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THE FROST PHISICAL WEATHERING IN THE GREAT WALL STATION AREA, ANTARCTICA

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Abstract Some weathering observation sites were set up at different height and face in Great Wall Station area of King Geroge Island, Antarctica, since 1989. Baced on the data series obtained from 1987—1991, the relationship between physical weathering of rock and season, height, face are discussed in this paper. We also compare the results to that of other periglacial area in the world in order to know the special features of King George Island in physical weathering of rock.

The rock weathering in south—east face of sea stack is higher than that of north—west face in same environment. Get rid of influence of elevation, rock type, weathering time and organisms, the main reason which caused physical weathering of this area is climate and orientation of rock.

The King George Island of Antarctica belong to high latitude area. The temperature time of below zero is 6—8 months in a year, so the process of freeze—thow is restricted. Compared with other periglacial area in the world, the weathering rate of rock is middle in this area.

Key words Antarctica, physical weathering, rate

The Face of Cliff Wall and Frost Weathering

On the eastern coast from the oil depot of the Great Wall Station to the Fog Valley there is a large amount of cliff walls at whose base the weathered clastic debris can be found. What we are interested in is that the weathered clastic debris amount is different at the base with different wall faces. A statistics of the weathering and denudation amount is made for 20 cliff walls selected here. The selected cliff walls must meet: (1) an independent cliff wall not close to other cliff walls, so as to avoid the measurment errors caused by the overlapping accumulation of the weathered debris from different cliff walls; (2) The cliff walls have their faces basically in Northern, Eastern, Southern and Western directions respectively, so we can easily analyze relationship between their different faces and weathering degree; (3) The bases of the cliff walls are at the same height, in other words, the cliff walls were basically exposed out the sea surface at the same time and the time they suffered weathering is identical; (4) Lithology is also similar and all of them consist of volcanic agglomerate. The statistics of the total area, the weathered area and the volume of the weathered clastic debris at the base have been respectively made for each face of the cliff wall. The statistical result is shown in Fig. 1 and 2. According to the diagrams drawn and the linear formula calculated on electric computer, the weathered area or the weathered volume, the maximum is for the eastern face of the rock cliff, second for the southern face, third for the weastern face, and minimun for the northern face. For the first case, the slope of the linear formula of the weathered area is 1.24, 1.44, and 3.85 times much than that for the latter three cases respectively. And the slope of its weathered volume for the first case is 1.52, 5.74 and 24.89 times much than that for the latter three cases. Therefore, the weathering strength at the eastern face is much greater than that at the western and northern faces. The main reason causing the different weathing rates at different fases is as follows: These cliff walls near the coast is largely affected by oceanic humid air. In summer a large amount of humid vapour carried by the southeastern gale is usually stopped by the eastern and southern faces of the cliff walls. The water freezes and thaws repeatedly in the environment with sudden changes of temperature, which makes the rock surface be strongly denuded. Just in contrast to this, the northern and western faces receive a little of humid vapour in summer, there a long—term freezing occurs in winter, with a weak weathering, and the northern faces of some cliff walls are not basically weathered. The juncture of the eastern and southern faces is strongly weathered. It also confirms the conclusion mentioned above. In addition, there is a high salt content in the coastal area. The heat expansion and growth of salt crystals and hydration of salt are also the reason for the strong weathering at the eastern and southern faces. Regardless of the faces of cliff wall, the weathering at their lower parts is much stronger than that at their upper parts in general. This is because the water on the upper cliff walls flows downward to the lower parts, and at the same time the cliff walls are located at a beach, with a very damp base, and the lower parts with much water is strongly weathered in the repeated freeze—thaw process. However, the upper parts are drier, because of little water, freeze—thaw action is weak and weathering is also weak, although the frequency of temperature fluctuation around 0℃ is very high. Thus, only with a temperature fluctuation but without enough water, the freeze—thaw action is very weak.

These cliff walls on the coastal front were exposed out of sea by thawing and breaking of ice sheet, and the relative fall of sea level due to post—glaciation crustal rebound. By using geomorphic—stratigraphic method Xie Youyu (1987) has infered that the isostatic uplift rate in the Great Wall Station area is 10mm/a (Xie, 1987). According to ^{14}C age of the coastal terraces, Krzysztof (1978) infered that the isostatic rebound uplift rate is 9mm/a. Therefore, it is more reliable that the uplift rate of the coast in the Great Wall

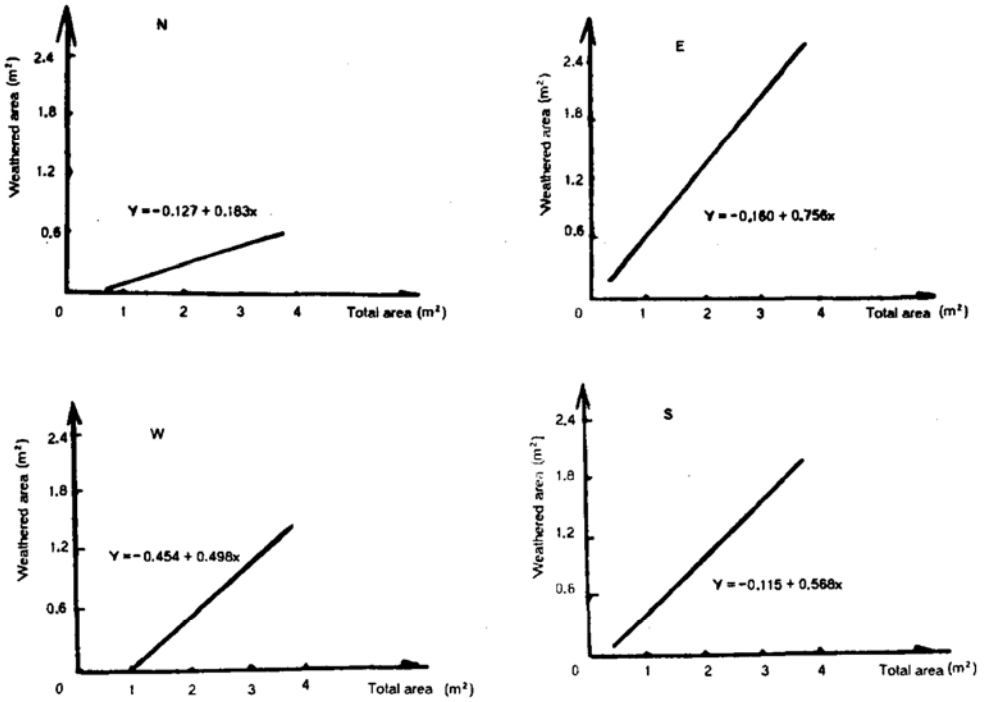

Fig. 1. A Statistic diagrams of the weathered areas at different faces of cliff walls.

Station area is 10mm/a. From this it is concluded that the cliff walls whose bases are 4.5m high in average exposed at about 450 years ago, and the weathering rates of these cliff walls can be caclulated (Table 1). The weathing rate of the eastern faces is 2.28—60.9, 6.5—2911 and 19.7—1747 times much than of the southern, western and northern faces respectively. For these different cliff walls with different faces, distributd at the same height, with a same lithology, and suffered by weathering at the same time and in the same environmeent, the weathering strength differ so grealy that it is beyond our expectations. Therefore, a major feature of weathering in this area is that the weathering of the different faces differs greatly in a small extent. This also indicates that

Table 1. The weathering rates of rock walls in different direction on the eastern coast of the Great Wall Station, Antarctica.

Direction / Weathering rate	N	E	S	W
Maximum weathering rate (mm/a)	0.0052	0.10264	0.045	0.01587
Minimum weathering rate (mm/a)	0.000003	0.00524	0.000086	0.0000018
Average weathering rate (mm/a)	0.0026015	0.05394	0.022543	0.0079359

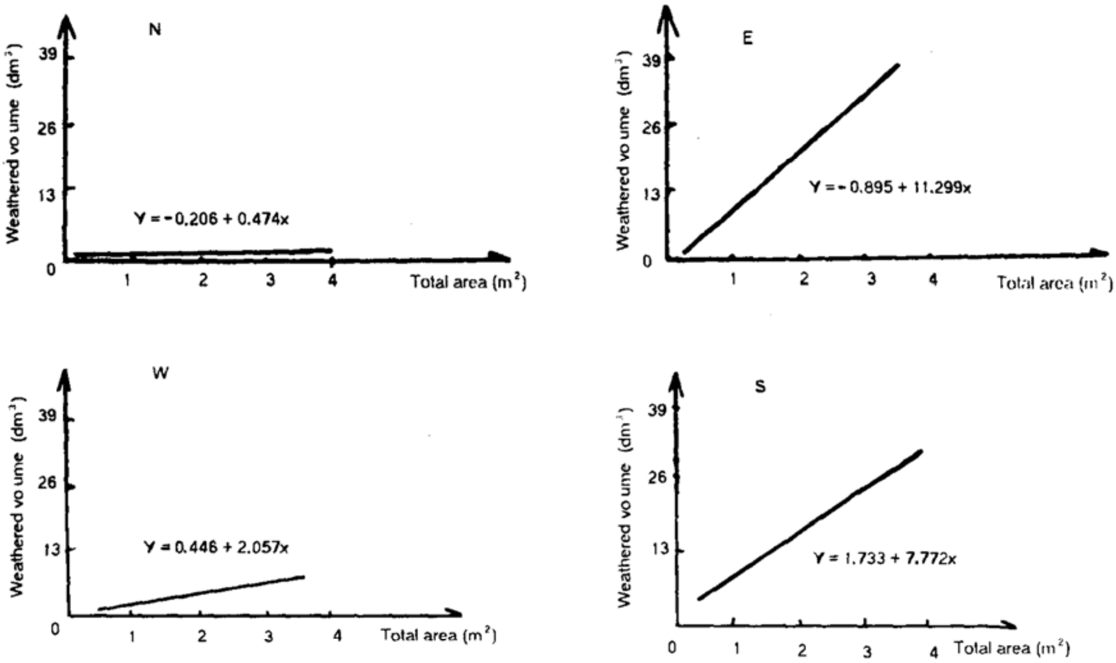

Fig. 2. A Statistic diagraams of the weathered debris volumes at different faces of cliff walls.

the climate and the face direction of cliff walls are the main cause for the weathering here in addition to the influence of the soil—making factors, such as lithological, biological and time factors.

Frost Expansion of Bedrock Fissures

In order to understand the expansion of bedrock fissures in the frost weathering, four observation sites had been set up. A stable bedrock without fissures is taken as a control point, the fissures in the vicinity of the point are numbered and the fixed measurement line is marked. Then change of the fissures is measured by using a steel rule in different time.

1) Observation site W2 is located at the northeastern slope foot of the Guishan Hill with volcanic agglomerate. Two fissures occour on the whole section with total width of 52cm. During a year and twenty days from December 15, 1987 to January 5, 1989 the two fissures were expanded by 3mm and 9mmm respectively (Table 2).

2) Observation site W3 is located at the root of sea stack east of W2, and lithology is similar to that of W2. In the time over one year from 1987 to 1989 three fissures were

Table 2. The change of bedrock fissures at each observation (W 2, W 3, W 4) from 1987 to 1989.

Observation Site	Number of fissure(mm)	Width of fissure(mm)	
		December 15, 1987	Junuary 5, 1989
W2	1	7	10
	2	1	10
W3	1	1	28
	2	1	8
	3	11	13
W4	1	2	2
	2	8	10

expanded by 27mm, 7mm and 2mm respectively (Table 2).

3) Near W3, lithology at Observation site W4 is also similar to that of W2. Of the two fissures only one was expanded by 3mm, another not changed in the same time interval (Table 2).

4) Observation site W6 is located on a cliff wall of the sea stack at 50m east of the meteorological station. The whole length of the section is 149cm, with a similar lithology mentioned above, there the fissures not obviously changed in the same measurement interval.

From the data mentioned above, the fissures in volcanic agglomerate in the Great Wall Station area, can be expanded by 2—27mm in a year around. Although this is a conclusion drawn only from data at four observation site, it reflects these features are different from the fissure change in both expansion and contraction of siliceous slate, gneiss, etc. in periglacial area of the inland Tianshan Mountain region, China. This may be related to the uneasy contraction of the volcanic rock, which will be tested in further study.

Discussion of Frost Physical Werthering Strength

Compared with the weathering rates of periglacial area of other continents (Table 3), the physical weathering strength in this area is of a middle level. It is similar to that in Yukon Territory, Ellesmere, Canada and Spitsbergen region of North Europe near the North Pole Circle, and also at the high latitudes. Since the period of ice and snow freezing weather is often as long as 6—8 months, freeze—thaw process is restricted, with a lower weathering and denudation rate. By using a simple map, Hewitt(1968) explained a variety of terms of measurring weathering strength and measurement method in a frost period. The averge freeze—thaw rate is dependent on the two periods of freezing and thawing. Frost heaving can be completely explained by a freeezing rate. The change rate of the temperature and wave length of a period is a key factor deciding the weathering

Table 3. Comparsion between weathering rates in periglacial environment.

Region (periglacial area)	Lithology	Weathering rate(mm/a)	Data Source
Easteern coast of the Great Wall Station, Antarctica	Basatic lava	0.0314—0.41	Authors
Southeastern slope of Flat Top Hill, Antarctica	Basaltic lava	0.0169—02.0415	Authors
Southwestern slopee of Flat Top Hill Antarctica	Basaltic lava	0.012—0.722	Authors
Tianshan mountain, China	Sericite—quartz schist	4.89—16	Li Shude, Cui zhijiu, etc., 1981
Spitsbergen	Sandstone	0.34—0.5	Rapp, 1960
Spitsbergen	Limestone, flint	0.02—0.2	Rapp, 1960
Karkevagge	Mica Schist	0.04—0.15	Rapp, 1960
Ellesmeere I., Canada	Dolomite	0.30—0.80 0.50—1.30	Freach, 1976
Yukon Territory, Canada	Quartzite dolouite and shale	0.02—0.17	Gery, 1971
Yukon Territory, Canada	Sianite and qaffre	0.007—0.03	Gery, 1971
Alpine, Austrla	Gneiss and Schist	0.7—1.0	Freach, 1976
Narvik	Granite	0.00105	Dalil, 1967
Co, Clare	Limestone	0.003—6.3	Trudgill, 1976
N. England	Carbonaceous limestone	0.025—0.042	Sweeting, 1960
N. England	Carbonaceous limestone	2.2—3.8	Sweeting, 1960
N. England	Carbonaceous limestone	11.5	Sweeting, 1960

strength. In a freeze — thaw period there should be three fluctuations of temperature around 0℃. Therefore, the more frequent temperature fluctates around 0℃ (the shorter the period is), the higher the rate of temperature changes is and the larger the weathering strength is. At high latitudes temperature can fluctuate around 0℃ only in summer in short time and with low frequency. Thus, regardless of lithology, topography and vegetation, the weathering rate is relatively low in general, ranging from 0.007 to 2.0415mm/a. This is much lower than the weathering rate in the continental climate region in the middle latitudes such as in the Tianshan Mountain region of China. In the periglacial area of the middle and low latitudes temperature can fluctuate around 0℃ in the spring, summer and autumn, with a long — time fluctuation, high frequency and strong weathering. In the mountainous regions of the middle latitudes, such as on the Alpine and the Tianshan Mountain of China, the weathering rate is very high, ranging from 0.7 to 16mm/a.

Generally speaking, the weathering rate in the area with a relatively humid and warm climate is lower than in the area with a relatively dry and cold weather. The weathering rate of rock on the coast of King George Island, Antarctica, is very low, but that at higher slope at only several hundred meters from the coast is much stronger. And the lithologic conditions are similar in the both areas, but the weathering rate differs by 8—100 times. Similary, as the climate on the Alpine in Austria is relatively warm and humid, where the weathering rate is very low, only 1/7 — 1/16 of that in the Tianshan Mountain, although the lithology is quite similar to that in the Tianshan Mountain region of China with its continental climate, where the fast freeze of water in fissures is favourable to weathering. Mellor (1970) considered that both freeze rate and freezeing tension are very important, the fast freezing pure water can suddenly expand to a tension at which rock starts to break up and it can exceed the tension of rock breaking in theory. Especially, when water content is over 50%, it is most favourable to weathering. In the periglacial area with a warm and humid climate, although temperature can fluctuate around 0℃, it fluctuates slowly, with a little rate of temperature change, and the water in the fissures freezes into ice gradually, with a little freezing tension. In a relatively dry and cold periglacial area the frequency of temperature fluctuation is high and the amplitude is large. With a high freezing rate, water fast freezes and suddenly expands. Due to large freezing tension, the rock is liable to be broken, and the weathering strength is high.

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