THE STRUCTURAL TYPE OF TEMPERATURE AND MECHANISM OF MOVEMENT OF ROCK GLACIER AT THE HEAD OF ÜRÜMQI RIVER, TIANSHAN MOUNTAINS*

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The head of the Ürümqi River is situated on the northern slope of the main Kalawucheng Mountains in the middle section of the Tianshan Mountains (43°04′ N —43°08′ N and 86°48′ E —87°00′ E). It is a modern periglacial region. Ji Zi-xiu[1], Li Shu-de et al.[2] and Qiu Guo-qin et al.1) made preliminary analyses about rock weathering, stone circle, rock stream, heaving stone and frozen heavy mound etc. in the area, and accumulated some precious materials. But the predecessors hardly touched on the rock glacier. From 1985 to 1987, the authors systematically and fixedly observed and studied the rock glaciers in this area, and obtained the following results.

I. Shape and Distribution

More than a decade rock glaciers were found at the head of the Ürümqi River. Nearly all of them evolved from talus or protalus rampart. By genetic classifying, they belong to talus-type rock glacier (e. g. RG (rock glacier) Nos. 3—5) or protalus rampart-type (e. g. RG No. 2). According to the first author's classification, most of them belong to Colorado type[3] (i. e. evolved from talus).

The rock glaciers in this area occur singly or collectively. The following features were found on the single rock glaciers: (1) generally, 30—60 m long, 100—150 m wide, front edge 20—40 m high; (2) relatively steep front slope (30°—41°—60°),

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1) cf. some new data in high mountain permafrost and periglacial phenomena in the vicinity of Tianshan Station. *Annual Report on the Work at Tianshan Glaciological Station*, No. 1, pp. 113—121.

an obvious turning belt from the top to the front slope; (3) in some rock glaciers there existed a crowed out step at the bottom of the slope or depressions and ridges on the top. The original talus does not have these features and shapes.

Genetic analysis shows that the rock glacier which evolved directly from talus is different from the protalus rampart type. The former is due to that most of taluses in this area were concentrated in shady slope; under low temperature rain water and melting snow water after seeping into the talus hardly melt; and the talus has a character of creeping forward influenced by the topographic slope. Hence an infant rock glacier, and further, recent lobate rock glacier. The latter is due to that the single rock fall of cliff or steep rocky slope from the surface of the original snowbank fell down and accumulated under the snowbank, and then an arc-shaped dike (i. e. protalus rampart) occurred along the front of the talus after the snowbank melted away. Because the melting water of the snowbank and the rainwater seeped into the dike and refroze, the dike contained mixture of ice and rock, and a creeping phenomenon often occurred, and furthermore, the talus behind the dike also continuously enlarged its own size. Therefore, as the time went by they would combine into one body and become a typical lobate or tongue shape rock glacier (Fig. 1). A counter-inclined slope (8°—17°) is the main characteristic for this

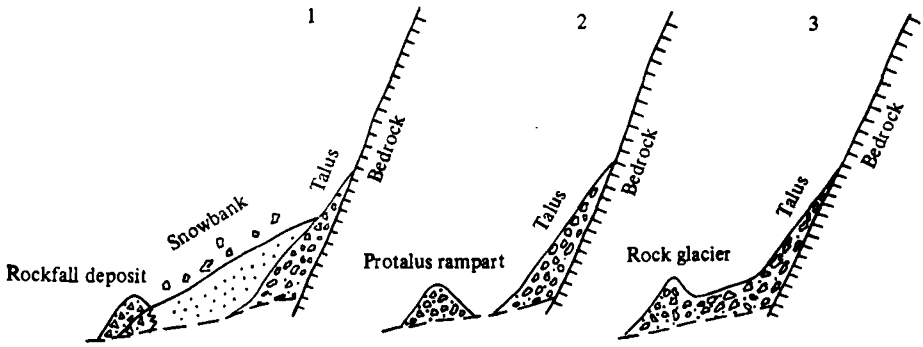

Fig. 1. Form of protalus rampart and its conversion toward rock glaciers (1—3).

kind of rock glacier. It is also an obvious difference from the talus-type rock glacier.

RG No. 2 is a typical protalus rampart-type one (Fig. 2). It is situated under the triangular cliff of glacial eroding beside the Daxigou valley meteorologic station (3600 m a. s. l.)

The Swiss scholar W. Haeberli suggested a theoretical model of the distribution of rock glaciers according to the Alps conditions[4]. At the head of the Ürümqi River the glacial equilibrium line is about 4050 m a. s. l., and the upper limit is about 3900

Fig. 2. Rock glacier No. 2 (arrow).

m a. s. l., so the state is roughly the same as the Haeberli's distributive model.

II. Structural Model

1. *Data of Exploring Pits*

At the end of June, 1986, we found a piece of ice lens (20 × 15×8 cm) 1.31 m below the surface of RG No. 3. The ice body was clean, having no flowing-line characteristics with some gneisses around it. Among the gneisses were some fine debris. We also found the frozen horned-conglomerate ground with particulate ice 0.8 m deep. The frozen debris were cemented by interstitial ice and there existed many ice layers of 1—3 mm thickness and 1.2 m below the surface of RG No. 5. A similar phenomenon was found at the end of July, but with greater depth.

From the data, we know: There is an active layer and a frozen layer in the rock glaciers in this area. The depth of the active layer is about 1.43 —1.90 m at the end of July. The frozen layer consists of the frozen debris with ice lenses and interstitial ice. Because the ice has no characteristics of long-distance removing, it was not a surviving glacial ice, and it should have been frozen at the present position and belong to the ice body of the perennial frozen layer. These are typical characteristics of the ice-cemented-type lobate rock glacier.

2. *Data of Physical Sounding*

By the data of the electrical D. C. resistivity soundings[1)] we can divide the rock glaciers in the area into three layers. The first, active layer, resistivity = 2500 Ωm, thickness = 1.5 m (measured by two-layer plate); the second, frozen sand and gravel layer (according to data of exploring pits) containing ice body, resistivity = 3.7×10^4 Ωm. The resistivity gradually decreased to 3.2×10^4 Ωm where AB/2 = 110 m. Because the depth >100 m, it is an order of magnitude higher than the unfrozen sediments (resistivity = $0.5^{-5} \times 10^4$ Ωm), we can consider that the layer should be bedrock whose resistivity is lower than the frozen sands and gravels with ice. The

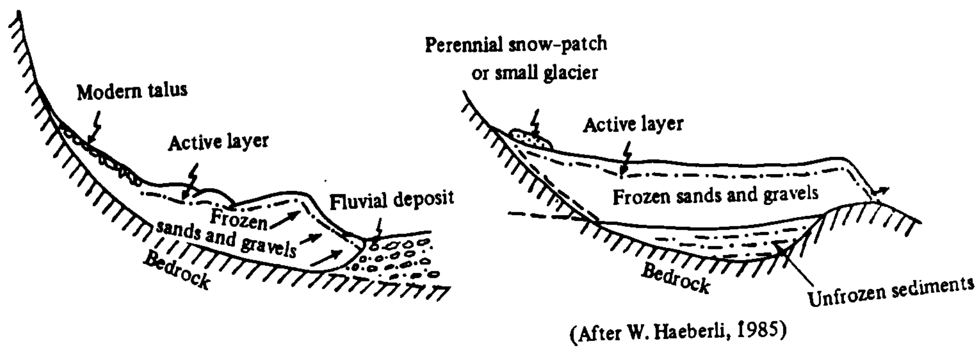

Fig. 3. Comparison of structure of the rock glaciers between the Tianshan type (left) and the Alps type (right, from W. Haeberli, 1985: Fig. 63).

1) YAO Zhen's help in the translating of the curves of the physical sounding is very gratefully acknowledged.

resistivity increased again to 3.7×10^4 Ωm or so where $AB_2 \sim 160$ m. It should be a result of the lithology change of the bedrock. According to data from exploring pits and physical sounding, we can get a scheme of comparison on the structure of rock glaciers between the three-layer in this area and the four-layer type of the Alps (Fig. 3).

It can be said that we have first discovered the two kinds of rock glaciers which have different temperatures and structures, namely, the former shows a character of the continental Alpine cold-bottom rock glacier, the latter shows a maritime "warm bottom rock glacier" character.

III. Characteristics of Movement

From our observation, we can obtain the following characteristics.

1. *Low Movement-Gradually Stable Type*

RG No. 1 more than 100 m by 60 m is one of the few tongue-shape rock glaciers in this area, and it is 250 m away from the upper general hydrographic station. We found that its front edge moved forward at only 1 cm/a or so based on our survey of the painted basic line whose ends are fixed at bed rock. According to its recent increasing surficial plants, it would be gradually stable.

2. *Active Type*

The 37 painted boulders on the top of RG No. 2 were found to move at 11 cm/a or so by a repeated observation of the fixed painted basic line. We also found that each surveying point of RG No. 3 moved forward by 75 cm/a averagely along the main flowing direction, 49 cm/a for No. 4 and 15.5 cm/a for No. 5 by the repeated surveying of the platform instrument.

3. *Discharge and Accumulation*

The foot of the front slope of rock glacier No. 4 was a surface of a highway abandoned in 1960. The original width was 5.5 m, but because of the movement of the above rock glacier, the debris has made the highway 4 m wide. We can get a general discharge during 1960—1985 as follows:

General discharge $= S \cdot L = ab \sin\alpha \times L = 1764$ (m^3), where $L(=100$ m$)$ is the width of the front edge; a, the displacement of the rock glacier; b, length of the front slope and α, angle of the slope. Further, we can obtain a mean discharge (70.56 m^3/a) and a unit discharge (0.47 $m^3/m^2/a$). These data furnished some actual information for highway maintenance squad for their manshift.

4. *Irregular Characteristics of Movement Rate*

From the above mentioned, we can reasonably conclude that RG No. 4 moves forward at a mean rate of 6 cm/a in the past 25 years. But during 1985—1986, surveying of a platform instrument of 15 points of the rock glacier provides a much faster rate i. e. 49 cm/a. The irregular movement is a common phenomenon of rock glaciers, for example S. E. White[5] found that the surficial painted boulder of

Arapaho rock glacier moved at 2 cm/a averagely during 1961—1964, but the rate increased to 12 cm/a during 1964—1966. Similar phenomena also occurred in the observation of rock glaciers on the Swiss Alps and other regions. It can be seen that the rock glacial movement is similar to glacial movement, both having irregular characteristics.

IV. Discussion of the Moving Mode

Analysis shows difference for different layers in movement.

1. *Frozen Debris Layer of Active Movement*

On the front slope of relatively active RG No. 2, rocks within 20 m of its middle part move faster and most of the ab planes of gravels lie along the slope, while in the upper and lower parts, the rocks move more slowly, most of the ab planes of the upper part are embedded in the slope horizontally and of the lower part lie in imbricate shape. It is worth noticing that in the lower segment of the middle part appear a great number of fine particles of the debris, which, by the analysis in the laboratory, are shown to be identical with filled substance of frozen debris 1.91 m deep of RG 5 and 1.45 m deep of RG 3 in percentage of different-class particles. Therefore, it can be inferred that these fine particles are filled substance of frozen debris and pushed out along the shearing plane due to the internal stress. They are similar to the shearing till in the glacier but are not easily identified. As to the difference for different layers of the rock glacier in movement, we can infer that the frozen layer under the active layer moves faster than its bottom and the surface layer, according to fast movement for the middle part of RG 2's front slope, appearance of fine particles on the surface and partly backing phenomenon for the gravels on the surface of each rock glacier, etc. In other words, the active movement is for the layer of frozen sand and gravel layer between the bottom of the frozen layer and the surface, and the passive movement for the active layer of loose debris on the surface. When the frozen debris layer in the middle moves in adversely along the shearing plane, it draws the loose debris above it rolling and slipping locally, which results in the complex phenomenon of advancing and descending, backing and ascending.

2. *The Surface Layer of Passive Movement and the Form of Its Flowing Field*

Repeated survey of active rock glacier shows a general trend of horizontal advance and height descending as well as partly adverse movement and height ascending for the surveying point (or gravel). The reason is mentioned above. In addition, it is a general rule that the flowing speed in the middle of the rock glacier surface is the highest.

The debris fabric shows a certain form of surficial flowing field of the rock glacier. By surveying the fabric at different positions, such as front slope, top of front slope, east and west slopes and the talus of the head of RG 2, and the depths of the active layer of RG 3, we found that

(1) There is a main dense part for the inclination of ab plane of each deposit

position on the surface layer of RG 2. The highest density reaches 19—22%, and the decline degrees of the main dense part and each sedimentary plane are basically the same.

(2) Based on the fabric within the active layer of RG 3, axis *A* declines 284° NW averagely, nearly equal to the main flowing direction of the rock glacier which is 285° NW. However, ab plane has two declining directions, and the direction, 75° NE of the biggest main dense part is nearly opposite to the main flow direction of the rock glacier. This is probably because the internal part of the rock glacier was pressed and deformed by gelifluction and rocks were drawn when they crept along the flow direction.

(3) Based on the surface flowing field of the rock glacier reflected by fabric of each surveying point, in this region the general flowing direction of lobate rock glacier is from the wall of valley extending outside and perpendicular to the contour on the surface of the rock glacier, i. e. along the direction of released pressure, and locally there are debris rolling and slipping on the adverse slope of the top of the front part.

References

[1] 季子修，冰川冻土，**2**(1980)，3: 1—10.

[2] 李树德、崔之久、张振栓，同上，**3**(1981)，增刊: 114—118.

[3] Cui Zhijiu, *Kexue Tongbao*, **30**(1985), 3: 365—369.

[4] Haeberli, W., *Creep of mountain permafrost: Internal structure and flow of alpine rock glaciers*, Nr. 77 Mitteilungen der Versuchsanstalt fur Wasserbass, Hydrologie Und Glazioloie, Zurich, 24—105.

[5] White, S. E., *Arctic and Alpine Research*, **3**(1971), 1:43—64.