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Glacial geomorphological features in upper reaches of the Yurunkax River on the north slope of the West Kunlun Mountains

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Abstract

According to the distributional pattern of glacial landforms and ages estimated by ^{14}C dating, five glacial advances took place in this region. The extents of the older three glacial advances were larger than the others, which correspond with the Neoglacial and the Little Ice Age. The oldest glacial advance was largest in the Quaternary: during that period, an ice cap glacier extended down to the Yurunkax River Valley and formed broad morainic platforms and various erosional forms. The extent of the fourth glacial advance was smaller than the oldest: the original ice cap disintegrated into net-shaped valley glaciers. The glaciers in the third advance retreated into branched shapes in valleys and some glaciers developed cirques. Lateral and terminal moraines were left in glacial troughs. Tills in the Neoglacial and the Little Ice Age are distributed only inside of the moraines of the third glacial advance.

1. Introduction

The headwaters of the Yurunkax River are in the northern part of the West Kunlun Mountains, 35°22′–25°36′N, 81°14′–81°40′E, with an elevation of over 5000 m except the lower Yurunkax Valley in the northwest part of this region. During the Quaternary period, this region experienced several glacierization and various kinds of glacial geomorphology were left there, such as glacial troughs, glaciated round-hills, glacial erosion lakes, and morainic platforms and ridges (Li *et al.*, 1986). All these are a reliable bases for study of glacial history in this region in the Quaternary.

There are many existing glaciers in the upper reaches of the Yurunkax River. Larger glaciers include the Yulong Glacier, Xiezhi Glacier, Alakesayi Glacier, Bulakebashi Glacier, Yake Glacier, and Yakebake Glacier. Other small glaciers had been the branches of them in the past, and were separated from their main bodies during their retreating period.

During the summer of 1987, the authors, as members of the Sino-Japanese Joint Glaciological Expedition to West Kunlun, investigated glacial landforms on the north side of the West Kunlun Mountains.

According to the field observations and aerial photo-interpretation, spatial sequences, morphological characteristics, and surface features of moraines were investigated. In general, moraines located near the glacier fronts represent well-preserved fresh features, while these far from the glacier fronts show subdued forms. These features are also clearly shown on aerial photographs. Content of fine materials is small in young tills, while it increases as the age of moraines becomes old. Grain size (Jiao *et al.*, 1989) and mineral combination of glacial deposits also investigated. Measurements of absolute ages (^{14}C dating) of several glacial deposits were carried out in the laboratory of Lanzhou University. Then we divided the moraines into five different stages and mapped them as shown in Fig. 1. Five different glacial advances took place in this area. From the youngest to

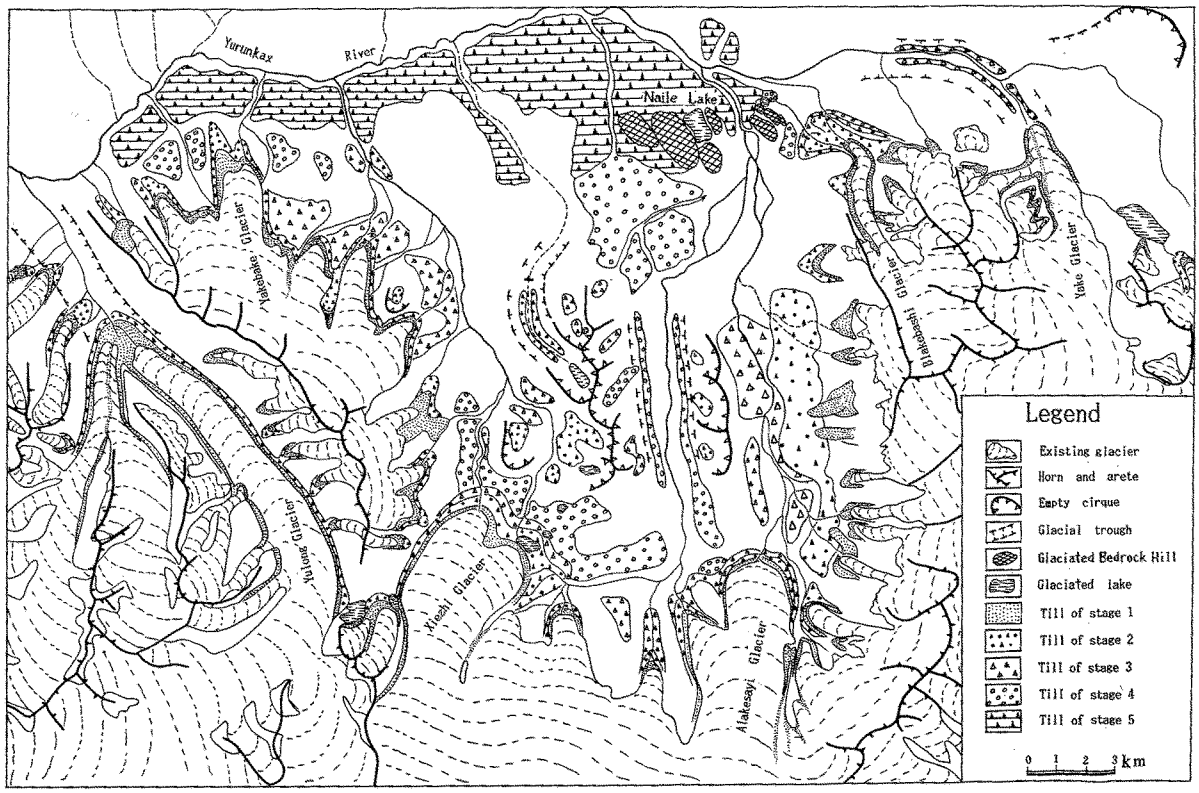

Fig. 1. Distribution of glacial landforms on the northern side of the West Kunlun Mountains.

the oldest, we call them the first, second, third, fourth, and fifth stages. The first and second ones belong to the Little Ice Age and Neoglacial, respectively. They are within 2 km of the ends of existing glacial termini. Moraines of the third stage are located outside of those of the above two stages. There are few moraines of the fourth stage in this region. Some of them are scattered on shoulders of glacial troughs. At the outer end, morainic platforms were formed by the fifth advance. Some other glacial landforms also were investigated and mapped.

2. Landforms of glacial deposition

Morainic platforms and various types of morainic ridges are the main types of glacial depositional landforms in this region. Based on the degrees of the glacial activities in different ages, the distribution of morainic landforms is quite different. Because the locations and directions of accumulation area of each glacier are different, the distribution and extent of morainic landforms are also different even in the same glacial stage.

2.1. Moraines of the Bulakebashi Glacier

The Bulakebashi Glacier is 18 km long, the height of the snow line is 6160 m and its terminus is 5200 m in altitude. The glacial area has turned out to be smaller and smaller and moraines have been left in different areas outside of the terminus. According to the locations, morphological characteristics, and the unstable mineral content of tills as well as ^{14}C dating, we conclude that moraines of Bulakebashi Glacier are divided into four different stages. Their characteristics from the latest to the oldest are as follows:

The first stage moraines: Two end-moraine ridges were formed at around the glacier terminus. They are 40 m different in height from each other: The inside one is about 50 m away from the end of the glacier. The frontal part of the end moraine has a slope of about 15°; it drops down to 5080 m in altitude. The end moraine stretches 4 km upward as lateral moraines on both sides of the glacial tongue. These moraines are

mainly composed of unsorted gravels of black slate and schist filled with a little coarse sand. The ferric oxide content of these materials is below 1%.

The second stage moraines: The distribution of tills extends 1.5 km away from the glacial tongue. It spreads like a fan with mean inclination of 6°–10°. The slope changes clearly at the place where moraines of the first and second stages meet. The outer part of it covers the inside part of tills of the third glacial stage. The basal and ablation tills were observed inside the end moraine where the glacier had retreated. The moraine surface is uneven because of melting of dead ice below. A few moraine-lakes appear on the moraine, and ice is exposed in some places.

We could observe that an ablation till 3 m thick covers the dead ice in an exposure. It can be divided into three layers as follows: The upper layer is a sand layer with gravels 90 cm thick; the middle is a layer of light gray silty-clay 30 cm thick, which is similar to the volcanic ash at the lakeside of Ashikule Lake; the lower is a brown boulder-clay layer.

A tongue-shaped moraine of the second stage is located outside of the left bank of the first stage lateral moraine[1]. In most places, second stage moraines were covered with first stage lateral moraines. The former were 40–80 m lower than the latter.

It is clear that the second stage tills have finer grain size than those of the first stage. The ferric oxide content in the tills is more than 1%.

The third stage moraine: This is 2 km away from the end of the glacier tongue at most. The northern part has been reformed and destroyed by the melt water from the glacier, but the moraine with many arc-shaped ridges remains only in the south. It is about 200 m wide.

Although the end moraines of the second and third stages are connected with each other, we can easily distinguish one from the other by morphological features. The second-stage moraine is yellow in color on the whole, the grain size of surface stones is larger, and many hollows exist with only a few stones and sands inside. Dead ice under the till layer could be observed. The surface of the moraines is uneven, and quite a few morainic lakes are there. On the other hand, the third stage moraine is grey. Big boulders settled in the till can be found here and there. Poor grass vegetation grows on the surface covered with a thin layer of fine materials.

At the outside of the third stage end moraine, we dug profile (Fig. 2). It was mainly made of gravels,

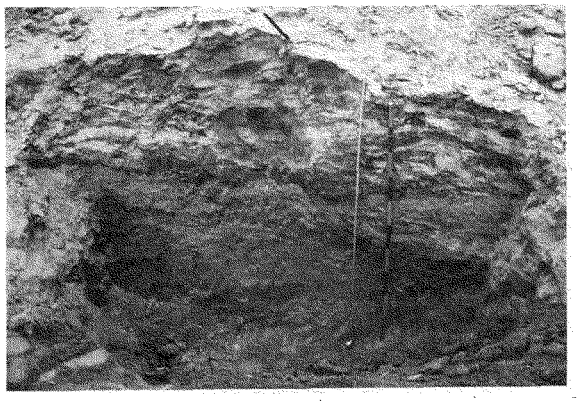

Fig. 2. The profile of the third-stage moraine of the Bulakebashi Glacier.

coarse sands, silt, and silty-clay. There are as follows from top to bottom:

A. Alternative layers of coarse sands, gravels, and silt, 15 cm thick.

B. Alternating layers of silt and silty-clay, 35 cm thick.

C. Fine sand layer with crumple phenomenon, 5–10 cm.

D. Silty clay with gravel layer, 15–20 cm.

E. Layer of mixture of silt, coarse sands, and gravels, 20 cm thick.

F. Silty clay in horizontal veins, 10 cm thick.

G. Yellow silty clay with gravels and roots of grass, 20 cm thick.

H. Grey silt-clay, as permafrost layer.

Samples which were taken from the F and G layers were dated by ^{14}C analysis of calcium carbonate; their ages are 12,025±195 Yr. B.P and 18,250±625 Yr. B.P. These results of dating suggest that this moraine belongs to the Last Glacial period, but the dated deposits contain no clear concentration of calcium carbonate and organic materials, and they are not tills but marginal-lake deposits so that dating is unlikely to indicate the age of glacial advance. Iwata suggested that this moraine does not belong so much to the third stage as to the second stage according to the rather fresh morphological features. The ferric oxide content of this till is 3%.

A lateral moraine in the third stage remains wholly in the north side of the glacier tongue. Gravels on the lateral moraine became purple in color by strong oxidation. All of the hollows on the surface were filled and covered by fine materials, and scattered grasses grow on it.

The fourth stage moraines: There are much older moraines outside the end moraines mentioned above. They falls in the fourth stage. The surface of the moraine is 5-10 m lower than that of the third stage. The moraine surface becomes higher and higher westward until the moraine connects with the glaciated hill mentioned below. The fourth stage end moraine is made of coarse sands and small gravels. Boulders can seldom be seen on it. The surface is covered with grass, and it is a grazing place for wild sheep and wild yaks.

2.2. Moraines of the Alakesayi Glacier

The Alakesayi Glacier is one of the largest glaciers on the northern side of West Kunlun. Two glacial troughs exist; the main body of Alakesayi Glacier spreads to the glacial trough on the eastern side (East Alakesayi Valley). The glacier tongue is 2 km wide and the end is 5300 m above sea level. The ice body in the West Alakesayi Glacier, together with several other glaciers, enters the glacial trough on the western side (West Alakesayi Valley). Ice pinnacles (seracs) are formed by melting of the glacier surface within an area 500 m long from the end of the glacier terminus.

Four hundred metres away from the end of the present glacial tongue, an end moraine ridge remains. Its relative height is 30-50 m above the surrounding ground. A sample from the outer slope of the moraine was dated by ^{14}C to 22,904±950 Yr. B.P. and that from the inner slope to 10,553±123 Yr. B.P., corresponding to the third-stage moraine in front of the Bulakebashi Glacier. Inside of this end moraine, there are two end moraines which correspond to the first and second stages, respectively. These three moraines are located side by side; therefore they seem to be almost one body.

In the middle section of the East Alakesayi Valley, several glaciers develop on the east valley slope. Moraines indicate that they spread to the mid-line of the valley in the second and third stages. The ^{14}C date of 7,078±340 yr. B.P. was obtained from second stage tills east of the mid-line.

Several small glacier tongues are located between a small branch of the Alakesayi Glacier and the eastern part of the Xiezhi Glacier at the head of the West Alakesayi Valley. Moraines corresponding to the first, second, and third stages are within a few kilometers away from existing glaciers, but even the third-stage tills are distributed on both sides of the trough at height of 5200-5300 m. They are remains of lateral moraines. Fourth stage moraines are distributed south of the fifth stage moraine platforms, south of the Naile Glaciated Hills mentioned below.

2.3. Xiezhi Glacier

Moraines correspond to the first and second stages along the whole margin of the glacier. The plan shape is like a new moon. The former is situated in an area of 300 m, the latter in an area of 0.1-1 km outside. They are separated by meltwater fan and lakes. Tills of the third stages, not in obvious morainic shape, are distributed in an area 1-2 km in front of the second stage end moraines, because a large amount of meltwater rushed down on steep slopes.

2.4. Yakebake Glacier

The Yakebake Glacier is located on the north-facing slope of the ridge which runs along the right bank of the Yulong Glacier. This is formed by several glaciers connected side by side. There are only several end moraines around the glacier. End moraines of the first and second stages are in the form of ridges, being with 1 km of the end of the glacier tongues. On the front slope third stage tills are distributed. They include huge gravels over 1 m in diameter. Fourth stage tills are distributed separately on the platforms, which are 0.5-1 km wide and 400 m above the river floor of the Yurunkax River.

2.5. Yake Glacier

The Yake Glacier is located at the source of the Yurunkax River. Moraines of the first stage are found at the end of the glacier tongue. Lateral moraines of the third stage occur along the river, and a fluvial terrace landform, 30-50 m above the river floor, spreads 5 km downward.

2.6. Fifth stage moraine platforms

Moraine platforms along the southern side of the Yurunkax River, about 200 m above the river bed, are the oldest tills in the region. They are fifth stage tills. The eastern part is wider, about 4 km wide. The surface is even, with a thick layer of soil and scattered grass. Boulders were seldom found. These moraines indicate that in the time of the fifth stage an ice cap was formed on the northern side of the main range of the West Kunlun Mountains.

2.7. Yulong Glacier

The Yulong Glacier, about 30 km long, is one of the longest valley glaciers in this region. Lateral moraines of the first and second stages occur about 13 km along the glacier tongue. They are connected with the end moraines. There are few third stage lateral moraines on the shoulder of the trough at the lower reaches. Four glaciers in the south have end and lateral moraines which correspond to the first and second stages.

3. Landforms of glacial erosion

According to the till distribution in various periods, the glacial extents tend to be smaller and smaller from the fifth to third stages. Glaciers retreated only 1-2 km during the second and third stages. Therefore glacial erosional landforms were produced before the third stages. Typical glacial erosional landforms are glaciated hills, glacial erosional lakes, glacial troughs, and empty cirques.

3.1. Glaciated bedrock hills (Stoss and lee topography)

At the confluence of the lower reaches of the trough of the Alakesayi and Yurunkax Rivers, there are two groups of glaciated bedrock hills. They show typical smoothed abraded stoss slopes. The group in the west is located around Naile Lake; therefore, it is named the Naile Glaciated Hills Group. The one in the east, named the Bulake Glaciated Hills Group, is in the lower reaches of Bulakebashi Glacier. The latter is composed of three round hills of different size. The long axis direction is N42°W. Each hill is about 1 km long and 400 m wide, rises 100 m above the river floor, and the distance between hills is about 300 m. The bedrock is exposed, with no tills on it. Slopes facing upstream are about 20° and those leeward about 12°. Strikes of the bedrock are vertical to the long axis of the hills. Four rock hills constitute the Naile Glaciated Hills Group, have long axes of N40°W, are about 150 m high, and the biggest one is about 4 km long and 1.5 km wide. The slope facing upstream is 13-15° in angle and the of leeward one 4-6°. The hill to the east of Naile Lake is smaller than the others, shaped like an ellipse, and less than 100 m high.

3.2. Glacial erosion lake

Lakes made by glacial erosion are classified into two types: cirque lakes and glacier-excavated lakes. The former is distributed in empty cirques. The latter occurs on the trough floor, such as Naile Lake. Basins in different scale formed by glacier-digging processes were filled with water, after the glacier receded. Naile Lake, 1.2 km long and 0.5 km wide, is a permanent lake deeper in the southeast and shallow in the northwest.

In the western part of the Bulake Glaciated Hills Group, there is a small lake, about 200 m in diameter. This is a seasonal lake: part of the Bulakebashi Glacier melt water enters the lake. This is not a glacial erosional lake but a moraine-dammed lake, only about 200 m in diameter.

3.3. Glacial trough

Troughs downstream from the Yake, Alakesayi, and Yulong Glaciers are typical glacial troughs in this region. Their geomorphological characteristics are wide and shallow: The proportion of depth to width is 1:5-1:9. Triangle truncated spurs by glacial erosion exist on both trough walls and tills distributed almost everywhere in the troughs.

3.4. Empty cirque

There are many empty cirques in this region. Bottoms of empty cirques on either side of the West Alakesayi Glacial Trough are 5100-5200 m above sea level, and surrounding horns are about 5500 m high. As the snow-line rose and the Alakesayi Glacier retreated, these small branch-glaciers disappeared and empty cirques appeared. According to the tills in the empty cirque, none of these cirque glaciers have been there since the third stage.

4. Development of the Quaternary glaciations

Results of the ^{14}C dating suggest that the third stage corresponds to the late subglacial of the Last Glacial (Q_3^3 in Chinese Quaternary sequence). Subsequently, it is sure that the second and first stages correspond to the Neoglacial and the Little Ice Age. No absolute age of older stages, the fourth and fifth stages, has obtained yet, therefore chronological positions of them are still an open to question. Li *et al.* (1986), Zheng (1987) and Zheng *et al.* (1989) reported that the West Kunlun Mountains experienced three rather great glaciations in the Pleistocene. According to their chronological hypothesis, the fourth and fifth stages correspond to the early Late Pleistocene (Q_3^1)

and the Middle Pleistocene (Q_2), respectively. The above-mentioned chronological sequence of the glacial landforms seems to coincide with the glacial sequences in Quaternary China which have been studied by Chinese Scientists (e.g. Li *et al.*, 1986). In this chronology, however, the Alpine sequence has been accepted without concrete correlation. Accordingly there are two different interpretations on the age of the fourth stage in the study area. Ma, Zheng, and Jiao insist that the fourth stage corresponds to the early phase of the Middle Pleistocene, which is considered to coincide to the Riss Glacial in the Alps. On the other hand, Iwata and Fushimi insist that the fourth stage corresponds to a younger stage; probably the early stage in the Last Glacial. Detailed chronological discussion will appear elsewhere.

Their main features of the glacial evolution in the study area are followings: In the fifth stage, the ice cap on the West Kunlun Main Range spread down to the Yurunkax River valley. Glaciers in the region almost merged at Yakebaketake where a wide morainic platform was formed. At that time glaciers on the northern side of the West Kunlun Main Range were almost united as one, and horns stood above snow and ice. Glaciers obviously shrank in the fourth stage; the ice-cap has turned into valley glaciers and bedrock areas between glaciers were exposed. Some glaciers in the third stage retreated up to 1-2 km outside of existing glaciers. The obvious end and lateral moraines at the end of the existing glacier were formed. Branch glaciers on both sides of the trough have disappeared, and left empty cirques there.

Acknowledgments

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Note

1) According to the aerial photo-interpretation, Iwata concluded that this moraine belongs to the first stage.

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