CHINESE GEOGRAPHICAL SCIENCE
Volume 3, Number 2, pp.126–137, 1993
Science Press, Beijing, China

THE STUDY ON CLIMATIC CHANGES AND LAKE LEVEL FLUCTUATIONS OF QINGHAI LAKE IN HOLOCENE ①

Chen Fahu (陈发虎)　　Pan Baotian (潘保田)

(Quaternary Glacier and Environment Research Center of China, Lanzhou University, Lanzhou 730000, PRC)

ABSTRACT: According to loess and palaeosol climatic record, field observation, analysis data and ^{14}C dating, we discuss the climatic changes and the water level fluctuations of Qinghai Lake. It is pointed out that there were four relatively warm and moist stages in Qinghai Lake basin during the Holocene. They formed in the periods from 10,300 yr.B.P. to 8,500 yr.B.P., 7,000 yr.B.P. to 3,500 yr.B.P., 2,800 yr.B.P. to 2,000 yr.B.P. and from 1,300 yr.B.P. up to now. The climate in the Holocene optimum period, from 7,000 yr.B.P. to 3,500 yr.B.P., was much warmer and moister than that today. Polypodium plant grew luxuriantly around Qinghai Lake. The annual temperature was 2.5℃ higher than that today, but there was no forest at Qinghai Lake shore. It is found that there was a good relationship between precipitation and water level fluctuation. In warm and moist period water level was high and in the cold and dry period it was low in the Holocene. There were four high water level periods for Qinghai Lake in the Holocene, but the highest level was less than 30m above present water level.

KEY WARDS: Qinghai Lake, Holocene loess section, climatic changes, water level fluctuations

I. INTRODUCTION

Qinghai Lake is located between 99° 36′ E−100° 47′ E and 36° 32′ N−37° 15′ N. It is 106 km long and 63 km wide with perimeter of 360 km. Its shape is like an oval. The average annual temperature in the lake basin is between −1℃ and 1℃. The average annual

① This research is supported by Youth Foundation of Natural Science Foundation of China (No. 49101015).

precipitation of five stations around the lake is 336.6 mm, but the average annual evaporation is as high as 870 mm. Therefore, Qinghai Lake belongs to the climatic region of semiarid and cold plateau.

Scientists at home and aborad began to note the origin, development, depth of lake water, water level fluctuations, Quaternary geology and geography and other problems related to Qinghai Lake in the 1800s[1-4], but scientific researches to the lake mainly began in the early 20th century , especially from the 1950s[5-9]. It is approved that Qinghai Lake developed to inland salty lake in Middle and Late Pleistocene from neotecnic fault basin in the Early and Middle Pleistocene[10]. The problem of lake level descent have been noted generally by scientists in recent years[11-13]. However, the climatic changes and lake level fluctuations over the last 10,000 years in Qinghai Lake area need to be further studied, which have affected the forecast of the lake water level fluctuations.

II. CLIMATIC CHANGES

1. Loess and Palaeosol Sequence

Palaeosol contains rich information of past climatic changes. There are one to three palaeosol layers developed in aeolian loess, aeolian sand and alluvial deposits of Holocene stratigraphy around Qinghai Lake. Halali section at south bank of Qinghai Lake is one of the typical aeolian loess and palaeosol sections. The section is located at 17 km west of the Heima River at an altitude of 3,220 m. It consists of six layers from bottom to top (Fig.1).

There are three layers of loess (Q_{L-1}, $Q_{L-3}$and Q_{L-5}). Among them $Q_{L-1}$is at the bottom of the section. Its exposed thickness is 50cm. The total thickness of the layer is estimated to be more than 5m based on land morphology. It is typical Malan loess with 68% silt content. $Q_{L-3}$and $Q_{L-5}$are only 20cm and 10cm thick. They are also coarse, yellowish in colour, no statum and high content of silt and $CaCO_3$, but have weak pedogenesis comparing with Q_{L-1}loess layer.

In the section there are three palaeosol layers (Q_{L-2}, $Q_{L-4}$and Q_{L-6}). Q_{L-2}, 30cm to 40cm thick, is light dark in colour with low organic content and relatively high clay content (21%). One organic ^{14}C dating at bottom of the layer is 10,290± 120 yr.B.P. $Q_{L-4}$and $Q_{L-6}$are two thick palaeosol layers (70cm and 65cm to 70cm) with strong pedogenesis and clear soil structure. Q_{L-4}isblack to dark brown in colour and hard with block to granule structure and highest organic content and clay content (25.0%). It is the strongest developed palaeosol in the section. Palaeosol $Q_{L-6}$is light black to black in colour and relatively hard with block structure, but its clay and organic content is lower than that of Q_{L-4}. The organic ^{14}C dating at middle of $Q_{L-4}$and $Q_{L-6}$are 4,730 ± 50 yr.B.P. and 2,080 ± 60 yr.B.P. respectively. Q_{L-7}, about 25 cm to 40 cm thick, is modern soil with high silt content (67.5%). It has clear boundary with palaeosol Q_{L-6}below it and clear developed structure, which shows that there was a period of silt deposition between the end of palaeosol Q_{L-6} development and the beginning of modern soil development.

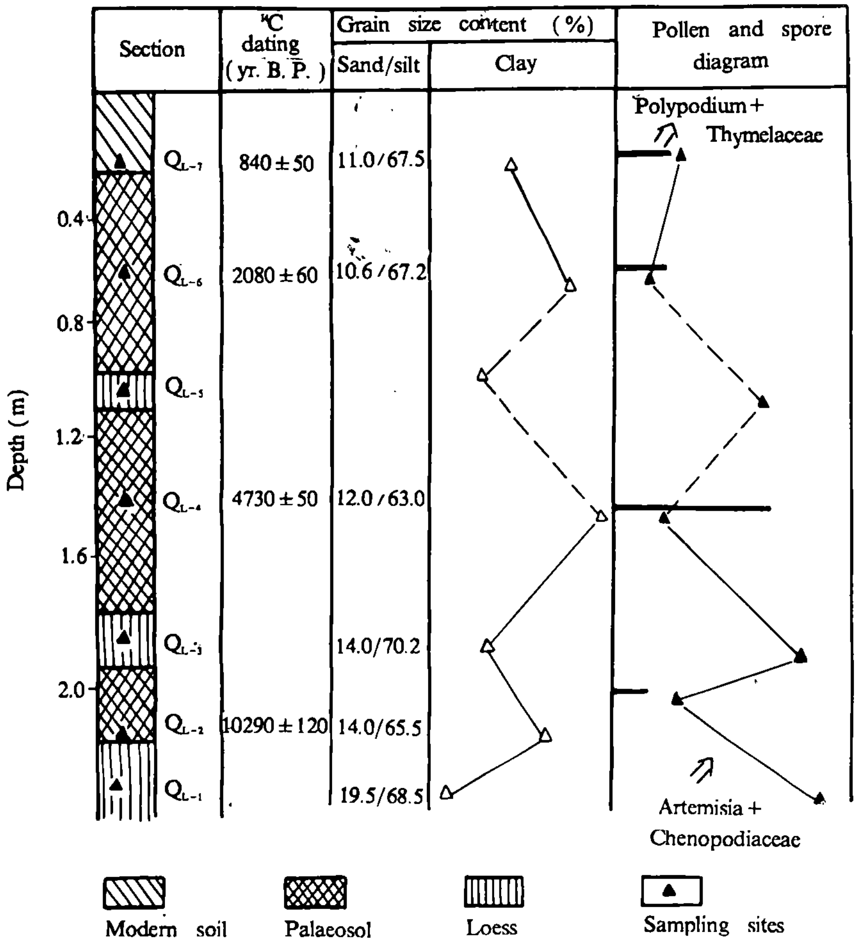

Fig.1 The comprehensive figure of Halali section at Qinghai Lake

2. Formation Ages of the Palaeosols

According to sampling location and organic ^{14}C date, the ^{14}C age at the first palaeosol layer (Q_{L-2}) should represent the beginning age of the palaeosol development. It is suitable to take it as 10,300 yr.B.P., which is also the beginning age of the Holocene in Gansu and Qinghai region. The layers of the palaeosol in the period are widely distributed in the region. Their organic ^{14}C ages are between 8,500 yr.B.P. and 10,300 yr.B.P. Among them a $_{14}C$ age at the second palaeosol of a loess section at Biandukou in Minle County of Hexi Corridor is 8,630 ± 90 yr.B.P., which can basically represent the end age of the palaeosol layer. We take 8500 yr.B.P. as the end age.

The second palaeosol layer in Halali section is the strongest developed one. It is also quite thick. The ^{14}C sample is taken at middle of the layer. So it is impossible to determine the beginning and end ages of the palaeosol. However, the palaeosol in the period is quite widely distributed in Qinghai Lake basin and in Gonghe Basin at south of Qinghai Lake. A layer of palaeosol at Jiangxigou in the south bank of Qinghai Lake has been dated at 4,140 ± 50 yr.B.P., which is basically as same as that of the palaeosol in Halali section. Ancient dunes at the source area of the Daotang River stopped developing in the period. A layer of sand palaeosol dated at 5,960± 100 yr.B.P. formed on them. A palaeosol layer dated at 6,180± 90 yr.B.P. also formed on dunes at Tamai in Gonghe Basin, while a palaeosol layer dated at 3,960± 100 yr.B.P. formed in depressed ground among the ancient dunes. The other palaeosol age are also mainly between 4,000 yr.B.P. and 6,000 yr.B.P.[14], which was a main period of Holocene palaeosol formation. The palaeosol in this period may began to form as early as 7,000 yr.B.P. and stop at as late as 3,500 yr.B.P., referred to the stages of Holocene palaeosol development in the Loess Plateau[15-16]. It should be pointed out that there were two to three palaeosol layers formed in Lanzhou area in the period where the resolution of loess and palaeosol climatic record is highest.

The third palaeosol is still affected by modern vegetation roots. Therefore, it can't be denied that the result of ^{14}C dating is younger than the real development age. However, the palaeosol has clear development structure and should represent a warm and moist period which may reflect the warm period in the Qin and Han dynasties. Its developing age is taken as between 2,000 yr.B.P. and 2,800 yr.B.P. The Q_{L-6}palaeosol is not the parent material for modern soil formation, so it is shown that there was a period of loess deposition after 2,000 yr.B.P. Two organic ^{14}C dating have been got at the bottom of modern soil at Jiermeng at the north bank of Qinghai Lake and at Halali section. They are 1,030 ± 60 yr.B.P. and 840 ± 50 yr.B.P. respectively. However, the two dates don't represent the beginning age of modern soil. The real beginning age should be older than the two dates. It is estimated that modern soil began to form at the warm period in the Sui and Tang dynasties at about 1,300 yr.B.P.

3. Formation Environment of the Loess and Palaeosol Layer

The grain size characteristic of the Halali section is shown in Fig.2. The grain size distribution of the loess and palaeosol at the section has typical feature of Chinese loess and palaeosol in loess stratigraphy, that is, silt content is the absolute predominance. It is as high as 75% in loess and about 65% in palaeosol. Clay is the second predominance fraction. Its content is from 5% to 15%. It has been pointed out that there is no stratum structure in the section. The probability curves (Fig. 2) is also similar to aeolian loess and different from alluvial loess. Therefore, the Holocene loess in Halali section is aeolian loess, and the Holocene palaeosols formed from parent material loess. The section is a typical aeolian loess—palaeosol section. Clay content in loess stratigraphy reflects argillification degree to some extent, which reflects the degree of climate warmness and moist. The clay content in Halali section is shown in Fig.1.

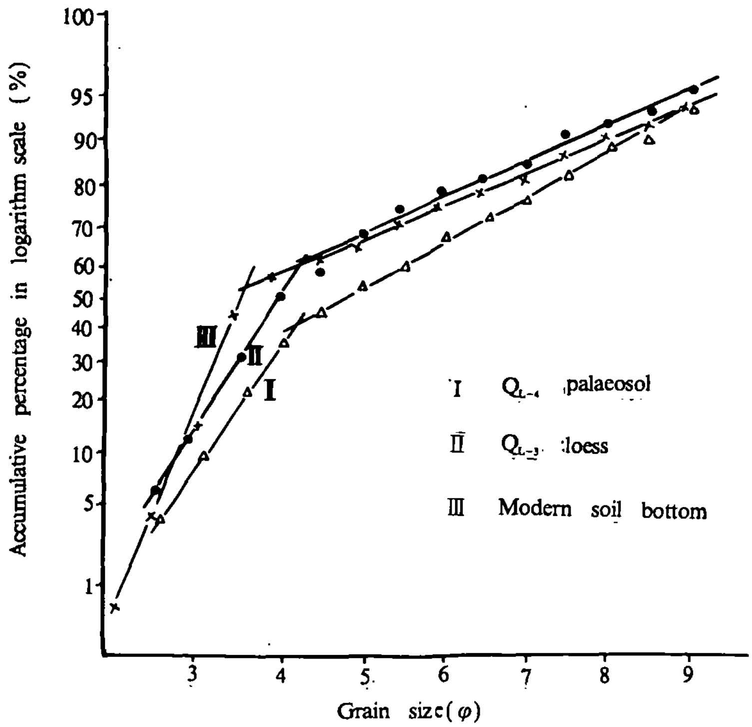

Fig.2 Probability curves of grain size of Halali section at Qinghai Lake

There are 1,347 grains of spores and pollen in 28 families or genera (Table 1) counted from six samples in seven layers in Halali section (Q_{L-5}layer isn't analysed). Herb pollen is absolute predominance whether in loess samples or in palaeosol samples, while pollen content of woody plants is quite low. *Artemisia* sp., Gramineae and Compositae pollen is the main contents in herb pollens, which shows that vegetation has not greatly alternated since the Holocene in Qinghai Lake shore, and alpine forest zone has not descended to the lake shore.

Although vegetation in Qinghai Lake shore did not alternate greatly in the Holocene, spore and pollen assemblages between loess and palaeosol layers and among different palaeosol layers still have greatly diferences (Table 1). The spore and pollen assemblages in loess layers is *Artemisia* sp.—Gramineae—Compositae. The total pollen content of the three families or genera is more than 85%. The other pollen and spores have quite low content. By comparing with loess layers, the *Artemisia* sp. pollen content in palaeosols and modern soil decreases, while the contents of Gramineae and other plant pollen increase. There are also some differences among the three palaeosol layers. The first palaeosol layer (Q_{L-2}) has

Table 1 Statistics of Spore and pollen assemblage of Halali section (grains)

Sample No.	QL−1	QL−2	QL−3	QL−4	QL−6	QL−7
Artemisia SP.	79.66	34.42	73.42	24.39	17.34	28.34
Compositae	3.95	11.69	6.96	6.50	1.11	2.67
Chenopodiaceae	2.82	1.95	4.43	6.10	4.06	4.29
Polygonaceae		6.17	1.90	2.85	12.92	7.49
Ephedra	0.56					
Gramineae	5.08	10.06	5.70	12.20	28.87	28.34
Liliaceae		0.97	1.90	2.44	0.74	1.60
Leguminosae		2.22	0.63		0.97	
Ranunculaceae		3.96		0.81	1.85	1.60
Labiatae	0.56	5.52	0.63		1.11	1.60
Crucifere	1.13					
Convolvulaceae		10.39		0.81	0.37	
Scrophulariaceae		1.95		0.81		
Rosaceae	0.56					
Thymelacaceae		0.65		13.01	2.95	4.81
Typhaceae		0.65	0.74			8.56
Polypodiaceae		0.65				
Polypodium		0.32		11.38		
Umbellifarae		0.65				
Potamogetonaceae	1.63				0.74	
Plantaginaceae	0.56	1.47	1.90	11.79	10.79	4.29
Rosaceae	0.56		1.27	0.41		
Picea	0.56		0.63			
Betula	1.69		0.63		3.69	
Betulaceae		0.32		0.81		0.53
Cupressus	2.26	4.07			4.43	
Populus	7.01					4.81
Indet.	1.85				0.74	
Cryptogramma	1.11					1.07
Families (Genera)	13	18	12	16	18	14
Total grains	177	302	158	246	271	187

the characteristic of high content of Compositae. Its spore and pollen assemblages are *Artemisia* sp.–Compositae–Conveleulaceae, while the assemblage of the second palaeosol layer is *Artemisia* sp.–Thymelaceae–Gramineae–Plantaginaceae–*Polypodium* sp.. The spore and pollen grains in the layer are richer than those in the first palaeosol layer. It should be mentioned that Thymelaceae pollen and *Polypodium* sp. spore contens are high in the layer, which shows that the climate during the palaeosol formation period was warmer and moister than that during the other palaeosol formation period. In the spore and pollen assemblage the content of *Polypodium* sp. spores is up to 11.38%. This indicates that *Polypodium* sp. grew in Qinghai lake shore at least in mountain slopes around Qinghai Lake. There are 12 species of *Polypodium* sp. in China, but only *P.pseudoamoenum* Ching species is distributed in Northwest China. It grows in damp valleys below an altitude of 900 m to 2,800 m. Taking the altitude of 2,800m as its growing upper limit to caculate, the average annual temperature in Qinghai Lake during the palaeosol formation period was at least more than 2℃ higher than that today. The spore and pollen assemblages in the third palaeosol are similar to those in the second one (Table 1). The difference of spore and pollen assemblages from the second palaeosol layer is that there is not *Polypodium* sp. spore, and the pollen content of Thymelaceae plant is low. This shows that the climate during its formation is not as warm and moist as that during the second palaeosol formation.

4. Climatic Changes in the Holocene

Palaeosol, as a result of past natural environment, records natural conditions such as climate, vegetions and landscape during its formation. It has pedogenesis structres, which is similar to modern soil and different from normal deposits. Palaeosol in loess stratigraphy is a good recorder of past climate and environment. They formed in warm and moist period. Loess and aeolian deposits in geological epoch or historical period were the result of dry and cold climate. Palaeosol layers alternate with loess layers in Halali section, which in fact reflects cold – dry and warm – moist fluctuations of the Holocene climate in Qinghai Lake shore. Climate during the Holocene has the following stages.

4.1 The first warm and moist stage (10,300–8,500 yr.B.P.)

This was the period of the first palaeosol layer formation in Halali section. According to spore and pollen data and the degree of palaeosol development, the annual temperature then was lower than that today, but was much warmer and moister than that in the period of Malan loess deposition in which Qinghai Lake became dry and deposited loess silt[17]. The warm period marks the beginning of the Holocene in Qinghai Lake basin.

4.2 The first cold and dry stage (8,500–7,000 yr.B.P.)

This was the period of the second loess deposition in Halali section. According to grain size and spore and pollen data, the cold and dry degree was almost as the same as that in the period of Malan loess deposition (at section bottom). The lower permafrost limit descended at least to Shazhuyu Lake shore in Gonghe Basin. The annual temperature then was 5℃ to 6℃ lower than that today[14]. Loess also deposited in loess plateau in the period[15]. Therefore, the cold period has general significance in the northern China.

4.3 The second warm and moist stage (7,000–3,500 yr.B.P.)

This was the Holocene climatic optimum period. The annual temperature was 2.5℃ higher than that today. *Polypodium* grew in Qinghai Lake basin. The fossil dunes in east lake bank stopped developing and a layer of palaeosol formed on them, which indicate that precipitation was higher than that today. This stage lasted for a long period. It had been interrupted by two short cold and dry periods, which has been recorded by Lanzhou loess[16].

4.4 The second cold stage (3,500–2,800 yr.B.P.)

There was loess deposition in Qinghai Lake shore in the stage. Mobile dunes formed on the east of Qinghai Lake shore in the stage. Permafrost zone in the mountains arond Qinghai Lake also descended by 400 m to 500 m, which shows that annual temperature was 2℃ to 3℃ lower than that today[14]. The stage corresponds to Holocene neoglaciation or the cold period in the Zhou Dynasty in history of China[18].

4.5 The third warm and moist stage (2,800–2,000 yr.B.P.)

This stage corresponds to the period of the third palaeosol formation. It was the reflection of the warm period in the Qin and Han dynasties[18]. The palaeosol formed in the period is widely distributed in the west Loess Plateau.

4.6 The third cold stage (2,000–1,300 yr.B.P.)

This was the period of parent material formation of modern soil as mentioned above, that is, the period of aeolian loess deposition. The cold stage was clearly reflected in a lot of loess sections in the west Loess Plateau, such as Dadiwan section in Qinan, Gansu. It has also been recorded by glacial advances in a lot of glaciers[19].

4.7 Modern soil development stage (from at 1,300 yr.B.P.)

Modern soil began to form in the warm period of the Sui and Tang dynasties of China. It represents a warm and moist period to some extent. The period has been called the Little Optimum[20].

III. WATER LEVEL FLUCTUATIONS

1. Ranges of Water Level Descent

The descent ranges of water level of Qinghai Lake were determined by former researchers based on the heights of lake terraces[6–7,10]. Lake terraces consist of two types. One is erosion terraces and another is deposit terraces. Erosion terraces are distributed on the mountain slope below the third planation surface around Qinghai Lake. They consist of three to five grades which are 20 m to 200 m above present water level[6,10]. There are four grades of erosion platforms, niches and other makers, which can represent the past lake surfaces. They are 100 m, 65 m, 45 m and 25 m above present lake surface. It was thought by some scientists that they reflect four times of water level balances and descents during the Holocene except those in few locations where neotectonic activity was strong[6]. Although the viewpoint didn't totally received by the late researchers, the conclusion has been widely quoted[10,12–13,21]. There is a very important problem that is whether the terrace height can represent the descent range of lake surface. The problem can also be expressed as whether the lake terrace formation was because of the lake surface descent making lake shallow, or because of different movement between mountains around Qinghai Lake, or because of their joint actions. That is, whether the lake terraces resulted from water movement reason or earth movement reason. Only can the former be used to caculate the ranges of lake water level descent.

According to field investigation and research results made by former researchers[7,10], erosion terraces around Qinghai Lake are mainly formed by different intermittence uplift of structure movement. They are at least effected by mountain uplift around Qinghai Lake. The reason are as follows: (1) The third planation surface on mountains around Qinghai Lake was formed by the crust uplift in the Late Pleistocene. It has risen 300 m to 400 m above water level at present. It was the structure activity in the early period of the Late Pleistocene that led Qinghai Lake to become an inland lake[7]. Therefore, it is no doubt that the erosion terraces, distributed on mountain slope below the third planation surface, formed with the uplift of the third planation surface. (2) There are two lowest river source places in Qinghai Lake basin, which are connected with other rivers. One is Yaoshui River source place which links with Huangshui River system. The lowest point in the place is 103 m above water level. Another is Daotang River source place which links with the Huanghe River (the Yellow River) system. The lowest point in the place is 125 m above present water level[6]. However, the base levels of many erosion terraces are about several ten meters higher than the two places. Two highest erosion terraces at Heishan area, for example, are 50 m, 75 m and 25 m and 5 m higher than the two places respectively. The fact can't be understood if it isn't explained by crust different movement. (3) The height of the same erosion terrace grade is different greatly in different locations around Qinghai Lake, resulted from earth crust different movement. Based on the above reasons, the height of erosion terraces above present water level doesn't represent the descent ranges of water level or at least represent the descent ranges only after deducting the rise height of structure movement. It is worth to discuss that the lake level in the Early Holocene was more than 100 m higher than that today, and lake water area was 1/ 3 larger than that today.

Lake deposit terrace is different from lake erosion terrace. It is located around relatively depressed lakeshore. It consists of three grades with stable distribution. Therefore, they result from the joint actions between intermittent ascent–descent and relative sbility of laje level, and reflect the water level fluctuations. Because they formed in the Holocene, these deposit terraces were weakly affected by structure movement. Their heights above present water level can be considered as the range of water level descent. It is quite similar to deposit terraces to use lake dykes to caculate water level descent range. There are some large scale and long extent lakeside sand dykes around Qinghai Lake shore. The sand dykes in Erlangjian consist of five to six groups. The oldest and highest one is located at about 25 m above water level. It is distributed on the third deposit terrace. The lowest lakeshore dyke is in the same height as or a little lower than the first deposit terrace in Erlangjian. Two higher groups of dykes can be compared with the second deposit terrace.

Halali section, more than 20 m (less than 30 m) higher than present water level, hasn't been submerged by lake water since 10,300 yr.B.P., so it should be careful to discuss the problem of water level fluctuations of Qinghai Lake. According to the data in this paper the water level descent ranges of Qinghai Lake are less than 30 m during the Holocene, which needs further verified by other data.

2. Stages of Water Level Descent

There are three groups of deposit terraces generally distributed around south side of Qinghai Lake, especially in Erlangjian and Jiangxigou areas. Because the highest sand dyke is about 6 m to 7 m higher than the third terrace surface, there were three long stable stages with high water level for Qinghai Lake since 10,300 yr.B.P. This also indicates that water levels have had four long stages in the flunctuations during the Holocene. An organic ^{14}C dating of 6,080 ± 170 yr.B.P. and an inorganic ^{14}C dating of 9,070 ± 50 yr.B.P. are obtained from lacustrine mud at the third terrace front in Erlangjian. The structure of the terrace is observed in a pit for sand sampling in Jiangxigou as follows: lakeshore sand layer is in the pit bottom, lakeshore sand gravel layer covers the sand layer and is covered by a palaeosol layer with thickness of 1.5 m. The palaeosol layer has clear soil structure in its upper part and contains lakeshore gravel in its lower part. Modern soil, 0.6 m thick, is on land surface. An organic ^{14}C dating at lower part of the palaeosol is 4,140 ± 50 yr.B.P., which can basically represent the end age of the terrace development. According to above results, the third terrace began to develop at about 6,000 yr.B.P. and end at a little later than 4,000 yr.B.P. An inorganic ^{14}C dating of 15,620 ± 80 yr.B.P. is got at top of the lakeshore dyke on the third terrance. Based on the relationship between organic and inorganic carbon—14 data at the third terrance front, the dyke formed at about 10,400 yr.B.P.. It is difficult to infer the formation age of the first and second deposit terrances because of lack of dating data. However, modern soil formed on the first terrance, and the soil structure is similar to that on Halali section, so its formation age is at about 1,000 yr.B.P.

3. The Relationship between Water Level Fluctuations and Climatic Changes

The one to three deposit terraces and three to five lakeshore dykes around Qinghai Lake shore show that the water level of Qinghai Lake tended to descend during the

Holocene, but the descent is not linear. The lake terrace formed in a long stable period, while the terrace slope formed in the transformation period from one stable period to another. The transformation period, of course, may be the period of lake water level ascent. Therefore, there are at least four long stable periods of lake water level in the Holocene. The present, even over last one hundred years is the descent period when water supply and consumption is unbalanced.

Qinghai Lake is an inland lake. Its water income directly or indirectly depends on precipitation in lake basin, while its water expenses is directly achieved by lake surface eveporation. Therefore, the water level fluctuation should directly relate to precipitation, which is verified by the good relationship between lake level fluctuations and precipitation from 1956 to 1986 (Fig.3). It is shown in Fig.3 that all of the rich rain years are the years

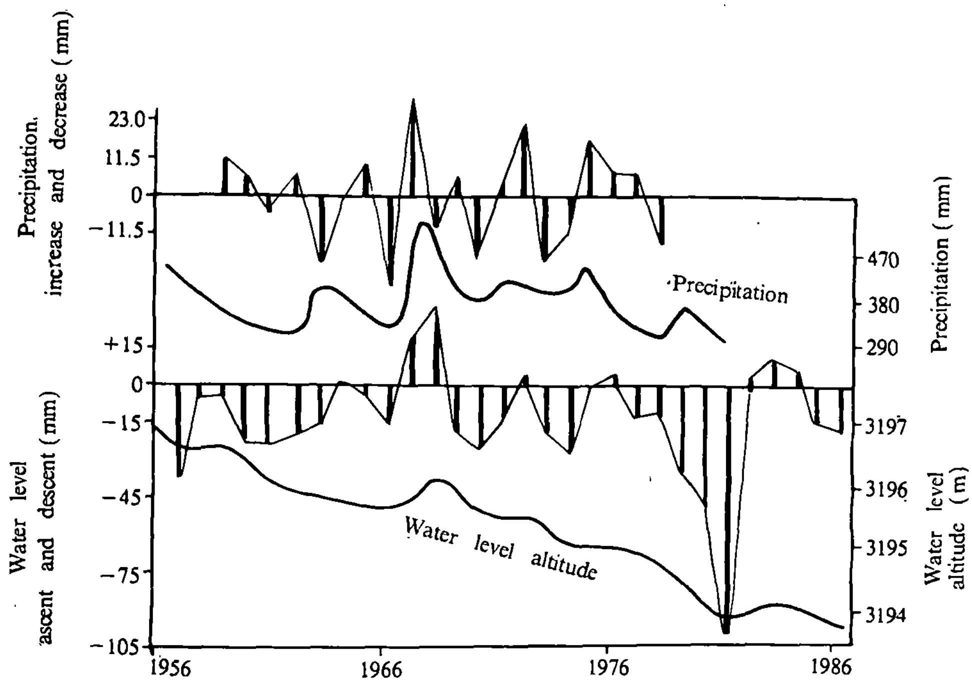

Fig.3 The relationship between lake water level fluctuations and precipitations

of lake water level ascent, while all of the poor rain years are the years of water level descent. Precipatation, for example, was the highest in three years from 1956 to 1959 and the water level also reached its highest level in the three years. On the contrary, 1965—1966 was a low precipitation year, and the lake water level also became low in the year. In summary, the high and low precipitation is totally coincided with lake water level ascent and descent. It should be said that the same process of water level and precipitation fluctuations during 1956—1986 must be the epitome of the relationship during the whole Holocene. The difference is that the range in the late situation is much large and the time is much longer.

In fact, Because the main change tendency of Qinghai Lake level in the Holocene was that the water expenses was greater than water income, lake water level descended. Because the water level stable period was the period of water income and espense equilibrium, therefore, the equilibrium period also was the moist and rich rain period and relative high lake level period. It is a good proof that the lake bank dyke at 25 m above present water level and the third deposit terrace developed in warm and moist periods in the Holocene and climatic optimum period.

In summary, the descent range of Qinghai Lake level was less than 30 m in the Holocene, while it was about 20 m since 4,000 yr.B.P. The four warm and moist periods in Qinghai Lake basin in the Holocene corresponded to the four high water level periods. The latter can be represented by lake bank dykes and deposit terraces.

REFERENCES

[1] 李子奇. 青海湖纪略. 新西北, 1931, 3(3).

[2] 刘增乾. 青海湖流域地理志. 西北通讯, 1935, 2(2).

[3] 孙建初. 青海湖. 地质评论, 1938, 3(5).

[4] 李式金. 青海湖区之初步探讨. 边政公论, 1942, (1): 11—12.

[5] 施雅风, 等. 青海湖及其附近地区自然地理(着重地貌)的初步考察. 地理学报, 1938, 24(1): 33—47.

[6] 方永. 青海湖湖盆地貌的基本特征、成因及其演变. 地理集刊, 1963, (5): 100—120.

[7] 陈克造, 等. 青海湖的形成与发展. 地理学报, 1964, 30(3): 214—233.

[8] 黄第藩, 等. 青海湖第四纪地层. 中国第四纪研究, 1965, 6(2).

[9] 杨惠秋, 等. 青海湖盆第四纪孢粉组合及其意义. 地理学报, 1965, 31(4): 321—335.

[10] 中国科学院兰州地质研究所, 等. 青海湖综合考察报告. 北京: 科学出版社, 1979. 9—21.

[11] 魏振铎. 青海湖盆的森林变迁. 青海环境, 1987, (3): 24—29.

[12] 应百才, 等. 青海湖水位下降及其原因分析. 青海环境, 1987, (2): 26—29.

[13] 徐叔鹰, 等. 青海湖东岸的风沙堆积. 中国沙漠, 1983, 3(3): 11—17.

[14] 徐叔鹰, 等. 青藏高原东北边缘区冰缘发展探讨. 冰川冻土, 1984, 6(2): 15—26.

[15] 刘东生, 等. 黄土与环境. 北京: 科学出版社, 1985. 106—113.

[16] Chen Fahu, Li Jijun and Zhang Weixin. Loess stratigraphy of the Lanzhou profile and its comparison with deep-sea sediment and ice core record. Geo Journal, 1991, 24(2): 201—209.

[17] Zhou, S Z et al., Environmental changes during the Holocene in western China on a millennial timescale. The Holocene, 1(2): 151—156.