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Glaciological Studies on Qingzang Plateau, 1989
Part 2. Glaciology and Geomorphology

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Abstract

Glaciological and geomorphological observations were carried out in the East Kunlun, Tanggula and Nyainqentanglha Mountains, as a part of the China-Japan Joint Glaciological Expedition to Qingzang Plateau, 1989. The main objective of the glacier research is to compare the characteristics of glaciers in different climates, namely the continental and the maritime ones. Preliminary results of the research are described.

1. Introduction

The China-Japan Joint Glaciological Expedition to Qingzang Plateau, 1989, aimed to study the characteristics of glaciers in different climates, the evolution history of the cryosphere and the role of the cryosphere in meteorological and hydrological processes on the plateau. An outline of the project and basic results of the meteorological and hydrological observations are reported in Part 1 and Part 3 of this expedition report, respectively.

On Qingzang Plateau, there is much difference in precipitation between the northern and the southern parts. This climatic difference separates the glaciers on the plateau into two types: 'the continental-type' with little annual water exchange and 'the maritime-type' with much annual water exchange. Comparison of the characteristics of the both glacier types is important to understand the water cycle in Asian highland regions.

The field researches of the expedition were carried out in arid East Kunlun, semi-arid Tanggula and humid Nyainqentanglha. This report describes preliminary results of the observations during the expedition.

2. Observations in East Kunlun Mountains

Glaciological observations were carried out on Meikuang Glacier at a distance of about 20 km east from Kunlun Pass on the north slope of the East Kunlun Mountains. This glacier was selected as a representative glacier in Xidatan area for study of glacier mass balance and other glaciological characteristics under a dry climate. Meikuang Glacier flows to north, and the highest and the lowest altitudes are 5520 m and 4790 m, respectively. The length and the area of the glacier are about 1.8 km and 1.1 km^2, respectively (Fig. 1).

Snow stakes were set on May 6 and 7, and measured again on September 7. The change of the glacier surface levels during 4 summer months is shown in Fig. 2. Since the altitude range of the stake positions on the glacier was limited to the lower 30 % of the glacier in altitude, all data in the figure show surface lowering due to negative mass balance in summer. Since precipitation is relatively large in summer but little in winter in this region, the accumulation area on the upper part of the glacier is assumed to have positive balance during this 4 months. Evidence of avalanches debris fallen from the upper slope was found around the highest zone of the stake line.

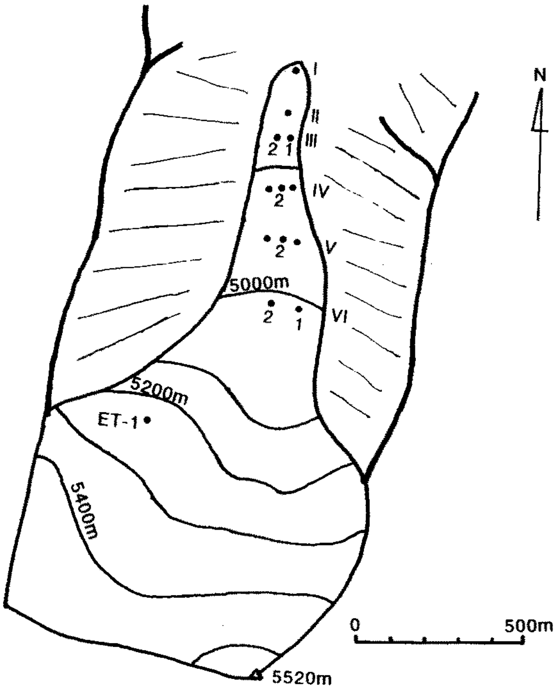

Fig. 1. Map of Meikuang Glacier in the East Kunlun Mountains. (temporary mapping)

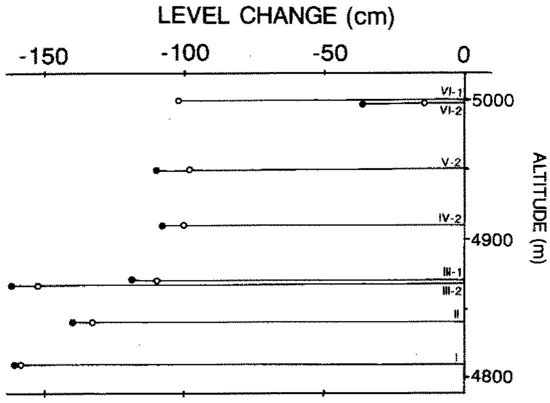

Fig. 2. Change of snow and ice surface levels of Meikuang Glacier from May 6-7 to September 7, 1989. Open circles and solid circles indicate change of snow surface level and ice surface level beneath snow cover from the glacier surface level on May 6-7, respectively.

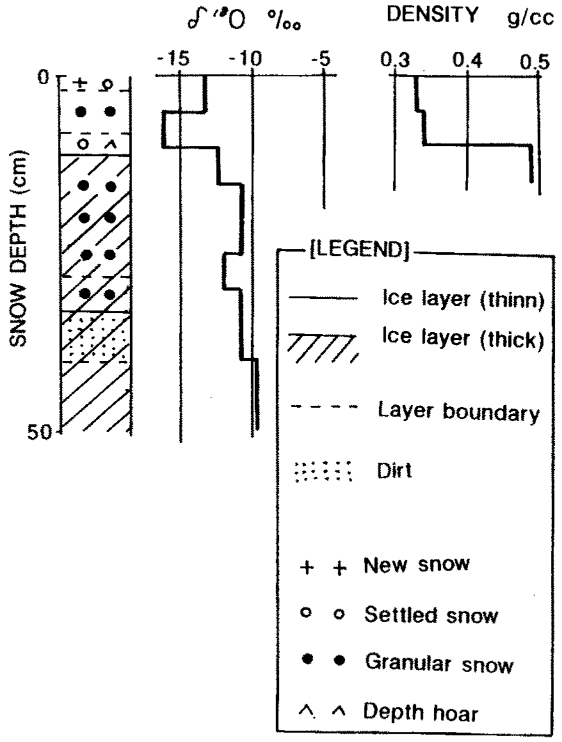

Fig. 3. Stratigraphy and oxygen isotopic composition at St. ET-1 (5240 m a.s.l.) of Meikuang Glacier on September 8, 1989.

For example, the upper part of stake VI-2 was broken during this period. The large difference in the surface lowering indicated by stakes VI-1 and VI-2 (Fig. 2) seems to show the effect of the avalanches.

Observations on the upper part of the glacier were made briefly only on the western part of the glacier at an altitude of around 5250 m in May and September. The snow/ice stratigraphy in early September is shown with oxygen isotopic composition in Fig. 3. The surface level at this site did not change between early May and early September. However, mass balance during this period was positive, since the surface of loose superimposed ice in snow rose approximately 20 cm higher.

The accessible part of the accumulation area of this glacier is limited due to avalanches and crevasses. We are considering changing the glacier to be observed continuously in this area, to another one. During the 2 days stay, each in May and September, for glaciological observations and acclimatization around Meikuang Glacier, geomorphological observations were also carried out in the Xidatan area.

3. Observations in Tanggula Mountains

At the head of Dongkemadi Valley in the Tanggula Mountains, there are two glaciers, namely, Dongkemadi and Xiao Dongkemadi Glaciers. Dongkemadi Glacier flows southward; its highest and lowest altitudes are 6100 m and 5270 m, respectively. The length and the area of the glacier are about 5.4 km and 16.4 km^2, respectively. Xiao Dongkemadi Glacier is located east of Dongkemadi Glacier and flows southwestward. The highest and the lowest altitudes, the length and the area of the glacier are 5930 m, 5400 m, 2.8 km and 1.8 km^2, respectively (Fig. 4). Since Dongkemadi Glacier has a terminal cliff that is hard to climb and is too large to observe the whole glacier on foot, glaciological observations were carried out on Xiao Dongkemadi Glacier as a representative glacier in the Tanggula Mountains in a semi-arid climate.

As described in Part 1, shallow ice core drilling was carried out in May in the accumulation area of Xiao Dongkemadi Glacier by Chinese members. Ice cores 17 m and 14 m long were obtained at 2 sites; the latter, obtained at an altitude of 5700 m, were analyzed intensively in Lanzhou for oxygen isotopes, conductivity, PH, anions and cations. The Chinese group is using these results to study climatic warming and environmental change of the Qingzang Plateau.

Snow stakes were set on May 13, 16 and 17 on the glacier and measured again on September 13. The change of the glacier surface levels during 4 summer months is shown in Fig. 5. As seen in Fig. 5, the glacier surface rose during summer except the lowest part.

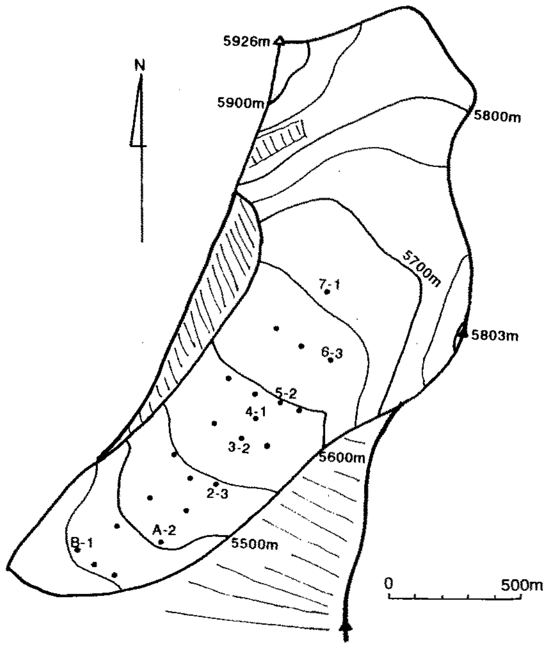

Fig. 4. Map of Xiao Dongkemadi Glaciers in the Tanggula Mountains. (temporary mapping)

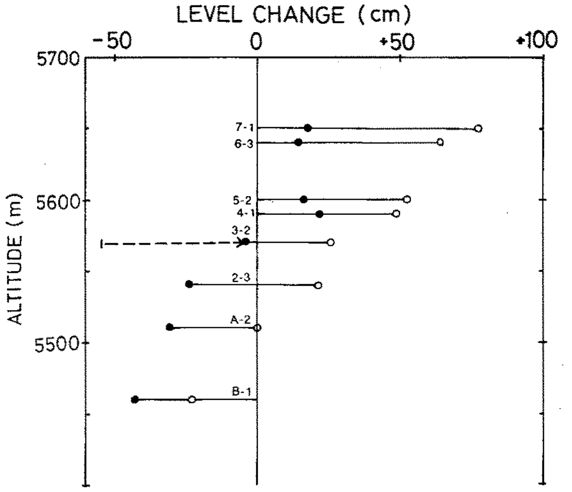

Fig. 5. Change of snow and ice surface levels of Xiao Dongkemadi Glacier from May 13-17 to September 13, 1989. Open circles and solid circles indicate change of snow surface level and ice surface level beneath snow cover from the glacier surface level on May 13-17, respectively. The dashed arrow indicates the rise of superimposed ice surface from May 28.

On the upper part of the glacier in September, the surface of superimposed ice beneath snow cover became higher than the snow surface in May (Fig. 5). Snow/ice stratigraphy on the upper plateau of the glacier in the middle of September is shown with oxygen isotopic composition in Fig. 6. On September 13, the glacier surface was 78 cm higher and the surface of superimposed ice beneath snow cover was 18 cm higher than the glacier surface on May 13. As a whole, the mass balance of the glacier during this period was positive, and the growth of the superimposed ice was remarkable.

A self-recording snow-depth gauge was set at an altitude of 5570 m (Station 3-2) around the equlibrium line of the glacier on May 27. This gauge detects snow surface level from the light that enters its fiber glass sensor. The recorder paper was replaced on September 13. The recording is still continuing. The change of glacier surface level obtained by use of the gauge is shown in Fig. 7. The surface rose in early summer and descended in mid-summer, then kept steady in late summer. At this altitude, almost all precipitation, even in the middle of summer, is considered to be snow. The superimposed ice at this site grew remarkably in this summer, and its surface beneath snow cover rose 49 cm during this period as shown in Fig. 5. Therefore, the mass balance during

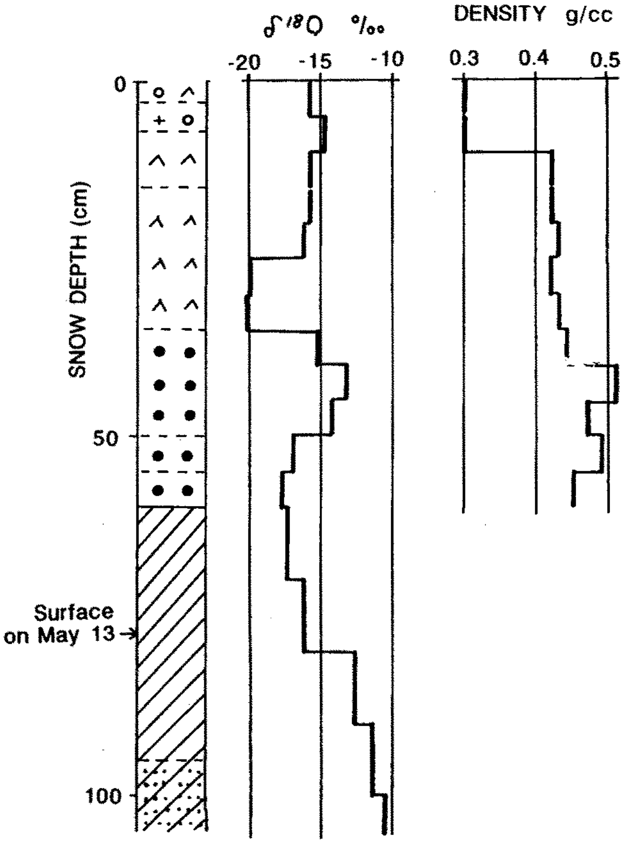

Fig. 6. Stratigraphy and oxygen isotopic composition at St. 7-1 (5650 m a.s.l.) of Xiao Dongkemadi Glacier on September 13, 1989. (Legend: same as shown in Fig. 3)

summer at this site was positive. Growth of superimposed ice in the melting season is important for mass balance of the sub-polar type glacier in this semi-arid area.

4. Observations in the Nyainqentanglha Mountains

As a typical maritime glacier region, the Nyainqentanglha was observed many times. In the 1930s, F. K. Ward went to the region many times and reported on his expeditions. In the 1960 s, Chinese scientists studied several cirque and hanging glaciers in detail during their observations of glacial debris flow around Guxiang. At the same time, they also observed glaciers at the head of Lequ Zangbu River. During Chinese scientific expeditions in the 1970s, the Nyainqentanglha was an important region studied. The glaciers investigated were Roguo, Zhuxi, Kajia and Zepu Glaciers.

In mid-September and early October, 1989, the China-Japan Joint Glaciological Expedition to Qingzang Plateau visited the Nyainqentanglha Mountains, and made the research on the existing glaciers, geomorphology and Quaternary glaciation at the head of Bodui Zangbu and Yigong Zangbu Rivers. This region is on the south slope of the middle Nyainqentanglha Mountains which face the "Great Bent" of the Yalu Zangbu River. This "Great Bent" is generally considered as a main corridor through which moist monsoon air penetrates into the inland part of Qingzang Plateau. Because of the high topographic relief combined with the moist monsoon air mass, the studied region has high precipitation and humidity, resulting in the development of large glaciers. During Quaternary glacial ages, glaciers were much larger than those at present. The Nyainqentanglha region is an ideal region to study not only existing glaciers, but also Quaternary glaciations.

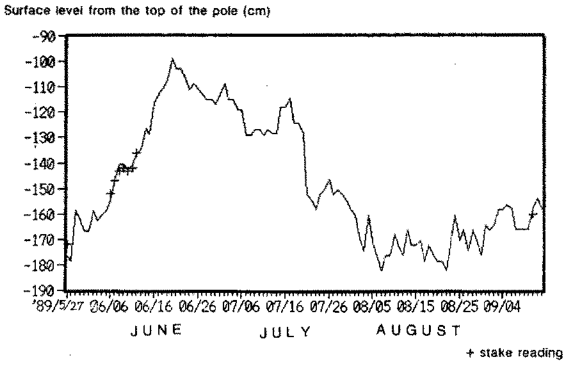

Fig. 7. Change of glacier surface level at St. 3-2 (5570 m a.s.l.) on Xiao Dongkemadi Glacier obtained by a self-recording snow-depth gauge from the end of May to the beginning of September, 1989.

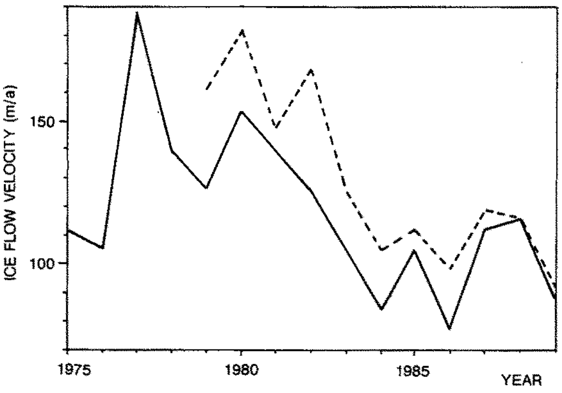

Fig. 8. Ice flow velocities reconstructed from observation of ogives on Zepu Glacier in the Nyainqentanglha Mountains.

4.1. *Study of existing glaciers*

a) Glacier distribution

There are 1269 glaciers with a total area of 3,589 km^2 in the Bodui Zangbu and Yigong Zangbu Rivers watersheds. These account for 44 % and 61 %, respectively, of the total number and area of glaciers in the Nyainqentanglha Mountains. Almost all of the glaciers longer than 10 km on Qingzang Plateau are concentrated in the Nyainqentanglha Mountains. The longest glacier on Qingzang Plateau, the Kaqin Glacier (35 km long with an area of 151.5 km^2), is at the head of the Yigong Zangbu River. The distribution pattern of the glaciers in the mountains reflects the precipitation distribution, with over 80 % on the south slope. This is opposite to the general glacier distribution in the northern hemisphere.

b) Glacier types and snowline distribution

Because of the intensive uplift of the mountains, there is no place suitable for development of ice caps. But all other types of glacier exist in the Nyainqentanglha Mountains. Hanging glaciers are the most numerous, accounting for 53 %, while only 8.3 % are valley glaciers. But valley glaciers occupy 43 % of the total glacier area, hanging glaciers only 10.1 %. The lowest snowline appears on Gongpu Glacier with an altitude of 4,200 m. The highest snowline (5,700 m) appears on Xibu Glacier located in the southern part of the mountains. The snowline distribution reflects the transport direction of water vapor. The difference of snowline altitude is largest near the "Great Bent" of the Yalu Zangbu River. The snowline altitude near Tongmei is 4,300 m; it increases northward to 5,100 m to the north slope of the Nyainqentanglha. Near the ridge of the Nyainqentanglha Mountains, the snowline on the north slope is 300 m higher than that on the south slope. This difference indicates that the ridge makes an important climatic boundary.

c) Recent glacier fluctuation

The glacier fluctuation here has been observed in the last 20 years or so. During the 1989 expedition, we observed Zepu and Kaqin Glaciers. Based on the observation of new moraines left at the terminus of Kaqin Glacier, retreat is obvious. Since the terminus of Zepu Glacier reaches into the forest, it was difficult to see the fluctuation of the terminus. On the surface of Zepu Glacier, there was much vegetation when we observed the glacier in 1989. But there was no vegetation in the 1970s according to Li Jijun (personal communication). This suggests that the glacier is retreating or stable, allowing the stabilization of surface moraines and growth of vegetation. Much evidence including air-photo interpretation indicates that these two glaciers are retreating.

d) Glacier ogive

In expeditions during the 1970s, glacial ogives were found on Azha, Table, Ruoguo, Kajia and Zepu Glaciers. During the 1989 expedition, we mainly concentrated ogive study on Zepu Glacier. The ogives of Zepu Glacier are developed below the icefall. Ogives were separated by white and black colors. During the 1989 expedition, we did some field work to reconstruct the fluctuation history of ice flow velocity. On Zepu Glacier, there are at least 3 sets of ogives which formed below the icefalls of three branch glaciers; two of them were measured. The basis for reconstructing the annual velocity of a glacier is that the width of an ogive band represents one year's movement. Fig. 8 shows the results. The first set of ogive measurements includes 15 years' annual movements (1975-1989); the annual movements fluctuate between 77 m and 189 m with an average of 119 m. The second set includes 12 years' annual movements (1978-1989) which fluctuate between 90 m and 182 m with an average of 125 m. The annual velocities from both of these two sets showed an obvious decreasing trend (Fig. 8.). This trend coincides with the retreating tendency of the terminus of Zepu Glacier.

4.2. *Studies of Quaternary glaciations*

a) Glacier advances

Based on the studies in "Glaciers in Xizang" (Li *et al.*, 1986), there appeared two glacier advances in the Bomi region of the southeastern Tibet. These two are called "the Guxiang Stage" and "the Baiyu Stage". During the Guxiang Stage, the glaciers in Bodui Zangbu and Yalong Zangbu formed into an united glacial system. At that time, the length of the main glacier was up to 100 km, and the terminus reached to an altitude of 2,600 m a.s.l. During the Baiyu Stage, the glaciers in the Bodui Zangbu and Yalong Zangbu were completely separated. The length of the main glacier was 80km and the terminus reached to an altitude of 2,900 m a.s.l. In the Holocene, there were two glacier advances which can be distinguished from the glacier advance in the Little Ice Age.

b) Glacial evolution since the last glacial maximum

After the last glacial maximum (19,700±300 ~24,390±7,500 B.P.), glaciers began to retreat. Some features during the glacial retreat are: (1) Two glacial retreat stages, the Linqong and the Yuren, can be recognized. (2) After the Linqong glacial retreat stage, many rounded moraines with heights between 40 m and 60 m were formed in the fluvioglacial plain. (3) After the Yuren glacial retreat stage, the main and tributary glaciers were separated and formed many moraines.

The Neoglacial advance of Zepu Glacier is separated into two obvious stages: the Dana and Baitong glacial advances. The former appeared in 3,242±101 B.P., and the latter glacial advance appeared in 1,056±115 B. P. The Little Ice Age maximum appeared in 197±80 B. P.

c) Variation of snowline altitudes since the last glacial maximum

Based on calculations, the snowline altitudes were lower than that at present, 700 m-1,000 m lower in the Last Ice Age, 461 m in the Yuren glacial retreat stage, 157 m-217 m in the Neoglacial Dana glacial advance, 90m in the Baitong glacial advance and 40-100 m in the Little Ice Age.

5. Concluding remarks

At present, data analysis is in process. Stake observations and the self-recording of snow depth on Xiao Dongkemadi Glacier in the Tanggula, and stake observations on Meikuang Glacier in the East Kunlun, are being continued. In 1991-93, new intensive study in the Tanggula is planned as part of the International Hydrological Programme-Phase IV. Although the mass balance of the maritime-type glacier could not be measured in the field work of 1989, it will be estimated from climatological data in that area and other information. The results of further analyses, including the new data, will be published in the near future.

Reference

1. Li J. *et al.* (1986): Glaciers in Xizang. Science Press, Beijing, 328 pp (in Chinese).