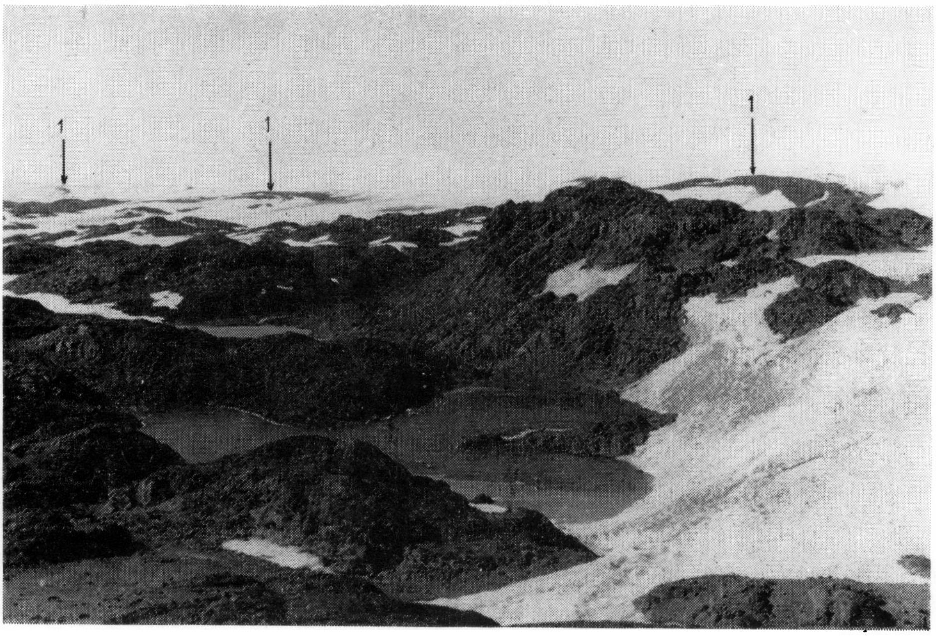


Fig. 2. The contact of ice-sheet with Bunger Hills
1 — icy-cored moraines

(Photo E. Wiśniewski)

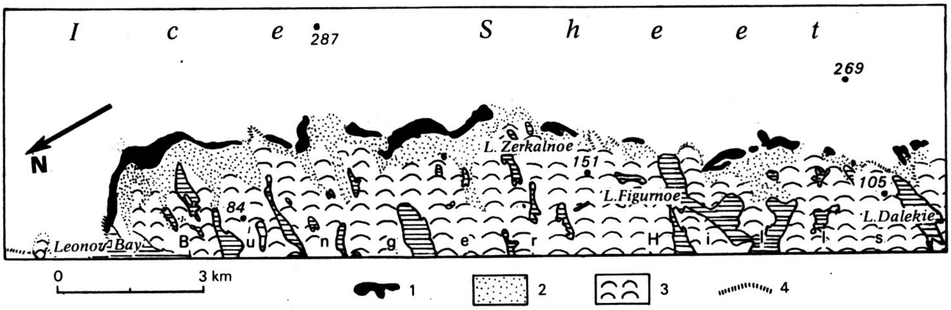


Fig. 3. Schematic map of ice-cored moraines on the front of ice-sheet close to Bunger Hills 1 — ice-cored moraines, 2 — many years old snow drifts, 3 — hilly-undulating area, 4 — icy cliffs

Snow-drifts are called "sneżniki" in russian. The perpendicular walls of the front of ice-sheet are icy very often so a foliation is uncovered. A big amount of transported morainic material is observed inside (Fig. 4). The biggest lake of oasis, Lake Figurnoe is only partially uncovered from under the ice-sheet. The margin of the ice-sheet crosses the basin of this lake (400 m wide in this place), a distinct depression and fissures are visible on it. This dependence of deformations on the surface of ice-sheet margin in relation to the basement reduces very fast as the distance from the Bunger Hills grows.

The marginal zone of the ice-sheet characterizes itself by poorness of sediments and glacial forms present. The only distinct forms being the result of accumulation work of the ice-sheet are sequences of morainic hills. They are present on its margin from Dalekoe Lake to Leonov Bay (Figs. 2 and 3). These morainic hills can be classified as moraines with an ice-core because they had been formed on ice, which is present inside, under a layer of morainic sediments too.

The icy morainic hills continue themselves on long distances usually having the form of belts. They lie on the margin of the described fragment of the ice-sheet, in the one sequence, but they have differential dimentions. Simonov (1971) describes some sequences of similar morainic belts in Schimacher Hills. The moraines with the ice core occur in some places between Dalekoe Lake and Figurnoe Lake. Two longest belts of ice-cored moraines of arc shape with the bulged parts of them directed to the ice-sheet side continue on the distance about 900 m (Fig. 2). The widths of them are changeable oscillating from 80 m on their outskirts to 150 m in the central parts. The elevations do not exceed 10 m or so. The bigger area with ice morainic hills is situated close to Dalekoe Lake, too (a square shape with the side 250 m). Moraines with ice-core have smaller surfaces in the remaining cases.

The ice-cored morainic belts of small dimentions occur also, but in the two places only: they lie on 3.5 km long sequence of the ice-sheet margin between Figurnoe Lake and Zerkalnoe Lake. The first one, close to Figurnoe Lake is 250 m long and 75 m wide, the second one is 450 m long and about 100 m wide. The elevation of these ice morainic belts are 6 to 5 m only.

The biggest one ice-cored moraines (height to 10 m) lie close to the ice-sheet margin between Zerkalnoe Lake and Leonov Bay. The two, jointed arcs of ice-cored moraines, with the bulged parts from the ice-sheet side continue on the distance about 2.5 km in the NE direction from Zerkalnoe Lake. The widest places of them reach about 180 m. Three other fragments of the ice-cored moraines are seen in the direction of Leonov Bay — but their dimentions are much more smaller (longiness: 700—400 m, width: 120—30 m, height: 7—5 m). The longest ice-cored moraine lies in the northern part of described area — it is 3.5 km long, without a gap. The width of this belt is however changeable: 100—75 m in the part lying in the E direction from Ščel Lake on its first kilometer, than the width grows continously to 300 m in the cental part of moraine (Fig. 5). The farther part of mentioned belt belongs to very weak formed. Its coarse is marked by stones stick out from under the snow along the outcrop of the sheer plane nearby the front of ice-sheet (Fig. 6). The last sequence of ice-cored morainic belt nearby the Leonov Bay is well formed, being about 1 km long, 70—60 m wide and 7 m height.

The distal slopes of all ice-cored moraines are buried by snow which had been blow in their shadow by the slope winds, blowing from the ice-sheet side. This snow does not melt in the period of short antarctic summer — so the precise estimation the width of morainic sequences is difficult. The proximal slopes of these moraines have a smooth inclinations (15°—12°).

The surface of described forms is covered by rocky stones of different dimentions, sometimes by rocky blocks (up to 3 m high), under them layes a clayey sediment. The ice-cored moraines which appear in the northern part of studied area have small percentage of stony fraction, comparing with the ice-cored moraines from the southern sequence of the ice-sheet margin. The stony fraction is shape-edged in substance, but we can meet well rounded stones with glacier flaws sometimes. They were formed in a transport process in the glacial environment.

The thickness of sediments, that cover the ice core is small and oscillates between 1 m and dozen or so cm as it is visible on profiles of moraines (Fig. 7). Such sediments melting themselves from the shear planes of the ice-sheet near its margin protect the ice under them against ablation. The process of degradation of marginal zone of ice-sheet, uncovered by morainic material caused by melting, lead to the isolation itself of hills or icy-morainic belts, as it is seen on Fig. 8. The mechanism of formation of this type landscape was described widely by Kozarski and Szupryczyński (1973) on the basis of studies on Iceland.

The most intensive processes of ablation were observed during a short period of antarctic summer in zones under base foots of proximal slopes of ice-cored moraines. It is caused by the occurence of great amount of rocky fragments (of different dimention) melted from ice, which do not compose a compact cover, yet. This dark, rocky material sinks into an ice, sometimes to the depths of some dozen centimeters, in the result of

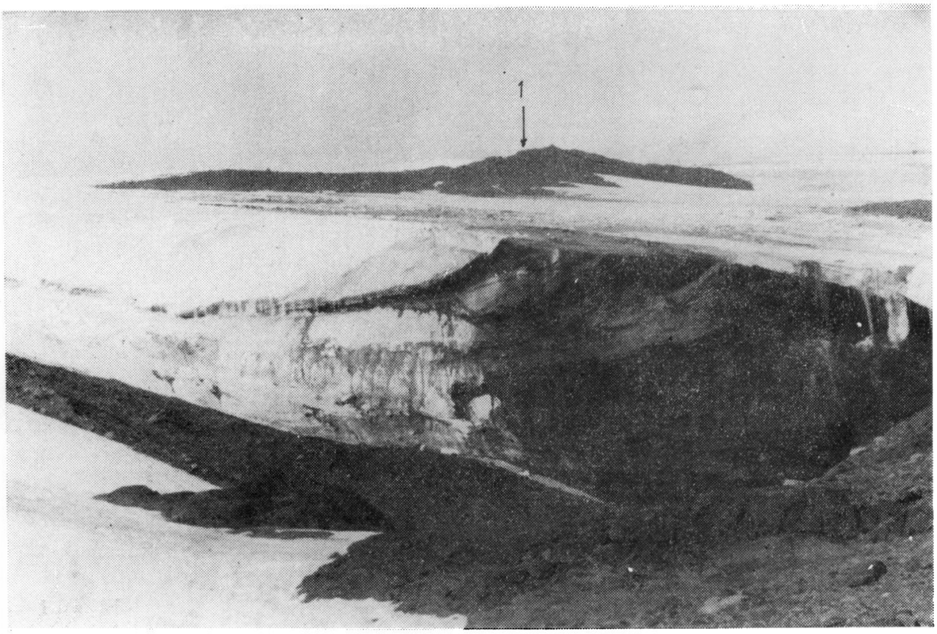


Fig. 4. Ice-wal with the big amount of morainic material (about 40 m high)
1 — ice-cored moraine on the front of ice-sheet
(Photo E. Wiśniewski)

Fig. 5. The ice-cored moraine in the NE direction from Ščel Lake
(Photo E. Wiśniewski)

Fig. 6. Morainic deposits along the shear plane close to the ice-sheet front, the first step to the formation of the ice-cored moraine
(Photo E. Wiśniewski)

Fig. 7. Morainic deposits protecting the ice under them against ablation
(Photo E. Wiśniewski)

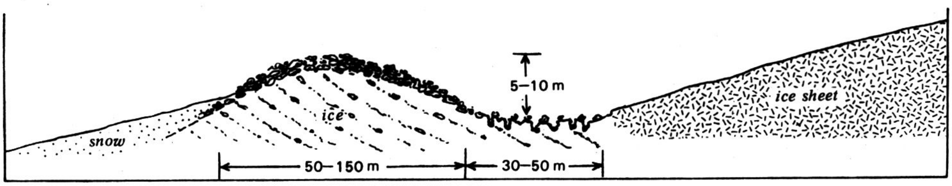


Fig. 8. Schematic cross section through the ice-cored moraine

absorption of the big amont of heat, causing the formation of krioconic depressions of different dimentions. These phenomena contribute themselves to constitute a depression on gentle slope of the ice-sheet margin on the base of the ice-core moraine (Fig. 9). This type forms do not exist on the distal side of moraine belts as a result of masking role of permanent snow-drifts present here.

The influence of the ice-sheet on the present shape of ice-cored moraines in the contact zone of Bunger Hills have thermokarst phenomena, which were observed earlier by Grigorev (1965). The intensity of them is, however, is conditioned by the thickness of morainic cover lagging the ice lying beneath. The seasonal melting of morainic sediments reaches 30 cm of depth according to observations made by Grigorev. The degradation of ice occurs mainly in these places on ice-cored moraines, where the morainic cover is thin, consequently. The vanishing of ice causes a creation of holes within the limits of moraines, which are filled by a melted water sometimes (Fig. 10). These classical kettle-holes deepens to a moment when their bottoms fullfill themselves by morainic sediments of suitable thickness, slliping off on their slopes. The presence of kettle-hole forms full of water inside the ice-cored moraines is not usual still.

The stony circles, one of the kind of periglacial structure (Fig. 11), can be noted, but not very often also, in depressions of morainic belts, where the thickness of sediments is bigger. Some of them is destroyed and deformed as a result of surface flow of sediments.

Melted waters have also a certain influence in a modification of relief of the described ice-cored moraines. A certain quantity of water release from melting ice-cores in the very short period of antarctic summer, what causes the partial removing of morainic cover and favors the degradation of ice, which lies beneath. Coarser fractions, washed out from sediments on distal morainic slopes, are transported down in narrow channels of streams. Such melted water streams are cut in snow drifts of many years, which mask the contact of the ice-sheet with the oasis. The streams are some scores centimeters wide usually (Fig. 12) and they have outlets in bigger or smaller lakes (Fig. 13). Sediments draged in the melted water channels accelerate the deepening of them thanks the absorption of heat.

The ice-cored moraines are cut by narrow depressions in some places of sequence between Zerkalnoe Lake and Leonov Bay (Fig. 14). A greater quantity of melted water migrating on the base of proximal slopes caused the formation of small fractures in the long ice-cored morainic belts of mentioned sequence. This water was forced to look for outflow ways on the outside of belts (Fig. 15), using the places predisposited by termokarst phenomena.

## 3. Mechanical composition of morainic deposits

The 16 samples of deposits building the described ice-core moraines have been collected to characterize their mechanical composition. The samples were collected from the depth of 20—30 cm. or from the material melted directly from ice, without stony and boulder fraction, very common in the formations covering the ice-cored moraines. The mechanical composition was elaborated thanks the sieve and areometric method. The following fractions have been segregated: 10 mm, 10—7, 7—5, 5—3, 3—2, 2—1.5, 1.5—1.2, 1.2—1.02, 1.02—0.75, 0.75—0.5, 0.5—0.385, 0.385—0.25, 0.25—0.15, 0.15—0.12, 0.12—0.102, 0.102—0.05, 0.05—0.02, 0.02—0.006, 0.006—0.002 mm. The following indexes were calculated to characterize statistically the mechanical composition of each sample using the cumulative curves on the probability charts in the Phi scale:

— the graphic skewness (after G. M. Friedman)

$$\alpha_s = (\varnothing 95 + \varnothing 5) - 2\,(\varnothing 50),$$

— the kurtosis (after R. L. Folk and W. C. Ward)

$$K_G = \frac{\varnothing 95 - \varnothing 5}{2.44\,(\varnothing 75 - \varnothing 25)}$$

— the standard deviation (after Mc Cammon)

$$\sigma = \frac{\varnothing 95 + \varnothing 85 - \varnothing 15 - \varnothing 5}{5.4}$$

— the mean grain diameter (after R. L. Folk and W. C. Ward)

$$M_Z = \frac{\varnothing 16 + \varnothing 50 + \varnothing 84}{3}$$

— the index of siltiness (after A. Karczewski)

$$I = \frac{< 0.002\ \text{mm}}{> 0.002\ \text{mm}}.$$

The percentage contribution of the individual twenty fractions in the collected 16 samples of sediments is seen in Table I. The good exposure of character of mechanical composition of morainic sediments gives the syntetic cartogramm of six, cumulated fractions choosen from all twenty analised, and the diagram of the calculated indexes of graining (Fig. 16). It facilitates a space analysis of the mechanical composition of sediments along ice-core moraines, also.

There is no essential differences in graining of boulder clay of the ice-cored moraines, as it results from cartogramm. The boulder clay contains 57 to 55% of silt fraction. The lowest amount of this fraction was found

Fig. 9. Proximal slope of the ice-cored moraine, loose lying stones on the base foot — the zone of kriokonic kettle-holes

(Photo E. Wiśniewski)

Fig. 10. Kettle-hole on the ice-cored moraine

(Photo E. Wiśniewski)

Fig. 11. Stone circle on the ice-cored moraine
(Photo E. Wiśniewski)

Fig. 12. Narrow stream-bed of melted waters cut into the many years old snow-drifts
(Photo E. Wiśniewski)

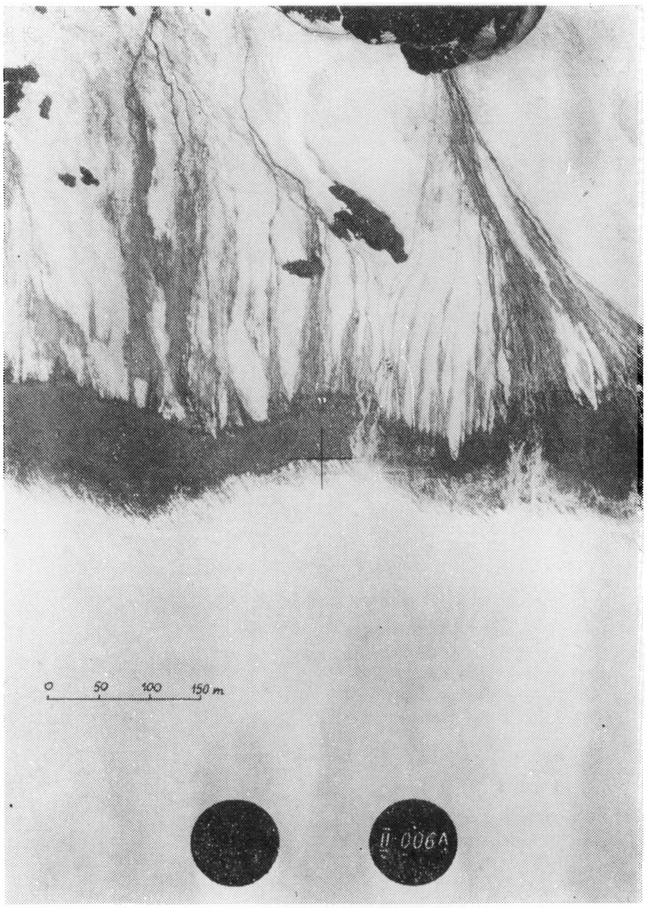


Fig. 13. The system of flow of melted waters from the ice-cored moraine in the direction of Bunger Hills on the surface of many years old snow-drifts near Dalekoe Lake (February, 1979)

(Photo Z. Battke)

Fig. 14. Transversal depressions on the ice-cored meraine formed as the result of melted waters migration from its base to the foreland
(Photo E. Wiśniewski)


Fig. 15. The ice-cored meraine cut on the edge by narrow, water-gap valley, which drains of melted waters from the kriokonic, kettle-holes zone in the direction of Bunger Hills (February, 1979)

(Photo Z. Battke)

Table I

Mechanical composition of boulder clay samples from the ice-cored moraines (%)

| Fraction (mm) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| > 10 | 10.8 | 4.7 | 5.1 | 6.0 | 3.0 | 4.9 | 4.6 | 9.7 | 6.4 | 2.5 | 6.3 | 6.7 | 8.9 | 2.3 | 4.0 | 2.8 |
| 10 — 7 | 3.7 | 2.6 | 2.9 | 2.7 | 1.7 | 1.0 | 3.5 | 2.4 | 2.1 | 1.6 | 3.0 | 3.4 | 3.4 | 1.9 | 3.1 | 1.2 |
| 7 — 5 | 3.2 | 3.5 | 2.3 | 4.5 | 2.6 | 2.2 | 2.9 | 3.7 | 2.1 | 2.1 | 3.1 | 2.5 | 3.4 | 1.0 | 3.1 | 3.3 |
| 5 — 3 | 3.1 | 4.0 | 3.6 | 4.5 | 3.1 | 3.4 | 5.2 | 3.3 | 2.9 | 3.2 | 4.4 | 3.3 | 4.3 | 2.3 | 4.6 | 3.3 |
| 3 — 2 | 1.2 | 1.4 | 1.2 | 1.5 | 1.1 | 1.3 | 1.9 | 1.4 | 1.4 | 1.1 | 1.6 | 0.8 | 1.1 | 1.0 | 1.5 | 1.2 |
| 2 — 1.5 | 3.1 | 3.8 | 3.0 | 3.4 | 3.5 | 3.3 | 5.4 | 3.1 | 3.7 | 2.9 | 3.6 | 2.6 | 3.6 | 2.4 | 3.6 | 3.3 |
| 1.5 — 1.2 | 0.7 | 0.9 | 0.8 | 1.1 | 0.9 | 0.7 | 1.3 | 0.7 | 0.9 | 0.7 | 0.7 | 0.5 | 0.7 | 0.6 | 0.7 | 0.6 |
| 1.2 — 1.02 | 1.4 | 1.6 | 1.6 | 1.7 | 1.3 | 1.6 | 2.3 | 1.2 | 1.7 | 1.3 | 1.6 | 1.2 | 1.5 | 1.0 | 1.8 | 1.5 |
| 1.02 — 0.75 | 6.5 | 8.0 | 5.9 | 7.5 | 6.9 | 6.7 | 10.7 | 5.3 | 7.7 | 6.3 | 7.1 | 5.4 | 7.0 | 4.7 | 7.4 | 7.1 |
| 0.75 — 0.5 | 1.8 | 2.2 | 1.9 | 2.2 | 2.0 | 2.1 | 2.7 | 1.6 | 2.1 | 2.1 | 2.0 | 1.7 | 2.0 | 1.4 | 2.0 | 2.3 |
| 0.5 — 0.385 | 3.3 | 4.2 | 3.4 | 4.6 | 4.1 | 4.1 | 4.9 | 2.9 | 3.8 | 4.2 | 3.5 | 3.4 | 4.2 | 2.8 | 4.0 | 4.2 |
| 0.385 — 0.25 | 3.3 | 4.2 | 3.6 | 4.8 | 4.1 | 4.1 | 4.7 | 3.0 | 3.8 | 4.7 | 3.5 | 3.6 | 4.4 | 3.1 | 4.2 | 4.5 |
| 0.25 — 0.15 | 3.5 | 4.1 | 3.9 | 4.7 | 4.2 | 4.3 | 4.9 | 3.3 | 3.7 | 4.9 | 3.4 | 4.0 | 4.6 | 3.1 | 4.6 | 4.5 |
| 0.15 — 0.12 | 1.4 | 1.7 | 1.6 | 1.7 | 1.8 | 1.6 | 1.8 | 1.4 | 1.7 | 2.0 | 1.3 | 1.7 | 1.7 | 1.3 | 2.0 | 1.9 |
| 0.12 — 0.102 | 1.0 | 1.1 | 1.2 | 1.1 | 1.7 | 0.7 | 1.2 | 1.0 | 1.0 | 1.4 | 0.9 | 1.2 | 1.2 | 1.1 | 1.4 | 1.3 |
| 0.102 — 0.05 | 6.0 | 6.0 | 9.0 | 8.0 | 13.0 | 8.0 | 9.0 | 6.0 | 8.0 | 8.0 | 7.0 | 6.0 | 8.0 | 13.0 | 10.0 | 7.0 |
| 0.05 — 0.02 | 9.0 | 7.0 | 6.0 | 6.0 | 2.0 | 6.0 | 7.0 | 8.0 | 7.0 | 7.0 | 5.0 | 7.0 | 6.0 | 11.0 | 8.0 | 8.0 |
| 0.02 — 0.006 | 9.0 | 9.0 | 10.0 | 10.0 | 9.0 | 10.0 | 9.0 | 12.0 | 12.0 | 11.0 | 13.0 | 11.0 | 9.0 | 12.0 | 11.0 | 11.0 |
| 0.006 — 0.002 | 9.0 | 7.0 | 10.0 | 6.0 | 10.0 | 8.0 | 5.0 | 10.0 | 8.0 | 9.0 | 9.0 | 9.0 | 6.0 | 9.0 | 7.0 | 10.0 |
| < 0.002 | 19.0 | 23.0 | 23.0 | 18.0 | 24.0 | 26.0 | 12.0 | 20.0 | 20.0 | 24.0 | 20.0 | 25.0 | 19.0 | 25.0 | 16.0 | 21.0 |
| Graphic skewness ($\alpha_s$) | 0.34 | 1.15 | −0.12 | 2.20 | 1.53 | 1.15 | 2.83 | −1.88 | 0.14 | 0.29 | 0.45 | −0.92 | 1.57 | −0.50 | 1.12 | 0.60 |
| Kurtosis ($K_G$) | 0.76 | 0.73 | 0.74 | 0.84 | 0.75 | 0.76 | 0.91 | 0.77 | 0.82 | 0.77 | 0.77 | 0.72 | 0.77 | 0.87 | 0.86 | 0.76 |
| Standard deviation ($\delta$) | 5.11 | 4.86 | 4.80 | 4.84 | 4.70 | 5.17 | 4.26 | 5.06 | 4.82 | 4.53 | 4.91 | 5.00 | 5.00 | 4.55 | 4.63 | 4.58 |
| Mean grain diameter ($M_z$) | 3.47 | 4.08 | 4.37 | 3.44 | 4.56 | 4.85 | 2.71 | 3.84 | 4.16 | 4.82 | 3.88 | 4.37 | 3.33 | 5.17 | 3.80 | 4.58 |
| Index of siltiness (I) | 0.23 | 0.30 | 0.30 | 0.22 | 0.32 | 0.35 | 0.14 | 0.25 | 0.25 | 0.32 | 0.25 | 0.33 | 0.23 | 0.33 | 0.19 | 0.27 |

Number of sample: columns 1–16.

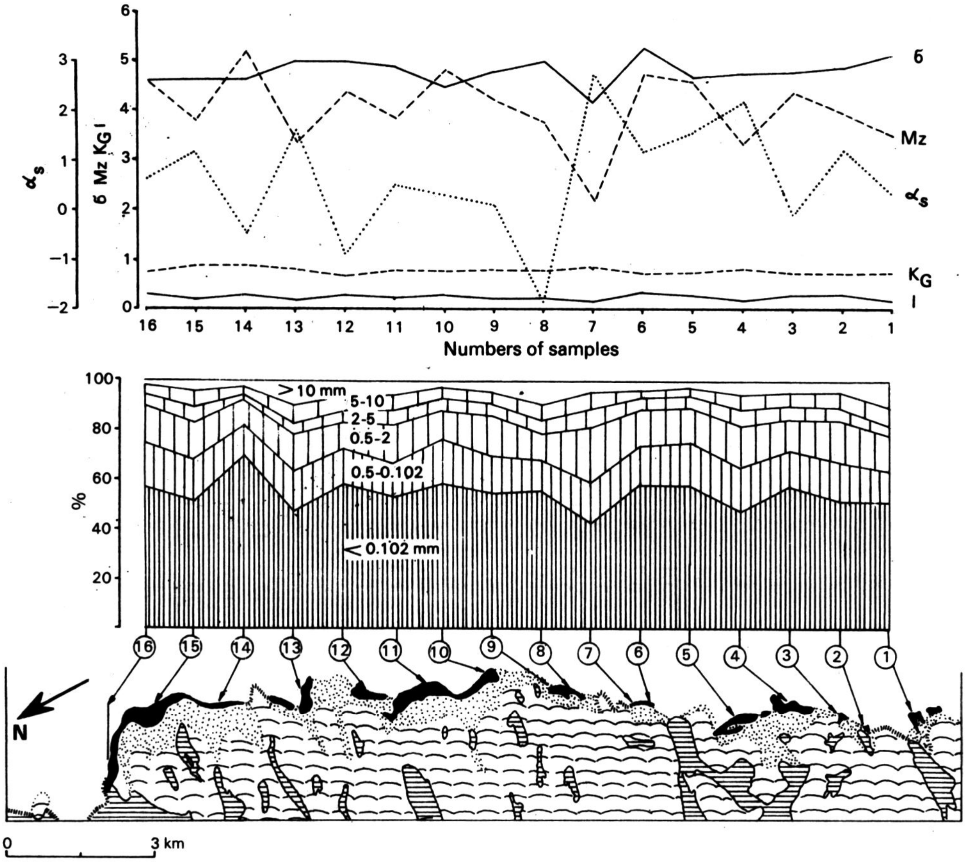


Fig. 16. Synthetic cartogramm and the plots of indexes of mechanical composition of boulder clay from ice-cored moraines

$\sigma$ — standard deviation, $M_Z$ — mean grain diameter, $\alpha_s$ — graphical skewness, $K_G$ — kurtosis, I — siltiness, 1—16 — numbers of samples. The other explanations — see Fig. 3

in the sample 7 (42%), which was taken from the moraine near Figurnoe Lake, the highest value (70%) was in the sample 14 from the place situated in the east direction from Ščel Lake. The standart deviation ($\sigma$), being the measure of disperation of diameters of grains in the relation to the mean value of them, gives the more accurate information about a character of boulder clay. The calculated values of standart deviation (among them: the lowest index: 4.26 in the sample 7 and the highest: 5.17 in the sample 6 — Table I, Fig. 16) indicate clearly on a very bad sorting of sediments, this means on the distribution of the material in many subdivitions. Analysing the values of graphical skewness, we can see they are positive in majority, what indicate on culminations in rough fractions. These values are negative only in four cases (samples 3, 8, 12, 14 — this means culminations apear in coarse fractions.

The calculated indexes of kurtosis ($K_G$) for sample 12: 0.72 and for sample 7: 0.91 stress one again a very bad sorting of sediments building the ice-core moraines. All curves of granulation are flattened in relation to the log-normal distribution (Grzegorczyk 1970).

The mean grain diameter (M) oscillates between 0.15 to 0.03 mm as results from the analysis of calculated indexes for sample 7 (2.71) and for sample 14 (5.17). The index of siltiness (Karczewski 1963) indicating the weight relation of amount of coloidal silt fraction (0.002 mm) to amount of all other fractions in the sample, argue as the boulder clay contains the great quantity of very coarse parts. The indexes of siltiness are high for every sample and their values oscillate between 0.35 (sample 6) to 0.19 (sample 15). It is worth to add, that sediments of marginal zone of Werenskield Glacier (Spitsbergen), analized by Karczewski and Wiśniewski (1979) have the indexes of siltiness much smaller — from 0.15 in a subglacial morainic material to 0.0 in glacifluvial sediments.

Summarized results of the mechanical composition analysis for the samples of boulder clay collected from the ice-cored moraines of antarctic ice-sheet nearby Bunger Hills let to state, that these forms are covered by badly segregated material melted itself from the shear planes. The big quantity of coarse fractions, and a coloidal silt also, indicate on the priomordiality of sediment, which was not influenced yet by an eolic degradation, so intensive here. This conclusion was confirmed by the rough microscopic analysis of the grains abrasion. It shows that the quartz grains have no evidence of obrasion and they have the typical features of fresh grain, as in the weathering deposits. It means that the transport of them in the glacial environment was very short.

## 4. Conclusions

The described study of forms and deposits of the Antarctic ice-sheet in the contact zone with Bunger Hills indicate as the only representants of glacial forms, the ice-cored moraines are, a different longiness (5 to 3 km), width (up to 300 m) and altitude (up to 10 m), which continue along the ice-sheet front. The ice-core moraines of Antarctic ice-sheet are not spectacular, when to compare their dimentions with the similar forms in the marginal zones of contemporary glaciers, on Spitsbergen for example (Karczewski and Wiśniewski 1977). It is very interesting, becouse — they are an effect of work, of the huge ice-sheet dome, which exists here as long as 20 mln years, continously, changing own extent, only. It is difficult to explain this fact by the lack of transported material in the ice-sheetbecouse its quantity is big, as it is seen in high icy cliffs (Fig. 4). The thickness of the stratum containing morainic material in the ice-sheet near Bunger Hills is about 40 m (Evteev 1964). The content of material in the ice oscillates between 0.11% to 13.8%, and it increases as the depth grows. This material, melting from cliffs, and falling down under their base foots, forms also not very high morainic belts there. The cause, that the forms described are weakly shaped in the marginal zone of Antarctic ice-sheet near Bunger Hills is the small supply of morainic material by shear-planes to its front, because the ice-sheet is almost motionless.

Simonov (1971) describes (after G. A. Avsjuk, K. K. Markov and P. A. Šumskij) that the ice-sheet near the Bunger Hills flows with the velocity 0.5—1.0 m per year. Much more higher velocity have glaciers running from the ice-sheet (as Denman, Scott, Apfel and Adisto), sometimes up to 1 km per year (Atlas Antarktiki, 1966).

Not very big transformations of ice-cored moraines, as the result of thermokarst phenomena, are determined by local climatic conditions. The dry climate causes the evaporation of almost all waters, during the very short summer ablation of the ice-sheet, the small part of them only, flows down on its slope, transporting the material taken from the ice-morainic belts on short distances to water reservoirs. This week work of melted waters demonstrates on the foreground of the ice-sheet and on the area of the earlier uncovered oasis — as the lack of forms and deposits of glaciofluvial origin (as outwashes, eskers or kames).

The results of granulometric analysis of samples of deposits building the ice-core moraines indicate the very bad segregation of them. The different dimention fractions from blocks to colloidal silt are present. The individual stones have the good abrasion often.

On the other hand the quartz grains sized 0.5 — 1.5 mm characterize by the bad abrasion being the evidence for the short, transport of them in the ice-sheet.

## 5. Summary

There is no glacial forms on the Bunger Hills area. But they can be found in the marginal zone of the ice-sheet and on the ice-cored moraines, which continue in the one line between Dalekoe Lake on the south and Leonov Bay on the north (Figs. 2, 3 and 4). The dimentions of these forms are different (Figs. 4, 5 and 6): they can be 3.5 km to 250 m long, 300 to 30 m wide, and are elevated 10 to 5 m. The thickness of morainic cover which lags the ice-core is changeable, up to 1 m (Fig. 7) and it is builded by rocky blocks (high to 3 m), stones and boulder clay.

The processes of deformations of ice-cored moraines by melting of icy cores from under morainic cover plays a small part (Fig. 10) till now. It is, probably, caused by the dry climate what do not conducts to melting, and to the work of melted waters on the big scale (Figs. 12, 13, 14 and 15). The weak formation of the ice-cored moraines is the result of the small supply of morainic material to the front of ice-sheet, because it is almost motionless.

To characterize the mechanical composition of deposits of ice-cored moraines 16 samples of sediments without stony and gravel fraction were collected.

The following indexes were calculated in the statistical description of mechanical composition: the graphic skewness ($\alpha_S$), the kurtosis ($K_G$), the standard deviation ($\sigma$), the mean grain diameter ($M_Z$) and the index of siltiness (I).

There is no considerable differences in graining in the boulder clay, which covers the ice-cored moraines (Table I, Fig. 16). It contains 57 to 55% of silt fraction. The analysis of determined indexes indicates — it is a very bad sorted formation.

The introductory microscopic analysis of the quartz grains abrasion being the evidence for the short transport of them in the glacial environment.

## 6. Резюме

На территории оазиса Бунгера не наблюдались никакие ледниковые формы. Зато их можно встретить на крае суши, а их единственными представителями являются ледяно-моренные валы, протягивающиеся в одной линии с Далекого озера на юге до залива Леонова на севере (рис. 2, 3 и 4). Размеры этих форм разны (рис. 4, 5 и 6). Их длина колеблется от 250 м до 3,5 км, ширина 30—300 м, а высота 5—10 м. Мощность моренного покрова, окутывающего ледяное ядро, изменчива в пределах до 1 м (рис. 7). Ее составляют валуны и скальные блоки до 3 м, а также морена.

Процесс деформации ледяно-моренных валов путем вытаивания ледниковых ядер из-под моренного покрова играет пока небольшую роль (рис. 10). Это вызвано выступаящим сухим климатом, не содействующим освобождению и деятельности малых вод в широком масштабе (рис. 12, 13, 14 и 15). Слабое образование ледяно-моренных валов вероятно является результатом небольшой поставки моренного материала для передней зоны суши, что вытекает из ее небольшой подвижности.

Для проведения характеристики по гранулометрии отложений на ледяно-моренных валах отобрано из них 16 проб без каменистой и валунной фракций. Проведен анализ механического состава и механическая обработка кварцевых зерн из этих проб.

В статистическом анализе механического состава вычислены следующие указатели: графической диагональности ($d_s$), куртозы ($K_G$), стандартного отклонения ($\sigma$), среднего диаметра зерна ($M_z$) и илистости (I).

Констатировано, что в морене, покрывающей ледяно-моренные валы, не встречается основных разниц в зернистости (таблица I, рис. 16). Она содержит 55—57% алевритовой фракции. Анализ вычисленных указателей доказал, что это образование характеризуется очень плохой сегрегацией. Вступительный микроскоповый анализ окатанности кварцевых зерн для фракций 0.5—1.5 мл указал их плохую обработку, что свидетельствует о коротком транспорте этих зерн в ледяной среде.

## 7. Streszczenie

Na terenie oazy Bungera nie zaobserwowano występowania jakichkolwiek form glacjalnych. Spotkać je można natomiast na skraju lądolodu, a jedynymi ich reprezentantami są wały lodowo-morenowe ciągnące się w jednej linii od Jez. Dalekiego na południu po Zatokę Leonowa na północy (rys. 2, 3 i 4). Rozmiary tych form są różne (rys. 4, 5 i 6). Długości ich wahają się od 250 m do 3,5 km, szerokości 30—300 m a wysokości 5—10 m. Miąższość pokrywy morenowej otulającej lodowe jądro jest zmienna, do 1 m (rys. 7). Stanowią ją głazy oraz bloki skalne do 3 m oraz glina morenowa.

Proces deformacji wałów lodowo-morenowych przez wytapianie się jąder lodowych spod przykrycia morenowego odgrywa, jak dotychczas, niewielką rolę (rys. 10). Jest to zapewne spowodowane panującym tu suchym klimatem, nie sprzyjającym do wyzwalania się i działalności wód roztopowych na szerszą skalę (rys. 12, 13, 14 i 15). Słabe wykształcenie wałów lodowo-morenowych jest prawdopodobnie rezultatem niewielkiej dostawy materiału morenowego do czoła lądolodu, wynikłej z jego małej ruchliwości.

W celu scharakteryzowania pod względem składu mechanicznego osadów występujących na wałach lodowo-morenowych pobrano z nich 16 prób bez frakcji kamienistej i głazowej.

W opracowaniu statystycznym składu mechanicznego obliczono następujące wskaźniki: graficznej skośności ($\alpha_s$), kurtozy ($K_G$), odchylenia standardowego ($\sigma$), przeciętnej średnicy ziarna ($M_z$) i ilastości (I).

Stwierdzono, że w glinie pokrywającej wały lodowo-morenowe nie spotyka się zasadniczych różnic w uziarnieniu (Tabela I, rys. 16). Zawiera ona 55%—57% frakcji mułkowej. Analiza obliczonych wskaźników wykazała, że jest to utwór o bardzo złej segregacji.

Wstępna mikroskopowa analiza obróbki ziarn kwarcowych frakcji 0,5—1,5 mm wykazała złą obróbkę, świadczącą o krótkim transporcie tych ziarn w środowisku lodowcowym.

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