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CHARACTERISTICS OF PERIGLACIAL GEOMORPHOLOGY IN THE SOURCE AREA OF THE HUANGHE RIVER

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ABSTRACT: There widely occur stretches of permafrost at more than 3,800–4,200 meters above sea level in the source area of the Huanghe (Yellow) River. The periglacial geomorphology develops quite well, including frozen disintegration geomorphology, freezing and thawing geomorphology in cold environments, periglacial dune, buried ices and fossil periglacial phenomena. In light of the relation between stratigraphy and periglacial phenomena, three periglacial periods can be divided, which are the Middle Pleistocene periglacial period, the Late Pleistocene periglacial period and modern periglacial period.

KEY WORDS: source area of the Huanghe River, periglacial geomorphology, periglacial period

I. OUTLINE OF GEOGRAPHIC AND GEOLOGIC FEATURES OF THE STUDIED AREA

The source area of the Huanghe River lies in the northeastern part of the Qinghai–Xizang (Tibet) Plateau and Qinghai Province. Its geographical position is between 33° 50′ –35° 40′ N and 97° 00′ –99° 40′ E. With Bayan Har Mountain in the south, the Buqin Mountain and Ngola Mountain in the north, the western bank of Gyaring Lake in the west and the A′nyemaqen Mountain in the east, the total area is about 28,000 km^2.

The Huanghe River flows into Gyaring Lake and Ngoring Lake from the west, after bypassing Madoi County it flows out of the studied area in the southeastern direction.

Along the whole distance of 300 km, it converges several tributaries such as the Doqu, Lunagqu and Heihe rivers etc. At the end of the studied area, it has a flow capacity of 100 m^3/ s. Gyaring Lake and Ngoring Lake are regarded as the two bright pearls in the upper reaches of the Huanghe River, playing an significant role of regulating the water resource in the source area of the Huanghe River. Based on exploration, the area of Gyaring Lake is 526.1 km^2. Its distance from the east to the west is 35 km and that from the south to the north is 21.6 km. The maximum water depth is 13.1 m and the average is 8.9 m. The area of Ngoring Lake is 610.7 km^2. Its distance from the south to the north is 32.3 km and that from the east to the west is 31.6 km, like a shape of triangle. The maximum water depth is 30.7 m and the average is 17.6 m.

The tectonic system of the region is part of Qinghai, Xizang and Yunnan zeta–type head periphery. The stratum is mainly composed of sandstone slate and limestone layers of the Permian and Triassic periods. The Quaternary stratum is mainly composed of the moraine and outwash of the Middle Pleistocene and the Early Pleistocene epoch, besides, there are also some lacustrine strata of the Late Pleistocene epoch and some alluvial, pluvial, aeolian and bog deposition etc. of the Holocene epoch.

The average elevation of the area is above 4,100 m and the highest is 5,262 m. It is characterized by an extremely cold and dry climate with much wind and snow, which is a typical continental plateau climate. The annual mean temperature is −4.1℃ ; the annual precipitation is 303.9 mm; the annual evaporation capacity is 1,374 mm; and the absolute humidity is 3.2 mb.

There widely occur high elevation type and continuous stretches of permafrost, which accounts for more than 88 percent of the total area. Influenced by the physical geographical and climatic conditions, the distribution of permafrost has a prominent three–dimentional zonality (latitudinal, longitudinal and vertical). In the area of the Ngola Mountain, permafrost exists at the elevation of 3,861 m (shady slope) to 4,100 m (shining slope) and increases towards the south to 4,100–4,442 m at the Bayan Har Mountain and its south–facing slope. The former permafrost is 51.1–71.53 m in thickness and the latter is 7.5–29.5 m by drilling exploration. In the hinterland of the Bayan Har Mountain the permafrost thickness is estimated to be over 50 m and the active layer is 0.6–1.6 m deep. There are taliks in the region of Gyaring Lake, Ngoring Lake and the major flowing area of the Huanghe River. The structural taliks exist along the tectonic fault at Wenquan Town in the Erla Mountain.

II. FEATURES OF PERIGLACIAL GEOMORPHOLOGY

Periglacial geomorphy is the result of integrated action by lots of physical factors. In the studied area there are many kinds of well developed periglacial geomorphic phenomena that their occurring and developing are carried out by repeated freezing and thawing of the

water in the surface soil (Fig.1). Under the influences of physical geographical and climatic conditions, the source area of the Huanghe River has many distinctive periglacial geomorphic types and apparent characteristics of alpine periglacial zone.

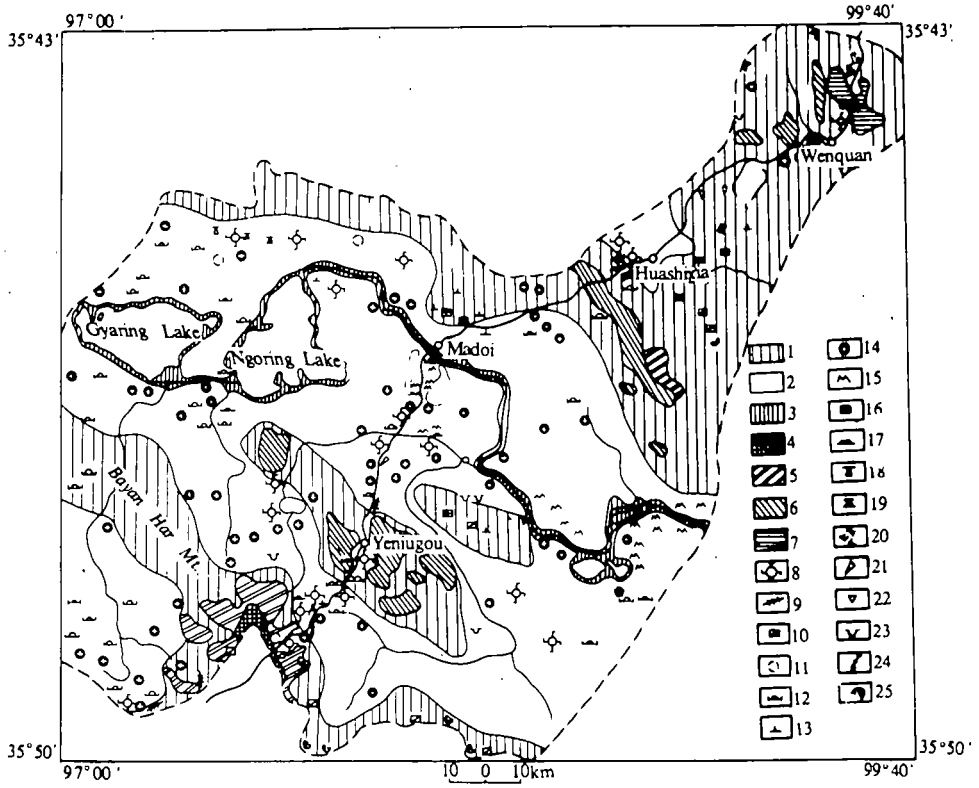

Fig.1 Periglacial geomorphology in the source area of the Huanghe River

1.Frozen disintegration geomorphological zone; 2.Freeze–thaw action geomorphological zone; 3.Talik; 4.The I level planation pediment; 5.The II level planation pediment; 6.The III level planation pediment; 7.The IV level planation pediment; 8.Frost heaving; 9.Ground crack; 10.Solifluction; 11.Stone circle; 12.Frozen ground bog; 13.Frozen disintegrated rock pillar; 14.Thermokarst lake; 15.Cold–generated dune; 16.Scale–form turf; 17.Mammatus ground; 18.Buried glacial ice; 19.Segregated ice; 20.Solifluction; 21.Sand wedge; 22.Collapsedstone heap; 23.Periglacial wide valley; 24.Stone stream; 25.Fossil cirque

1. Frozen Disintegration Geomorphological Zone

With the alpine snow–ice action, violent frozen action and weathering denudation as the major agents, the frozen disintegration geomorphological zone exists widely at 4,000m

above sea level in the Ngola Mountains and at 4,500 m in the Bayan Har Mountain and the Buqin Mountain. The annual mean temperature is −4.1−5.45℃, and the altitude of snow line is 5,100m a.s.l. The periglacial geomorphic types are as follows.

1.1 Cryoplanation Surface (Also Called Disintegrated Pediment)

It is a high−level platform caused by large−scale periglacial disintegration and can be divided into four levels according to the altitude of denuded planation surface. In the Bayan Har Mountain and the Buqin Mountain region, there are I−III levels which elevations are 5,080−5,100m, 4,800−4,900m and 4,500−4,600m respectively. While in the Ngola Mountain region there are III−IV levels, their elevations are 4,500−4,600m and 4,200−4,300m respectively. The I and III levels are modern denuded planation surface with thick modern debris deposited in the upper layer. The II and IV levels, went through a long period of repeated periglacial action after the Middle Pleistocene of the Quaternary period, are old−aged denuded planation surface upon which moraine and outwash materials pile up. In addition, on the top of denuded planation surface there are occasionally some residual mounds which are the residual topography during the development of the denuded planation and are composed of hard bedrock. Mostly around the residual mound are debris caused by freeze and thaw debacle.

1.2 Flowstone Slope

Rocks can be broken into pieces of stone by forces of expanding of the frozen water around them. The broken stone could then form flowstone slope by the effect of gravity, frost heaving sorting and retransportation. This kind of topography exists in the region of the Bayan Har, Buqin and Ngola mountains, and it is a special geomorphy formed by plenty of small pieces of stone on the mountain slope. In general, most of them are equal to the mountain slope degree, while the rest are a little less than the mountain slope degree and would keep on sliding down, the surface stone colour are usually fresh. In contrast, the colour of the surface stone become dark for the ceased developing flowstone slope. Some large−scale flowstone slope can extend from the summit to the bottom of mountains.

1.3 Stone Stripe

It is distributed in the region of the Bayan Har and Ngola mountains, especially it is typical in the north slope of the Ngola Mountain. Its formation features are nearly the same as flowstone slope. The differences between them are that the stone stripe develops in line or stripe forms with relatively small scale and it can extend from the summit to the foot of mountains with slope of over 35° −45° . Sometimes there can be dozens of parallel stone strips developed concurrently on the same slope.

1.4 Frozen Disintegrated Rock Pillar

It mainly develops at the north slope of the Bayan Har Mountain, the south slope of the Buqin and Ngola mountains etc. and mostly exists at the ridge of hard bedrock mountains. It is affected by actions of ice−cutting and frozen disintegration. The erect rock pillar is usually 3−5m high and can reach more than 10m for some higher ones. Some of the pil-

lars occur in rows. There can be seen some upheaving stone raised by frost heaving forces at the mountain ridge covered by turf.

1.5 Periglacial Wide Valley

It is well developed in the south and north slopes of the Bayan Har Mountain. It is characterized by wide and short valley, the same width at the source area and the lower reaches. Shallow low-lying lands are usually formed in the source region, presenting the U-shaped transversal section. There are talus deposits on the valley slope and they usually appear in rows or sometimes in single.

1.6 Stone Stream

It is the accumulation of stone exposed above the earth surface and usually develops in the shallow wide valley. By freeze-thaw sorting and regeneration action, the early aged moraine forms curved stone stream 3-10m wide and 20-100m long and the gravel are usually more than 0.3 m in diameter.

1.7 Collapsed Stone Heap

Under the ice-cutting and frozen breaking action, the naked bedrock disintegrates and forms large area of collapsed stone heap as well as talus cone. The stones are mostly in pointedness and irregularity and the volume increased from the upper to lower place. This kind of phenomena is usually seen at the foot of mountains.

2. Periglacial Action Geomorphological Zone

It has a large area and is widely distributed. The main actions are frost heaving, freeze-thaw sorting, solifluction and thermokarst settlement. The elevation is over 3,800-4,000 m and the annual mean temperature is -3-4.0℃. The following phenomena can be seen in the region.

2.1 Frost Heaving

It develops quite well in the north slope of the Buqin Mountain and can be divided into two types of seasonal and perennial ones. The frost heaving, distributed in the west side of the Mianshaling Ridge, freezes and upheaves in winter and thaws in summer, and has the strong feature of migration. The formation of this kind of the frost heaving is related to the migration and integration of the water above frozen layer and also related to the lithological property of water bearing layer and the changes of annual precipitation. The frost heaving is usually 0.5-2m high and the highest can reach 3-5m. Its long axis is 5-15m, and there are fissures in the top with gap width of 0.2- 0.4m. The direction of the major fissure is consistent with that of the long axis. In the north slope of the Bayan Har Mountain there exists perennial frost heaving which has ice core of 0.2-2m in thickness and may settle to concave pit of 0.5-1m deep in the top caused by freeze and thaw action. There are spring flowing out in lowlands along the lateral side.

2.2 Ground Crack

It is usually irregular shaped with certain direction. The ground crack is generally 0.1–0.2m wide and the widest major crack can reach 0.5m . It can extend to 35m with 0.1–0.3m of impure ice layer under it. The secondary crack mostly intersects the major crack oblique and the ground on the two sides of the crack is slightly tilt. This kind of phenomena is best–developed in the Bayan Har Mountain.

2.3 Stone Circle

It can be seen in the region of the Bayan Har Mountain and it is the kind of small stone circle with diameter between 1.5–2m. The middle part is fine soil and relatively higher, with developed turf and vegetation. Around it are pieces of stone half exposed to the ground surface, appearing to be irregular polygons of circles.

2.4 Mammatus Ground (Mound Ground)

It forms uninterrupted and separate mounds, like the shape of steamed bread. They are usually 0.1–0.2m in diameter and often serriedly distributed. It is a kind of frost upheaving phenomena caused mainly by horizontal frost heaving action in the vegetation growth zone.

2.5Frozen Ground Bog

It usually develops in the belt of shallow underground water level and is lump shaped meadow composed by little grass mound which sometimes link up into irregular network and distributes in large area. There are stagnant depressions among the grass mounds. Sometimes little patches of alpine frozen ground bog can be also formed in the slope where has spring overflowing.

2.6 Thermokarst Lake

Under physical geographic and outside conditions, the underground ice comes to thaw due to the air temperature gradients and the thermal balance action. Consequently the ground surface settles to depression and becomes lake after water accumulation. They usually occur in plain or valley and most of them often form patch–distributed single lake. They are irregular shaped, small ones are merely several square meters, but large ones are several square kilometers.

2.7 Scale–Shaped Turf (Also Called Scale–Shaped Ground)

It is actually disordered freezing and thawing type ground. Turf grows on the thin and barren soil surface under which is detritus layer. When the active layer becomes thawing, the detritus layer would slide down at uneven speed due to the gravity, thus splits the turf and reveals the talus deposit under it. As a result, a discrete and irregular grades, usually 0.2m high, can be formed along the slope. This is mostly seen in the Buqin and Ngola mountains.

2.8 Mud–Rock Flow (Solifluction)

It is distributed in fan–pattern in the north slope of the Ngola Mountain. After repeated freezing and thawing action, the structure of surface soil on the slope or gentle valley becomes loose. When the water content of the soil increases continuously and reaches satu-

rated state, the mixture of sand, mud and gravels can wriggle slowly along the frozen plane of the slope direction under the gravity action at certain topography. The sand content is high and the relatively bigger gravels mostly occur in the front of the solifluction lobe. Solifluction usually appears in mass at the fitted developed slope and also can appear in single. The individual is generally 5–20m wide and 20–30m long, while the widest can reach 50–100m and the longest can extend to hundreds of meters.

3. Cold–Generated Dune

The cold–genetated dune is one of the characteristics of continental climate and desert–typed alpine periglacial zone. It is the result of aeolian erosion and deposition action in the high cold and dry climate zone. It is distributed at the Mianshaling Ridge of the north slope of the Bayan Har Mountain and along the bank of the Huanghe River. According to the developing degree, it can be divided into two categories of semi–fixed dune and moving dune. The former one, mostly distributed at the periphery of the thermokarst lakes, is characterized by 3–5m in height, low and gentle and with sparse vegetation covered. It is best–developed in the region of the Mianshaling Ridge. The latter one, usually in intergrowth with bog which occurs at the boundary of dune, is characterized by clear morphology of barchan or dune chain with no vegetation above the surface and usually with underground ice buried it.

4.Buried Ice and Fossil Periglacial Phenomena

4.1 Buried ice

The underground ice preserves the original state of natural morphology under the condition uninfluenced by air temperature and other factors. It can be divided into two types: buried glacial ice and segregated ice.

During the process of stratum deposition, the glacial ice was buried to form buried glacial ice. It usually has a large area distribution, and is relatively thick. The ice and mud sand fixed and interspersed irregularly. There are mud–wedge formed by little ice fissure on the ice body. There exists such buried ice at the north foot of the Bayan Har Mountain where the elevation is 4,860m a.s.l. The thickness of the ice layer is 0.5 m at the edge and increases towards the central part. The buried depth is 0.62m. It forms an underground ice sheet of approximately 3 km^2 in size.

During the late period of stratum formation, the water in the soil separated out and condensed into block of ice by the frost heaving action under the frigid climate condition and consequently formed the segregated ice. It is in layer form or in discrete lens form and is also characterized by small volume, pure ice layer and occurring in polylayers. There exists such ice at the region of Kuhai, Zuimatan of the south slope of the Ngola Mountains and the north of Ngoring Lake to the south of the Buqin Mountain. In the south foot of

the Buqin Mountain, there exist at least four layers of ice from the surface to the depth of eight meter with transparent ice and pure texture, and the thickest ice layer can reach 1 m.

4.2 Sand Wedge (Psedu–Form of Ice Wedge)

It is only found in the north foot of the Ngola Mountain. According to the appearance of the wedge body, it was formed under the dry and cold climatic conditions. The upper part of the wedge is wide, 0.5–1.5 m in wide, the widest up to 5 m, while the lower part is narrow. Some wedges have the same width in the upper part and in the lower part and appear to be bag–shaped. The morphology of sand wedge is dependent upon the developing degree of the paleo–icewedge. The sand and mud deposit in it stand for the geologic chronology of the development of the ice wedge.

5. Talik

It is distributed in the region of relatively developed large rivers and lakes such as Gyaring Lake, Ngoring Lake, Kuhai Lake and the Huanghe River etc. with the elevation of 4,200 m. In these regions, due to the thawing and threading action of the flowing water, there exist loop and band shaped talik and can extend toe to two hundred meters away from the two banks of the rivers or lakes. These regions are mostly the first and second level terraces with geomorlogical patterns of alluvial flat, sand embankment and sand beam etc. The river freezes in winter and can form seasonal river icings.

At Wenquan Town of the south slope of the Ngola Mountain, there exists talik of approximately 100 m in width along the structure zone. Along the fault zone there is exuberant vegetation and the ground surface water doesn't freeze even in frigid winter.

III. PRELIMINARY ANALYSIS OF THE QUATERNARY PERIGLACIAL PROCESS IN THE SOURCE AREA OF THE HUANGHE RIVER

The periglacial process in the source area of the Huanghe River is correlated to the periglacial climatic environment from the Quaternary period in the whole Qinghai–Xizang Plateau. According to the survey data along the Qinghai–Xizang Highway[1–3], there occurred seven times of ice ages from the early stage of the Quaternary period in the Qinghai–Xizang Plateau and there were periglacial environment during each ice age in a certain scope. In addition, paleo–periglacial thaw fold was found in the lacustrine stratum of the Early Pleistocene epoch from the paleo–geomagnetic chronology of 1,500,000 years ago in the northeastern part of the Qinghai–Xizang Plateau[4]. It is sure that in the source area of the Huanghe River which has wide exposed stratum of the Early Pleistocene the periglacial process should coincidently occur, but we can not prove it furtherly by the mere available data. From the Middle Pleistocene epoch, with the rapid upheaval of the Qinghai–Xizang Plateau. there developed cirque glacier and valley–foot of mountain gla-

cier in the Bayan Har, Buqin and Ngola mountains in the source area of the Huanghe River. Therefore paleo-glacier topography and moraine deposit are still reserved in these regions at present. There distributes paleo-stone sea in the planation surface of 4,800-4,900 m a.s.l. at the north slope of the Bayan Har Mountains. In addition, there are great sand wedge and bag-shaped structure in the Q_2 outwash and outwash mud deposition at the Saheba River and the two sides of the Qinggen River in the Xinghai Basin. All of the above facts illustrate that the source area of the Huanghe River is in the periglacial environment at the time of interglacial period of the Middle Pleistocene epoch.

Table 1 Correlation between ice age and periglacier in the source area of the Huanghe River, Qinghai-Xizang Plateau

Division of ice age along the Qinhai -Xizang Highway	Region of Mt. Kunlun	Region of Mt. Tanggula	Source area of the Huanghe River	
			Region of Mt. Bayan Har	Region of Mt. Erla
Little ice age New ice age	Contemporary periglacier Mordern periglacier	Contemporary periglacier Mordern periglacier	Contemporary periglacier Mordern periglacier	Contemporary periglacier in the Holocene epoch
Bentoushan ice age	Periglacier in Bentoushan period	Periglacier in Basichuo period	Periglacier period in the Late Pleistocene	The Late Pleistocene periglacial period
Xidatan ice age	Periglacier in Xidatan period	Periglacier in Zhajiazangbu period		
Nachitai ice age	Periglacier in Nachitai period	Periglacier in Buqu Period	The Middle Pleistocene periglacial period	The Middle Pleistocene periglacial period
Wangkun ice age	Periglacier in Wangkun period	?		
Jingxian ice age	Shizhishan periglacial period	Nagqu periglacial period	?	?

The climatic fluctuation is relatively great in the source area of the Huanghe River in the Late Pleistocene epoch. There developed cirque glaciers in the region of the Bayan Har, Buqin and Erla mountains in the Ngola and Late Pleistocene epoch. Based on the data from Xu Shuying and Zhang Weixin[5] on the planation surface of 4,200-4,300m above sea level in the Ngola Mountain there widely develops fossil stone sea which belongs to the late period of the Late Pleistocene epoch. In Wang Jiyu's[6] surveying of the Quaternary stratum of Gonghe Basin, thaw-freeze fold layer which was in the Dali ice age was dicovered at the south side of the Basin. Besides, great sand wedge or mass of sand wedge were discovered at

the upper-level terrace in Xinghai and Gonghe basins. The sand wedge's side loess ^{14}C age is 173,000± 250 yr. B.P., belonging to the result of ice age. The lower limit height of the periglacial zone in the Late Pleistocene is estimated by the available data to be 2,200 -2,300m.

The periglacial phenomena in the frigid period of the Holocene epoch developoed well in the source area of the Huanghe River. The distribution height of periglacial zone from the Holocene to the modern time is between 3,500-3,600m or so. Overall, according to the geomorphology, stratum, paleo-periglacial phenomena and the absolute age, we preliminarily divided the source area of the Huanghe River into there periglacial periods (Table 1). Furthermore, we made a contrast with the periglacial period along the Qinghai-Xizang Highway in the Qinghai-Xizang Plateau.

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