Bulletin of Glacier Research 5 (1987) *103－109*

Permafrost and periglacial phenomena in West Kunlun Mountains of China

Li Shude

Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, China

(Received January 5, 1987 ; Revised manuscript received January 12, 1987)

Abstract

The West Kunlun mountains in inland China possess an extreme continental climate. The present snow line reaches to 5700－6100 m above sea level. The lower limit of permafrost, about 4600 m approximately corresponds to the －4.3℃ isotherm of mean annual air temperature, 400－600 m higher than that in the middle and east part of the Kunlun Mountains. The active layer varies in thickness with elevation and the type of soil. For instance, it is 150 cm in coarse gravel soil and 50 cm in fine grained soil at 5000 m a.s.l. Ground ice can be divided into two categories according to its origins. One is buried ice (glacier ice and lake ice) which exists in the till on the fringe of the Guo Zha and Zhong Fen glaciers. The thickness of the exposed ice layer with soil reaches 10 m. The other type is fabric ice which was discovered in the lacustrine deposits near the Tianshui hai Lake. Both the ice layer with a small soil－content, 7 to 8 m in thickness exposed in a natural section near a thermokarst lake and the pure massive ice layer, 0.8 to 1.0 m in thickness, found in the foundation of a building are rarely seen in China. Because of high altitude, dry and cold climate and violent frost weathering, there are lots of periglacial phenomena in this region. The lower limit of periglacial zone is about at 3800 m. Main periglacial phenomena are as follows : sorted rock－circles, stone nets, solifluctions, pingos, frost mound stony mound, upheaving stones, thermokarst lake, perennial and seasonal river icings, and so on.

1. Introduction

The expedition organized by the People's Republic of China and Japan explored the permafrost and glacier on a south－facing slope in the West Kunlun Mountains in the People's Republic of China (Fig. 1). Based on the field information, this paper mainly deals with the distribution of permafrost, ground ice and periglacial phenomena in this region.

2. Geological and geographical environments

The Kunlun Mountains stretches for 2500 km from the Pamirs in the west to the western part of Sichuan Province in the east, with the ridges in the west being higher than those in the east. Modern glaciers developed on the top of mountains. The West Kunlun Mountains, with Qinghai－Xizang Province. There is a great difference in the local relative relief, but no obvious vertical zonation. The upper part of the mountains is occupied by tundra desert, directly connecting with the permanent snow cover and the periglacial zone (Scientific Expedition to Xin Jiang and the Qinghai－Xizang Plateau, 1978 ; 1983).

The Chinese glaciologists and geocryologists explored middle and eastern Kunlun Mountains several times. The Chinese geocryologists have been specially researching frozen ground along the Qinghai－Xizang highway since 1960's. The investigation indicates that the lower limit of permafrost in the Kunlun Pass and Xitatan area along Qinghai－Xizang Highway is about 4,150 m ; while the lower limit of widespread permafrost is about 4,350－4,560 m. Pingos and rock glaciers are the typical periglacial phenomena found there. The expedition sponsored by the People's Republic of China and Western Germany in 1981 explored the Animaqing Shan in the East Kunlun Mountains. The preliminary results show that the lower limit of permafrost on north－facing

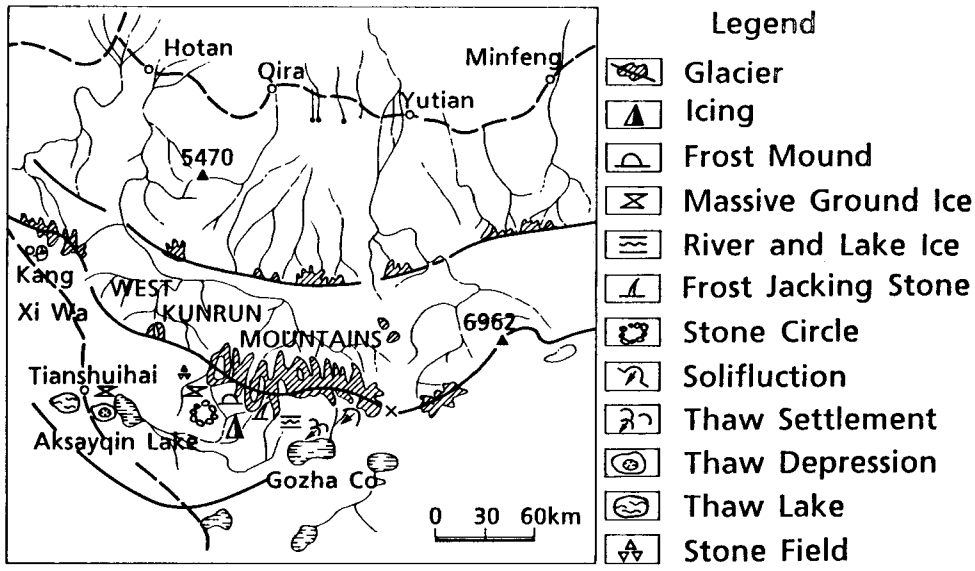

Fig. 1. Periglacial Distribution Map of the West Kunlun Mountains in China.

slopes is about 4,000 m while on sough-facing slopes it is about 4,400 m. The mean annual air temperature at the lower limit of permafrost is between −2.0°C and −3.6°C. The main periglacial phenomena are turf hummocks, thaw collapse and thermokarst, *etc*.

The West Kunlun Mountains are higher than the Tianshan and Altai Mountains, but due to the influence of its geographical location, the precipitation is much less than that in the Tianshan and Altai Mountains. The West Kunlun Mountains is one of the driest mountains in China. According to the records of the Kangxiwa weather station in West Kunlun Mountains, the annual precipitation is about 36.3 mm, relative humidity 33−36% (from 1968 to 1985) ; 64 mm at the height of 5,243 m ; 71.1 mm at Gan Weather Station at the height of 4,232 m ; 23−25 mm at Kalahashi Weather Station. Because precipitation is very rare, the recent snowline lies at about 5,700−6,100 m. Mean annual air temperature decreases with increasing elevation. The 0°C isotherm usually coincides with the 3,800 m isohypse. According to the records, mean annual air temperature is −0.6°C at Kangxiwa weather station at the height of 3,975 m and −9.7°C at the height of 5,243 m. The lapse rate of decreasing temperature to elevation is 0.65°C/100 m. Precipitation at the end of Guoza Glacier in July of 1985 was only 3.4 mm. Two recent snowfalls were only 0.3 cm and 7.5 cm in thickness.

3. Distribution of permafrost

The distribution of permafrost in the West Kunlun Mountains depends mainly upon vertical zonation. There are some river icings with a height of 1−2 m in the river bed near Shengli Bridge at the height of about 4,000 m. Turf hummocks, seasonal frost mounds and gelifraction terraces develop in the marshland in low depressions. Little glaciers develop above 4,800 m. All of those have the characteristics of permafrost and periglacial phenomena. The lower limit of permafrost in this region is 4,600 m, where sporadic permafrost develops in the marsh land, while widespread permafrost develops above 4,800 m. Debris slopes and debris cones develop in Mazha, located at the second terrace in the upper reaches of the Yarkant River, with strong frost weathering great sandstorm sand, no vegetation being features of the arid alpine valley ; the depth of seasonal frost is 1.2−1.5 m at the height of about 4,000 m. Kangxiwa is located in a flat valley at about 4,000 m, mean annual air temperature is −0.6°C, precipitation 36.3 mm, and the depth of seasonal frost is about 1.5 m. Seasonal frost mounds develop and some paleo-pingo remants exist in marsh land. For instance, there is an elliptic depression with a diameter of 10−15 m (Fig. 2). The formation of this

Fig. 2. Thaw Depression in the West Kunlun Mountains.

depression resulted from the thaw of a large pingo. Near Tianshuihai, numerous pingos develop, the heights usually are about 1 m, the maximum is up to 1.5 m ; minimum 0.5 m at the height of 4,800 m in a wide spread permafrost region. Mean annual air temperature is about −5.6℃. According to the field investigation, the depth of thaw is about 1.5 m. Dry ground surface, no vegetation and a salinization cemented layer are the features on the surface.

4. Frozen ground texture and ground ice

On the south−facing slopes of the Western Kunlun mountains, ground ice developed widely in the upper layer of permafrost and soil (rock) forms massive, layered and conglomerated textures, with most of them being horizontally layered. For instance, on the southeastern bank of Tianshuihai along the Xing−Zang Highway, ground ice of 6 m in thickness was observed in profile undergoing thawing collapse. The profile between the bank surface and lake surface was about 8 m. The ground surface was very dry with no vegetation. From 0 to 1.2 m in the profile was a sandy clay layer with a little fine gravel at the top of the layer. From 1.2 to 6.5 m was an ice layer with soil, volumetric ice content from 1.2 to 2.5 m was about 60−70% with a 10 cm pure ice layer ; from 2.6 to 5.0 m, about 50% with a conglomerated texture ; from 5.0 to 6.5 m less than 40% with gravel ; below 6.8 m, greater than 50% volumetric ice content increased again. Below 8.0 m and beneath the lake surface the profile became unclear. On the other bank in the thaw collapse profile the thawed depth as of the 18 th of July was about 80 cm. From 0 to 0.4 m was dry, wind−deposited sand ; from 0.4 to 0.8 m, wet and granular sandy clay ; from 0.8 to 1.5 ma was layered and micro−layered humus sandy clay without obvious ground ice.

In addition, an ice mass of about 1 cubic meter was discovered near new buildings in Tianshuihai. According to reports from the local people, when building those houses, they discovered this kind of pure ice mass at many sites. Perhaps it was river or other surface ice (river ice, lake ice, *etc.*) buried by wind−deposited sand. The buried depth was about 1.0 to 1.5 m.

Around the lake at the end of Zhongfeng Glacier, about 10 m ground ice can be seen. According to the field investigation, there are two possible explanations of how that it is kind of ground ice formed, one

is that it is buried glacier ice ; another is that it is pingo ice resulting from freezing glacier meltwater or spring water.

As a whole, the West Kunlun Mountains has a very dry continental climate, annual precipitation is only several centimeters, but it is really rare that massive ground ice is developed and preserved, especially massive ground ice as found on the natural profile in Tianshuihai. The formation environment and age of massive ground ice still needs to be investigated in future.

5. Periglacial phenomena

High altitude, dry and cold climate conditions result in strong frost weathering and numerous kinds of periglacial phenomena. The types of periglacial action with vertical zonation belong to the alpine periglacial zone. The lower limit of the alpine periglacial zone can extend down to the height of 3, 800 m while normally the extent of the periglacial zone is about 4,000 m. There are many typical periglacial phenomena (Fig. 1). The following discussion mainly deals with the characteristics and formation processes of some typical periglacial phenomena.

5. 1. Periglacial phenomena by frost heaving action

5. 1. 1. frost mound

Frost mound is one typical periglacial phenomena in permafrost regions. According to the length of time that it exists, it can be divided into two types : *i. e.* seasonally frost mound and pingo. According to the lithological character, it can be divided into frost mound earth and lithical frost mound. Earth frost mound widely develops in Tianshuihai area along the Xing-Zang Highway in the West Kunlun Mountains, with a height usually about 1.0 meter. The creaks with the "+" shape appear on the top of frost mound. The depth was about 20-40 cm. Seasonally thawed depth was about 1.1-1.5 m. Beneath the active layer, was the ice layer with soil. The lithical frost mound widely develops in wet land at the height of 4, 800-5,200 m between Hekesayi Lake and Litian River on the south-facing slope in the West Kunlun Mountains. Broken stones in the top of frost mounds stand up straight, with the height of about 50-100 cm, forming a string lithical frost mound group. Chen (1979) discovered many lithical frost mounds on Qinghai-Xizang Plateau. In addition, there are some pingos with a height of about 10 m on the end moraine of Zhongfeng Glacier at the height of 5,400 m in the upper reaches of Litian River, and some new frost mounds with a height of about 1 m near the thawing lake.

5. 1. 2. Frost jacking of stones

Frost jacking of stones is often discovered in permafrost regions and moraine hills. Some almost straight up and down stones with a height of 20-30 cm were observed at a high lateral moraine of the Guoza Flat Top Glacier. There was a disturbed gravel layer between the lower part of the frost jacking stones and the upper table of the permafrost with an ice layer. Therefore, frost jacking stones were formed in saturated fine grained material under repeated freezing and thawing conditions.

5. 1. 3. River ice

River icing and spring icing are widely distributed phenomena in cold regions. During the exploration period, seasonal river ice and river icing were found in several places, usually distributed in flat shallow river beds at the height of 4,000 m, while permanent river ice or river icing was developed at the end of Zhongfeng Glacier, with a thickness of about 1.0-1. 5 m. From natural profile observation, the ice layer has laminations and a dirt surface. River icing of 1. 0-1.5 m thickness develops on the river. Seasonal spring icing develops in thawing lakes at the height of 5,400 m.

5. 2. Sorting by frost action, Stone circle, stone net and stone rose

Stone nets are mainly distributed in the wide valley of the upper reaches of the Litian River at the height of 5,200 m, with a diameter of about 10-40 cm, taking the shape of an ellipse of a circle. The center is occupied by fine grained soil with great water content, while the edge is of broken stones. During the middle of july, the center of the stone dish freezes in the morning, while it thaws in the afternoon with some water cover. The stone dish is the primary stage of the stone circle. Cui Zhijiu named it the micro-stone circle (Fig. 3).

Stone circles and stone roses develop not only in the wide valley in the upper reaches of litian River in the west Kunlun Mountains, but also in the moraine around the Guoza Flat Top Glacier. The diameter

Fig. 3. Stone circle in the West Kunlun Mountains.

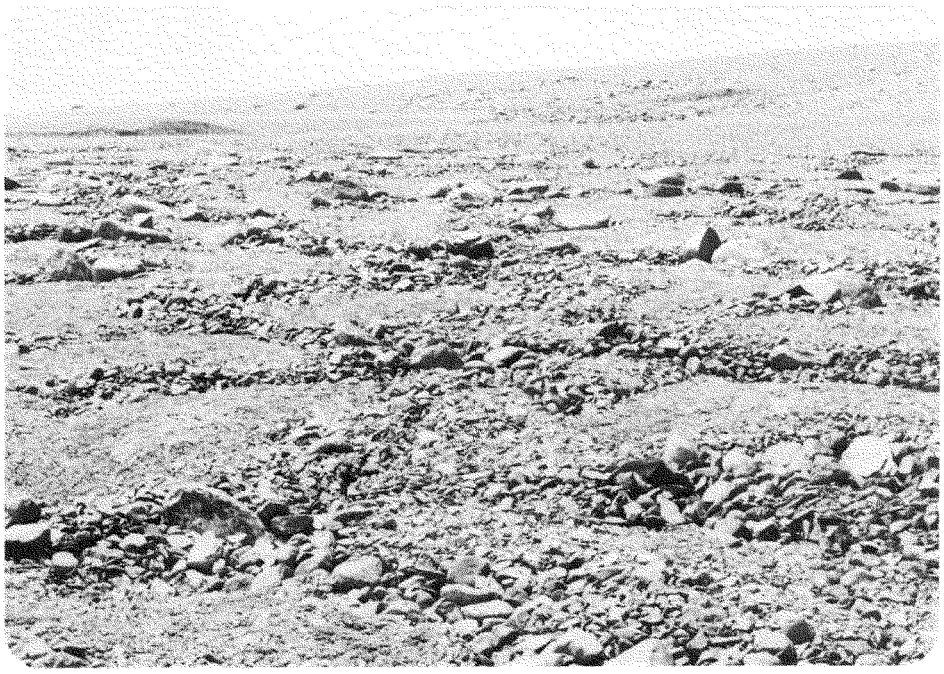

Fig. 4. Stone circle group in the West Kunlun Mountains.

Fig. 5. Gelifluction at 5,800 m in the West Kunlun Mountains.

Fig. 6. Thaw lake in Tianshuihai Area in the West Kunlun.

of stone circles are usually about 2.0—4.0 m up a maximum of 8.0 m. The sides are broken gravel with a diameter of 2—10 cm. The lithological character is granite, sandstone and Limestone. There is a micro—polygon texture in the center (Fig. 4). A great number of stone roses were observed on the gentle lope in front of a moraine lake at the height of 5,700 m. The individual diameter was about 2—4 m forming a beautiful picture on the ground surface.

5. 3. Periglacial phenomena by gelifraction

After seasonal thawing, the saturated soil moves down along the slope. This phenomenum is called gelifraction. The saturated sandy clay moving down along a seasonally freezing surface on a 30° slope forms the Little gelifraction, where the thawed depth in the last 10 days of July was only 50 cm (Fig. 5). This is one of the highest regions where solifluction distributes in the world.

5. 4. Periglacial phenomena by frost weathering and gravitation

5. 4. 1. Debris slope and debris cone

Under the dry and cold climate conditions, bare bedrock on the upper part of mountains suffers strong frost weathering, with broken rocks gradually moving down the slope and at the bottom of slope, forming a slope covered by broken rocks, called "rock slope". Broken rocks deposited at the bottom of a slope is called "rock cone". Rock slopes and rock cons are widely distributed in the Maza—Tianshuihai mountainous areas.

5. 4. 2. Rock field and rock stream

Rock field generally develops on the top and upper slope of mountains consisting of hard bedrock. Rock fields were observed on top of almost every mountain in the West Kunlun Mountains. Rock streams usually were developed on the moraine in front of modern glaciers at the height of 5,000 m.

5. 5. Periglacial phenomena by thawing : thaw lake and thaw settlement

Due to the change of natural conditions and the influence of artificial factors, the heat balance conditions of permafrost is destroyed, resulting in differential thaw settlement of the ground surface which causes an escape of water, from the melting of excess ice in the frozen ground, until a thaw lake is formed. Without water in the center, it is called thaw depression. Massive ground ice widely develops in the lacustrine deposits in the Tianshuihai Region in the West Kunlun Mountains. After the thawing of ground ice, a thaw lake is formed with an area of about several square kilo—meters (Fig. 6). Such a lake is very seldom seen along the Xing—Zang Highway. Because of the influence of a warm spring at the end of Zhongfeng Glacier, the melting of glacier and ground ice in permafrost forms the thaw lake developed on modern moraine. It is also rare in modern glacier regions.

References

Chen Guodong (1979) : Lithical frost mounds. (in Chinese), Journal of Glaciology and Cryopedology, No. 1, 49—50.

Geomorphology Group in the Comprehensive Expedition Team to Xin Jiang (1978) : Geomorphology of Xin Jiang. (in Chinese), Science Press, Beijing, 145—154.

Scientific Expedition to the Qinghai—Xizang Plateau (1983) : Geomorphology of Xizang (Tibet). (in Chinese), Science Press, Beijing, 137—147.