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Recent research on glaciers on the Chinghai-Tibet Plateau

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Abstract. Results of recent research on glaciers on the Chinghai-Tibet Plateau are briefly reviewed. Statistical and inventory work have been carried out in two main glacier areas, the Nyenchintangla Range and west Kunlun Shan, as well as in other areas. Development of glaciers on the plateau is greatly influenced by monsoons from the Indian Ocean. Glaciers can be classified as maritime or continental, the former being concentrated in west Szechuan, north Yunnan and southeast Tibet. Research on glacier fluctuations shows that the Little Ice Age was also experienced here with maxima occurring during the nineteenth century. This was followed by a strong retreat from the 1930s with recent signs of the initiation of a new period of glacier advance.

Recherches récentes portant sur certains glaciers du Plateau du Chinghai-Tibet

Résumé. On donne un bref aperçu des résultats qui ont été obtenus lors de récentes recherches portant sur certains glaciers du Plateau du Chinghai-Tibet. Des travaux à caractère statistique et des travaux d'inventaire ont été effectués dans deux des principales régions englacées, à savoir la chaîne de Nyenchintangla et l'ouest du Kunlun Shan, ainsi que dans d'autres régions. Le développement des glaciers du plateau est fortement influencé par les moussons provenant de l'océan Indien. Les glaciers peuvent être classés en glaciers maritimes et continentaux, les premiers étant concentrés dans l'ouest du Szechuan, le nord du Yunnan et le sud-est du Tibet. Des recherches portant sur les fluctuations des glaciers montrent que la région a également connu le 'Little Ice Age' dont l'intensité maximale a eu lieu au cours du dix-neuvième siècle. Cette époque a été suivie d'une période de forte décrue à partir de 1930; récemment, on a observé des signes indiquant le début d'une nouvelle phase de crue des glaciers.

The brilliant oriental civilization bears close relations to the names of the great rivers, the Yellow River, Yangtze, Ganges and Indus. All of them take their sources from the Chinghai-Tibet Plateau, which is known as the roof of the world. They are abundantly nourished by glaciers and perennial snow cladding the stupendous and undulate mountains. Wissmann (1959) calculated that the total glacier area in the Himalayas was 33 250 km^2, while that on the Chinghai-Tibet Plateau was 32 150 km^2. It seems that the two figures are out of keeping with the facts. In the sixties, Chinese glaciologists began to make observations on some glaciers on the plateau and to engage in statistical and inventory work.

According to the data we obtained, the existing glaciers on the plateau, except those in the Himalayas, have developed mainly in the Nyenchintangla Range and Pome Nan Shan near the big bend of the Yalu Tsangpo River in the southeast of Tibet and in west Kunlun Shan in the upper reaches of the Kelakeshih and Yulungkeshih rivers.

From the south of Namu Lake in the Nyenchintangla Range eastwards to Pome, there are 2752 glaciers with a total area of 4880 km^2 (Fig. 1). The glaciers to the east of Pome have not been calculated yet. The chief peak at the eastern end of Pome Nan Shan is as high as 6800 m. The famous Aza Glacier develops there and its terminus is at an elevation of 2400 m, the lowest in Tibet. The mean annual air temperature there reaches 10°C or so. In the thirties, Ward (1934) reported that the glacier was about 10 miles long, In fact, the Aza Glacier is no shorter than 20 km. The southeast facing Kachin Glacier lying to the north of Yigron Lake is 35 km long and has an area of 172 km^2. Its ice tongue ends at an elevation of 2530 m. It is the longest glacier in Tibet. In addition, there are also some big glaciers as long as 20 km.

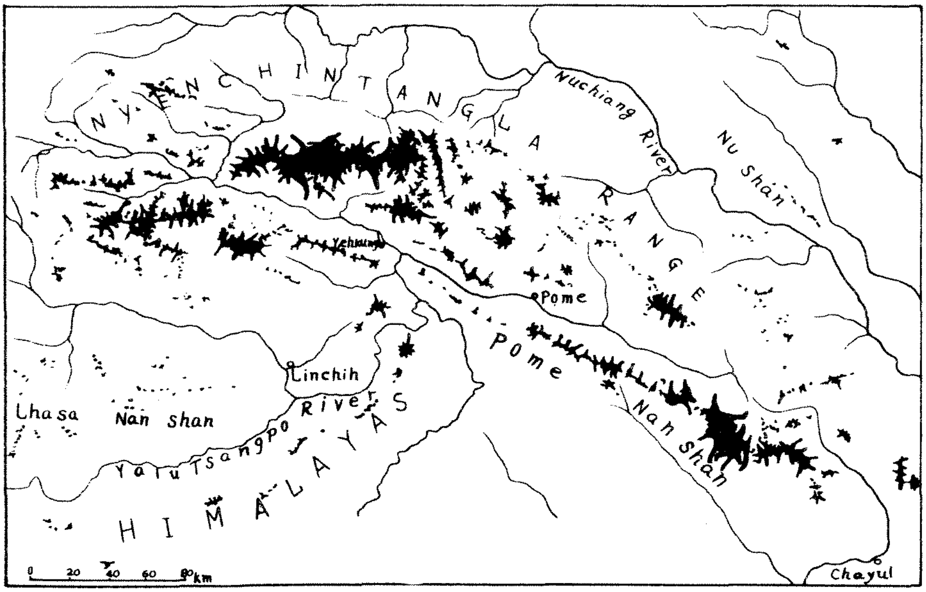

FIGURE 1. Sketch maps of distribution of glaciers in southeastern Tibet.

Another major glacier area on the Chinghai-Tibet Plateau has been formed in west Kunlun Shan which retains a large amount of westerly precipitation. It has been calculated that, to the west of 80°30′E, there are 3180 existing glaciers with a total area of 4331 km². To the east, the glaciers are even larger. Among them, the Yulung Glacier is the largest (Fig. 2), about 29 km long. Their meltwater feeds the Yulungkeshih, Kelakeshih, Keliya Rivers, etc., irrigating the Tarim Basin.

Besides the above-mentioned two major glacier areas, the glaciers scattered in other parts of the plateau are smaller. But the Tangla Range has comparatively more glaciers. The Kelatantunghsueh Shan, one of the chief peaks in the western section, has glaciers with a total area of 750 km². It is the main source of the Yangtze. The Peichiahsueh

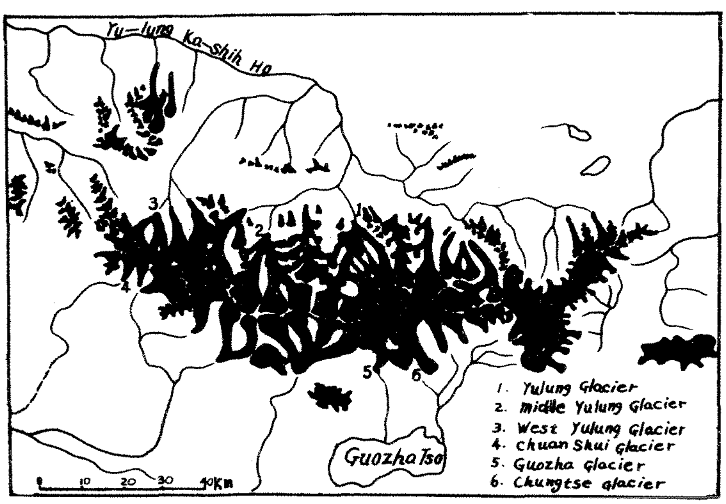

FIGURE 2. Sketch map of distribution of glaciers in west Kunlun Shan.

Shan, the chief peak in the eastern section, has glaciers with a total area of 183 km^2. But the longest glaciers in the two regions are only 10 km or so, much shorter than those in the Nyenchintangla Range and west Kunlun Shan.

Besides those we have reported on Mt Jolmo Lungma and near Mt Shisha Pangma in the Himalayas inside our territory, the Menpajih Glacier is known to be the biggest on the northern slope of Mt Kamet in the western section. It is 15 km long and has an area of about 130 km^2. The Poaputso Glacier on Mt Paohanli near Yatung is 9 km long. There are glaciers of over 10 km in length on the northern slope of Mt Namcha Barwa at the easternmost end. Because of steep slopes there, ice falls and avalanches occur frequently, forming reconstructed glaciers.

Kalesnik said that there was a glacier area of 7300 km^2 in the Gangdise Range and 6210 km^2 in Hengtuan Shan. Though at present we cannot provide exact figures in these mountainous regions, his figures are apparently exaggerated. Table 1 shows some data for the glaciers on the Chinghai-Tibet Plateau.

The development of the glaciers on the plateau is greatly influenced by the precipitation brought by monsoons from the Indian Ocean. Meteorological data indicate that the Bay of Bengal serves as the main source of water vapour for the plateau. The rainy season on the plateau as a whole begins first at Chayul and Pome in the southeast of the plateau. A great deal of precipitation keeps coming from March till the end of September or the beginning of October. Westward from here, the rainy season comes later and later, but it ends earlier. In fact, the rainy season of the Ali region in the west of Tibet lasts only two months (July and August). The annual precipitation decreases correspondingly from about 1000 mm in the valley (3000 mm can be attained at the elevation near the snow line in the southeastern part) to less than 50 mm in the farthest northwestern corner with desertlike scenery. All this shows that the Himalayas serve as a barrier for monsoons from the Indian Ocean. The water vapour from the Bay of Bengal enters the plateau mainly through the Yalu Tsangpo River valley and spreads westward gradually (Table 2).

There exist two types of glaciers on the Chinghai-Tibet Plateau: maritime and continental glaciers. The maritime glacier according to our criteria is, in general, similar to the temperate glacier described by Ahlmann. It means, in particular, that the ice temperature below its active layer is always at the pressure melting point all the year round. The difference is that the maritime glaciers in our country are formed under the influence of a monsoon climate. Precipitation mainly comes in the warm seasons. Somewhat higher temperature and heavy rain in summer make the glaciers soaked by water throughout. The bottoms of crevasses from the ice tongue up to the col on the back wall of the firn basin, are all filled with water. Therefore, the temperate infiltration zone occupies the whole accumulation area. But in winter, the entire plateau is under the control of westerly currents, resulting in low air temperature and little snowfall. And so, ice veins and depth hoar appear very extensively on the maritime glaciers in our country, and occasional superimposed ice can be seen on steep slopes.

According to recent observations, we think that west Szechuan, north Yunnan and southeast Tibet are places where maritime glaciers are distributed. Let us draw a line between Piju County and Tingchin County and lengthen it through Chiali and Kungpochiangda up to Tsomei. To the west of the line, the climate has become very dry. The snow line ascends rapidly. The glaciers there undergo a transition from maritime to continental.

We have also begun research on the fluctuations of glaciers on the Chinghai-Tibet Plateau. Our analysis of annual tree rings tells us that air temperature on the plateau began falling during the second half of the sixteenth century, and thus, the plateau experienced the Little Ice Age like other parts of the world. Up till now, the temperature has not reached the level before the Little Ice Age.

TABLE 1. Data of the glaciers on the Chinghai-Tibet Plateau (incomplete)

Region	Hanging glaciers		Cirque glaciers		Cirque-hanging glaciers		Cirque-valley glaciers		Valley glaciers		Ice caps		Total	
	No.	Area [km^2]	No.	Area [km^2]	No.	Area [km^2]	No.	Area [km^2]	No.	Area [km^2]	No.	Area [km^2]	No.	Area [km^2]
West Kunlun Shan (west of 80° 30′ E)	2430	1440.8	119	266.5					619	2592.8	12	30.90	3180	4331
Gangdise Range (p. Kangrenpuchi)	148	29.7	39	29.3			19	26.7	1	0.7	1	2.4	208	88.8
Nyenchintangla Range (west of Pome)	1467	493.2	794	1586.1	157	140	110	517.2	220	2101.6	4	41.9	2752	4880
Lhasa Nan Shan	186	61.5	55	87.7			1	4.2	6	7.9			248	161.3

TABLE 2. Precipitation data according to season

Meteorological station	Annual Precipitation [mm]	Spring (April-May) [%]	Summer (June-Sept.) [%]	Autumn (Oct.-Nov.) [%]	Winter (Dec.-March) [%]
Chayul	767	23	50	7	20
Pome	936	22	56	10	12
Shigatse	439	3	96	1	0
Gar	60	3	83	2	12

According to the lichenometry method (*Rhizocarpon geographicum* (L) DC.), we learned that some glaciers near Yatung in the Himalayas attained their maximum in 1818, 1871 and 1885 respectively. The growth of trees on the late moraines of the Aza Glacier shows that the glacier advanced to its maximum extent at the beginning of this century. Our on-the-spot investigations, documental records and information from local residents all tell us that, beginning in the thirties, the glaciers in Tibet underwent a period of strong retreating. The air temperature began to fall after the fifties. From meteorological records, we know that the temperature in the sixties was universally 0.7°C or so lower than in the fifties, but the precipitation increased by 5-27 per cent.

Some highland lakes, like the Yangchoyung Lake, rose in the sixties and flooded the highways built in the fifties. On the whole most of the glaciers in Kunlun Shan have been advancing since the sixties. At present, the glaciers in the Nyenchintangla Range are still retreating. But, there are signs of a new advance in this retreat. For example, the ice tongue of the famous Aza Glacier retreated 195 m from 1973 to 1976. But we discovered that the middle section of the glacier had swelled obviously. The ice volume of 1976 was much larger than that of 1973. It seems to us that a kinematic wave is transmitting downwards, resulting in an advance of the glacier snout in the near future.

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DISCUSSION (on the three Chinese papers together)

Vohra:
You have mentioned the use of lichenometry. Please tell me whether growth rate curves were obtained for these areas and, if so, what method was used for this purpose?

Li Chi-chun:
A mud flow occurred in 1940 which left a lot of lichen-free boulders in the valley. Map lichen (*Rhizocarpon geographicum*) grew on the surface of these boulders and from measurements we made in 1975 we obtained the growth rate. Using this growth rate we calculated the ages of moraines formed during the Little Ice Age. This method is valid because the growth rate of lichens is still constant within a period of three hundred years.

Meier:
Which mountain ranges in China contain surging glaciers?

Shih Ya-feng:
Up to now, we have only found surging glaciers in western Kunlun and the Karakoram.

Vivian:
Did you register catastrophic events in China resulting from the leakage of ice-dammed lakes?

Shih Ya-feng:
On the northern slope of the Karakoram, in the upper reach of the Yarkand River,

several glaciers extended to the valley of the Yarkand and dammed the river. In the 1950s and 1960s they caused catastrophic floods twice. The flood peaks amounted to 5000 to 6000 m^3/s.

Aellen:
You pointed out the white colour of one of the glaciers shown in the pictures and you gave us some figures showing the existence of cold ice in some of your glaciers. Is there a connection between the low ice temperatures and the white colour of the ice? The same question also goes to Higuchi and Müller with respect to the white ice on the Khumbu Glacier.

Shih Ya-feng:
I do not think that there is connection between the low ice temperature and the white colour of the ice. For example, in the lower reach of Rongbuk Glacier which is debris-covered the ice temperature at 10 m depth is -2.1°C (May, 1966).

Higuchi:
We measured ice temperature in the upper part of the ablation area of the Khumbu Glacier and found that the temperature was below 0°C.

Aellen:
Until recently it was believed that all alpine glaciers were temperate in the ablation area but a few years ago cold ice was observed at the tongue of Gornergletscher near Zermatt. The cold part of Gornergletscher is very well distinguished by the white colour of its ice. White ice is present in the tongues of other alpine glaciers as well.

Müller:
Many glaciers in the eastern Himalayas have portions of the suspiciously white ice which Aellen refers to as indicative of cold ice. The Khumbu Glacier, for example, contains such ice. However, at this point it is impossible to say if all of the markedly white ice on Himalayan glaciers has a temperature below the pressure melting point.

Barry:
How was your map of snow line altitude in China prepared?

Shih Ya-feng:
We used direct glaciological observations and air photographs as our main sources as well as the interpretation of topographic maps and the analysis of records of travellers, geographers, etc.

Higuchi:
You said that 37 per cent of the heat used by melting was supplied by condensation of water vapour on the ice surface. How did you estimate this?

Shih Ya-feng:
We have made direct measurements of radiation and micrometeorological elements on a number of glaciers for periods of 1-2 months. The actual figure of 37 per cent refers to the sum of heat supplied by condensation and sensible heat flux which was measured on the Kouhsiang Glacier in July and August 1965.

Corte:
I have observed that ice pyramids are formed in those areas which are characterized by a strong continental climate with strong evaporation and sublimation of ice. We

call these features penitents. Areas like the Andes with penitents and pyramids are characterized by the large developments of debris-covered glaciers. Do you have debris-covered glaciers in your country?

Shih Ya-feng:
The kind of ice pyramids which I talked about are much bigger than your névé penitents and they have a much longer lifetime (50-100 years). We have studied the genesis of these features and I would like to refer your attention to our paper in *Scientia Sinica* (vol. 18, 1975) for more details. We certainly do have debris-cover on the tongue areas of many glaciers but this is below the reach where the pyramids are formed.