CHINESE GEOGRAPHICAL SCIENCE
Volume 6, Number 2, pp. 166－176, 1996
Science Press, Beijing, China

PRELIMINARY STUDY ON THE HOLOCENE ENVIRONMENT CHANGES IN XINJIANG—— GEOLOGIC RECORDS AND SEQUENCE

Zhong Wei (钟巍)
Department of Geography, Xinjiang University, Urumqi 830046, *PRC*
Wang Jianmin (王建民)
Department of Geography Science, Lanzhou University, Lanzhou 730000, *PRC*
(Manuscript was received in May 1995)

ABSTRACT: A great number of geologic records has shown that the climatic environment in Xinjiang in the Holocene was mainly characterized by warm-dry, although alternated with sub-fluctuations, several important boundaries of environmental changes can also be determined as follows: 12,000 a B. P., 9000 a B. P., 3000 a B. P., 1500 a B. P. and 400 a B. P.. Since the Holocene, Xinjiang has undergone the influence of two kinds of environmental development patterns (the westerly type and the monsoon type), so the hydro-thermal disposal here was much more complicated. Generally speaking, the neoglacials of Xinjiang are characteristics of cold (cool)-humid and in the Climatic Optimal, it is dominated by warm-humid conditions in spite of being intercalated several sub-fluctuations of warm-dry intervals.
KEY WORDS: Xinjiang, Holocene, environmental changes, geologic record

Xinjiang, the most arid area in China, lies in the heart of Eurasia. Paleoenvironmental evolution here was different from the eastern China monsoon areas, and also not as the same as the westerly-affected parts in Europe. Since the Holocene, it has undergone two kinds of environmental change patterns, so to further understand and to grasp its processes of the Holocene environmental changes are of great significance to enrich the contents of paleoenvironmental studies and to probe into the environmental tendency of the arid area in China.

Recent advance in paleoenvironmental studies of Xinjiang makes it possible to resum synthetically the sequence and processes of the Holocene environ-

mental development.

I. THE GEOLOGIC RECORDS OF THE HOLOCENE ENVIRONMENTAL CHANGES IN XINJIANG

The Holocene environmental changes are extensively recorded by lakes, mountain glaciers, paleosol and the man's culture development in tnis area.

1. The Lake Records

Lake studies of the North Xinjiang are more thorough than that of the South Xinjiang. During the Holocene, the lake development of the North Xinjiang and South Xinjiang are synchronous. i From Fig. 1, it is easily found that the lake level fluctuations of these two parts are roughly the same. Under the condition of ruling out the tectonic factors, the lake level fluctuation is a sensitive indicator of climate. There existed two causes leading to the high level: the first was warm-moisture conditions during the interglacial; the second was the relative cold-moisture ones during the neoglacials. For example, the high lake level occurred widely during the "Climatic Optimum" was exactly the product of warm-moisture climate; but the two appearances of high level of Barkol Lake in North Xinjiang and Lopnur Lake in the South Xinjiang at about 3000 a B. P. and 5000 a B. P. were mainly related to a relative cold-moisture conditions during the neo-ice age.

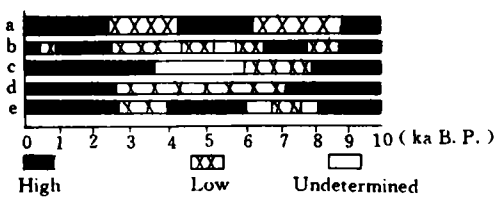

Fig. 1 The Holocene lake level fluctuation in Xinjiang
("a". "b" after literature[1--2]; "c". "d" after literature[3])

The time-space comparison of lacustrine sediment played an very important role in providing the useful information for reconstructing the sequence and time-spatial patterns of paleoenvironment. The lake sediments of the South and North Xinjiang have recorded the lacustrine paleoenvironment information since the Holocene (Fig. 2), for instance, the 3 mirabilite and mirabilite with gypsum layers occurred in Barkol Lake at respectively 12,530 a B. P. —10,870±280 a B. P., 10,870 a B. P. —6600±700 a B. P. and 2310±90 a

B. P.[2] are in fact the inflection of 3 warm-dry intervals. The sand layers alternated with the mud or clay layers in Lopnur Lake and Beilikol Lake in west Kunlun Mountain[4] reflected the shrinkage or development of the lakes. In Ebinur Lake the burned layers, intercalated with the turf and clay[5] are also the concret manifestation of climatic dry-humid and cold-warm fluctuations.

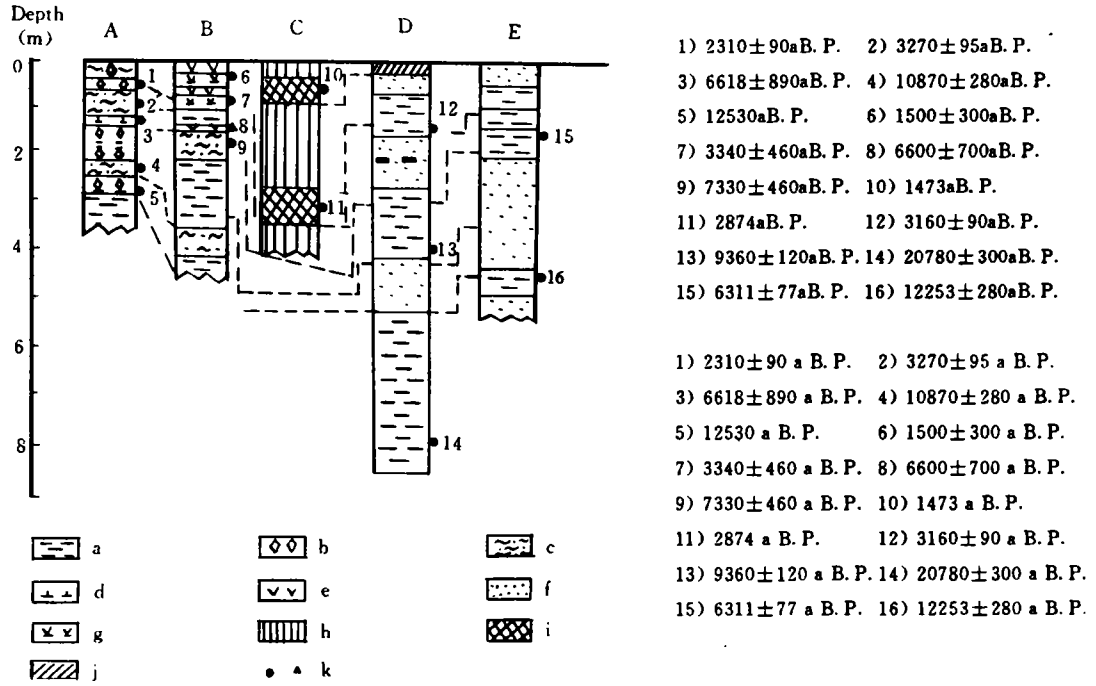

Fig. 2 The comparison of the sediment profile of South and North Xinjiang
A: Barkol Lake[2]; B:Ebinur Lake[6]; C:Kaisu loess[7]; D:Lopnur Lake[8]; E:Beilikol Lake[4]
a:silt; b:mirabilite; c:clay; d:gypsum; e:burned layer; f:sand;
g:turf; h:loess; i:paleosol; j:salt crust; k:dated site

With the features of continuity, sensitivity and high-resolution, the physiochemical and biographic index of lacustrine sediment are the ideal indicators of climatic changes. The humidity index C and the sporo-pollen density of the total and the woody plant have provided the most perceived incarnation for detailed inquisition into the Holocene climatic changes in Xinjiang, on one hand, the regulation of migration and accumulation of chemical elements in arid salt lake is deeply dominated by environment, from the formula as follows[6]:

$$C=\frac{\text{humid}\ \sum(\text{Fe}+\text{Mn}+\text{Cr}+\text{V}+\text{Co}+\text{Ni})}{\text{dry}\ \sum(\text{Ca}+\text{Mg}+\text{Ba}+\text{Sr}+\text{Na}+\text{K})}$$

the value of C just reflects the dry or humid conditions at the time of element accumulation; on the other hand, under the extreme dry macroscopic back-

ground formed in the early Pleistocene, especially since the Holocene, the flora assemblage varied little, the changes of environment influenced even more on the cover degree of desert-type plant, so the sporo-pollen density of the total and the woody-plant were of more significant indication of environment than the sporo-pollen assemblage. Taking the hole zk0024 of Barkol Lake and the hole Lo-4 of Lopnur Lake into consideration, the above-mentioned indices of these two holes and comparison with the mountain glacier sequence of the Tianshan Mountain (Fig. 3) show that it was still mainly dominated by drought in Xinjiang since the Holocene. The intercalated relative moisture periods were of different causations, one incarnated the "Climatic Optimum" at about 6000 a B. P. and the other, however, reflected the cold-moisture conditions during the neoglacials, which seems to be much more beneficial to plant growth.

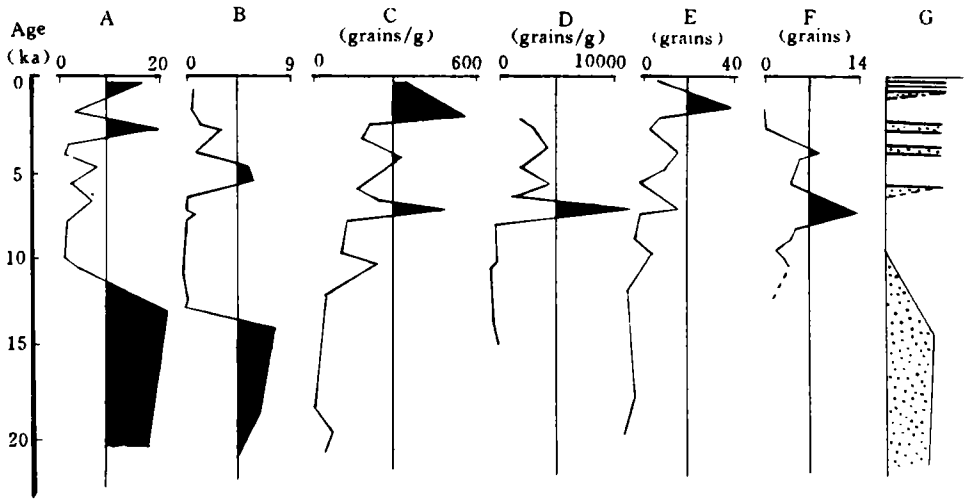

Fig. 3 The humidity index and the sporo-pollen density of the total and the woody-plant of lacustrine sediment and the glacier sequence of Tianshan mountain

A: humidity index *C* of Lopnur; B: *C* of Balikun Lake; C: sporo-pollen density of core Lo—4; D: sporo-pollen density of core zk00A; E: woody-plant sporo-pollen density of Lo—4; F: woody-plant sporo-pollen density of core zk00A; G: glacier sequence of Tianshan Mountain (The original data of "a", "c", "e" based on literature [9] and[10]; "d", "f", on literature[11] and "g" on literature[12] respectively)

2. The Mountain Glacier Records

After entering the Holocene, mountain glaciers of the northwest area in China were retreated with fluctuation, the length of modern glaciers and the

snow line are shrunk and rised in a great amplitude compared with that of Late Pleistocene, for instance, the length of modern glaciers of Tianshan and Kunlun mountains only reaches the 1/3—1/5 and 2/3 respectively of that in the Glacial Maximum, the snow lines uplifted respectively up to 500—800 m and 500—600 m[13]. The most complete Holocene glacier sequence in Xinjiang is in the Tianshan Mountain, 6 moraines with absolute datings in front of the glacier tongue coincided with the 4 Holocene neoglacials in north hemisphere (Fig. 3 and Table 1).

3. Turf Records

Turf generally formed under the conditions of stagnant water or marsh, so its existence was often regarded as the indicator of moisture conditions. Turf developed around many modern lakes in Xinjiang. At the east bank of Caiwopul Lake, the turf development commenced at about 7000 a B. P. and ended at 1600±178 a B. P. or 1350±150 a B. P. Turf were also discovered with ^{14}C datings at 9360±120 a B. P., 7065±100 a B. P., 3610±90 a B. P. and 2075±75 a B. P. around Lopnur Lake[14]. The development of turf in Xinjiang mainly assembled between 2—3 ka B. P.[7]. The others in Ebinur lake, The second turf layer in Ebinur Lake was dated at 3440±340 a B. P.[6], Kanas Lake at 2170±80 a B. P., Beidukeli Lake in Yumin County at 2450±100 a B. P. and Bosten Lake at 2570±100 a B. P. Besides the lakes, on the river terrace turf also often developed during this period, for instance, on the Wulungu bank of the Qinghe River, the turf formed at 2480±100 a B. P. and 2090±750 a B. P.

4. The Paleosol Records

The information of climatic changes recorded by the paleosol in Xinjiang is less sensitive and complete than that in the Loess Plateau in the central China. Studies show that the development of paleosol in Xinjiang were mainly in two periods, namely 3000 a B. P. and 1500 a B. P. In the Lujiaogou and the Wuyi road at 117-m site, two layers of the Holocene burial and residual black loam was dated by ^{14}C at the north piedmont of the Tianshan Mountain at 1430±150 a B. P. Several muck ^{14}C datings of the secondary loess profile deposited on drift bed and river terrace were at 2930±200 a B. P., 2760±200 a B. P., 2260±230 a B. P. and 2235±100 a B. P. near Nileke County. The drift surface soil of "The Heavenly Lake" in the Tianshan Mountain and the south slope of the west Kunlun Moutain were formed at 2380±177 a B. P. and 2740±850 a B.

Table 1 The Holocene glacier sequence of Xinjiang

Source area of Urumqi River[11,12]	Hantengri Peak[12]	Tuomer Peak[12]	Bogda Peak[12]	Artay Mountain[12]	West Kunlun Mountain[13]	Neoglacials in north hemisphere[12]
Three LIA morains (400, 210 and 70 a B. P.)	Arc moraines	Three moraines	Three moraines (4500, 4000, 4050 m a. s. l.)	Three moraines in front of glacier		430—30 a B. P. (1500 — 1920 A. D)
Shanbei group III moraine (2800 a B. P.)	Moraine (2710 m a. s. l.)	Tugbieli moraine	Neoglacial II moraine (3500 m a. s. l.)	Arkule moraine	Second moraine of Chongce glacier (2720 ± 85 a B. P.)	3300 — 2400 a B. P.
Shanbei group II moraine (4085 ±150, 3949±145 a B. P.)	Moraine (2630 m a. s. l.)	Neoglacial I moraine (3200 m a. s. l.)			First moraine of Chongce glacier (3983 ± 120, 3522±117 a B. P.)	
Shanbei group I moraine (5680 ±150 a B. P.)	Moraine (2560 m a. s. l.)		Lixingdaban moraine (2730 m a. s. l)			5800 — 4900 a B. P.
Upper Wangfen surface soil (9170±400 a B. P.)	Moraine (2520 m a. s. l.)		Shimen moraine (2300 m a. s. l.)		Guliya glacier moraine	8200 — 7000 a B. P.
Lower Wangfen moraine (14900 ±150 a B. P.)	Moraines (1950 — 2500 m a. s. l.)		Luweibaliang moraine (2900—1950 m a. s. l.)			

P. [15]. All mentioned above show that the 3rd neoglacial epoch in the Holocene took place at about 3000 a B. P. was an important pedogenic period in Xinjiang. The pedogenic process in Xinjiang perhaps was of special characteristics and different from the eastern monsoonal area[16].

5. The Other Records

In the Holocene, the flow of rivers in Xinjiang was decreased, the course shortened or dissociated, even interrupted. For example, the changes of the Tarim, Konqi and Qarqan rivers resulted in lake surface fluctuations of Lopnur Lake[14]. The Tarim River had formed its modern drainage system at the 17th—18th century, and emptied into Lopnur Lake all the year round until up to 19th century, but since the 20th century, due to the arid climate and mankind's activities, the flow decreased drastically, and Lopnur Lake dried up progressively. Tectonic also can affected river system in the Holocene, for example the Urumqi River[17].

Along with the Holocene environment development, the deserts of Xinjiang have the records of encroachment or fixation. The Kumtage Desert in the eastern part of Tarim Basin began to expand northward at 4600±100 a B. P. [13]. The two carbonated layers intercalated in the dunes of the south fringe of Gurbantunggut Desert with ^{14}C date of 2460±110 a B. P. and 2780±170 a B. P., combined with the fossil nail taken from the accumulated water depression in the front of the dune dated by ^{14}C of 2810±130 a B. P. show that during 2800—2400 a B. P., this place underwent the relative humid condition and the dunes were fixed[15].

Coelodonta antiquitatis and Mammoth etc. lived around Urumqi distincted after coming into the Holocene[18]. The forest belt of the north slope of the Tianshan Mountain could moved down to the piedmont during warm-humid periods[19], the desert steppe expanded even to the low hill belt in cold periods. Plant belt had apparent vertical movement, although there had little variations in sporo-pollen combination.

The man's culture development was closely related to the environment. The declination of the ancient Loulan City and the Silk Road to be moved southward constantly were all the product of climate getting dry[20]. However, the relative optimal periods were still beneficial for the development of human being's civilization, the widely discovered painted potteries, copper wares and ironwares at about 3000 a B. P. in Xinjiang, together with the ground stone axes and stone knives at about 7000 a B. P. [12] reflected two important development periods of man's culture.

II. THE HOLOCENE SEQUENCE OF ENVIRONMENTAL CHANGES IN XINJIANG

The Holocene bottom boundary was placed reasonably at 12,000 a B. P. based on the severe variation of climate and stratigraphic studies[21]. To synthesize the various geologic records, several important boundaries , i.e. 12,000 a B. P. , 9000 a B. P. , 3000 a B. P. , 1500 a B. P. and 400 a B. P. can be determined to deeply comprehend Holocene environmental changes in Xinjiang, detailed Holocene sequence of climate changes can established as Fig. 4 and Fig. 5.

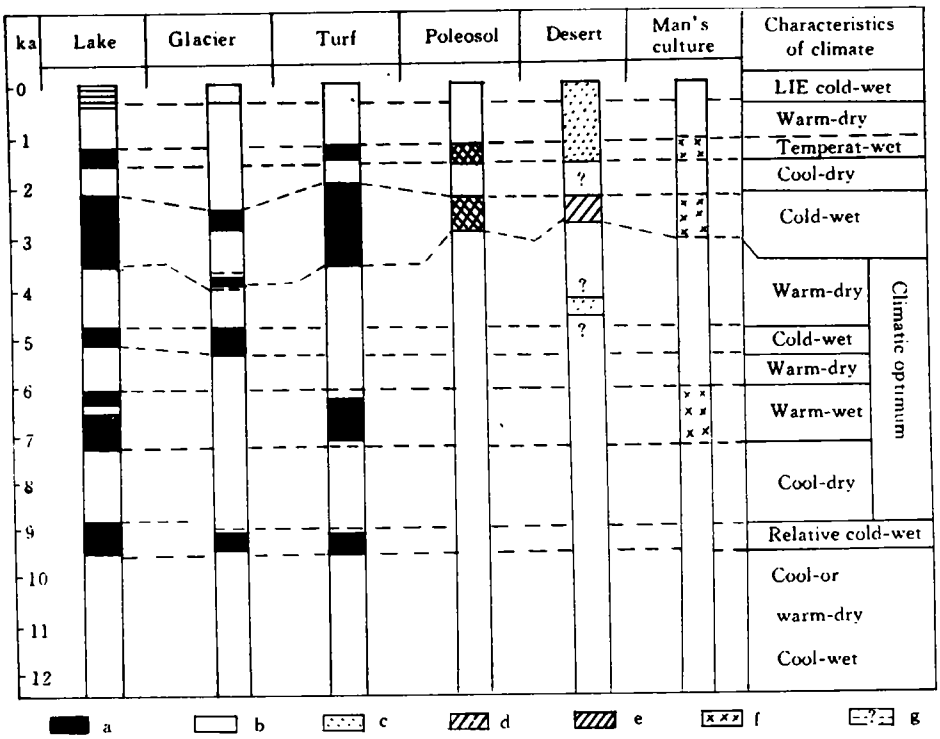

Fig. 4 The sequence of Holocene environmental changes in Xinjiang
a:development of lakes, turf and glaciers; b:shrinkage of lake and glaciers;
c:developed desert; d:fixed desert; e:paleosol;
f:developed man's culture; g:undetermined boundary

1. The Early Holocene (12,000–9000 a B. P.)

Due to termination of the late Glacial epoch, the climate in this period generally tended to be dry and warm, so that the glaciers shrunk widespreadly, humidity index C reduced, however the plant just got rid of at last the

drastic biotope of the Glacial Maximum and flourished, plant belt expanded. The first neoglacial epoch took place at about 9000 a B. P. resulted in the development of lakes and turf for the first time.

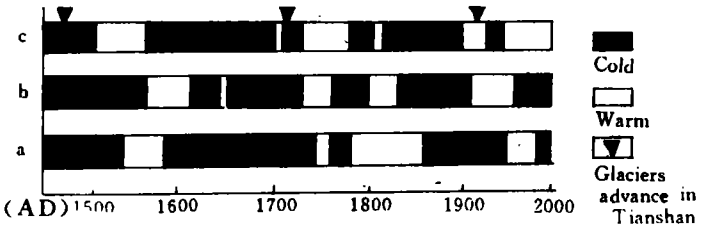

Fig. 5 The comparison of the various recordes during the Little Ice Age
a: tree-ring record of Barkol Lake[22]; b: lake sediment core of Barkol Lake[22]; c: dunde ice core[23]

2. The Middle Holocene (9000—3500 a B. P.)

Global climatic optimum in the Holocene also dominated Xinjiang in this period. Under the macroscopic background of the warm-humid, intercalated with the neoglacials, Xinjiang underwent several alternations of warm-humid, warm-dry, cold-humid or cool-dry periods, for instance, the 3rd burned layer occurred in the Ebinur Lake[6] which reflected extreme dry condition was just a sub-fluctuation during 7500—6000 a B. P.. The 2nd neoglacial happened at 5000 a B. P. led to another high level of lakes and development of glaciers and turf. In the late of this period, it turned to warm-dry.

3. The Late Holocene (3000 a B. P. —Present)

3.1 *The period of* 3000 *a B. P.* —1500 *a B. P.*

Various geologic records show that 3000 a B. P. is an important boundary of environment changes in Xinjiang. The manifestation of the 3rd neoglacial in Xinjiang was development of lakes, glaciers and turf, the fixation of desert, the formation of paleosol etc. After 3000 a B. P., the lakes shrunk sharply[16], showing the increase in aridity.

3.2 *The period of* 1500—400 *a B. P.*

This period was characterized generally by warm-dry, but around 1500 a B. P., there was a short cold (or cool) humid interval. The first paleosol mainly developed around this time. General feature of the period was turned into warm-dry rapidly from early cold (or cool)-humid.

3.3 *The period of* 400 *a B. P. — present*

This period is often named the Little Ice Age (the LIA), also called the 4th neoglacial epoch. Based on the obtained results and from Fig. 5, we can draw the conclusion that in this period, it presented mainly cold-humid characteristic, but the temperature and precipitation presented constant increase and decrease respectively. Because of the regional difference, the LIA sequence of various records has different starting and ending ages.

III. CONCLUSION

From the above-mentioned, we can draw some knowledge about the Holocene environment changes in Xinjiang. The processes of Holocene environment changes here were very complicated, it has undergone two kinds climatic patterns, i.e the monsoonal one and the westlies' one. The development of high lake level or the turf has the same or different causations as the eastern area in China at a certain period. The moisture is the uttermost important factor to affect the environmental features here, differentiated from the eastern parts of China, no matter what a cold or warm period, relative humid was just the optimal.

The knowledge obtained here is very helpful for people to further understand paleoclimatic evolution in Xinjiang. In view of the Holocene Climatic Optimal features in Xinjiang and in the light of the global temperature increase at present and in future, a "Man-made Climatic Optimal" to be appearred in future in Xinjiang is possible because of the temperature increase resulting in enhancement in east-Asia monsoon force so that it is able to stretch into the heart part of Eurasia.

ACKNOWLEDGEMENT

Prof. Li Jijun is gratefully acknowledged for critically reading the manuscript.

REFERENCES

[1] Han Shuti et al. Climatic change sequence of Balikun Lake since 35,000 a B. P. in Xinjiang. Acta Geographica Sinica, 1990, 45(3):350—361. (in Chinese)

[2] Han Shuti et al. The climatic changes in Balikun Basin since the late stage of Late Pleistocene. In: Quaternary Glacier and Environment in western China. Beijing: Science Press, 1991. 184—196. (in Chinese)

[3] Pu Qinyu. Evolution of natural environment in China since the last glacial period and its position in

the global change. Quaternary Science, 1991,3:245—256. (in Chinese)
[4] Li Shuanke. Lake-level fluctuations and environmental changes in Kumkol basin since 17,000 a B. P. In: Quaternary Glacier and Environment in Western China. Beijing: science Press, 1991. 226—236. (in Chinese)
[5] Chen Kezhao et al. Late Pleistocene salt lake development in Qaidam basin. In: Proceedings of China—Australia Quaternary Symposium. Beijing: Science press, 1987. (in Chinese)
[6] Wen Qizhong et al. Late Pleistocene climatic environmental changes in northern Xinjiang. Science Bulletin, 1988,10:771—774. (in Chinese)
[7] Qiao Yulou. Regional record and environmental changes of the moisture periods since 3000 a B. P. in Xinjiang. In: Environmental Geochemistry and Health. Guizhou Scientific Press, 1990. (in Chinese)
[8] Xia Xuncheng et al. On the problem of whether did Lopnur vacillate? In: Scientific Investigation and Research on Lopnur. Beijing: Science Press, 1987. 68—94. (in Chinese)
[9] Comprehensive Exploration Team of Lopnur. Background value of trace elements in soil in Lopnur district. In: Scientific Investigation and Research. Beijing: Science Press, 1987. 199—209. (in Chinese)
[10] Yan Fuhua et al. Significance of spore-pollen combination of core Lopnur—4 in Lopnur in Xinjiang. Seism and Geology, 1983, 5(4). (in Chinese)
[11] Han Shuti. Holocene environmental changes sequence of Balikun Lake, northern Xinjiang. Scientia Geologica Sinica, 1992(supplement):247—259. (in Chinese)
[12] An Zhisheng et al. Preliminary study on poleoenvironmental change in China since latest 20,000 a B. P. In: Loess • Quaternary • Global Change. Beijing: Science Press, 1990. (in Chinese)
[13] Xu Shuying et al. Discussion on Holocene natural environmental changes in northwest arid area. In: Advance in Geomorphology and Quaternary Research. Beijing: Cartographic Press, 1991. 47—54. (in Chinese)
[14] Wang Wenxian. Studies on Quaternary and lake development history in Lopnur and neighbour area. Chinese Quaternary Research, 1986, 7(2). (in Chinese)
[15] Zhou Shongzhe et al. Preliminary studies on Holocene environmental changes in western China. In: Environment Archaeological Research(1). Beijing: Science Press, 1991. (in Chinese)
[16] Li Jijun. The patterns of environmental changes since late Pleistocene in northwestern China. Quaternary Science, 1990, (3):97—203. (in Chinese)
[17] Han Shuti et al. On the sedimentary environment of the late Pleistocene in Cangfanggou formation near Urumqi. In: Proceedings of Quaternary Research in Arid Xinjiang Area. Urumqi: Xinjiang People's Press, 1985. 41—50. (in Chinese)
[18] Han Shuti. On the sedimentary environment of the piedmont glacio-fluvial terraces of the Tianshan Mountains. In: Proceedings of Quaternary research in Arid Xinjiang Area. Urumqi: Xinjiang People;s Press, 1985. 32—40. (in Chinese)
[19] Zhou Kunshu. Paleontologic studies on the glacier ice and Quaternary sediment in Tianshan Urumqi River source. Glaciology and Geocryology, 1981,3(supplement). (in Chinese)
[20] Li Jiangfeng. Climatic variation of Xinjiang in recent 3000 years. In: Proceedings of Quaternary research in Arid Xinjiang area. Urumqi: Xinjiang People's Press, 1985. 1—5. (in Chinese)
[21] Bai Meiyang. Discussion on the division and correlation of Holocene series in Xinjiang. In: Proceedings of Quaternary Research in Arid Xinjiang Area. Urumqi: Xinjiang People's Press, 1985. 161—172. (in Chinese)
[22] Wan Chengyi. Temperature variation in past 500 years of Balikun area. Journal of Xinjiang University, 1991. 8(1):70—74. (in Chinese)
[23] Yao Tandong et al. Climatic change since Little Ice Age recorded by Dunde Ice Cap. Science in China, 34(6):760—767. (in Chinese)