

# HISTORICAL DESERTIFICATION PROCESS IN HEXI CORRIDOR, CHINA

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**ABSTRACT:** Over the last 2000 years, approximately 38 ancient cities were abandoned through desertification in Hexi Corridor, Northwest China. Among them, 21.05% were abandoned during the Northern and Southern Dynasties, 21.05% during the end of the Tang Dynasty and the Five Dynasties, and 57.9% during the Ming and Qing dynasties. At the same time, main lakes were shrinking rapidly from the 5th Century to the 6th Century and the end of the Qing Dynasty. The climate in these periods was relatively arid and cold with frequent dusts. The phase of these changes indicated that there were three periods of desertification enlargement in the northern China. They were Northern and Southern Dynasties, the end of Tang Dynasty and Five Dynasties, the Ming and Qing dynasties. The macro-process of desertification in the study area was controlled mainly by the climatic changes. But from the facts that the population density in the middle of Qing Dynasty had exceeded the critical index of population pressure in arid area and the usage rate of water resources had exceeded 40% in Hexi Corridor, this paper also suggests that human activities have played an important role in desertification processes of the study area mainly during the recent 300 years.

**KEY WORDS:** historical desertification; climate change; human activities; Hexi Corridor

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## 1 INTRODUCTION

Historical desertification is not only the key issue on the interaction between nature and human process, but also the most challenging issue in the complex relationship between human and land. Previously, most Chinese scientists in this field carried out their research work mainly from the perspective of historical geography or archeology. One approach to analyze environmental change is to study the rise and fall of the ancient cities in desert and to study the historical relics that recorded human activities. That is to say, they took the sites and relics as the age signals of desertification. Another approach is to study land collection and cultivation in historical periods from mainly to take the stratigraphic relationship between soil in culture layer and the soil in topsoil layer as the historical basis to confirm desertification. The lower part of surface horizon is quicksand formed during geologic time, while the upper part of surface horizon is re-born sand formed during historical periods. The ancient cities buried by sand and some famous grasslands in the past in the northern China take on the

sight of undulate dunes at present. It is the clear proof of desertification in nearly 2000 years. According to the geographic distribution and characteristics of desertification, we can generalize these lands into 2 types: one type is land where desertification took place near the oasis of downstream river in desert regions, such as Hexi Corridor and its surrounding regions, the other one is land where desertification took place in semi-arid and semi-humid regions, with the most typical cases of Mu Us Desert in Ordos Plateau and Horqin Desert in the Xiliao River valley.

There are various complicated causes that lead to desertification during historical periods, including both the natural factors and the human dimensions. But during certain periods, the status and influence degree of the two kinds of factors fluctuated in the desertification process. As for the study on the formation of the first type, much fruitful research has been done since the 1990s. This paper takes the desertification around the Hexi Corridor and its surrounding regions as the example to explain the climatic and humanistic background when the first type of desertification happened (Fig.1).

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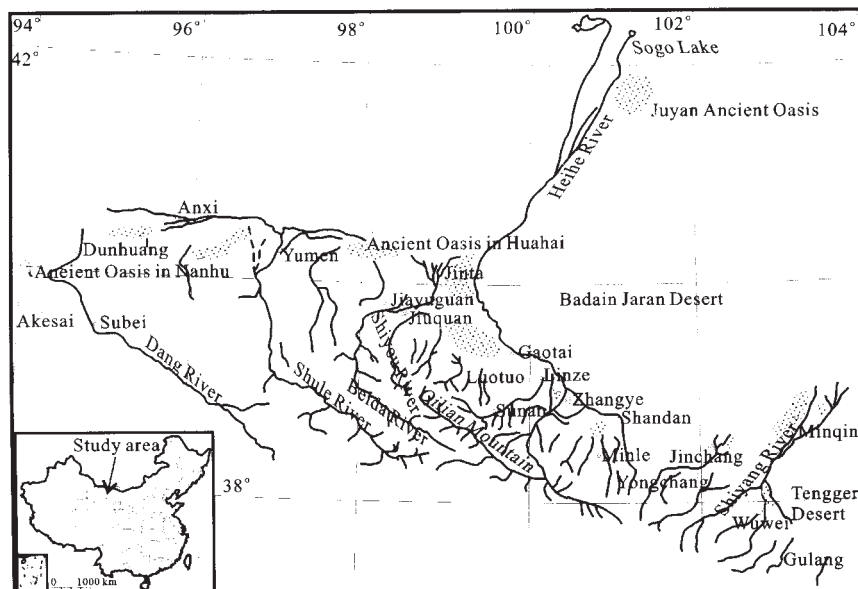


Fig. 1 Distribution of the deserted ancient oases in Hexi Area

## 2 METHODS

This study included the scientific expedition to the ancient cities and the  $^{14}\text{C}$  dating besides the analysis of the historical document. Samples of wood block, grass rope and other types were dated at the Laboratory of Science Technological Archaeology & Cultural Relics' Protection in Peking University and at the Laboratory of Chronology in Lanzhou University.

## 3 RESULTS AND DISCUSSION

### 3.1 Climatic Background of Historical Desertification Process

The occurrence time of desertification in different regions can be compared, which is of significant importance to discuss the desertification genesis. According to statistics, the abandoning times of ancient cities in Hexi Corridor and its surrounding regions have good consistency (Table 1). Among the deserted cities, 21.05% were abandoned during the Northern and Southern Dynasties, 21.05% from the mid-Tang Dynasty to the Five Dynasties and 57.9% in the Qing Dynasty.

On the other hand, when we compare the fluctuation of climate and the age when the ancient cities were abandoned, we can easily find that climate was obviously cold and dry when the ancient cities fell to dust largely, such as the Northern and Southern Dynasties, from the Late Tang Dynasty to the Five Dynasties and the Ming and Qing dynasties. During the dry period of the 4th –

6th century, countries such as Loulan, Qiongfeng, Kuobuzhuang, Niya, Keladun, Guminfeng and Jingjue in the Tarim Basin all collapsed one after another during that time. It is not unique, but has its counterpart: the time when the lakes around the cities shrank and disappeared has relative consistency to these ancient cities' disappearance. For example, Zhuye Lake's highest altitude of its water table was about 1310m in natural water system epoch of prehistory (7000–6000a B.P.), but during the Han Dynasty and several hundred years after that, it gradually separated into two unconnected parts: the West Lake, which is now called Qiongtu Lake, and the East Lake, which is now called Baiting Lake. The biggest area of Juyan Lake once reached over 4300km<sup>2</sup> in prehistory stage. It lied at the end of the Heihe River and was made up of old Juyan Lake, Suogunuoer Lake and Geshunuoer Lake. In the Han Dynasty, the cultivated area in Juyan region reached a stage of unprecedented growth. These lakes once were a good size because of a plentiful supply, but they shrank greatly in the 5th and 6th century A.D. During the Pre-Qin Dynasty, Lop Lake had once a larger area. From its lacustrine sediments and shoreline length, it can be estimated that its maximum area could once reach 5350km<sup>2</sup> during its development. Till the 5th century, its girth was only 150km (from *Biography of Xiyu in the Book of Han Dynasty History*), and the stage was the cold-arid phase of the Northern and Southern Dynasties (about 200 to 589 A.D.).

What were associated with desertification were dusts release, transport and larger range influence in the at-

Table 1 Radiocarbon ages and abandoning times of main ancient cities in Hexi Corridor

Ancient city	Material dated	$^{14}\text{C}$ age	Existing stage	Age of desertification
1. Gaogoupu Fort of Wuwei	Grass rope	195±50a B.P.	Qing Dynasty	Middle Qing Dynasty
2. Qinfeng Town of Mingjin			Han, Tang and Ming dynasties	Qing Dynasty
3. Baitingjun Town of Mingjin	Wood block	1305±58a B.P.	Han and Tang dynasties	After middle Tang Dynasty
4. Xishawo Town of Mingjin	Wood block	1207±34a B.P.	Han, Tang and Western Xia dynasties	After middle Tang Dynasty
5. Sanjiao Town of Mingjin	Wood block	2520±80a B.P.	Han and Tang dynasties	End of Tang Dynasty
6. Duanzhao Town of Mingjin	Carbon debris	1270±48a B.P.	Han and Tang dynasties	Ming and Qing dynasties
7. Dong'an Fort of Mingjin	Wood bar	120±80a B.P.	Western Xia, Yuan and Ming dynasties	End of Qing Dynasty
8. Hongsha Fort of Mingjin			Tang, Song, and Ming dynasties	Middle and late Qing Dynasty
9. Qingsong Fort of Mingjin			Ming and Qing dynasties	Middle and late Qing Dynasty
10. Shashan Fort of Mingjin			Ming and Qing dynasties	Middle and late Qing Dynasty
11. Nanle Fort of Mingjin			Ming and Qing dynasties	Middle and late Qing Dynasty
12. Hongya Fort of Mingjin			Ming and Qing dynasties	Late Qing Dynasty
13. Shacheng Town of Yongchang			Han, Jin and Tang dynasties	Middle Tang Dynasty and Five Dynasties
14. Dichi County Town of Minle			Han and Jin dynasties	Northern and Southern Dynasties
15. North Heshuiguo Town of Zhangye	Wood block & grass rope	780±50a B.P.	Han and Tang dynasties	Qing Dynasty
16. South Heshuiguo Town of Zhangye	Wood block & grass rope	190±50a B.P.	Tang, Western Xia and Yuan dynasties	Middle and late Qing Dynasty
17. Luotuo Town of Gaotai	Wood block	1428±56a B.P.	Tang Dynasty	Middle Tang Dynasty and Five Dynasties
18. Jiankangjun City of Gaotai			Han and Jin dynasties	Northern and Southern Dynasties
19. Xusaiwan Town of Gaotai			Han, Tang and Ming dynasties	Qing Dynasty
20. Minghaizi Town of Sunan	Wood block	484±50a B.P.	Ming Dynasty	Qing Dynasty
21. Xindunzi Town of Sunan	Bones	1840±80a B.P.	Han, Tang and Ming dynasties	Qing Dynasty
22. Caogoujing Town of Sunan	Wood bar	613±58a B.P.	Ming and Qing dynasties	Qing Dynasty
23. Huishui County Town of Jinta	Wood block	1580±70a B.P.	Han and Jin dynasties	Northern and Southern Dynasties
24. K710 Town of Ejina			Han Dynasty	Northern and Southern Dynasties
25. A8 Town of Ejina			Han Dynasty	Northern and Southern Dynasties
26. K688 Town of Ejina			Han Dynasty	Northern and Southern Dynasties
27. F84 Town of Ejina			Han Dynasty	Northern and Southern Dynasties
28. K749 Town of Ejina			Han Dynasty	Northern and Southern Dynasties
29. K789 Town of Ejina	Wood block	2380±62a B.P.	Han, Tang and Western Xia dynasties	Ming and Qing dynasties
30. Lucheng Town of Ejina	Wood bar	2607±62a B.P.	Han, Tang and Yuan dynasties	Ming and Qing dynasties
31. Heicheng Town of Ejina	Wood block	1008±40a B.P.	Western Xia and Yuan dynasties	Ming and Qing dynasties
32. Pochengzi Town of Yumen	Wood block	1390±50a B.P.	Han, Tang and Ming dynasties	Qing Dynasty
33. Jinchangjun City of Anxi	Wood block	1017±60a B.P.	Han and Tang dynasties	End of Tang Dynasty and Five Dynasties
34. Bulongjiao Town in Anxi	Reed	1585±76a B.P.	Han and Tang dynasties	End of Tang Dynasty and Five Dynasties
35. Mingan County Town of Anxi			Han, Tang and Qing dynasties	Qing Dynasty
36. Suoyang Town of Anxi	Wood block	1230±58a B.P.	Tang, Yuan and Ming dynasties	Qing Dynasty
37. Toubao Town of Anxi	Grass rope	364±64a B.P.	Qing Dynasty	End of Qing Dynasty
38. Shouchang County Town of Dunhuang			Han and Tang dynasties	End of Tang Dynasty and Five Dynasties

Note: The  $^{14}\text{C}$  ages were measured in the Laboratory of Science Technological Archaeology & Cultural Relics' Protection, Peking University and in the Laboratory of Chronology, Lanzhou University.

mosphere. With the rapid development of desertification, the occurrence frequency and intensity of paroxysmal wind-sand disaster or dust storm were growing. According to the statistics of dust storm occurrence, there were 5 times in the 1950s, 8 in the 1960s, 13 in the 1970s, 14 in the 1980s, and 23 in the 1990s. The frequent occurrence of dust storm corresponded to the expansion of desert at the same period in China. From the

above facts, we can suggest that dust record is one important index of desertification during historical periods. ZHANG De'er (1984) has even drawn a frequency curve of the rain and soils since 300 A.D., in which there are 5 frequent occurrence stages over the last 1000 years. They were from 1060 to 1090, 1160 to 1270, 1470 to 1560, 1610 to 1700 and 1820 to 1890 A.D. respectively. We can relate these stages with the corre-

sponding stages of the temperature curve in the latest 5000 years that ZHU Ke-zhen (1973) simulated. Then we can find out that, on the whole, dust storm's frequent occurrence periods were consistent with low temperature periods. At the same time, when we compare them with the humidity index curve in the eastern China during the latest 2000 years, we can find out that the periods were also consistent with dry climate stages. The difference in dust frequency under cold or warm climate backgrounds was caused by the dynamical condition that attributes to the change of the atmospheric-circulation under both cold or warm climate periods. During the cold stage, the center of Siberian high and Aleutian low shifted southward, winds in winter became stronger and the polar front region shifted southward to  $25^{\circ}$ – $30^{\circ}$  N. On the other hand, the lacustrine deposits and the abandoned farmlands in ancient oasis were exposed to surface because of the drought or shrinkage of lakes. These regions would usually become the origins of sand storm or desertification under strong wind erosion. The time consistency between the falling of the ancient cities, lake shrinkage or drying up and dust storm's frequent occurrence is more than a coincidence, which indicates that the dry and cold periods of the last 2000 years were the physical background that controls the macro-progress of the occurrence of desertification. First of all, the long-term transition to dry and cold climate would gradually make the environment of the ancient cities for human inhabitation worse, leading to decrease in water supply and abandonment of the cities in the end. Secondly, climate could affect the fall of the ancient cities not only directly through affecting water supply, but also indirectly through other social factors. For example, war once had an important effect on the destruction and fall of some ancient cities. In dry periods, the successive drought did great harm to agricultural production, especially grazing sector. The yield could not meet the basic needs of the rising population in warm and humid stages, consequently, speeding up the aggression from nomad people. For example, the Tibetans broke in after the AN and SHI's Rebellion on the 14th year of Tianbao in the Tang Dynasty (755 A.D.). Hexi Corridor and its surrounding regions were captured one after another, which led to sharp decrease in the population and abandonment of vast fertile farmlands. During the 200 years between the 2nd year of Guangde in the Tang Dynasty (764 A.D.) and the periods of Chunhua in North Song Dynasty (990 to 994 A.D.), Hexi regions were basically out of the control of Central Plains government administration. Former research showed that there was a cold stage of about 150

years from the middle of the Tang Dynasty to the Five Dynasties (middle period of the 8th century to end of the 9th century) (ZHANG 1996). And it was very likely that it was this cold stage that led to frequent wars in Hexi regions. One famous Chinese poet YUAN Zhen (from 779 to 831 A.D.) wrote a poem named *Dancing in Xiliang*, in which there was a few sentences as following: "I have heard that there were so many people in Xiliang State and there was abundant output of agriculture before." "But after the Tang Dynasty's control in China, the Huanghe (Yellow) River and the Huangshui River turned to dry up and there were only sand dune left." These verses record environmental change of that period, especially the last sentence showed that desert started to expand and many ancient cities or tribes began to fall at this stage. One famous scholar MA Du-an-lin, who lived between the late Song Dynasty and early Yuan Dynasty (from 1254 to 1323 A.D.), recorded the following in his works *All Study of Literature*: "After the middle period of the Tang Dynasty, the lands in Hexi regions suddenly turned to desert, which was controlled by outer tribes and did not have the same degree of fertility." All lands in the northwest of China were not the same degree of fertility as before since the confusion of AN and SHI in the Tang Dynasty. Even if the famous general YUAN Hao had great valor in war and controlled lands as broad as Liang State, who was just one of the outer tribes living in the barren lands. What is worthy of attention is what was depicted in this treatise. For example, it was pointed out that Hexi regions changed into deserts or barren lands after the middle of the Tang Dynasty. The economic boom of Hexi Corridor lasted over 100 years since the Sui and the Tang dynasties, and the scale of its exploitation was nothing less than that during the Ming Dynasty. But why did the desertification begin rapidly during the Tang Dynasty? The key answer to the question is connected with the climate of China, which was warm and humid in the Sui and the Tang dynasties but cold and dry in the late Tang Dynasty.

### 3.2 Human Activities as Main Factors of Desertification since Middle of Qing Dynasty

The study of desertification of ancient oasis and ancient lakes in Hexi Corridor involves many unresolved important academic questions about the environmental evolution of the northwestern China, such as whether the climate turned dry or not, whether discharge of rivers decreased or not, the degree of influence of human activities on the shrinkage or dry-up of inland lakes and the desertification of ancient oasis. The rea-

son for the dry-up of so many lakes and desertification of ancient oasis might be the change of climate and river channels, or unreasonable human activities, or both of the physical and human progress. The key to determine the result lies in separating human factors from the eco-destruction information obtained from lacustrine deposits and ancient cities' site, such as the relationship between population and resources carrying capacity, relationship between sharp degradation of environment and the appearance of refugees, fights or wars for resources control. According to these principles or characteristics, we knew that overpopulation in the 18th century in this region has deep and significant meaning.

We have just discussed the climatic background of desertification of ancient oasis during historical period, and in fact, human activities made a rather important impact on the desertification too. Among all kinds of human factors, population is not only the most important index that reflects human activities, but also the basic factor that leads to occurrence and expansion of the desert. With the rapid increase in population and the wide use of bronze wares and iron wares, the impact of human activities on environment was gradually strengthened. However, it has both positive and negative function clearly leading to opposite results. On the one hand, to make a living, human being carried out a series of activities such as farming, logging and even fighting. Vegetations and soils on the land surface were so greatly transformed that the process of desertification began in the form of wind erosion, wind transportation and wind-drift sand accumulation and so on (DONG *et al.*, 1998). On the other hand, we cannot deny the fact that the reverse process of desertification has ever partly taken place under the influence of human activities, especially in the process of the transformation from arid desert to oasis. For instance, with the deep influence of human activities, the area of Nanhu Oasis in Dunhuang increased by about  $10\text{km}^2$  compared to the ancient.

The population of Hexi Corridor rarely exceeded 400 000 from the Han to the Tang dynasties, and water resources were mainly used to meet the need of irrigation and everyday life, so land exploitation did not play a leading role in the change of water ecological or physical environment. According to the record of *Records of Geography in the Book of Han Dynasty History*, there was a population of 76 000 in W uwei Shire, 88 000 in Zhangye Shire, 77 000 in Jiuguang Shire and 38 000 in Dunhuang Shire respectively till the end of the Western Han Dynasty. So if we included the number of soldiers engaging in farming, the population could reach 400 000 or so in Hexi Corridor at that time. Then the

population in the drainage area of the Shiyang River in W uwei Shire would exceed 100 000. With the estimation of  $0.79\text{ha}$  of cropland per capita in the Han Dynasty, the total area of cropland in the drainage area of the Shiyang River would be  $80\,000\text{ha}$  or so. Supposed that the annual runoff amount and gross irrigating ration in the Western Han Dynasty were the same as today, i.e.  $1687 \times 10^6\text{m}^3$  and  $6930\text{m}^3/\text{ha}$  respectively, the using rate of the water resources at that time was 33% in the whole drainage area, so the water resources was abundant for human use. In fact, we can also get the result to know the prosperity of Hexi Corridor regions through the record in *Records of Geography in the Book of Han Dynasty History*: "Once there was a party, everyone of that the country can attend to have a good time whether his status is gentle or simple. Even when there was a bad harvest after natural disasters, the price of cereal was low as usual and the thieves or robbers seldom turned out. The reason is that the air of the whole country was so united and harmonious that it had superiority to the inland countries". Because of the social stability, economic progress and traffic fluency, W uwei Shire, Zhangye Shire, Jiuguang Shire and Dunhuang Shire, not only were the important martial beachheads and local administrative centers of northwest borders in the Han Dynasty, but also played an important role in international trade between China and other countries. *Biography of Kong Fen in the Book of Post-Han Dynasty History* recorded: "Guzang (former name of W uwei) was a wealthy city because of the trade with other minorities lived there at that time, and there were four times for trade every day. The residents in the city could have become rich in several months." According to the market trade in the ancient time, there were generally three times for trade everyday in the past. For example, in Luoyang, capital of the Eastern Han Dynasty and Chang'an, capital of the Western Han Dynasty, there were three times for business every day, a normal market, a morning market and an evening market in the Han Dynasty. All facts mentioned above reflected the business prosperity at that time. *Biography of Xiyu in the Book of Post-Han Dynasty History* described: "Pedlars were weighed down with business among post houses every month and gathered frontier fortress every day". It related to national politics and economy in that regions, but it must be emphasized that it was the second warm climatic stages over the recent 5000 years (ZHU, 1973). In contrast to this, the population in the whole Hexi Corridor decreased to 25 000 according to *A Survey of Landform in the Book of Wei Dynasty History*, while the area of desert expanded because of a rela-

tively dry and cold climate before the mid-6th century. One clear proof was that Zhuye Lake was separated into two discontinuous parts: the West Lake, and the East Lake. The area of land under cultivation (including the area cultivated by soldiers, farmers, temple or nun and so on) was  $213\times10^3\text{ha}$ , which was equivalent to one third of that nowadays. There were 22 462 households in five counties of Liang State in the first year of Tianbao in the Tang Dynasty (742 A.D.). The population was about 120 000. According to the standard of 4.3ha per household, the total area of cropland was about  $97.3\times10^3\text{ha}$ , corresponding to  $78.6\times10^3\text{ha}$  in present value in the drainage area of the Shiyang River valley. The total was about  $89.3\times10^3\text{ha}$  if cropland cultivated by soldiers was included. In fact, the using rate of water resources was about 37% at that time, which indicated that the exploitation and utilization degree was still under the threshold value of 40% used widely in the world though human activities had more effect on physical background than the Ming Dynasty.

Supposed that climatic change affected mostly the slow expansion of the desertification in the northern China before Little Ice Age, the effect of human activities became the primary cause in the process of desertification during the recent 300 years. The cultivated area was 16 300ha in ancient district of Hexi and Xining region in the early Ming Dynasty. It became 45 995ha during the years of Wanli in the Ming Dynasty (1574–1620 A.D.), which was 2.82 times that of the earlier

Ming Dynasty according to the 13th volume of *Actual History of Royal Genealogy in the Earlier Ming Dynasty*. The population was about 338 000 according to the population growth rate calculated through the increase rate of the cultivated area east to Jiayuguan State in Hexi region after the mid-Ming Dynasty. The Turpans occupied the drainage area of the Shule River west to Jiayuguan State, where the population was about 10 000. The total population was about 350 000 in Hexi region after mid-age of the Ming Dynasty, among them, the drainage of the Shiyang River accounted for 48%, the Hei River valley 49%, the Shule River valley 3%. A great deal of immigrants came to Hexi region because of political stability in the Qing Dynasty. According to *A New General Survey During the Year of Jiaqing in Qing Dynasty*, there were 255 000 households in Gan State, Liang State, Su State and Anxi State of Hexi Corridor. The total population would be 1 274 000 on the assumption of 5 persons per household. For the first time, the population density in Hexi Corridor rose to 8.8 per square kilometer and broke through the critical index of population pressure in arid region (it was set at 7 persons per square kilometer in the international meeting of United Nations Conference on Desertification 1977). Human activities gradually replaced physical factors and became the chief impact on environmental changes in Hexi region. Actually, desertification of many lakes in Hexi Corridor began in past several hundreds years (Table 2).

Table 2  $^{14}\text{C}$  dating of sand dune of paleo-lake in Hexi Corridor

Sampling site	Sampling number	Altitude (m)	Position of physiognomy	Height of dune (m)	Material dated	$^{14}\text{C}$ age (A.B.P.)
East to Huasan well in Huahai Lake	HXSQ 01	1223	Terrace by the lake	4.0	Litter	260±70
East to Huasan well in Huahai Lake	HXSQ 02	1224	Terrace by the lake	5.0	Relict of <i>Tamarix</i> sp.	425±60
Luciao well in Huahai Lake	HXSQ 03	1225	Barrier of the lake	6.0	Relict of <i>Tamarix</i> sp.	240±40
Natural bank of Huahai Lake	HXSQ 04	1215	Bottom land of the lake	—	Relict of <i>Phragmites communis</i>	250±60
Glauber's salt mine in Huahai Lake	HXSQ 05	1205	Bottom land of the lake	5.0	Relict of <i>Tamarix</i> sp.	158±50
Beihaizi Lake in Jinta	HXSQ 05	1220	Terrace by the lake	2.1	Relict of <i>Tamarix</i> sp.	780±58
Chaiwan called Duanzi	DZHCW 01	1320	Delta of the lake	5.6	Relict of <i>Tamarix</i> sp.	295±50

Note: The  $^{14}\text{C}$  ages were measured in the Laboratory of Science Technological Archaeology & Cultural Relics' Protection, Peking University and in the Laboratory of Chronology, Lanzhou University.

In Shiyang River Basin, the population ranged from 30 000 to 50 000 in the upper and middle reaches of the river before the Qing Dynasty. For example, the total number of households was 7900 and the population was 46 300 in the whole region in the years of Yongle in the Ming Dynasty (1403–1424 A.D.). There were  $48.5\times10^3\text{ha}$  of farm lands totally with 1.05ha per person. Supposed the rate of gross irrigation at that time was the same as today, we can estimate the quanti-

ty of water for agricultural irrigation to be  $3.36\times10^9\text{m}^3$  or so, accounting for 19.9% of the gross water resources in the drainage area of the Shiyang River, which showed a surplus state. The area of farmlands increased by 8000ha and the irrigation rate of water resources was about 33% in the years of Wanli in the Ming Dynasty (1573–1620 A.D.). During the year of Qianlong in the Qing Dynasty (1736–1795 A.D.), the number of population jumped to 730 000 swiftly

in the middle and lower reaches of the Shiyang River. Among them, 660 000 were in the middle reaches of the river. If each person needed 200kg of food per year, annual supplies to meet the population of 730 000 was  $1.46 \times 10^9$  kg. Supposed that each hectare of farmland could harvest crops 75kg, then 13 000ha farmland must be brought under cultivation. Thus the water for agricultural irrigation of that time could be  $9 \times 10^3 \text{ m}^3$  or so, accounting for more than 53% of the gross water resources in the Shiyang River basin. According to international standard, the quantity of water exploitation from a river could not exceed the limit of 40% of water from upper regions (generally, the gross using rate of water resources is only 30% in arid region in the world). Thus it can be seen that the water resources of the Shiyang River was changing from overplus to saturation until exceeding the limit in the middle of the Qing Dynasty with the increase in population and farmlands (Fig. 2 and Fig. 3). The water discharge to Minqin Basin decreased rapidly, which led to the outbreak of ecological crisis. Many lawsuits happened, for instance, in order to resolve the conflicts in water use among the middle and lower reaches of a river between Minqin County and Wuwei County in the early Qing Dynasty, and *A Survey of Zhenfan State* had special chapter about lawsuits on water. We can look up the water using proportion between them stipulated by official literature. The lakes shrank and became dried gradually because of the increase in water use in the upper reaches, the decrease in water source supply and strong evaporation. In the past, the landscape of lake was all kinds of aquatic species and many dikes, especially fishes everywhere, which have become past history.

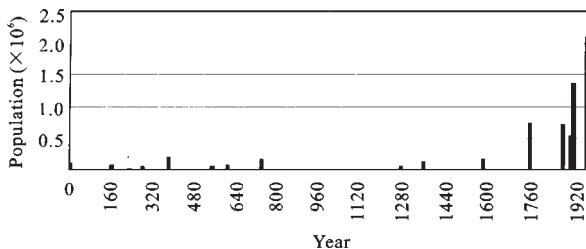


Fig. 2 Change of population in Shiyang River Basin in recent 2000 years

There were more than ten lakes in Hexi Corridor during historical period and these lakes had mostly dried up now. The terminal lake in the tail reach of the Shiyang River once was named Dadijionghai Lake during the Sui and the Tang dynasties, and Baijianhu Lake in the Qing Dynasty; and the terminal lake in the of the Jinchuan River was once named Changning Lake in the Sui and

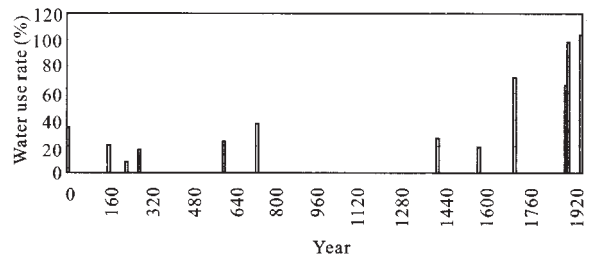


Fig. 3 Variation of the use rate of water resources in Shiyang River Basin in recent 2000 years

Tang dynasties. There was still the record that "the tide of Zhuyeze Lake in Zhenfan was so heavy that the well was deluged" in the 39th year of Kangxi in Qing Dynasty (1700 A.D.). But by the 26th year of Qianlong in the Qing Dynasty (1761 A.D.), the perimeter of Zhuyeze Lake was only 300 000m, and the area of the lake was probably less than 70km<sup>2</sup> (Table 3). The terminal lake in the tail reach of the Shiyang River began to shrink and became dry entirely after 1840, which led to the rapid expansion of desertification area. The areas of lakes in the east branch of the Shule River and of Huahai Lake in the tail reach of the Shiyang River ever got to 445km<sup>2</sup> 2000 years ago. But then forth because the course changes in the Shule River and artificial building of dam and dyke, the area of lakes shrank rapidly. At present, there are no dry lakes and billabongs formed during the progress of desertification except for Ganhaizi Lake, which is a terminal lake in the tail reach of the Beishi River with an altitude of 1204m. The area of Ganhaizi Lake that is the remnant of Huahai Lake is about 300ha and its depth is about 0.1–1.5m. The primary plants are *Phragmites communis* in the lake and *Tamarix* spp. around the lake. There are millions of migratory or residential birds of 26 species in the lake, such as *Egretta garzetta*, *Grus grus* and so on. So it was listed as natural reserve of birds in Gansu Province in April 1982. With the reclamation of farmlands in Sandun Shoal and Bijia Shoal on the south bank of the Beishi River by immigrants in recent years, the water of the upper reaches of the lake was dammed and used, leading the lake to dry up drastically in June 1999. The natural reserve for birds exists virtually only. It is a thousand pities that Huahai Lake, which had existed for 2000 years, vanished at the end of 20th century despite we emphasize ecological protection today. According to the survey, it could be attributed to excavating the ditch and using water to irrigate the farmlands besides the periodic changes of climate and hydrological wetness or dryness. The area of Juyan Lake, including Gujuyan Lake, Suoguoer and Gashunuoer, once was as more than 834km<sup>2</sup> in historical periods, which is the terminal lake in the tail reach of the

Table 3 Area changes of main lakes during the recent 2000 years in Hexi Corridor and its contiguous area (km<sup>2</sup>)

Name of lake	Qin and two Han dynasties	Early Qing Dynasty	Late Qing Dynasty and the Republic of China	1950s	1960s	1970s
Zhuyezze Lake	286	220	70	—	—	0
Huahuai Lake	445	49	10	>3	>3	3
Juyan Lake	834	695	352	352	50	58
Lop Lake	5350	—	Shrink obviously	—	660	0

Heihe River. Reclamation of farm lands was on a large scale in Juyan region in the Han Dynasty, but the three lakes such as East Juyan Lake, West Juyan Lake and Juyan Lake existed with a fairly large area because there was plenty of water at that time. First of all, Gujuyan Lake shrank and dried up because economic activities mostly focused in Hexi Corridor. Massive hydraulic structures were built in the middle reaches of the Heihe river, which lead to both reducing surface runoff of downstream and driving up riverbed on the east of river by mud and sand. Rivers flow into the East and West Juyan Lake since the 1900s and the area of Juyan Lake still achieved 262km<sup>2</sup> until 1958. According to the statistics from 1949 to 1984, the irrigated area in Zhangye region in the middle reaches of the Heihe River enlarged by more than 6.67×10<sup>3</sup>ha. The quantity of water for irrigation increased to 5.8×10<sup>9</sup>m<sup>3</sup> if we assumed the ration of gross irrigation with 38.67m<sup>3</sup>/ha. The quantity of evaporation was about 3×10<sup>9</sup>–4×10<sup>9</sup>m<sup>3</sup>/a in Juyan Lake. Both the irrigated area of farm lands in the upper reaches of the Heihe River and of the grass fields in the delta of the Heihe River enlarged, and the quantity of using water for irrigation increased too. The most important reason why the lake became dry-up eventually was that the quantity of water flowing into lake decreased continually during the late 50 years (approximately decreased by 7×10<sup>9</sup>m<sup>3</sup>). It is a usual natural phenomenon that the lake shrinks or becomes dried up, but it shrinks so fast that the area of lake decrease in a large scale. It only happened in arid region of the northwestern China. We cannot gain a full understanding if we only consider climate change as the sole reason. The reasonable explanation lies in that the growth of population was so quick that it exceeds critical limit of population pressure. For the sake of it, people had to make use of water resources and sacrifice ecological water on a large scale. In particular, human activities directly cause the rapid shrink of lakes, even desertification during the recent 300 years after the mid-Qing Dynasty, including destroying the forest reserve in the upper and middle reaches of rivers, reclaiming waste

land, building reservoir for water storage and so on. According to the paleobeach of terminal lake of the Shiyang River, the tendency of changes of lake level during the historical periods can be analyzed. If there was not the impact of human activities on environment, the lake would evolve in accordance with natural law, which means that the slope of lake area change in the recent 7000a B.P. should keep constant. In fact, the slopes of lake area change in the recent 7000a B.P. have changed due to the impact of human activities on environment. According to the varying range of slope of lake area in the different historical stages, the influence range of human activities on the shrink of terminal lake could be estimated. The impact range of human activities on the terminal lake was about 30% during the last 2000 years, and more than 80% in the recent 300 years (Fig.4).

### 4 CONCLUSIONS

In short, the population density in Hexi Corridor did not exceed the critical index of desertification before the Qing Dynasty. To a great extent, the progress of desertification was affected by climatic changes such as humidity and dryness. That is to say it is the result of a series of climatic geomorphological consequence at different special and temporal scales. Thus the impact of human activities on desertification is subject to natural factors. This statement is consistent with what ZU Rui-ping *et al.* (2001) found about environmental changes in oasis at the southern part of Tarim Basin during the recent 2000 years. The rapid growth in population exceeds the critical index of the population pressure in arid land, which makes human activities have more impacts on desertification than climatic changes after the mid-Qing Dynasty. Human activities become the principal factors in desertification over the recent 300 years. However, the period during the Ming and Qing dynasties was Little Ice Age globally and historical record showed an obvious increase in sand and wind disasters, so we could not exclude the control of cold-dry climatic background in the macro-progress of

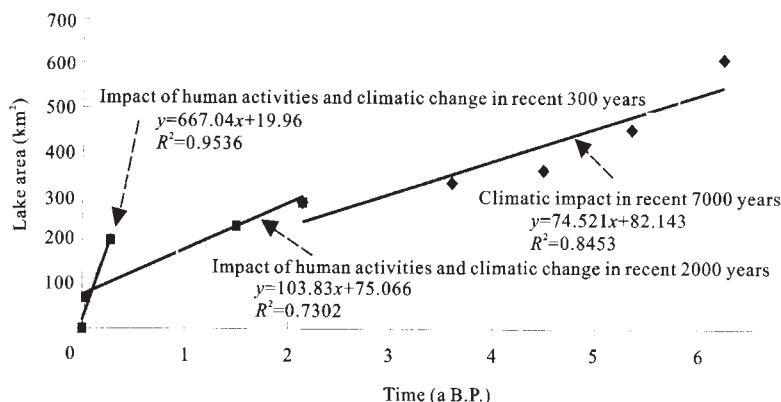


Fig. 4 Impacts of human activities and climate on the change of terminal lake in the Shiyang River

desertification.

## REFERENCES

- DONG Guang-rong, JIN He-ling, CHEN Hui-zhong *et al.*, 1998. Geneses of desertification in semiarid and subhumid regions of Northern China [J]. *Quaternary Sciences*, 18(2): 136–144. (in Chinese)
- DONG Guang-rong, JIN Jiong, LI Bao-sheng *et al.*, 1994. Several problems on the desertification of Korgin Sandy Land, Northeast China [J]. *Journal of Desert Research*, 14(1): 1–9. (in Chinese)
- DOND Yu-xiang, LIU Yi-hua, 1993. Study on the sandy desertification process of Hunshandake Sandy Land in recent 5000 years [J]. *Arid Land Geography*, 16(2): 45–50. (in Chinese)
- FENG Sheng-wu, 1963. The evolution of the drainage system of the Minqin Oasis [J]. *Acta Geographica Sinica*, 29(3): 241–249. (in Chinese)
- HOU Ren-zhi, YU Wei-chao, 1973. The archaeological finds in the Ulan Baha Desert and the changes in geographical environment [J]. *Archaeology*, (2): 92–107. (in Chinese)
- HOU Yong-jian, ZHOU Jie, WANG Yan-xin *et al.*, 2001. The natural and humane landscape in Ordos Plateau in the Bei Wei Dynasty (AD 386–534) [J]. *Journal of Desert Research*, 21(2): 188–194. (in Chinese)
- LI Bing-cheng, 1999. Several theoretical problems on historical geography of desert [J]. *Scientia Geographica Sinica*, 19(3): 211–215. (in Chinese)
- NIU Jun-jie, ZHAO Shu-zhen, 2000. Origin of desertification on Ordos Plateau in historical times [J]. *Journal of Desert Research*, 20(1): 67–70. (in Chinese)
- SUN Jimin, DING Zhong-li, 1998. Process and cause of land desertification in Northeast China [J]. *Quaternary Sciences*, 18(2): 156–164. (in Chinese)
- WANG Shou-chun, 2000. Fastly development and cause of desertification in West Liao River Basin of Inner Mongolia during the last 10 Century [J]. *Journal of Desert Research*, 20(3): 238–242. (in Chinese)
- WU Zheng, 1991. Superficial review about the desertization in the north zone of China [J]. *Acta Geographica Sinica*, 46(3): 266–276. (in Chinese)
- YANG Chuan-de, SHAO Xin-yuan, 1993. *The Changes of Lake in Central Asia During the Near and Later Epoch* [M]. Beijing: Meteorological Press, 92–99. (in Chinese)
- YANG Ping-lin, 1992. The population changes of the historical period and its impact on the natural ecologic-system in Hexi Corridor [A]. In: *The Environment Changes of Holocene and the Evolution of Human Civilization in Arid Northwestern China* [C]. Beijing: Geological Press, 83–90. (in Chinese)
- ZHANG De-er, 1984. The synoptic climatological analysis of dust in China since historical periods [J]. *Science in China*, 27(3): 278–288. (in Chinese)
- ZHANG Pei-yuan, 1996. *Climatic Changes of China in Historical Time* [M]. Jinan: Shandong Science-Technological Publication, 295–306. (in Chinese)
- ZHU Ke-zhen, 1973. A preliminary study on the climatic fluctuations during the last 5000 years in China [J]. *Scientia Sinica*, 2: 168–189. (in Chinese)
- ZHU Zhen-da, WANG Tao, 1994. The theory and practice of research on the desertification in China [J]. *Quaternary Sciences*, 14(1): 1–9. (in Chinese)
- ZU Rui-ping, GAO Qian-zhao, QIAN Ju *et al.*, 2001. Environmental changes of oasis at the southern part of Tarim Basin during the recent 2000 years [J]. *Journal of Desert Research*, 21(2): 122–128. (in Chinese)