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QUANTITATIVE FIELD OBSERVATION ON FROST PHYSICAL WEATHERING IN THE GREAT WALL STATION AREA

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Abstract Field observing sites were set to measure frost weathering of bedrock in the Great Wall Station Area of Antarctica from 1988 to 1990. The results show that: (1), the weathering rate is higher in summer that in winter; (2), the weathering rate is greater at higher place than at lower place; (3), the weathering rate is higher in east and southeast slopes than in other slopes; (4), the weathering rate is greater in higher mean annual air temperature year than in lower year.
Key words freeze—thaw, weather, Antarctica

In a frigid area the weathering process is dominated by physical weathering, which is the first stage of the whole geomorphic process (erosion — transportation — accumulation). Rock disintegration velocity, amount of accumulated material and geomorphic evolution and features are directly affected by the degree of physical weathering. The physical weathering gradually increases with increasing latitude and decreasing temperature. And freeze—thaw process is dominant in a variety of physical weathering processes, a thorough study on the weathering will better understand the basic characteristics of weathering in Antarctic region. This paper, therefore, will mainly discuss the characteristics of freeze—thaw weathering in the Great Wall Station area of King George Island, Antarctica.

In the Fildes Peninsula area, since most of bedrock consists of thick and block agglomerate lava of subvolcanic rocks produced by volcanism (Liu Xiaohan and Zhen Xiangshen, 1988) and these rocks are highly porous and generally contain auto-breccated angular gravels, they are liable to form granular, loose materials in frost weathering and easy to be wedged again by the previously procduced granular debris in the further weathering, which separates mineral particles and mineral aggregates having suffered the weak weathering. This shows the weathering process dominated by frost wedging and the process is specially distinct in volcanic breccia and volcanic agglomerate area.

Relationships between Height, Slope Face, Season and Freeze—Thaw Weathering

In 1988, some stationary sites used to observe the weathering rate of rock were set up on different slope faces and at different heights of elevation near the Great Wall Station (Table 1). the most reliable and accurate observation method is that a wooden frame with a given area is set under a rock wall and plastics or nylon mat, is nailed on the bottom of the wooden frame in order to separate the underlying debris. The freshly weathered clastic material falling in the wooden frame was measured regularly, the amount of weathered and eroded rocks in a unit area in a given time period can be calculated. In order to obtain the reliable observation data for ready analysis and comparison. In establishing observation sites requirements the observed rock wall must be met the following: (1) High slope gradient , so that the weathered clastic debris can directly fall into the slope—bottom wooden frames, without down—slope rolling and jumping of debris; (2) Lower height, it is liable to calculate the weathered area of the rock wall, and to avoid the weathered debris falling into the wooden frames from higher rock wall. The locations of different sites are listed in Table 1. the measurement data at each site from March 23, 1988 to March 2, 1990 are listed in Table 2. Analysis of the data in above—mentioned two Tables enables us to know characteristics of physical weathering on King George Island are as follows:

1. In the general trend, the weathering in summer (December to March) is stronger than that in winter (April to November). comparing the data for 63 days of summer from December 30, 1989 to March 2, 1990 with those for 315 days of winter from February 19, 1989 to December 30, 1989, we can see the denudation and weathering rates in summer at observation site W_5 are 7. 5 times as much as those in winter, and the both value in summer at W_7 is 3. 6 times as much as those in winter. In the Great Wall Station area, Antarctica, the temperature in summer fluctuates generally around 0℃, with strong freeze—thaw. At the same time there is much rainfall during this period. Since the temperature can change by ten degrees in a short time, rain and snow water freezes and thaws repeatedly. And ice volume in rock fissures changes greatly, "frost bursting" strengthens, and then the rock is liable to be disintegrated. However, the temperature in a long winter is mostly below 0℃, with a freezing land, freeze—thaw action basically stops.

2. The weathering rate in a high—elevation area is higher than that in a low—elevation area. Take February 11, 1990 to March 2, 1990 as an example, the annual denudation and weathering rates at W_7 are 3. 35 times higher than that at W_5, and that at W_8 is 1. 28 times faster than that at W_5. This is mainly because the temperature in summer in a lower—elevation area is relatively high, with a little fluctuation around 0℃

Table 1. Information about different sites for observation weathering rate.

Element / Number	Area of a frame (m^2)	Slope direction	Slope gradient (°)	Height above sea level (m)	Height of rock wall (m)	Width of a frame (m)	Weathered area (m^2)	Lithology	Geomorphic position	Locality
W_5	0.476	E	85°	5	1.90	0.82	1.56	Volcanic breccia	Coastal rock scarp	Seashore east of the Tern Lake
W_7	0.476	ES	83°	43	2.34	0.28	1.92	Volcanic agglomerate	Slope foot	Southeast of the Flat Top Hill at an elevation of 57m
W_8	0.476	WS	89°	47	3.15	0.82	2.58	Volcanic agglomerate	Slope foot	Southwest of the Flat Top Hill at an elevation of 57m

Table 2. The weathering rates at different observation sites on King Georgy Island, Antarctica.

Observation date	W_5			W_7			W_8		
	accumulational amount (g)	Denudation rate (g/a. m^2)	Weathering rate (mm/a)	Accumulational amount (g)	Denudation rate (g/a. m^2)	Weathering rate (mm/a)	accumulational amount (g)	Denudation rate (g/a. . m^2)	Weathering rate (mm/a)
Jan. 5, 1989	100	75.97	0.0314	665	410.45	0.1696	380	174.54	0.073
Feb. 19, 1989	39	207.4	0.0856	112	483.9	0.1999	9	28.94	0.012
Dec. 30, 1989	178.2	132.36	0.0546	2248.3	1356.86	0.5606			
Jan. 18, 1990							1299.6	552.13	0.228
Feb. 11, 1990	178.1	992.16	0.41	1091.5	4940.45	2.0415	296.5	1747.78	0.7223
Mar. 2, 1990	57	635.07	0.2624	235	2137.36	0.879	121	815.15	0.3368

and a weak repeated freeze—thaw action. The high—elevation area is easily effected by the external factors with a large transient change of temperature. In the day time of summer temperature increases fast as the sun shines brightly, and ice and snow are thawing. The thawed water or rain water fills in the fissures of rocks. In the night, temperature decreases fast as it is blowing hard or without the sun shining, the water freezes into ice body. As the ice volume expands, the rock fissures are gradually enlarged. thus the surface rock is fast weathered and denuded by this kind of repeated action.

3. Weathering on the eastern or the southeastern slopes is stronger than that on the western and southwestern or the northwestern slopes. from February 11 to March 2, the summer of 1990, the annual denudation and weathering rates at W_7 on the southeastern slope are 2. 8 time faster than that at W_8 on the southwestern slope. In the summer of 1989 , from January 5 to February, the former is over 16 times than the latter. The reason is because the humid oceanic air current is carried onto the island by the southeastern wind prevailing in summer, which makes the ice and snow on the southeastern slope thaw firstly. The thawing water, together with the fluctuating cold and warm temperature makes freeze—thaw frequency faster and the process longer, so that the weathering is intense. However, the temperature in winter is lower and the snowfall carried by the prevailing northwestern gale is mostly concentrated on the western slope. In general, the snow on the western (northwestern, southwestern) slopes is 1. 5—2. 5m thicker than that on the eastern (northeastern, southeastern) one. During the first ten—day period of November the bottom of the snow layer is still in

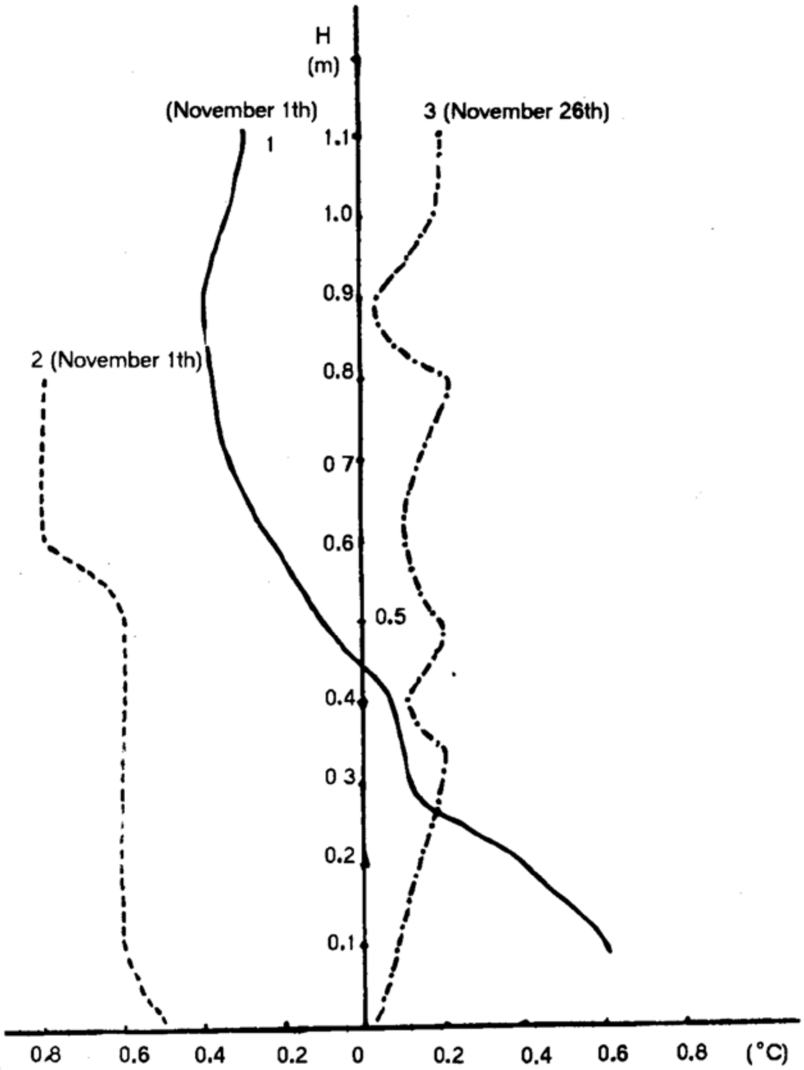

Fig. 1 Changes of snow temperature at three sites in the Great Wall Station area, Antarctica.

negative temperature, and it gradually changes into the positive untill the last ten—day period of this month (Fig. 1). At the same time the western slopes become lee side in summer, with a little of warm and humid air current from the ocean. It is not liable for snow to thaw. There is much thicker ice and snow on many places of the western slopes in the region, and it can not thaw completely in the whole summer. At present, on the western slopes of the western coast there are still several snow pieces remaining for many years. During the Sixth Antarctic Research Expedition from 1989 to 1990, in observing each weathering sites on December 30, the author found that the snow at W_7 on the southeastern slope of the Flat Top Hill had completely thawed long ago, but that at W_8

on the southwestern slope of the Hill at less than 100m from $W_7$was 2. 37m thick, and it did not thaw completely until the middle ten days of January. Therefore, the freeze—thaw action on the western slope is characterized by the short time, low frequency and weak weathering.

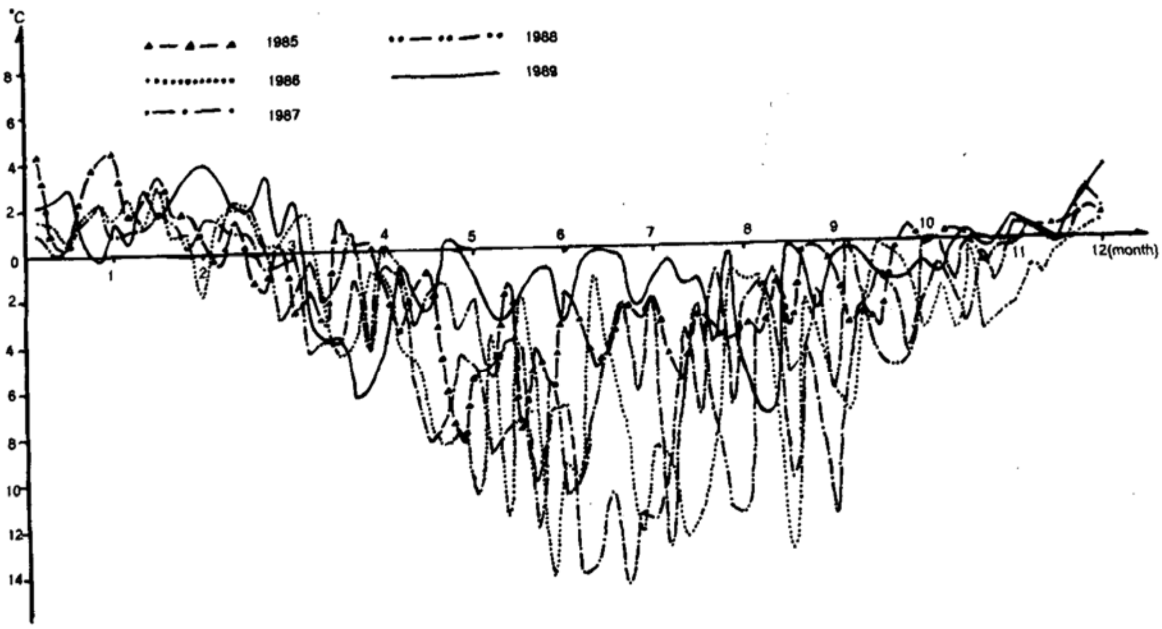

Fig. 2. Curves of monthly mean temperature in the Chinese Great Wall Station area, Antarctica (1985—1990).

4. The weathered debris amount in the year with high temperature is larger than that in the year with low temperature. The temperature in the whole year of 1989 was relatively high and the average one in winter reached 0℃ quite often (Fig. 2). As indicated by wintering members of the Fifth Antarctic Research Expedition Team, because of high temperature no freeze was basically found on the Great Wall Bay in the whole winter of 1989, which had never occurred since the establishment of the Great Wall Station in 1985. The ice in the Great Wall Bay was very thick since the temperature in the past winter was lower, and people can go to the Ardley Island on the ice directly. Because of higher temperature in the whole year of 1989 both frequency and time of temperature fluctuation around 0℃ were much higher than those in 1988, and thus freeze—thaw action was strong, with frost weathering and denudation rates. The annual

denudation and weathering rates at W_5, W_7 and W_8 in 338 days from March 20, 1988 to February, 1989 only account for 16.6%, 11.1% and 7.2% of those in 379 days from February., 1989 to March 2, 1990 respectively.

5. The weathering in the season with high temperature is more intense than that in the season with low temperature. the average temperature was 1.58℃ in 45 days of the summer from January 5 to February 19, 1989 and 2.56℃ in 43 days of the summer from December 30 to February 11, 1990. The annual denudation and weathering rates at W_5 and W_7 in the above—mentioned time of the summer, 1990 are 4.79 and 10.21 trimes higher than those in the summer of 1989, respectively. This might result from two factors. Firstly, high temperature and strong thawing produced much thawing water which can flow and scour on the rock surface, and hence the weathered and denuded debris increases. However, when temperature is low, ice and snow thaws slowly, with little thawing water, which is liable to be evaporated in gale or to slowly percolate down. As the water is not enough to form a flowing water along the slope. it is impossible to scour the rock surface and cause denudation of the weathered devris. Secondly, the frigid winter and long period of freezing weather in 1988, and weak freeze—thaw action have affected the weathering rate in the summer of 1989. But in the warm winter was in 1989, with a frequent fluctuation of the temperature around 0℃ (Fig. 2), freeze — thaw action was very strong. This resulted in a high — rate weathering weathering in the summer of 1990. It can be seen in Table 2 that from January to middle February, 1990, the weathering rate at each observation site was highest since the establishment of observation site, compared with that in other different periods. This reflects that the late weathering is greatly affected by the early weathering.

References

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