PAST GLACIERS ON NORTHERN SLOPES OF THE WEST KUNLUN MOUNTAINS AND RUINS ALONG THE OLD SILK ROAD, WESTERN CHINA: A PRELIMINARY REPORT

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Abstract Glacial fluctuation is considered to be one of the important causes of settlement abandonment in the Taklimakan Desert. The results of air-photo interpretation indicate that moraines on the northern slopes of the Kunlun Mountains could be classified into the Last Glacial and Holocene moraines. The areas covered by these moraines as well as debris-covered glaciers are large in the upper basins of rivers between the Hotan and Yutian oases. The large extent of glacial advance and delay of disintegration due to thick debris-cover brought continuous supply of river discharge. The main period of settlement abandonment (700-1300 years ago) followed one of glacial advances (1300-1800 years ago) during Neoglaciation. The abandonment of settlements in lower reaches of these rivers was caused by decrease in volume of river discharge, possibly due to the gradual shrinkage of glaciers originated by glacial advance during Neoglaciation.

Key words: glacier fluctuation, air-photograph interpretation, West Kunlun Mountains, Taklimakan Desert, Settlement abandonment

1. Introduction

Along the southern route of the Old Silk Road which passed over the northern piedmont of the Kunlun Mountains, settlement and temple ruins buried in the sand of the Taklimakan Desert, have been discovered and described by past Chinese travelers and historians, European and Japanese explorers, and scientists. The causes for the abandonment of these ancient sites have aroused considerable attention. Occurrence such as wars or internal disorders, invasions by other ethnic groups, spread of epidemic disease, destruction of irrigation canals, shift of river courses, decrease in river water, deforestation, vegetation change due to overgrazing, and increased ground salinity have been proposed as possible reason (Stein, 1925; Hoyanagi, 1965, 1976; Zhou, 1989). Changes in river water due to glacial fluctuations in the Kunlun Moun-

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tains in the past have also been suggested (Stein, 1925; Hoyanagi, 1965, 1976; Taira, 1988). However, no definite information on glacial fluctuation has been reported to date in this region.

The present authors had an opportunity to conduct a field research at the southern edge of the Taklimakan Desert and West Kunlun Mountains in summer season, 1987 (Zheng *et al.*, 1988), and in the following year, 1988, observed glacial landforms through the use of aerial photographs (black and white; 1:50,000 in scale) at the Lanzhou Institute of Glaciology and Geocryology, Academia Sinica. New findings on past glaciers in this area are presented and cause and effect relationship between past glaciers and the abandonment of human settlements are discussed.

2. Study Area

The study area is situated to the south of the Old Silk Road between Hotan (Khotan) and Yutian (Keriya), on the northern slopes of the northern range of the West Kunlun Mountains, named the Karatashi-Luishtag Mountains (Fig. 1). From this study area, several desert rivers flow to the north and disappear in the desert where numerous ruins are located. Such site distribution is greatest in the desert area between the Hotan and Keriya Rivers (Fig. 1). The Karatashi-Luishtag Range runs in an east-west

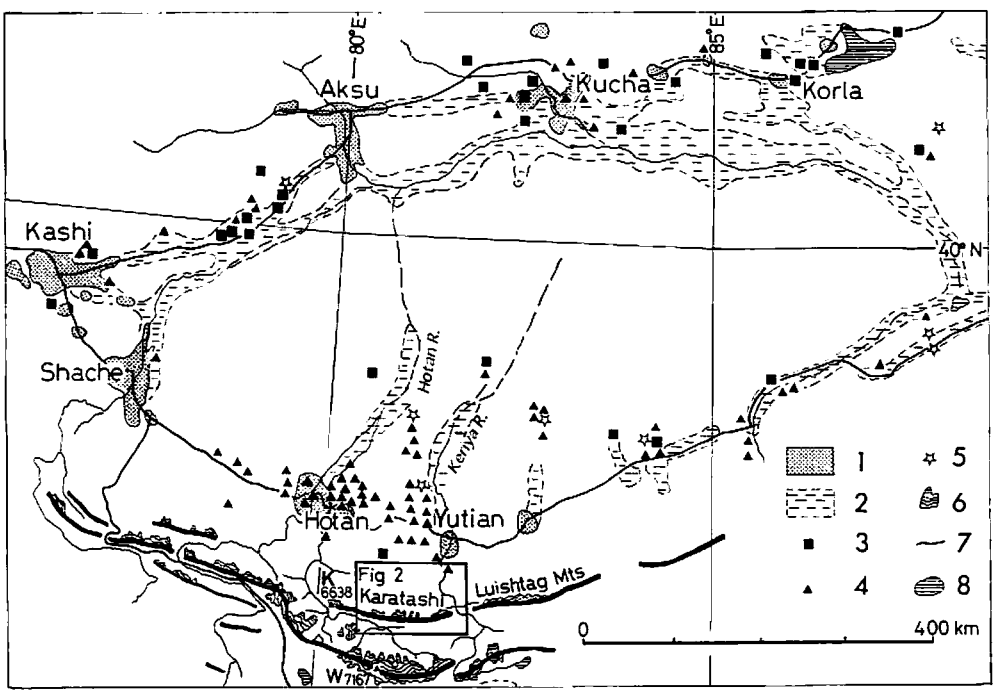

Fig. 1. Ancient sites of the Taklimakan Desert and West Kunlun Mountains
Study area is shown. 1: Oasis (cultivation), 2: Sandy tract with scrubs, 3: Ruined fort, 4: Ruins, 5: Ruined Stupa (3-5 Hoyanagi, 1965), 6: Existing glaciers, 7: Main road, 8: Lake.

direction and becomes separated from the main ridge of the West Kunlun (Yurungkax Nanshan) by the Yurungkax and Keriya Rivers and their tributaries. The highest summit of the Karatashi-Luishtag Mountains is Muztag (6638 m), located to the west of the study area. The main mountain ridge, from 5800 m to 6400 m in altitudes, is comprised of sharp ridges and steep slopes. Most existing glaciers occur on the northern side, as valley glaciers and small mountain glaciers such as cirque glaciers and ice aprons. The valley glaciers with debris-covered ablation areas can be found in deep and narrow valleys. Total glacier area is less than that on the main ridge of the West Kunlun Mountains where large ice fields and valley glaciers have developed (Scientific Expedition to the Qinghai-Xizang Plateau, 1986: 176–183; 250–251). Glacier fluctuations since the late Pleistocene in the main range of West Kunlun have been examined (Ma *et al.*, 1989; Zheng *et al.*, 1990), but the present investigation is the first in the Karatashi-Luishtag Mountains.

The Karatashi-Luishtag Mountains consist of Proterozoic metasedimentary and metavolcanic rock, and Late Paleozoic plutonic rock (Chengdu Institute of Geology and Mineral Resources, 1988). The western extension of the famous Altyn Tagh Fault makes sharp contrast with the steep mountains and flat piedmont plateau, whose thick-loess covered surfaces rise to an altitude of more than 3000 m.

In the eastern part of the study area, Kulapu Daiya River, a tributary of the Keriya River, flows in a deep gorge crossing the Karatashi-Luishtag Mountains. This valley has served as a passage to the Tibetan Plateau since ancient times.

3. Results

Figure 2 shows the results of air-photo interpretation. The debris-free clear ice of glaciers is to be found only on the upper slopes and valley heads, while considerably large and long debris-covered portions of glaciers stretch down into the valleys. Along the ablation areas of glaciers, there are lateral and terminal moraines which differ in chronological stage. The aerial photographs indicate that the moraines could be divided into younger and older groups, the former connecting with the existing glacier terminus, while the latter, to the outside of and downstream the younger group. Old moraines are also found at sites situated far from moraines located adjacent to the glacier terminus. Field observation in 1987 indicated that old moraines in the valley bottom of the Kulapu Daiya River (Location **A**, in Fig. 2) were formed during the Last Glacial period. Accordingly, the younger moraines may have formed during the Holocene period. Some of the oldest moraines and scattered morainic deposits were found at some places in the study area.

In the center of Fig. 2, features of moraines and glaciers in the river basins of the Tiyueuha, Shayihuke, and Akezhaiyin Rivers are conspicuous. The areal extent of both stages of moraines and debris-covered parts of glaciers is very much larger than in other river basins. Relative heights of terminal and lateral moraine ridges from valley bottoms are quite large, judging from the aerial photographs. A schematic diagram showing a transverse profile of a glacier terminus is shown in Fig. 3, as a feature

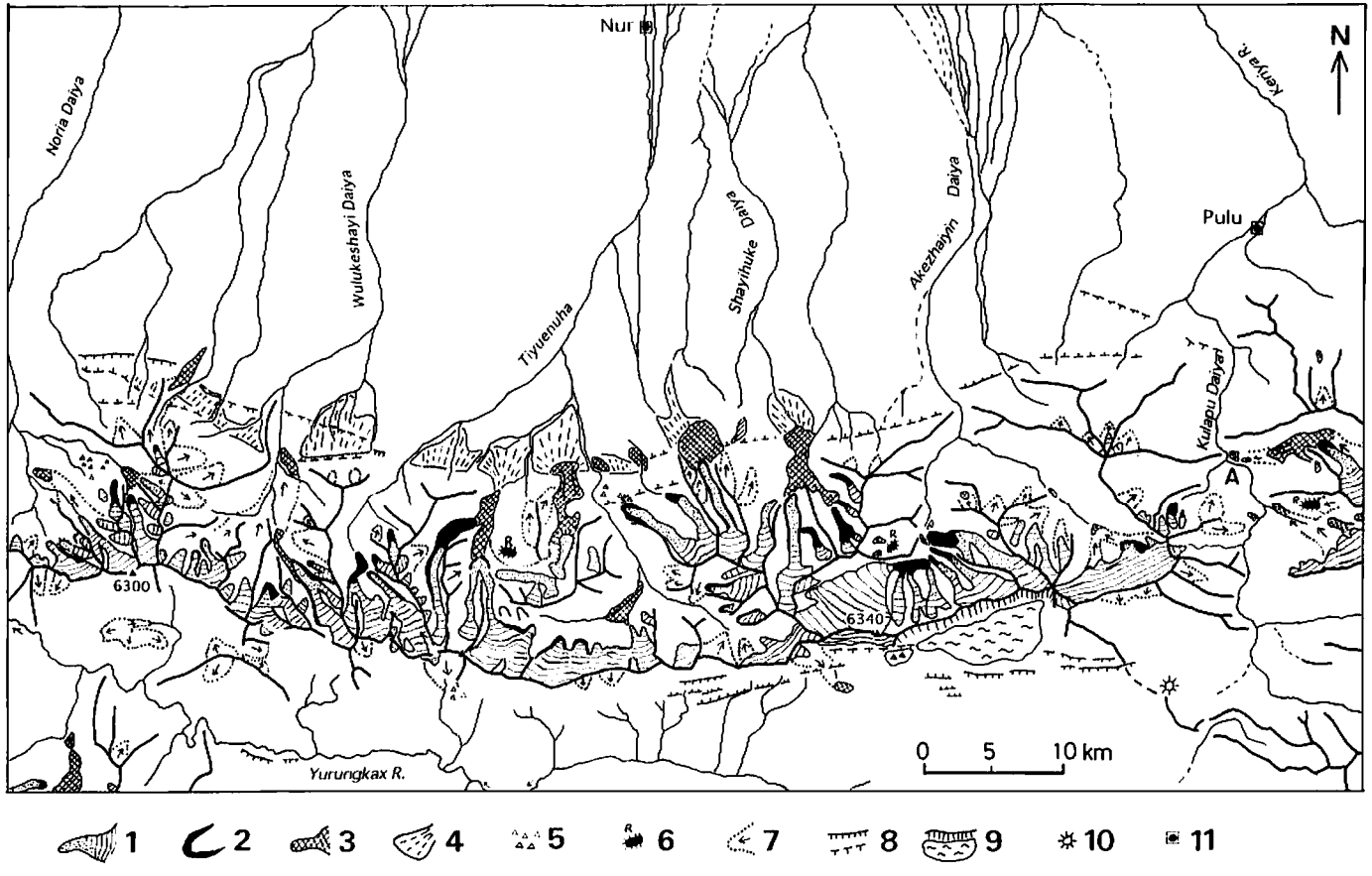

Fig. 2. Glaciers and moraines in the study area of the Kalatashi Range, West Kunlun Mountains
1: Snow and ice area, existing glacier, and debris covered snout, 2: Holocene moraine, 3: Last Glacial Moraine, 4: Fluvioglacial or debris-flow cone, 5: Oldest moraine and scattered morainic deposits, 6: Rock glacier, 7: Limit of glacial erosion, 8: Fault scarp and lineament, 9: Landslide and land creep mass, 10: Volcanic cone, 11: Main village.

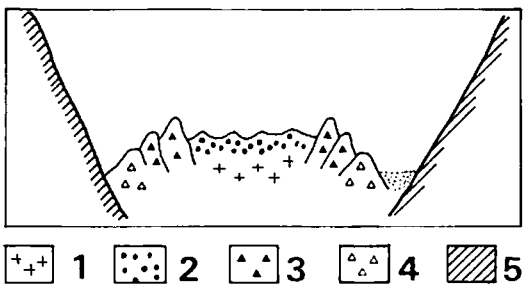

Fig. 3 Schematic cross-section of a typical Turkestan-type glacier snout in the Kalatashi Range, West Kunlun Mountains
1: Glacier ice, 2: Debris cover, 3: Lateral moraine in the Holocene period, 4: Lateral moraines in the Last Glacial, 5: Bedrock.

typical of that of the Turkestan-type glacier. Some moraines in the Last Glacial period are located outside the piedmont line and fluvioglacial or debris-flow cones have formed at lower valleys of the Last Glacial moraines. These landforms indicate glaciers in the Last Glacial period to have advanced to sites less than 3000 m in altitude.

4. Discussion

Most ruins situated on the southern edge of the Taklimakan Desert were discovered in the drift-sand region situated far from present settlements in oases, and some in the north of the present ends of rivers that come to be lost in the sandy desert (Fig. 1). Hoyanagi (1965) has summarized abandonment periods of ruins based on Chinese historical documents and archaeological remains. Some were abandoned between the 3rd-4th centuries (1700-1500 years ago), many in the 8th century (1200-1300 years ago), and others at a later period up to the 15th century (400-500 years ago) (Fig. 4-A). Zhou (1989) noted that desertification and settlement abandonment by shrinkage of the Keriya and Khotan river-systems occurred mainly between the 9th century and the 13th century (700-1100 years ago) (Fig. 4-A).

At the start of the 20th century, Stein (1912) observed debris-covered glaciers, called "fossil" glaciers, in the West Kunlun Mountains, and suggested that the shrinkage of rivers was possibly due to gradual decrease in "fossil" glaciers originated from the advance in the Last Glacial period (Stein, 1925). Delay of glacial disintegration due to the thick debris-cover on the glaciers brought long-lasting water supply to rivers, and the water supply to the rivers ceased when "fossil" glaciers vanished. Although Hoyanagi (1965) agreed with Stein's "fossil" glacier hypothesis, he pointed out the importance of "fossil" glaciers that originated from the advance during the Holocene period. It thus follows that changes in river water would be due to changes in glaciers during the Holocene. There is at present no definite date for the timing of glacial advance and retreat in the study area. Chronological sequence of glacial fluctuations has been established for many mountainous regions in Central Asia (Fig. 4-B). Based on these

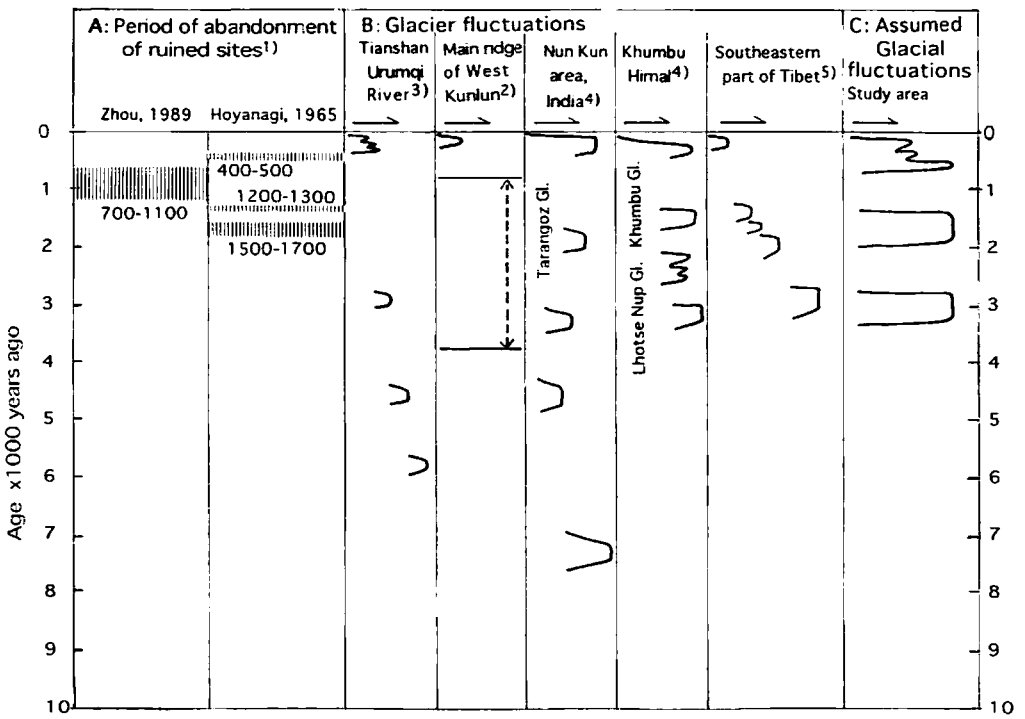

Fig. 4. Diagram showing timing of settlement abandonment (A), chronological sequence of glacial advance observed in numerous mountain regions in Central Asia (B), and possibly applicable to glacial advance in the study area (C)
1) Zhou (1989); Hoyanagi (1965), 2) Zheng *et al.* (1990), 3) Chen (1987), 4) Röthlisberger (1986), 5) Scientific Expedition to the Qinghai-Xizang Plateau (1986), Arrows indicate direction of glacial advance.

data, the authors have assumed the timing of the Holocene glacial advances in the study area (Fig. 4-C). The extent of older glacial advance during the Holocene period has not been known in this area. Röthlisberger (1986), however, reported that the individual glaciers in the Khumbu area, Nepal Himalayas, attained to the same extent at their several advances during the Holocene. These Himalayan glaciers are Turkestan-type glaciers as the same type as those in the study area. As the case of Himalayan glaciers, the older glacial advances during the Holocene in the study area may possibly have reached to the same position as the youngest advance (Fig. 4-C). The diagram in Fig. 4 shows that the periods of glacial advance between 1300 and 1800 years ago overlap with the older period of settlement abandonment of Hoyanagi (1500–1700 years ago). The main period of Hoyanagi's settlement abandonment (1200–1300 years ago) and settlement abandonment accompanied by desertification reported by Zhou (1989) (700–1500 years ago) followed the glacial advance occurred between 1300 and 1800 years ago showing in Fig. 4-C. In this period, continuous water supply occurred by the "fossil" glaciers (debris-covered dead ice) formed after the glacial advance between

1300 and 1800 years ago. Decrease in river water could thus appear to have due to finishing of gradual shrinkage of the "fossil" glaciers.

The close relationship between changes in river water and glacial fluctuations in the study area appears to arise from topographic conditions such as relatively short distances between ruined sites and fossil glaciers, extensive glacier advance, and the huge volume of debris cover on glacier ice. For confirmation of this possibility, glacial chronology in this area should be studied in greater detail.

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