Bulletin of Glacier Research 7 (1989) 49–58.

Conditions of glacier development and some glacial features in the West Kunlun Mountains

ZHANG Wenjing, AN Ruizhen, YANG Huian and JIAO Keqing
Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, China.

(Received December 5, 1988; Revised manuscript received January 18, 1989)

Abstract

The north slope of West Kunlun Mountains is quite steep, downward cutting is heavy and valleys are deep. These features show that the north slope is in a mature stage of geomorphologic evolution whereas the relief on the south slope of the mountains is relatively flat. Characteristic glacier types in this region are widespread ice caps (flat–top glaciers), slope glaciers and outlet valley glaciers, called plateau glaciers, which lie mainly on the south slope.

The annual mean air temperature around the glacier equilibrium line altitude (5930m) on the south slope is very low, about −14°C. The mass exchange is rather lower in this region. The main accumulation period is from May to September mainly due to the Tashkent cyclones. All precipitation is in a solid state. Much coldness stored in glaciers during winter refreezes infiltrated melt water in summer.

There are 4579 glaciers 7997km^2 in area and 920km^3 in water volume in the West Kunlun Mts. The glacier area in this region occupies 14% of that in whole China, and mainly belongs to Tarim inland river system. Guliya Ice Cap in the West Kunlun Mts., with an area of 119.3km^2 is the biggest ice cap in China. Results of geochemical analyses for trace elements in ice, snow and water and glacio–ecological observations in the West Kunlun region are also reported.

1. Introduction

The earliest report about glaciers in the West Kunlun Mountains can be traced back more than half a century (Stein, 1912; Sobolevski, 1919; Hedin, 1922; Trinkler, 1930). But, those are only simple geographical descriptions during journeys. Huang Jiqing, the famous Chinese geographer, also wrote about the glaciers in this region in the early 1940s (Huang, 1941). Since the mid–1970s, some general characteristics of modern glaciers in this region have been investigated by the Qingzang Plateau Integrated Expedition Team, Academia Sinica (Li *et al*., 1986). During that period, some ideas about the glacier development conditions were presented by Ren (1987). In 1985 and 1987, Sino–Japanese Joint Expeditions systematically studied the glaciers using temporary stations. Meantime, a glacier inventory of this region was done. This paper attempts a comprehensive review of the formation, amount, distribution and type of glaciers and some of their glacial property in the West Kunlun Mts. based on the results of the above expeditions.

2. Natural conditions of glacier development

2.1. Geological and geomorphological conditions

The geological and geomorphological circumstances are fundamental for the development of glaciers, especially at middle and lower latitudes.

The West Kunlun Mts. are situated in the northwestrn part of Qinghai–Xizang Plateau between Xinjiang and Xizang. They belong to the Hercynian foldbelt in geotectonics. The tectofacies mainly comprise the syncline foldbelt of the northern Kunlun Mts., the crystalline rock of the middle Kunlun Mts. and the syncline foldbelt of the southern Kunlun Mts. The whole mountain protrude southward archwise with the main peak—— Mt. Kunlun (7167m)—— as an inflexion.

The West Kunlun Mts. have been folded since the Paleozoic era, and gone through many upheavals, abrasion and various other tectonic movements, and became hilly land only 1000m a.s.l. in the late Tertiary period. From the end of the Tertiary period to the early Quaternary, the West Kunlun Mts. uprose in echelon fault blocks from north to south along with the upheaval of the whole Qinghai−Xizang Plateau; at last three ranges of parallel big mountains which we see nowadays were formed. The West Kunlun Mts., belong to both the peripheral mountains of the Qinghai−Xizang Plateau and the south screen of the Tarim basin from a geomorphologic viewpoint. So the north slope and south slope evolved different land forms (Fig. 1).

The south slope is relatively flat and wide, connected with the vast north Tibet Plateau; the maximum height difference between the mountain top and the foothills is less than 2000m, the mean height difference being 1300m. It is a very old geological and geomorphological body which can be seen in basal rock faces and morphological appearance. On the north slopes, the maximum height difference is 5000m, the mean height difference is about 3000−4000m, the slopes are relatively steep, the dissection is vehement and the valleys are very deep. These conditions show that the north slopes are in a mature stage of geomorphological evolution. The main range of the West Kunlun Mts. is colossal and lofty, and the mountain ridges are above 6000m. The mountains are not only great but also flat. For instance, around the conjunction of the Yurunkax River and Karakax River, the highest peak is 6802m a.s.l.. In the watershed region between the Yurunkax River and the Tibet Plateau, the mountains are especially high; the ridges are broad and flat. A large erosion surface about 6400m a.s.l. remains. One of the lofty peaks towering over the erosion surface is the highest peak of the West Kunlun Mts., Mt. Kunlun.

The high mountain massif, archform strike, flat and broad mountain ridges, and well preserved erosion surface are advantageous for catching water vapor and the consequent development of large glaciers. Alpine−type glaciers are usually developed on the north slope where the lands are severely cut and highly shadowed, whereas the ice caps (flat−top glaciers), slope glaciers and outlet valley glaciers are mainly developed on the south slope due to the different topographical conditions from the north slope.

2.2. Climatic conditions

Glacier development is determined by the amounts of solid precipitation and cold storage. Since this region has a typical continental climate, snowfall is relatively small and large cold reserves can be stored during winter against summer ablation. Such conditions are different from those of maritime−type glaciers.

The regions surrounding the West Kunlun Mts., have arid or semi−arid climates. It is well known that the landscape at the foot of the north slope is that of

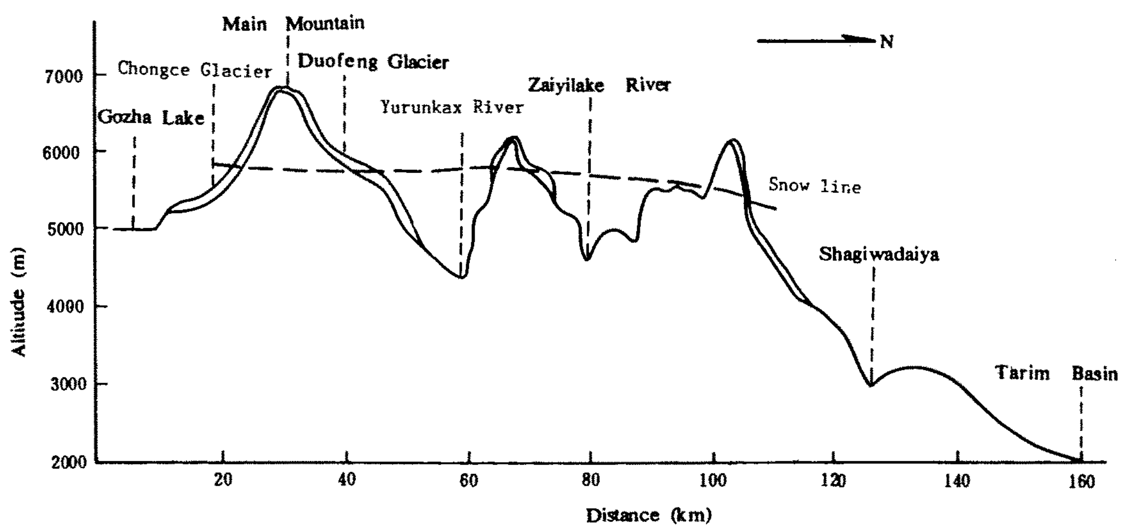

Fig. 1. Topographical profile and snow line of the Kunlun Mountains through south Hotan.

an inland arid desert region, whereas the area between 4900–5800m a.s.l. on the south slope is covered by high mountain–high plateau cold desert savanna and a periglacial belt. The flora are relatively simple, consisting entirely of herbaceous and graminaceous plants. Such flora are different from those on the maritime-type glaciers in China (Zhang, 1988), and are different from those in the adjacent Karakorum Mts.

The 0°C isoline of air temperature is about 3800m a.s.l. according to aerial data. The mean annual air temperatures at Kangxiwar (3986.4m) and Tianshuihai (4900m) on the south slope are respectively −0.6°C and −6.3°C. The temperature lapse rate between them is −0.62°C/100m. According to short term observations in 1987, at the Base Camp (5260m) on the south slope, the mean air temperature in July is 2.4°C, in August 2.6°C. From the above lapse rate and the temperature at Base Camp, the air temperature around the equilibrium line (5930m) during 1985–1987 on the Chongce Ice Cap in July was −1.8°C and in August −1.6°C. Using the Kangxiwar data and the above lapse rate, it can be calculated that the annual mean air temperature is about −13°C at the equilibrium line. The horizontal temperature difference between non–glacial regions and the glacier, is at least 1°C, the annual mean air temperature being lower than −14°C around the equilibrium line. The air temperature in this region is not only much lower than that on a maritime–type glacier, but also lower than that on other ordinary continental–type glaciers, for example on the north slope of Mt. Qomolangma (Xie and Su, 1975) and on Qilian Shan (Huang *et al.*, 1985).

Table 1. Precipitation and it's summer percentage around the West Kunlun Mts.

Station	Annual precipitation (mm)	Precipitation during May-Sept.(mm)	Percentage in annual total
Lur River	123.7	88.2	71%
Heshan	153.9	112.3	73%
Tashkurgan	68.2	51.3	75%
Kangxiwar	37.5	29.8	79%
Tianshuihai	20.6	14.1	68%
Shiquan River	77.5	68.5	88%

The monsoon air flux from the Indian Ocean and the Pacific Ocean as well as the cold–wet air flux from the Arctic Ocean cannot reach the West Kunlun Mts. Precipitation in this region is mainly brought by the west wind. A depression center forms above the western part of the high plateau while the westerly wind approaches the plateau and is impeded by it. It appears as a trough in Pakistan during winter, and the Tashkent cyclone during summer caused by the northward migration of the westerlies. On the 500mb isobaric field, the circulation shows the following characteristics: the warm season from June to August is usually dominated by trough activity; frequency and intensity of depression systems differ from month to month. For instance, there were 6 cyclones in July 1987. The precipitation at Base Camp was 75.2mm. There were 4 cyclones in August, with precipitation of only 16.0mm.

In winter the Pakistan trough which initiates weather processes on the western Tibetan Plateau usually runs across above 30°N (Ye *et al.*, 1979), so it doesn't play the main role in the West Kunlun Mts. In fact, the Tashkent cyclone which prevails in summer is the chief factor influencing precipitation in the region. This is well demonstrated by the seasonal distribution of precipitation (Table 1). Because of the

Table 2. Comparison of precipitation near snow line in main glacier regions of China.

Region	Snow line (m)	Precipitation (mm)	Data from
Henduan Mts.	4800–5200	1500–2000	Su Zhen, Wang Lilong
Namjagbarwa Mt.	4400–4800	1500–2500	Zhang Wenjing
Amnimarqing Mts.	4950	700–900	Jiao Keqing
Lenlong Range, Qilian Mts.	4409	700	Ding Liangfu
Daxue Range, Qilian Mts.	4675	300	Ding Liangfu
Bogda Peak, Tianshan Mts.	3900	600	Zhang Wenjing
Tomur Peak, Tianshan Mts.	4600	800–1500	Wang Lilong, Zhang Wenjing
Altai Mts.	2850–3350	600–1000	Wang Lilong
Karakorum	5000–5200	500–600	He Yuanqing
North slope of Qomolangma Peak	5800–6200	500–800	Xie Zichu, Su Zhen
Chongce Ice Cap	5920	250–350	Zhang Wenjing

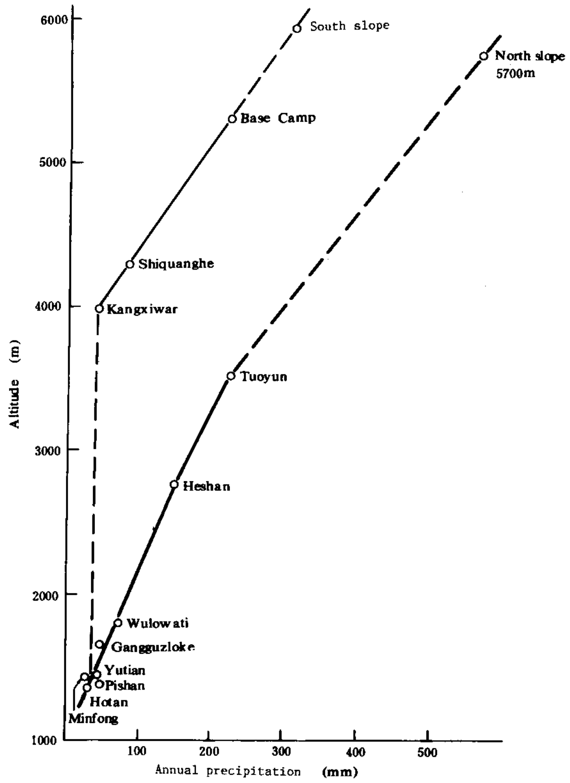

Fig. 2. Precipitation distribution in the West Kunlun Mts.

impediment and upheaval effect of the Karakorum and the Pamir Plateau, the height of the westerly current running over the West Kunlun Mts. is elevated, and the vapor content decreases accordingly. As a result, the precipitation is much less than that in many other glacier regions in China (Table 2).

Precipitation in the high mountain area is remarkably different from that in the lower/middle mountain area and piedmont areas. Fig. 2 shows clearly that precipitation on both the piedmont plain on the north slope and the interalpine basins on the south slope is under 40mm, whereas the precipitation in the 1800–3000m a.s.l. zone on the north slope amounts to 100–200mm, and that at 5700m a.s.l. is 571mm (Li *et al.*, 1986). The annual precipitation at 3986m a.s.l. (Kangxiwar station) is 37.5mm, and at Shiquanhe (4278m) it is 77.5mm. A notable increase of precipitation appears at Base Camp (5260m) in the Gozha Lake basin according to field observation. Observed precipitation from June 23 to August 31, 1987 was as great as 102.5mm. On the basis of ratios of observed precipitation during short periods between stations at different altitudes, much more precipitation at high altitudes is estimated, as shown in Fig. 2.

The precipitation in the West Kunlun Mts. glacier region is all snowfall according to observations during the warmest months (July and August). Some glacier nourishment comes from local precipitation supplied by evaporation of inland lakes on the south slope (Ren, 1987) and in the Tarim Basin (Wang and Han, 1984).

Based on the above analyses, it can be concluded that the West Kunlun Mts. have typical continental–type glacier formation conditions. That is, the local topography catches insufficient water vapor as solid precipitation and abundant coldness of glaciers from winter refreezes infiltrated melt water in summer. Thus, glacial area in the West Kunlun Mts. is fully developed.

3. Amount and distribution of existing glaciers

3.1. Glacier amount

Numbers, areas and volumes of glaciers are the most direct effective index for evaluation of glaciation and also the scientific foundation for rational exploitation of glacial water resources and correct assessment of the bearing capability of water resources in the ecological environment. Since the 1970s, glaciers in the West Kunlun Mts. have been counted three times. The first count (from the Yarkant River eastward to 80°30'E) yielded 3180 glaciers, totaling 4311km² in area (Xie *et al.*, 1982). The second (from the Yarkant River eastward to 83°30'E) yielded 4306 glaciers, totaling 8438.24km² in area (Li and Zheng, 1986). The figures in this paper were obtained according to international glacier inventory instructions formulated by the Temporary Technical Secretariat (TTS) under the International Commission of Snow and Ice (ICSI). It covers the area from the source (6270m at the peak) of Turisu Glacier (77°29'E) to the east boundary of Niya River basin (83°31'E). In the basins of Aksayqin Lake and Gozha Lake, only glaciers originating from the south slope of the main mountains are counted (Fig. 3). There are 4579 glaciers, with total area of 7996.96km² and the volume of 920.3157km³ in water equivalent (Table 3).

Among them 4262 glaciers belong to the Tarim inland river system, with total area of 6502.44km² and water volume of 669.1817km³; 317 glaciers drain to the northern Tibet Plateau inland river system, with area of 1494.52km² and water volume of 251.1340km³. Glacier area in the West Kunlun Mts. occupies 68.7%

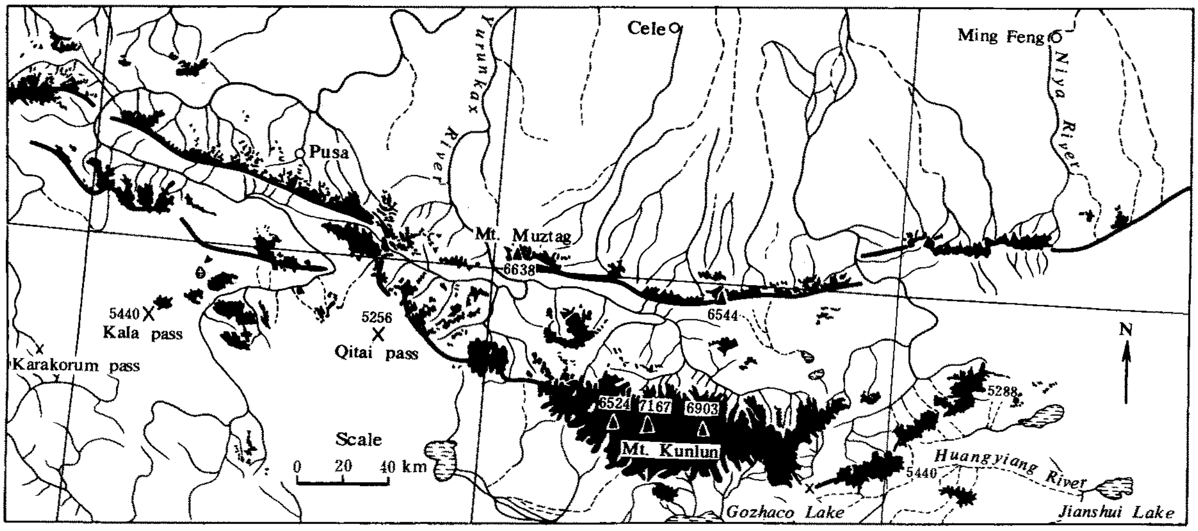

Fig. 3. Distribution of glaciers in the West Kunlun Mts.

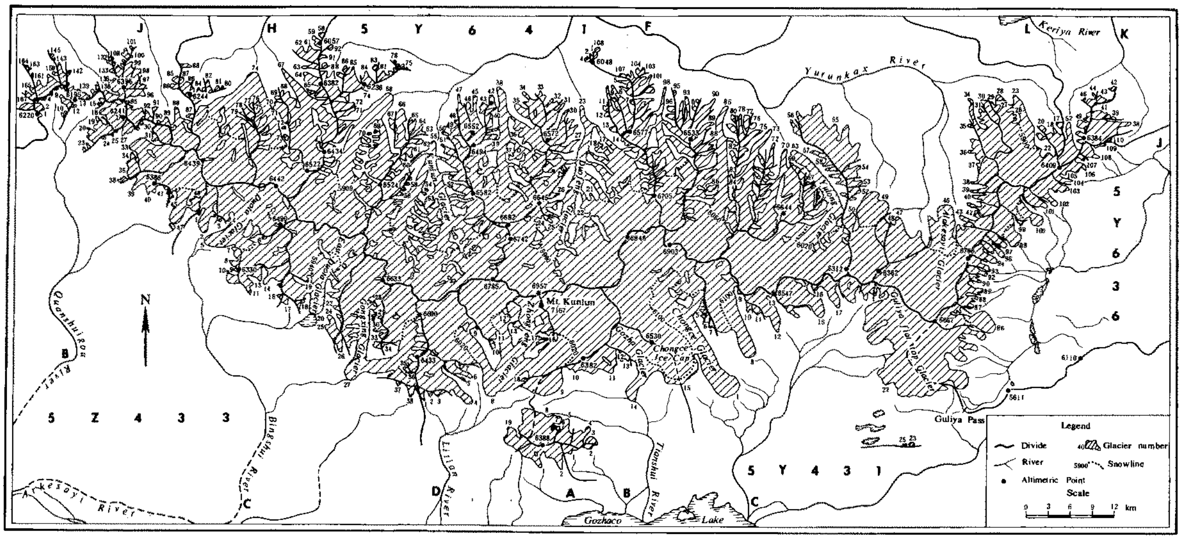

Fig. 4. Glacier distribution around Mt. Kunlun in the West Kunlun Mts.

of that of the Kunlun Mts. (11639km^2, Mi *et al.*, personal communication), and 14.2% of the total glacier area of China (56128km^2). Thus one can see that the existing glaciers in the West Kunlun Mts. occupy an important position in the glacial water resources in China.

3.2. Glacier distribution

The glaciers which belong to the Tarim inland river system have number, area and volume 13.4 times, 4.4 times and 2.7 times those in the northern Tibetan Plateau inland river system, respectively.

It can be seen also in Table 3 that the Hotan River basin and its secondary tributary the Yurunkax River have the most glaciers in the West Kunlun region. In the northern Tibetan Plateau inland river system, Aksayqin Lake has the biggest number on the south slope of the West Kunlun Mts., but it is small in comparison to that along the Yurunkax River.

In the West Kunlun Mts., all the large glaciers concentrate on the sides of the main peaks in the middle part of the mountains (Fig. 4). The relationship between glacier length and upper limit is shown in Fig. 5. From Fig. 5, glaciers 3–8km long and those longer

Table 3. Glacier inventory of the West Kunlun Mts. (77° 29'E−83°˙30'E).

River System	Basins	Rivers	Serial Number	Number of Glaciers	Area of Glaciers (km^2)	Water Volume of Glaciers (km^2)	Mean Area of Glaciers (km^2)	Snow line (m)	Glacier End		Largest Glacier				
									maximum (m)	Minimum (m)	Area (km^2)	Length (km)	Height Difference from E. L. A. (m) +	−	Serial Number
Tarim	Keria	Niya River	5Y635	60	73.06	4.2239	1.22	5520−5040	5760	4720	6.50	6.0	868	480	5Y635E27
Inland	River	Keria River	5Y636	430	760.59	63.3853	1.77	6060−5260	6330	4480	39.69	10.6	363	300	5Y636J69
River	and	Cele River	5Y637	217	331.81	22.8589	1.53	5560−4620	6000	4020	14.50	7.1	1164	480	5Y637A29
System	Others	total		707	1165.46	90.4681	1.51	6060−4620	6330	4020	39.69	10.6	363	300	5Y636J69
		Yurunkax River	5Y641	1331	2958.31	410.3246	2.22	6260−4820	6200	4400	251.70	31.0	997	1370	5Y641G23
		Karakax River (middle-lower reach, right side)	5Y642	702	1042.69	81.3867	1.49	6080−5040	6240	4200	39.76	13.3	1102	600	5Y642O37
	Hotan	Karakax River (upstream)	5Y643	427	438.98	27.2562	1.03	6020−5640	6240	5110	22.48	8.0	600	280	5Y643H38
		Karakax River (middle-lower reach, left side)	5Y644	858	681.50	47.4519	0.79	5740−5300	5980	4560	31.92	12.9	1056	540	5Y644J11
	Basin	Duwa River−Tasihong River	5Y645	237	215.50	12.2942	0.91	5500−4780	5600	3960	13.46	8.7	1028	860	5Y645C40
		total		3555	5336.98	578.7136	1.50	6260−4780	6240	3960	251.70	31.0	997	1370	5Y641G23
	Total			4262	6502.44	669.1817	1.51	6260−4620	6330	3960	251.70	31.0	997	1370	5Y641G23
North		Rivers north of Aksayqin River	5Z433A	8	17.87	1.4821	2.23	6070−6080	6000	5540	8.97	6.5	388	500	5Z433A8
Tibet	Aksayqin	Quanshui River	5Z433B	48	86.25	8.8791	1.80	5700−5935	6080	5440	30.64	10.8	526	310	5Z433B47
Inland		Binshui River	5Z433C	38	322.74	58.3493	8.49	5875−5960	6120	5360	113.80	20.5	781	580	5Z433C27
River	Lake	Litian River	5Z433D	22	277.74	67.4239	12.62	5910−5965	6240	5400	241.00	23.4	992	565	5Z433D8
System		Kushui Lake	5Z433K	20	4.37	0.1194	0.22		6080	5580	1.39	2.1			5Z433K10
	Basin	total		136	708.97	136.2538	5.07	6080−5700	6240	5360	241.00	23.4	992	565	5Z433D8
	Gozha	Rivers north of Gozha Lake	5Z431A	2	10.45	0.7945	5.23	5920−5820	5590	5520	5.37	4.8			5Z431A1
		Tianshui River	5Z431B	15	108.40	12.0471	7.23	6120−5860	6020	5390	33.47	13.1	610	530	5Z431B14
	Lake	Chongce Glacier River	5Z431C	30	413.28	78.8492	13.78		6090	5320	163.06	28.7	783	800	5Z431C1
		Duocha River	5Z431F	12	10.45	0.4822	0.87		5920	5600	2.02	1.6			5Z431F2
	Basin	total		59	542.58	92.1730	6.78	6120−5820	6090	5320	163.06	28.7	783	800	5Z431C1
	Jianshui	Huanyang Valley	5Z523C	28	114.62	13.2196	4.09	5910−5640	5800	5440	44.30	7.3			5Z523C28
		Heishibei Lake	5Z523D	58	110.67	8.8718	1.91	6060−5850	6070	5270	20.95	9.0	940	450	5Z523D35
	Lake	Wuming Lake	5Z523E	18	10.09	0.3809	0.56		6020	5540	1.92	2.7			5Z523E4
		Xiaokule	5Z523F	18	7.59	0.2349	0.42		6020	5300	1.17	1.7			5Z523F12
	Basin	total		122	242.97	22.7072	1.75	5640−6060	6070	5270	44.30	7.3			5Z523C28
	Total			317	1494.52	251.1340	4.53	6120−5640	6240	5270	241.00	23.4	992	565	5Z433D8
Total				4579	7996.96	920.3157	3.02	6260−4620	6330	3960	251.70	31	997	1370	5Y641G23

than 10km usually have the upper limits of 6000−6500m and 6400−7000m, respectively.

The orientations of glaciers also show clear patterns in glacier number, area and volume (Fig. 6). The glaciers facing north (including northwest, north and northeast) occupy 74.5%, 71.6% and 67.5% of the total glacier number, area and volume, respectively. This shows the predominance of glaciers on the north slope of the main range. The numbers of north−westward and north−eastward glaciers are 43.2% and 45.5% of the total northward glaciers, respectively. The proportion of area and volume of north−westward glaciers decreased, 34.2% and 24.3% of the totals of northward glaciers, respectively. Area and volume of north−eastward glaciers were respectively 52.9% and 63.1% of the totals for northward glaciers. The special orientational patterns of north−eastward and north−westward glaciers reflect the "工" shape development of the landforms in the West Kunlun Mts.

Table 4 shows that there are 38 glaciers longer than 10km in the West Kunlun Mts. Of them 27 belong to the Tarim inland river system, with total area of 1722.06km^2 and volume of 343.4434km^3, occupying 71%, 64% and 63% of the total number, area and volume of glaciers longer than 10km, respectively.

4. Some glacial characteristics

4.1. Morphological types of glaciers

The West Kunlun Mts. are a peripheral mountain range along the northwestern edge of the Tibetan Plateau. The intricacies of their geomorphological circumstances result in diversity of morphological types of existing glaciers. There are not only common

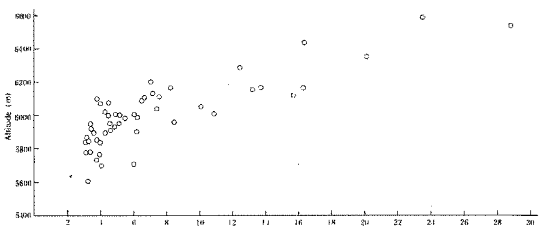

Fig. 5. Relationship between glacial length (>3km) and highest limit on the south slope of West Kunlun Mts.

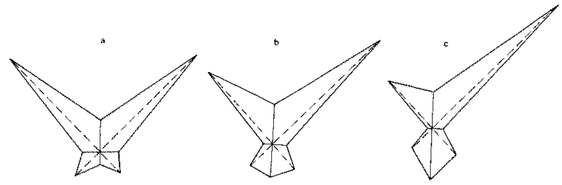

Fig. 6. Orientation of glaciers in the West Kunlun Mts.
a. Number of glaciers in various directions (%).
b. Area of glaciers in various directions (%).
c. Glacier volumes in various directions (%).

Table 4. Distribution of glaciers longer than 10km.

River System	Number of Glaciers	Area of Glaciers (km^2)	Water Volume of Glaciers (km^3)	Mean Area of Glaciers (km^2)
Hotan River (5y64)	22	1608.11	328.7581	73.10
Keriya River (5y63)	5	113.95	14.6853	22.79
Gozha Lake (5z431)	4	361.91	75.4032	90.48
Aksayqin Lake (5z433)	5	554.84	124.1248	110.97
(5z523)	2	44.15	5.4700	22.08
Total	38	2682.96	548.4414	83.09
Percentage of total number in the West Kunlun Mts.	0.8	32.8	59.0	

glaciers such as valley glaciers, cirque–valley glaciers, cirque glaciers, cirque–hanging glaciers and hanging glaciers, but also the other types of glaciers such as ice caps (flat–top glaciers), slope glaciers and outlet valley glaciers. The former group of glaciers are mainly in the upper reaches of valleys where the landforms are severely cut, the relative height of the mountain massif is great and the valleys are often shaded. Such glaciers are called mountain–type glaciers. The latter group of glaciers can be called plateau–type glaciers; most are situated on the broad and shallow valleys of the plateau surface, at the confluence of mountains and a flat ancient planation surface.

The largest valley glacier in the region is the Duofeng Glacier (5Y641 G23) at the source of the Yurunkax River, 31km long, 251.70km^2 in area. The height of the upper limit is 6757m, the terminus is 4590m, the snow line 5960m. The largest outlet–valley glacier is the Chongce Glacier (5Z431 C8) located on the south slope, 28.7km long, 163.06km^2 in area, the upper limit 6810m, and the tongue extends down to an ancient aqueoglacial fan. The glacier tongue is broad and curved, because of the freedom from valley walls. The largest ice cap is the Guliya Ice Cap (5Z431 C22). It develops on an ancient planation surface, the upper limit 6667m, the terminus 5500m, and total area 119. 33km^2. It is the biggest ice cap in China.

A number of glacier tongues protruded out from the ice cap in various directions. The coverage of firn on the surface of a ice cap and a slope glacier is usually about 80%, becoming 100% in some snowy and cold years. On this type of glacier, the ablation is not strong and the areal difference of ablation on a glacier is little. On valley glaciers and outlet valley glaciers, ice pyramids begin to develop from the snow line. The maximum height of them is 20–30m, much lower than that in Mt. Qomolangma region where the latitude is lower. The lower limit of ice pyramids can usually reach the termini of the glaciers. Sometimes a solitary pyramid can be seen near the terminus. Near the solitary pyramid, there are also occasionally ice mushrooms, surface lakes, ice caves, stalactitic ice and other thermokarst phenomena.

The glaciers in this region are typical clean glaciers nearly free from surface moraine. This means that erosion of rock surface is much weaker than that in Mt. Qomolangma area, the Nianqintangula Mts., Mt. Tomur of the Tianshan Mts., east part of the Qilian Mts. etc.

Table 5. Trace elements in ice, snow and water in the West Kunlun region (ppb, 1×10^{-9} g/g) *

Number	Sample type	Sampling place / Content	Ni	Co	Cu	Pb	Zn	Fe	Mn	Cr	V	Al
1	River water	Base Camp(5260m)	1.04	—	—	212.20	<0.1	3.00	0.13	0.91	—	274.17
2	Broken ice	End of Gozha Gl. (5280m)	0.91	—	6.00	—	14.61	391.04	14.61	—	—	256.04
4	River ice	End of Gozha Gl. (5280m)	0.26	—	10.04	—	82.04	87.65	9.00	—	—	132.65
5	Snowfall	End of Gozha Gl. (5280m)	0.27	—	<0.10	>0.10	2.80	72.27	3.73	—	—	252.53
6	Melting water	End of Chongce Ice Cap(5970m)	0.80	—	—	10.67	<0.13	98.53	3.20	—	—	258.67
7	New snow	Surface in the tongue of Chongce Ice Cap	0.13	—	8.87	—	10.83	74.22	2.74	—	0.88	171.78
8	Season covering snow	On lake surface at the end of Chongce Ice Cap	0.91	—	0.13	11.35	<0.10	176.35	4.30	—	—	370.43
9_{1-8}	Glacier ice	End of Chongce Ice Cap	0.95	<0.1	4.58	74.68	3.78	71.28	12.55	0.99	—	223.67
10	Frozen ice	On lake surface at the end of Chongce Ice Cap	0.13	—	4.43	—	9.65	27.39	6.26	—	—	132.65
12_{+1}	Graupel	Base Camp(5260m)	<0.1	—	4.74	<0.10	3.55	81.32	2.24	0.66	—	230.92
19_{1-4}	Infiltration firn	Middle firn area of Chonge Ice Cap(6200m)	1.15	0.02	6.06	0.15	19.76	72.46	8.81	—	—	111.92
24	Stalactitic ice	Chongce Gl. (5500m)	2.16	—	2.40	0.06	8.10	32.94	3.30	0.30	—	130.26
30	Lake water	North side of Aksayqin Lake	4.75	0.25	0.75	31.00	—	12.52	0.75	15.75	3.64	219.50
31	River water	Litian River near Zhongfeng Gl.	1.88	—	—	51.90	3.60	121.88	12.23	—	—	245.93
32	River water	Qongbinshui River near Gong-xing Gl.	2.52	—	0.06	23.16	0.96	24.30	0.24	—	—	160.73
33	Season covering snow	Shengli Pass	0.30	—	0.75	62.55	5.70	28.73	1.50	0.98	—	304.80
34	River water	Middle of Kekeya River	7.05	—	3.30	423.60	1.58	255.00	9.38	5.33	4.24	808.50

* Analyzed by Panjingyu, Gao Siden and Liyiyu of GueiYiang Inst. of Geochemistry, Academia Sinica.

4.2. Glacio – geochemistry

Snow and ice were sampled separately to analyze trace elements from the middle accumulation area and terminus on Chongce Ice Cap during the expedition in 1987. Meanwhile, melt water, river water, snowfall, graupel and glacier lake water were also collected (Table 5). In all samples the content of Al was highest, varying from 111.92ppb in the accumulation area on the Chongce Ice Cap and 808.50ppb in the middle of the Kekeya River. Second is Fe, which increased toward the end of a glacier or lower reaches of a river. For example, the content in broken ice in the Chongce Ice Cap terminus is 391.04ppb, and 255.00ppb in the water of Kekeya River out of valley. Contents of Pb in samples from rivers, lakes, glacier ice and some seasonal snow deposits are higher. Pb in the midstream Kekeya River is 423.60ppb; it is 212.20ppb in the river near Base Camp on the south slope and 74.68ppb in the ice of the Chongce Ice Cap terminus.

In the Gozha Lake region, the mineral content in glacier ice and ice surface runoff are lower, the mean (29.7mg/l) being a little lower than on Mt. Tomur (32.50mg/l) and Lenglongling Glacier (32.47mg/l); also lower than Nianqintangula Mts. (46.79mg/l) and Mt. Namjagbarwa (103.29–183.88mg/l) (Zhang, 1984). It is thus clear that they are fresh water of high quality. The total hardness is 0.349 in average, so they are soft water. The mean pH is 7.06, so the water is slightly alkaline. Anions are dominated by HCO_3^-, and cations

Table 6. Floral names in the glacier region of the West Kunlun Mts.

Sampling time : 1985.7		Sampler : Zhang W.	Judge : Li B. and others
Sampling Place	Number	Chinese	Latin
On the New Ice Age end moraine of Zhongfeng Gl. (5200—5400m a. s. l.)	001	Hongjintian	Rhodiola
	01	Kunlunfengmaoju	Saussurea depsangensis
	003	Shuqufengmaoju	Saussurea gnaphalodes
	004	Dantouyaju	Ajania scharnhorstii
	006	Dianzhuangtorongcai	Ceratoides compacta
	007	Yuzhuangzhengmao	Shipa subsesiliflova
	008	Huangqi	Astragalus sp.
	011	Xianzhuangzaozhui	Arenarea bryophylla
	016	Zhongyazaoshouhe	Poa litwinowiana
	018	Jilingmao	Potentilla
	019	Zanggaiji	Hedinia tibetica
On the New Ice Age end moraine of Chongce Ice Cap (5750m a. s. l.) (1987. 8.)	1	Xizangbianmangiu	Waldheimia glabra
	2	Jilingmao	Potentilla
	3	Shuqufengmaoju	Saussurea gnaphalodes
	4	Qingwotuercao	Lagotis decumbens
	5	Nepalhuangjin	Corydalis hendersonii
	6	Zongbaotingli	Draba involucrata
	7	Zhongyazaoshouhe	Poa litwinowiana
	8	Kunlunfengmaoju	Saussurea depsangensis
	11	Yiyehuangancai	Youngia tenuitolia
On the New Ice Age lateral moraine of Chongce Gl. (5450m a. s. l.) (1987. 8.)	13	Xianzhuangzaozhui	Arenaria bryophylla
	14	Zhongyazaoshuhe	Poa litwinowiana
	18	Shuqufengmaoju	Saussurea gnaphalodes
	19	Zongbaotinli	Draba involucrata
	20	Jidou	Oxytropes sp.
	22	Xizangbianmangju	Waldhemia glabra
	23	Himalayagaoyuanjai	Christolea himalayensis
	24	Kunlunfengmaoju	Saussurea depsangensis

by Ca^{2+}; the hydrochemical type is double calcium carbonate (Sheng, 1989).

4.3. The glacio-ecological environment

The ecological environment around glaciers is important in glacial classification. The composition and type of pioneer flora communities growing around glaciers, especially on the moraines of Neoglaciation and Little Ice Age (even on surface moraines), are closely connected with the climatic conditions around glaciers. Floral names in the glacier region of the West Kunlun Mts. are shown in Table 6.

The composition and type of flora communities on the Zhongfeng Glacier, Chongce Glacier and Chongce Ice Cap on the south slope of the West Kunlun Mts. are apparently different from those in the maritime-type glacier regions (Zhang, 1988). In southeast Tibet of China, which is a typical maritime-type glacier region, on the end moraine, lateral moraine and even surface moraine which formed during the Neoglaciation and Little Ice Age, the flora communities are mainly composed of Pinaceae, Cupressaceae, Salicaceae and Ericaceae. The Tortula Sinensis-C, Mull-Broth, so-called glacial mice, can be found on the ice surface in the maritime-type glacier region (Zhang, 1981). But, in the West Kunlun Mts., the ecological environment is characterized by Compositare, Cruciferae and Gramineae etc.

References

Hedin, S. (1922): Southern Tibet. Stockholm, Lithographic Institute of the General Staff of the Swedish Academy.

Huang, J. (1941): Glaciers in China. Journal of Literature and History, **1**, 8 (in Chinese).

Huang, M. *et al.* (1985): The temperature conditions of Glacier No. 5 in Yanglong River. Memoirs of Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, 5, (Utilization and variation of glaciers in Qilian Mt.), Beijing, Science Press, 54- (in Chinese).

Li, J. *et al.* (1986): Glaciers of Tibetan Plateau, Beijing, Science Press, 176-193 (in Chinese).

Ren, B. (1987): Several glacier development factors and conditions of its advances and retreats in Kunlun Mts. Proceeding of Second Conference on Glaciology held by Geographical Society of China (selection), People's Press, Gansu Province, 76– (in Chinese).

Sheng, W. (1989): The hydrogeochemical characteristics in the Gozha Lake area of the West Kunlun Mountains. Bulletin of Glacier Research, **7**, 119–122.

Sobolevski, G. (1919): The present and past glaciation of the Western Kunlun. Bulletin of Russian Geographical Society, **54**, 97– (in Russian).

Stein, A. (1912): Ruins of Desert Cathay. London, Macmillan, (2vols.) 546p, 517p.

Trinkler, E. (1930): The ice age of the Tibetan Plateau and in adjacent regions. Geogr. Jour., **75**, 225–.

Wang, Z. and Han, Y. (1984): A preliminary discussion on influence of Tarim Basin upon the glacier development in southern Tian Shan Mountains. Journal of Glaciology and Cryopedology, **6**, 1, 61–70 (in Chinese).

Xie, Z. and Su, Z. (1975): Glacier development conditions, the amounts and distribution in Mt. Chomolangma area. Scientific Research Report in Mt. Chomolangma area, 1966–1968. Modern glaciers and landforms, Beijing, Science Press, 1–13 (in Chinese).

Xie, Z. *et al.* (1982): Distribution, features and variations of glaciers in China. Proceedings of Symposium on Glaciology and Cryopedology held by Geographical Society of China (Glaciology), Beijing, Science Press, 1–13 (in Chinese).

Ye, D. *et al.* (1979): Mean vertical atmospheric circulation above East Asia and Pacific Ocean, summer (I). Science of Atmosphere, **1** (in Chinese).

Zhang, W. (1981): "Ice mouse" on Arzha Glacier. Journal of Glaciology and Cryopedology, **3**, 2, 51 (in Chinese).

Zhang, W. (1984): Earth chemistrical characteristics of glacier ice. Snow and Water in Namjagbarwa Area. Study of Alpine Region, **2**, 3, 155– (in Chinese).

Zhang, W. (1988): Modern glaciers in Namjagbarwa. Memoirs of Scientific Investigation in Namjagbarwa Peak Region, Beijing, Science Press (in press, in Chinese).