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Łódź

ON EOLIAN PROCESSES NEAR H. ARCTOWSKI STATION, KING GEORGE ISLAND, SOUTH SHETLANDS

Abstract

Eolian processes and some elements of King George Island climate such as air pressure, temperatures, humidity and winds have been discussed in the paper. The main and indispensable factor generating the eolian processes in this area is strong wind the average speed of which amounts up to 8 m/s. The geological structure, mainly Tertiary rocks of volcanic and sedimentary origin also enhances the eolian processes.

It has been stated that the greatest amount of loose material was transported in the air streams at the height of about 0.5 – 0.8 m above the ground level and at the same time it was the coarsest material. It is possible to suggest that air stream of 1 m^2 in diameter and 8 m/s of speed may transport as much as 22 g of sediment per day. The greater part of material blown away is transported by air and then accumulated on the icy, snowy or sea areas.

The investigations carried out during the second antarctic expedition – 1977/78 on the King George Island in the archipelago of the South Shetland Islands enabled the author to state that eolian processes play a considerable role in modelling of the relief of the areas free from the ice-sheet. The research work has been conducted during the antarctic summer in the region of the Admiralty Bay and the Ezcurra Inlet as well as of two smaller inlets – Martel and Mackellar (KRAJEWSKI, 1979).

CLIMATIC CONDITIONS IN THE REGION OF SOUTH SHETLAND ISLANDS

The weather in this region was being affected, in the antarctic summer, by general western circulation. More or less active depressions in the region of the South Shetlands and the local conditions of King George Island, and first of all the position of the Admiralty Bay, Ezcurra Inlet and the two smaller inlets – Mackellar and Martel influenced the course of the weather type in the investigated area.

Pressure distribution typical of that period was caused by stationary depression, with order of magnitude of 960 – 980 hPa situated over the Weddell

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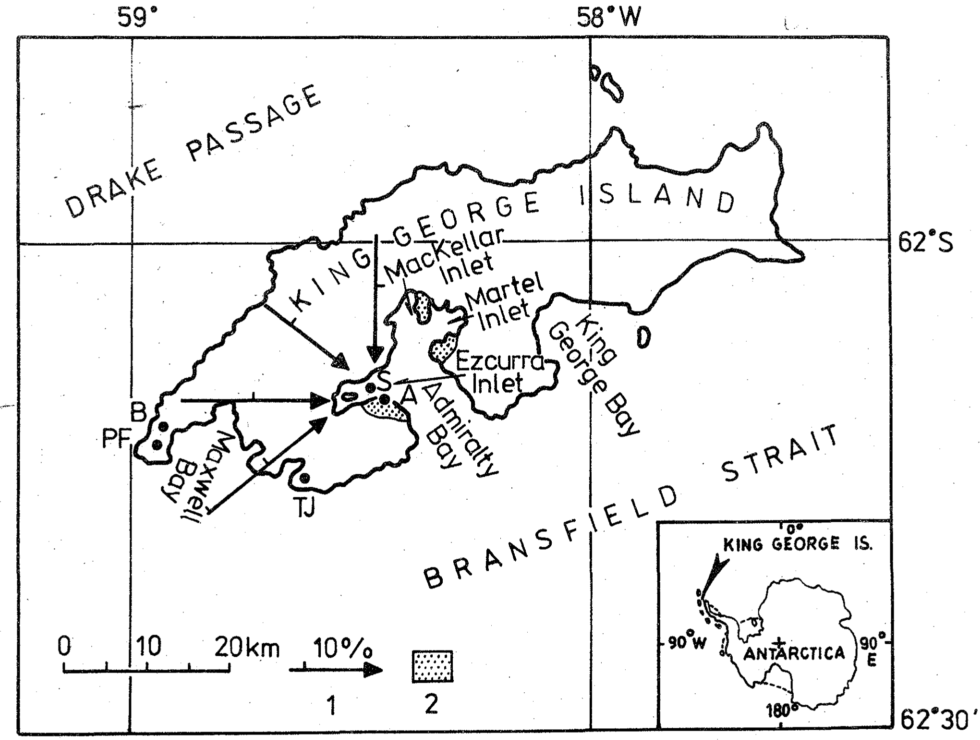


Fig. 1. King George Island. Situational sketch and predominant wind directions

1. the percentage of total amount of cases of recorded wind directions; 2. the investigated area; A – Arctowski Station (Poland); B – Bellingshausen Station (USSR); PF – Presidente Frei Station (Chile); TJ – Teniente Jubany Station (Argentine); S – the place of anchorage of the ship m/s A. Garnuszewski

Sea, and by the high pressure centres over the southern parts of the Pacific and Atlantic oceans. Depressions moved from the area of the Bellingshausen Sea through the South Shetland Islands and Drake Passage to E or ESE being separated by weak wedges of high pressure whose activity is due to the High extended to the south in the region of Patagonia and the Falkland Islands and from the Low deepening over the Weddell Sea. Sometimes the separated High produced over the Antarctic Peninsula affected the weather.

Atmospheric pressure showed a considerable variation caused by the proximity of the trajectory of the movement of cyclonic systems. The characteristic feature is low average pressure of order of 990 hPa (Fig. 2). The lowest value of the pressure – 971,2 hPa was recorded on February 5th, 1978, while the highest one – 1018 hPa was noted on March 3rd, 1978. The tendencies of the pressure are conspicuous when we take into account that it was the summer season. The decreasing tendencies, with the value of 7.4 hPa were observed for the last three hours of a day (February, 5, 11, 14, 1978). The increasing ones of somewhat lower values of 4.6, 4.4 hPa were noted on February 10th, 12th, 1978. It has been

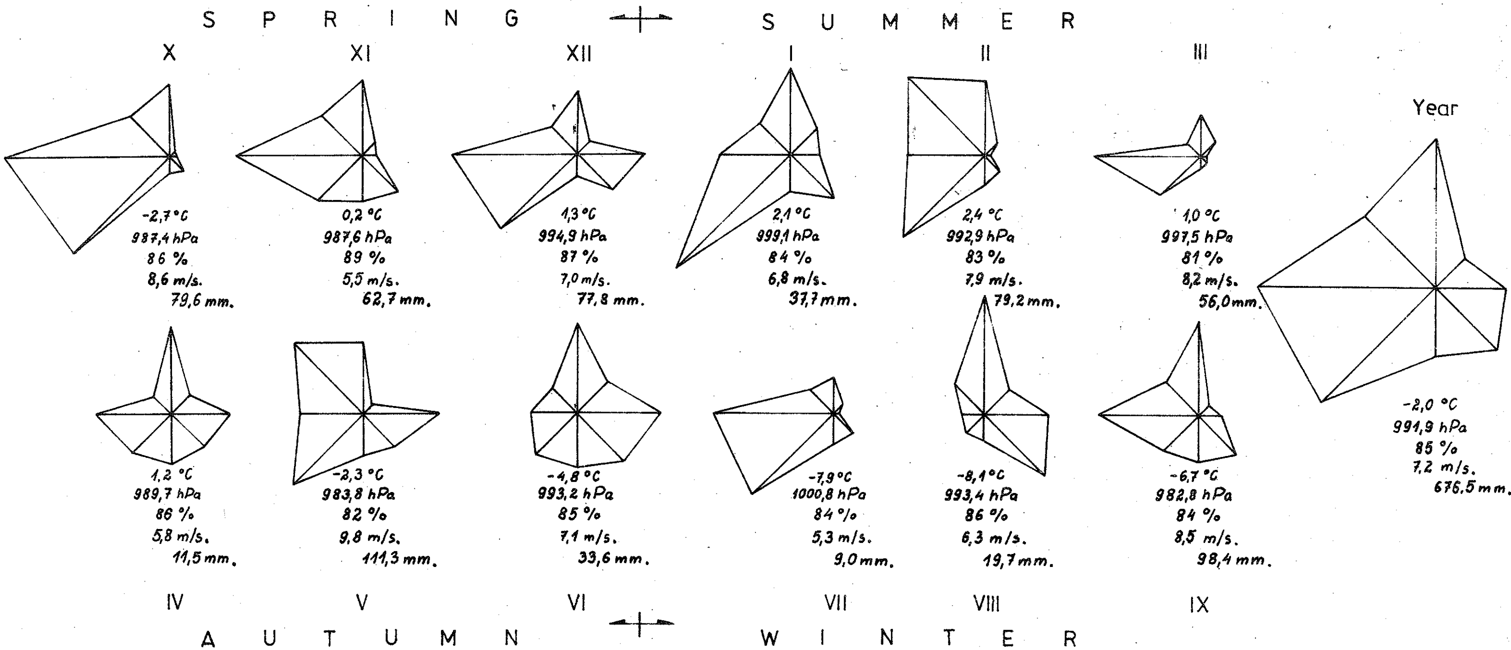


Fig. 2. King George Island. Wind roses and basic climatological data

°C – the average monthly temperature; hPa – the average monthly pressure; % – the average monthly humidity; m/s. – the average monthly wind speed; mm. – monthly total of precipitations ascertained that the changes in pressure were not always the reason for predicted changes in weather.

During antarctic summer air temperatures fluctuate most often between 0° and 4°C (Fig. 2). The highest temperature of 8.9°C was recorded on March 7th, 1978 during foehn heating of the mass PPM (Polar Maritime Air) with squally winds up to 18 m/s. Positive temperatures exceeding 6.0°C occurred about 30 times. The lowest temperature −5.7°C occurred with the cloudy and windy weather of March 16th, 1978. It has been noticed that some of the phenomena had the local nature e.g. on January 2nd, 1978, the temperature measured at the same time amounted in the Ezcurra Inlet (the ship m/s Garnuszewski) to 9.6°C while at the H. Arctowski station only to 4.9°C; it was the foehn heating of the mass PPM (Polar Maritime Air) with the squally winds exceeding 15 m/s in speed.

In reverse to temperature, relative humidity undergoes small changes. The average relative humidity amounted during the summer to 82% (Fig. 2), the lowest relative humidity of 59% was recorded on December 28th, 1977 and on February 5th, 28th, 1978. In spite of the high average humidity, fogs occur relatively rarely − 3 days of January.

DIRECTIONS AND SPEEDS OF WIND

The pressure systems described above, the pattern of landforms, islands, and considerable altitudes of slopes, usually covered with ice-sheet, play the essential part in the distribution of speed and wind direction during the antarctic summer as well as the other seasons of the year. After passing the western part of the island covered with ice-sheet, predominant winds with the component W (Tab. I, III) come into the Ezcurra Inlet with the increased speed and take the extorted direction (Fig. 1). Strong winds from the north observed on the basis of cloud movement and recorded at the H. Arctowski station met the western winds from the Ezcurra Inlet and became the baffling winds blowing at a speed of 3 to 30 m/s or shifting winds from both directions which could be observed many times on the basis of the appearance of the sea or on the basis of the behaviour of the ship anchoring in the region of the Admiralty Bay. Another example of the influence of local conditions on speed and wind direction is the occurrence of permanent winds W in the Ezcurra Inlet of order of 15 − 18 m/s while at the same time at the H. Arctowski station the winds of changing directions have been recorded with order of 6 − 10 m/s. The directions were from S to NW with predominance of SW, and in the gusts they reached 12 − 14 m/s in speed. In Ezcurra Inlet many calms or gentle winds, when compared with the H. Arctowski station, have been observed.

Depressions approaching the Shetland Islands from the west, produce the winds NE and E which turn into SW through NW and W together with a fast growth in speed. They reach the maximum speed before the passing of the front

Table I

Wind directions at the H. Arctowski station

Directions	N	NE	E	SE	S	SW	W	NW	Diffe-rent	Calm	Year
Number of cases	348	59	97	166	139	426	402	305	58	91	2091
%	16,6	2,8	4,6	7,9	6,6	20,4	19,3	14,6	2,8	4,4	100%

Table II

The number of observations during which the strong wind with gusts occurred (four times per day)

Months \ m/s	> 10	> 15	> 20	> 25	> 30	Month total
January*	40	28	6	5	–	83
February*	60	43	17	7	6	123
March**	23	23	7	6	3	62
April	14	6	4	1	3	28
May	20	14	11	2	2	49
June	18	6	6	2	–	32
July	13	4	7	2	3	29
August	15	9	7	4	8	43
September	22	17	18	8	18	83
October	27	14	12	13	17	83
November	8	5	5	4	3	25
December	25	12	5	3	4	49
Total	289	181	105	57	67	699

*The observations eight times.
**The observations only to March. 17.

and are very gusty. After the passing of the front a short term decrease in speed follows and lasts up till the moment when next depression starts to affect the weather. Many times the decrease in wind speed does not occur at all. The typical phenomena frequently observed with the growing wind speed are katabatic winds (ZUBEK, 1979), hitting the surface of the rocks and water situated at the foot of the ice-sheet at very great speed and bearing great quantities of dust and debris.

The strongest winds measured on February 11th, 1978 amounted to 30 m/s. In many cases the gusts of order of magnitude of 40 – 50 m/s have been noted (Tab. II, III). The longest duration of continuous gale occurred between the 7th and 21st of February 1978. The average wind speed calculated on the basis of the eight daily measurements for summer season, with the gusts neglected amounts to about 8 m/s; the detailed results are presented in the tables II, III and in the figure 2. The differences exist between the frequency of the occurrence of wind direction in different parts of the King George Island e.g. at the H. Arctowski station and in the Ezcurra Inlet on the m/s Garnuszewski.

EOLIAN PROCESSES

The main and indispensable factor generating the eolian processes is the wind blowing here throughout the whole year (Tab. II, III). It reaches high speed in gusts especially during the spring and autumn and then the eolian and nival processes operate very intensively. These processes are less intensive in the summer and the winter season is not the favourable period for their development because most of the area is ice-bound or snow-covered and only few strongly exposed parts are uncovered and experience weathering and removal of loose debris. The climatic conditions and rock lithology enhance the weathering. Most of the rocks occurring at the surface are the Tertiary rocks either of volcanic origin such as: andesites, lavas, ashes, or sedimentary rocks such as sandstones and shales which undergo the weathering relatively fast. The air-borne debris is spread continuously or insularly over the icy or snowy surface of the island which is most visible at a vast open surface of the ice-sheet during the intensive ablation in the summer. Eolian processes result in systematic covering of the icy surfaces with loose mineral material, depending on the force and rhythmicity of winds. In the observed vertical cross-sections the successive layers of mineral eolian

Table III

Distribution of directions of strong winds with gusts (the observations four times per day) January, February, March – the observations – eight times per day

m/s	N	NE	E	SE	S	SW	W	NW	Different	Total Year
> 10	59	5	7	34	12	60	58	52	2	289
> 15	41	2	2	8	3	41	30	50	4	181
> 20	27	–	3	–	4	13	23	34	1	105
> 25	10	1	–	1	1	13	10	20	1	57
> 30	16	–	3	1	2	11	7	23	4	67
Total Year	153	8	15	44	22	138	128	179	12	699

material occur within the snow and ice and alternate with snow or ice. Thus within the ice-sheets not only the material which crumbled off from the wall or that deriving from the substratum occurs but the ice-sheet also contains the air-borne material. Several times a considerable dustiness of the snowy or icy surfaces has been recorded in the marginal zones of the ice-sheets where the moraines develop (in front of the ice-sheet). The produced eolian deposits are continuously covered by new snow and then, during ablation sink into the mass of snow and ice; this is one of the characteristic features of the antarctic areas. Probably this is one of the main reason why the eolian forms are not produced everywhere (WEBB, MC KELVEY, 1959; NICHOLS, 1966). The further lot of the eolian sediments is connected with the movement of ice-sheet or with the melting of snow in the areas which are covered only with snow (CAILLEUX, 1972), about 2% of the area of the King George Island.

Snow melting or evaporation makes successive thin layers of eolian material, which had formerly got into the snow cover, join together, producing thicker and thicker layers. Partially flowing down over the surface and partially sinking into the snow, the material causes differentiated albedo which in turn produces, in the areas free from ice, the snow patches during the spring which decay at a different rate. The insular occurrence of eolian material at the ice-sheets results in the diversity of ice-sheet surfaces resulting from a phenomenon similar to the one described above. The water of melting snow sinks into mineral substratum situated under the snow cover and causes its considerable saturation; only partially it moves downslope in small streams. After a nearly total melting of the snow covers which occurs on the slope surfaces in the middle of January, the convex forms of different shape and size are left. They are most often built up of the eolian mineral material.

The greatest amount of debris situated at the surface is transported during the summer, when all the areas without ice-sheet are deprived of snow and when it is highly possible for the wind to blow away and to transport it. This is also enhanced by the dessication of the ground after the spring thaws.

QUANTITATIVE INVESTIGATIONS OF EOLIAN SEDIMENTS

On the slope of one of the valleys near the Ezcurra Inlet the instrument KD-1977 has been installed at the altitude of 127 m above sea level to catch and measure the sediments transported in air streams at different height above the ground surface (Pl. 1). The investigations have been carried out between January 2nd and March 13th, 1978. The eolian sediment has been captured in the instrument installed at the height 0.5, 1.0 and 1.5 m above the ground level. The instrument was self-steered and automatically exposed to the wind directions.

Table IV

Detailed quantitative data of the field investigations carried out in the period of January, 2 – March, 13, 1978

Period of observations	The height of the instrument above the ground level m	The weight of the sample (for the period) g	The average daily weight of the sample g	The average wind speed calculated on the basis of eight measurements a day m per s	The average air humidity in %
2 I – 22 I 1978	1,5	0,7057	0,0353		
	1,0	0,9104	0,0455	6,8	84,1
	0,5	2,6910	0,1346		
22 I – 1 II 1978	1,5	0,1219	0,0122		
	1,0	0,0435	0,0044	6,35	85,2
	0,5	0,1933	0,0193		
1 II – 22 II 1978	1,5	3,3955	0,1698		
	1,0	4,9203	0,2460	8,7	83,2
	0,5	13,6569	0,6829		
22 II – 13 III 1978	1,5	3,5617	0,1781		
	1,0	4,7122	0,2356	7,55	84,0
	0,5	22,0145	1,1007		

The carried out quantitative investigations (Tab. IV) enabled the author to ascertain that the greatest amount of loose material is transported in the air streams up to the height of 0.5 m above the ground level; at the same time it is the coarsest deposit. In the container of the instrument, the particles of the diameter exceeding 1.0 cm have been found. The transported material decreases its amount and fraction together with the growth of height above the ground level; the detailed data are presented in the table IV. The weights of the caught sediment have been correlated with relative humidity and with wind speed values measured at the station situated about 700 m away from the instrument. It has proved that the largest amount of caught material is not referred to the highest wind speed occurring throughout the investigated period. During the collecting of the samples from the instrument it turned out that at least 25% of the caught sediment is blown out of the tunnel of the instrument (deficiency of instrument); thus the results from the table IV should increase by 25%.

On the basis of the acquired results and the theoretical calculations it is possible to suppose that given wind speeds measured up to the height of 1.5 m above the ground level 22 g of sediment are transported daily in the air streams of 1 square meter in diameter. The result of this is that great quantities of air-borne material accumulate in the areas of the ice-sheets, snow cover or seas.

During the field observations conducted in different areas of the island very intensive mechanical weathering and falling of rock material from the solid rocks have been noticed within the zone of about 70 – 80 cm above the ground level. In these places undercuttings, recesses, caverns, hollows, and rock benches are produced (Pls 2 – 6). The forms of this kind are probably connected not only with mechanical frost and selective weathering but also with the existence of the coarsest fraction of eolian material in the air streams of about 80 cm.

After facing the obstacle the air-borne material crushes into it causing additional pounding and crumbling of debris off a rock. Debris is deposited as a loose deposit at the edge of recesses, caverns, rock benches and hollows. Thus operation of mechanical and frost weathering is deepened by eolian processes which lead to the production of the forms described above in a shorter time.

Moderately strong and very strong winds as well as the large amount of loose material, situated in the areas deprived of ice and snow do not lead, however, to the production of distinct accumulation eolian forms such as dunes. There are probably two reasons for this, one of them is the systematic snowfall which is turned into ice in some areas (the dome of the ice-sheet) and inundates the eolian sediment deposited in it. In other areas where the snow melts (the areas free from ice) the eolian sediment is covered with new snow fall. After melting of snow during the spring, summer and autumn, the eolian sediment accumulates on the slope. It is partially transported away by water from thawing snow covers and another part is blown over and moved to other places with further crumbling and granulating. Another reason for the difficulties in the production of the apparent

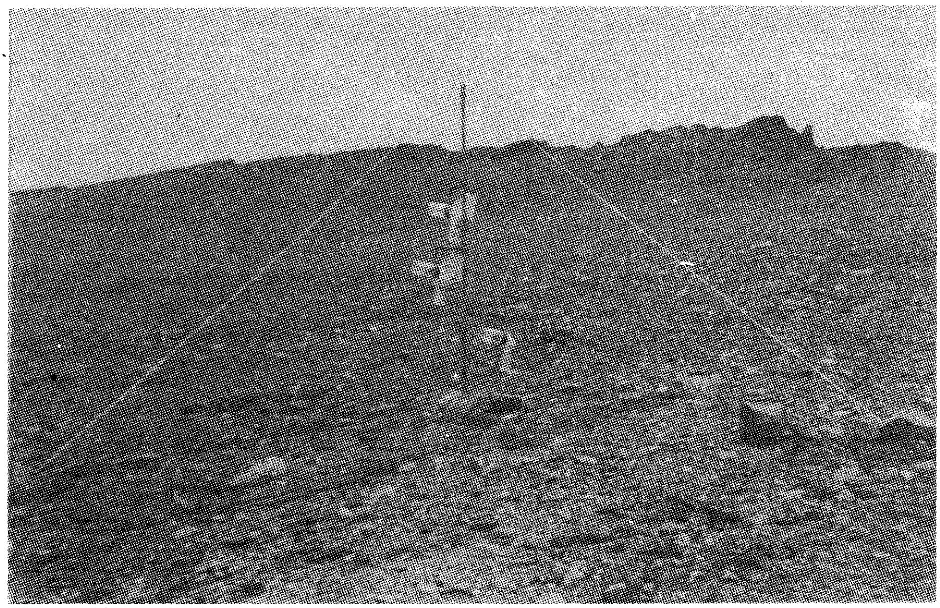
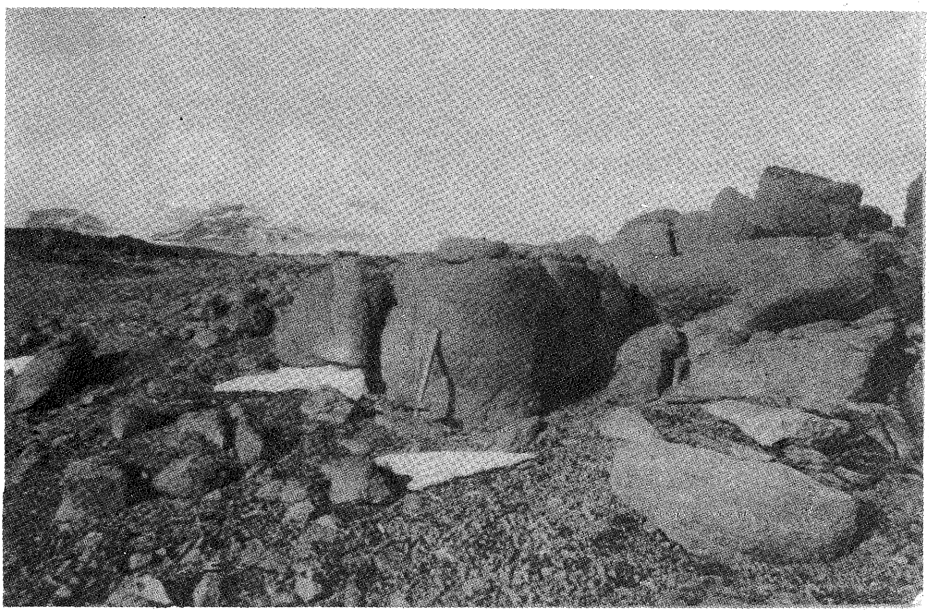


Photo by K. Krajewski

Pl. 1. King George Island. The instrument for catching of the eolian sediments installed in the valley situated near the Ezcurra Inlet



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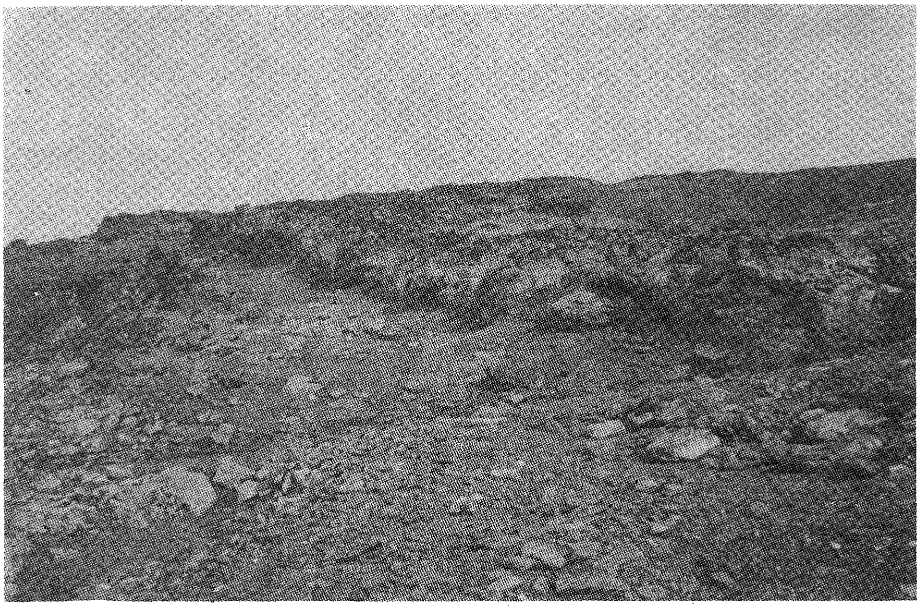
Pl. 2. King George Island. The recesses and undercuts in the rocks due to frost and selective weathering deepened by eolian processes



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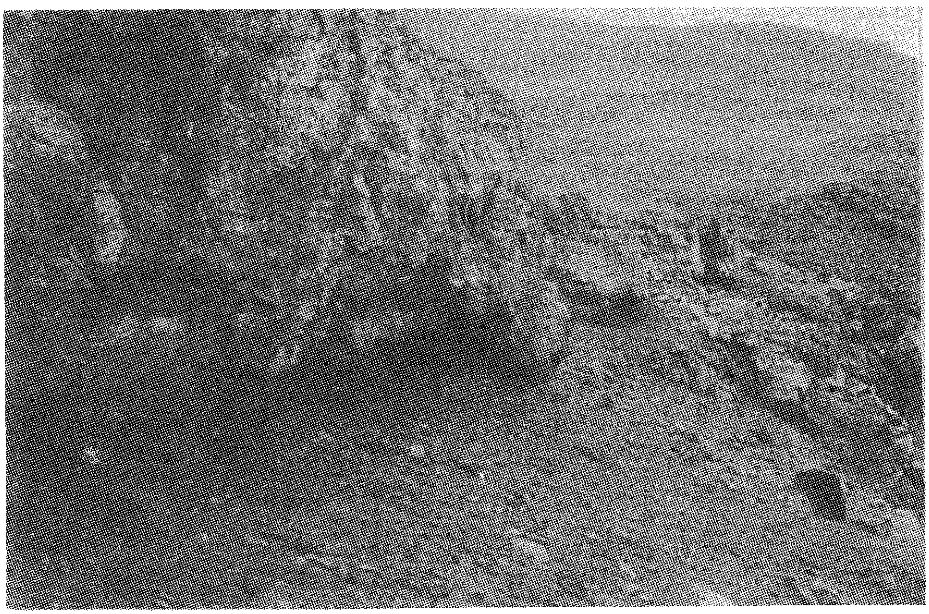
Pl. 3. King George Island. Explanation as in the Pl. 2



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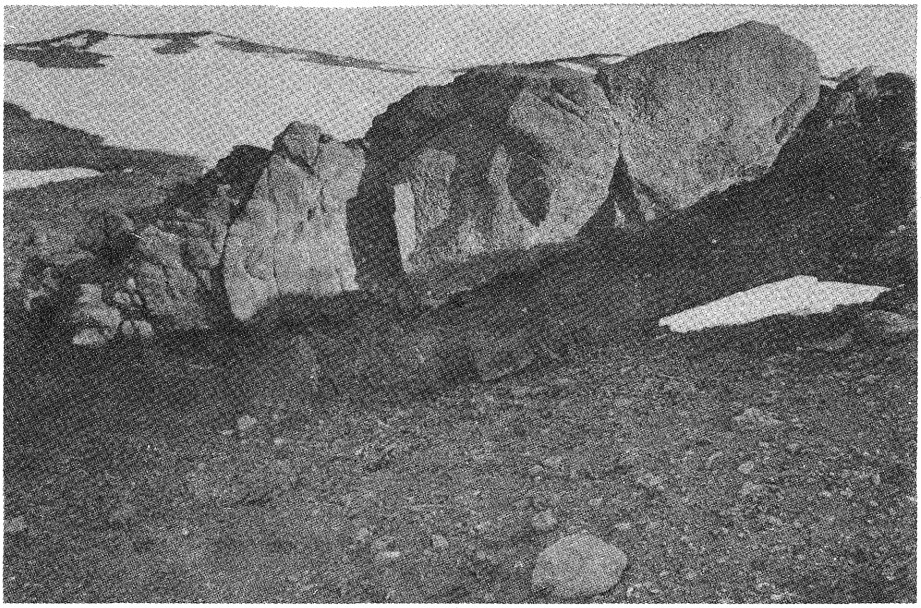
Pl. 4. King George Island. Explanation as in the Pl. 2



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Pl. 5. King George Island. Explanation as in the Pl. 2

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Pl. 6. King George Island. Explanation as in the Pl. 2

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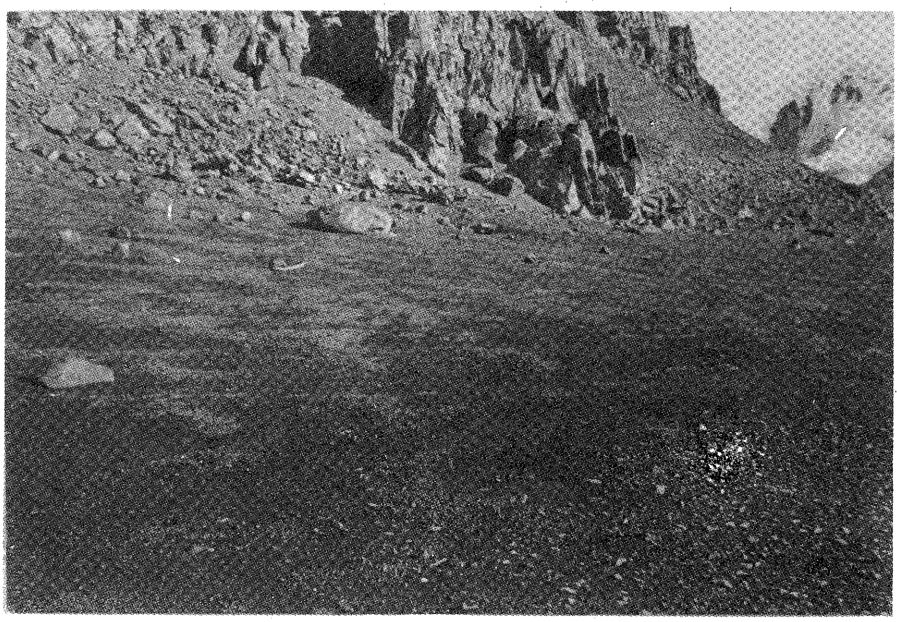
Pl. 7. King George Island. Deflation pavement on the slope of one of the valleys



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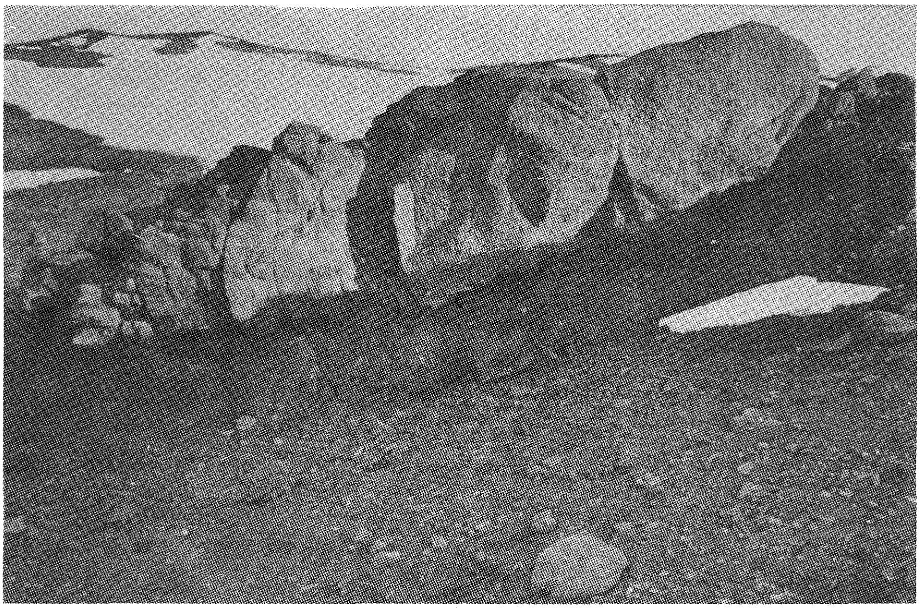
Pl. 8. King George Island. The examples of blowing over of the loose material from the slope surfaces



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Pl. 5. King George Island. Explanation as in the Pl. 2

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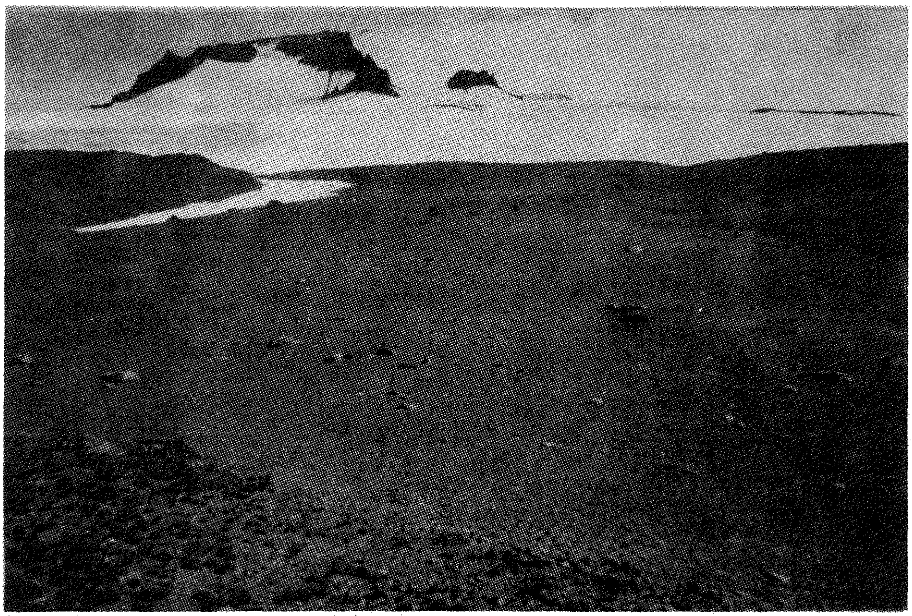
Pl. 6. King George Island. Explanation as in the Pl. 2



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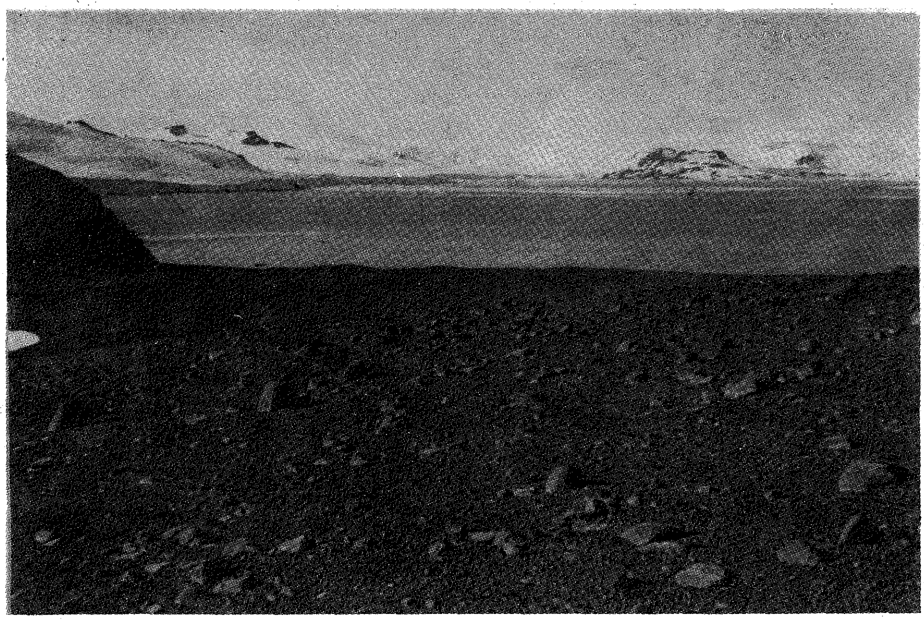
Pl. 9. King George Island. Explanation as in the Pl. 8



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Pl. 10. King George Island. Explanation as in the Pl. 8

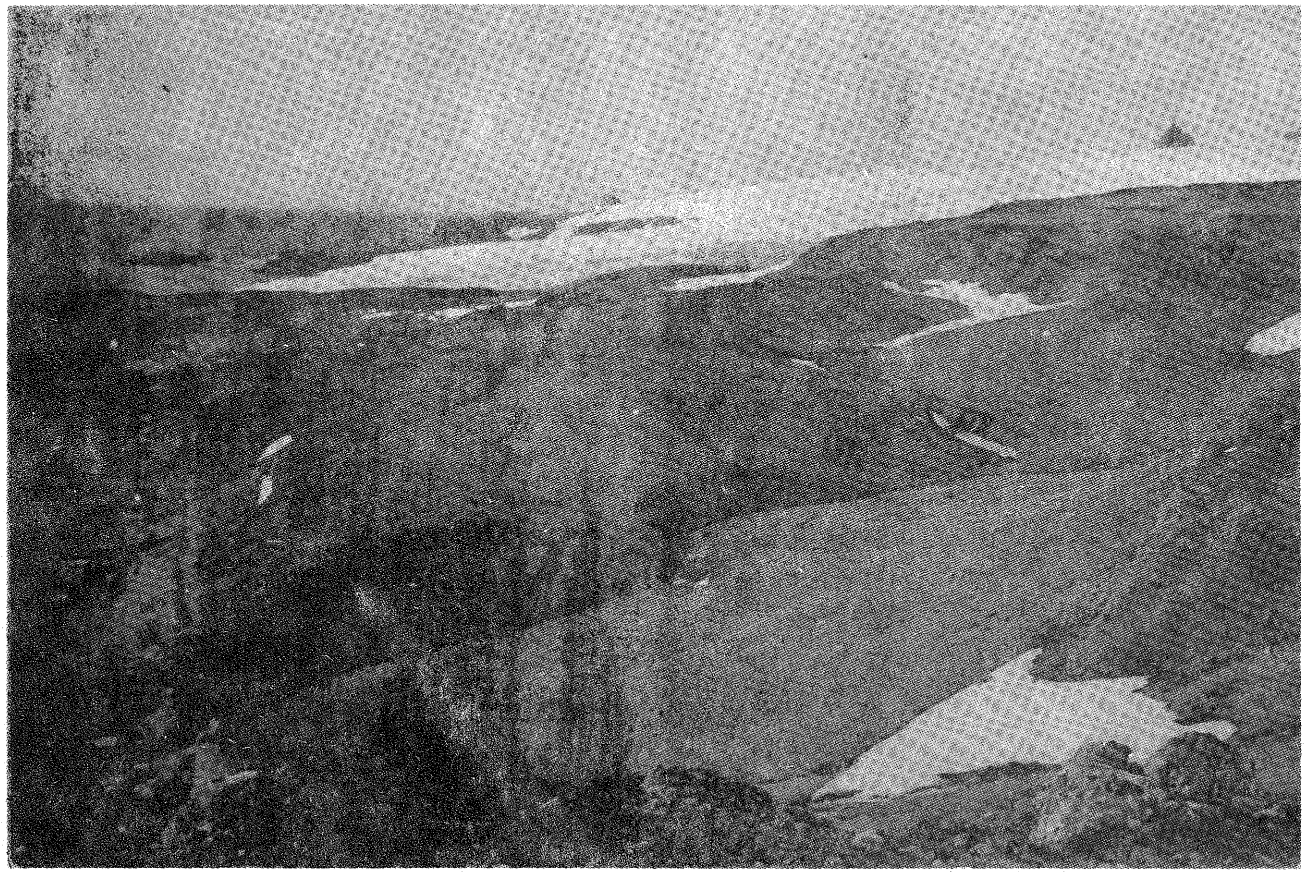

Photo by K. Krajewski

Pl. 11. King George Island. Modelling of the surface of slopes and uplands by the eolian processes accumulation of eolian forms is the wind which is too strong. Its activity results in continuous selection of loose material and in the fact that only the coarser material (Pls 7 – 10) is left on the slope, too coarse to be borne by the wind or the fine material situated in places not available for the wind e.g. rock obstacles and lee-side slopes.

All the above processes produce the quantitative changes in relief, giving rise to overlapping of some processes e.g. eolian process overlap the frost weathering ones. Eolian processes contribute to deeper modelling and touch-up of cryoplanation terraces and cryopediments (WASHBURN, 1979) which is reflected in the changes in relief of the antarctic and subantarctic areas which are not covered with ice (Pl. 11).

Translated by E. Załoba

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