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THE RELATIONSHIP BETWEEN INLAND LAKES EVOLUTION AND CLIMATIC FLUCTUATION IN ARID ZONE

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ABSTRACT: The evolution of the inland lakes in arid and semi–arid zones is accorded with the climatic fluctuation. The humid climate is in harmony with the higher water level and greater lake water quantity budget while arid climate is in correspondence with the lower water level and little water budget. Based on the analysis of the lake fluctuation and lake budget change, with the aid of the data of geomorphology, palynology, sedimentology and chronology, It is found that the climate experienced a warm and humid period during 7000–3500 yr. B. P. and showed a drying and warming trend in the last century in the Central Asia.

KEY WORDS: climatic fluctuation, inland lakes, lake evolution, arid zone

I. INTRODUCTION

The inland lakes in arid or semi–arid zones are sensitive to climatic fluctuation since they are located in a specific geographical environment, and have a fragile water circulation condition. The distinct feature is that the lake evolution can reflect precipitation fluctuation in different historical periods. High or low lake levels and the maximum or minimum lake balance are parallelled by a direct pattern of wet or dry climate. The study on inland lake evolution by means of geomorphology, sedementology and chronology can reveal climatic fluctuation in different geological periods. By the study on the change of lake water level and lake water budget in two inland lakes, the paper approaches the precipitation change during the warm and humid period of the holocene and reveals quantitatively the relationship between the inland lake evolution and the climatic fluctuation. The impact of climatic change in the last century upon lake budget is discussed.

II. THE BASIC FEATURES OF INLAND LAKE EVOLUTION SINCE THE HOLOCENE

The inland lakes in Inner Mongolia and northwest China have been studied in great detail by different researchars. Various research reports reveal a similar inland lake evolution process[1-2]. Take Daihai Lake in Inner Mongolia and Qinghai Lake in Qinghai Province as an example. The water level changes of the two lakes since 10,000 yr. B. P. are shown in Fig.1 and Fig.2 respectively. From the figures we can see that both lakes experienced a similar evaluation process:

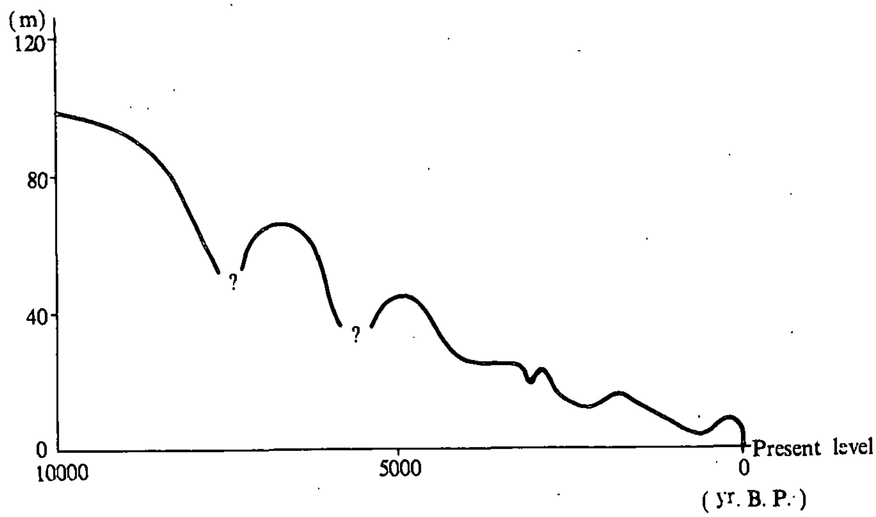

Fig.1 The water level fluctuation of Qinghai Lake

1. In the Middle Holocene (about 7500—3500 yr. B. P.), there existed a higher water level and a larger lake area for a long period.

2. Since the Late Holocene (about 3500 yr. B. P.) till now, the lakes storted to decline, water level dropped and the lake area shrank. Although there ware several rising periods in between, because of their short span and the little extent, the general trend is falling.

The palynological information reveals that the climatic fluctuation in the Holocene had the following pattern: from cool and semi—arid in the Early Holocene to warm and wet in the Middle Holocene, and then to the luckwarm and arid in the Late Holocene[3]. The warm and wet climate in the Middle Holocene is of signifucance. Temperature was about 2—3℃ higher the present followed by a warm climate zone moving northward. The rainfall was plenty and the forest expanded. The trace of this remarkable phase can be found in many places. A higher water level in the inland lake evaluation also reflects its occurence.

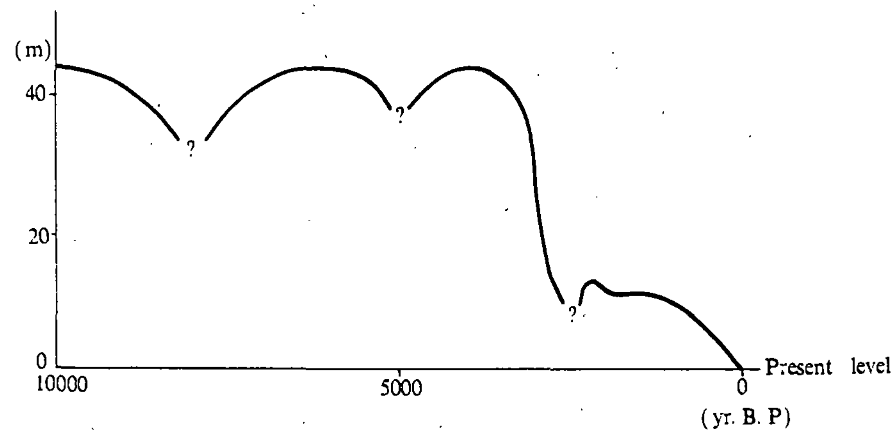

Fig.2 The water level fluctuation of Daihai Lake

III. THE RELATIONSHIP BETWEEN LAKE EVOLUTION AND CLIMATIC FLUCTUATION

As most inland lakes are closed drainage basins, the change of lake water level and badget depend primarily upon the climate differentration in the time span of a thousand years. Temperature change will result in the variation of evaporation from lake and ground surfaces; precipitation change will cause the variations of both surface runoff and evaporation. In addition, the change of these factors will lead to variation of other factors in relation to them, such as the factors of geography, hydrology and meteorology. Based on the analysis of 30—year measurement data from Qinghai Lake, it is found that the precipitation change has greater effect on the variation of lake water level and budget than the temperature for the inland lakes recharged mainly by precipitation (relevent to those recharged by glacier). This indicates that the inland lakes are very sensitive to precipitation change. For a closed drainage basin, if the recharge to and discharge out of it keep the same, which means the water level holds at a fixed level, the budget of the basin can be formalated as:

$$P \cdot A = E_L A_L + E_C (A - A_L) \quad (1)$$

where P is the average precipitation, E_L, E_C the evaporation from the lake and ground surfaces respectively. A, A_L the area of lake and catchment. If the evaporation and the lake area can be estimated in this formula, the precipitation can be easily calculated.

The paleo—evaporation can be extimated from the climatic condition which may be made known by paleo—vegetation condition, while the latter is ascertained and distinguished based on the palynological analysis data. According to the energy conservation law, the evaporation E, can be expessed as:

$$E = R / L / (1 + B) \tag{2}$$

where E is the evaporation, R net radiation flux, L the latest heat vaporization which is constant of 0.077 $w / m^2 \cdot mm$, B the Bowen ratio. R is calculated from:

$$R = (1 - a)(1 - c)G - A\varepsilon\sigma T^4 \tag{3}$$

where a the albedo, depending upon the characteristics of subsurface, c the fractional cloud cover, G the solar radiation flux, A the Angstrom ratio, ε and σ the emissivity and Stefan—Boltzmann constant respectively. The upward longwave radiation flux is a function of surface temperature. A feasible way to estimate these parameters is to use the observation data in a similar climatic region or use just the empirical formula.

Similarly, the lake balance can be formulated as:

$$P \cdot A_L + Q = E_L \cdot A_L \tag{4}$$

$$P \cdot A_L + P(A - A_L)r = E_L \cdot A_L \tag{5}$$

where Q and r are the runoff rate and runoff ratio respectively. Here, the precipitation difference of the catchment and the lake is neglected. This is acceptable for the middle to small drainage basins.

Qinghai Lake is the largest inland lake in China. The area of its closed drainage basin is 29,561 km^2. Till 1986, the lake level fell to 3193.84 m above see level; and the lake area shrank to 4304 km^2. In the middle Holocene, the lake experienced three times of stable water level periods and formed three corresponding terraces. The lake water level was respectively 65, 45, and 25 m higher than at present and correspondingly the area of the lake was 6776, 6326 and 5387 km^2 respectively[4]. Palynological analysis data show that the temprature was 2—3℃ higher than at present and the forest distributed widely on the catchment[3]. Substituting the above data to equation (1) to (5), we can calculate the paleo—evaporation, precipitation and runoff in that period as shown in Table 1.

From Table 1, we can see that the evaporation, precipitation and runoff of the paleo—lake is respectively 17.5%, 24—35% and 62—88% greater than at present.

Table 1 The budget of Qinghai Lake in the Holocene and at present

Terrace (R.height)	Age (yr. B. P.)	Evaporation (mm)	Precipitation (mm)	Runoff (mil. • m^3)
65m	7000	1112	566	3700
45m	5500	1112	551	3549
25m	3500	1112	520	3189
0m	present	955	407	2056

Daihai Lake, located in Inner Mongolia is another interior lake. Its drainage area is 2252 km^2. Till 1986 the lake level dropped to 1223 m and the area reduced to 133 km^2, while in the Middle Holocene (about 7500–4000 yr. B. P.), the water level was 45 m higher than at present and the lake covered an area of 420 km^2. We calculated the paleo–evaporation, precipitation and runoff as shown in Table 2. By contrasting with those items at present[5], we found that the conclusion is similar to Qinghai Lake. The rainfall is 35% greater; the evaporation 35% higher and the runoff rate is three times as much as at present.

Table 2 The Budget of Daihai Lake in the Holocene and at present

Age (yr. B. P.)	Evaporation (mm)	Precipitation (mm)	Runoff (mil. • m^3)
7500–5500	1190	554	267
present	916.3	407	91.4

After the middle period of the Holocene, the climate became dry. This can be seen from the less water budget and lower lake level. Though there were several times of water level rising, the precipitation had never reached the level in the Middle Holocene.

IV. THE LAKE EVALUATION IN THE LAST CENTURY AND ITS INDICATION ON CLIMATE CHANGE

In the last century, the general trend in climate is alternation between warm / dry and cool / humid, but the former is superior to the latter. The reflection of this climate change in the inland lakes is the rise–drop fluctuation of the water level with the general falling of the level as the major trend. Fig.3 and Fig.4 show the water level fluctuation and the water budget variation in Qinghai Lake and Issyk–kul Lake. The latter is located in the central Asia, Soviet Union. Its closed catchment area was 21,891 km^2, the lake area 6236 km^2 and the lake level 1607 m in 1986. From the figures (see Fig.3,4) we can find that the precipitation and runoff in Qinghai Lake show a decreasement pattern while the surface evaporation in Issyk–kul Lake tends to increase. And the atomspherical temperature in both lakes goes higher. It is parent that both lakes show a sharp declination of the water level and a rapid expansion of deficit budget. All of these facts indicate that the tendency of climate change in the middle Asia is getting warm. And they also reflect that the inland lakes in the arid and semi–arid zones are sensitave to the climatic change.

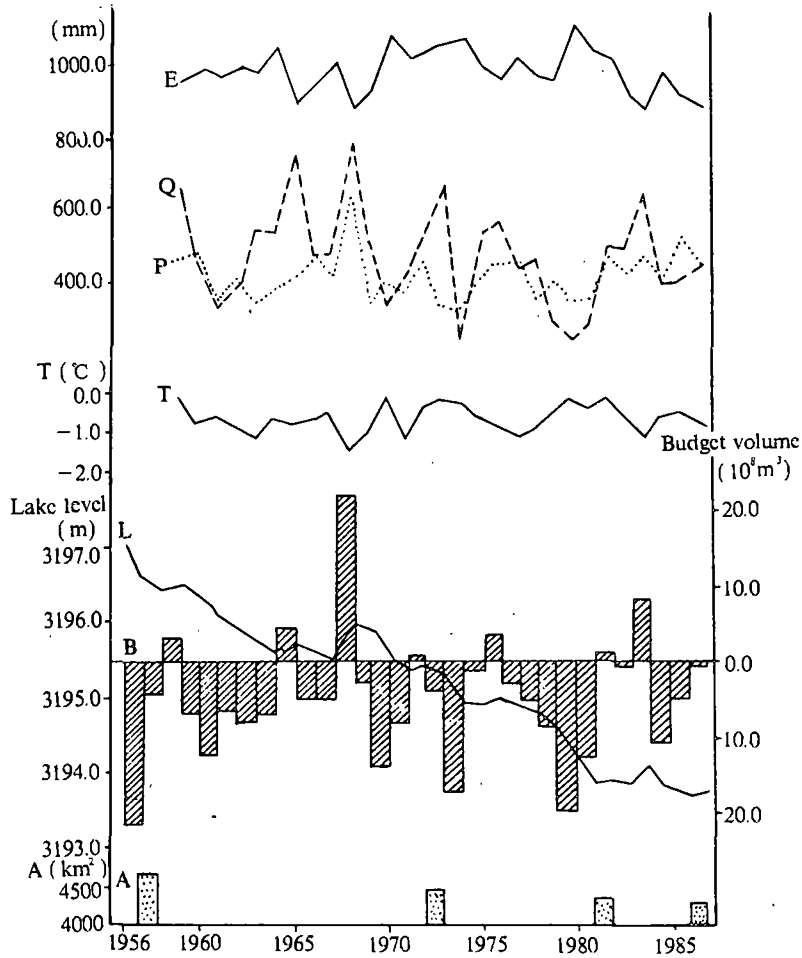

Fig.3 The water level and budget of Qinghai Lake and relative parameters

E—Evaporation, Q—Runoff feed, P—Precipitation, T—Temperature, L—Lake water level, B—Lake water budget, A—Lake area

V. CONCLUSION

The evolution of inland lakes in arid zones can sensitively indicate the climate fluctuation of the area. The high or low water level and the maximum and minimum lake water budget depend primarily on the changes of precipitation and temperature, particularly the former, since the precipitation change can effect not only the rainfall to the lake region but also the runoff rate and evaporation. The impact of the temperature change on the lake budget is subordinate compared with the precipitation. Therefore, based on the sensitivity feature of the inland lakes to climate change, especially the precipitation change, and with the aid of geomorphology, chnorology and palynology data, it is possible to set up the quantitative relation between the climate fluctuation and lake evolution, and to restore the paleolake budget and the alignment of paleo-precipitation in the order of a thousand years.

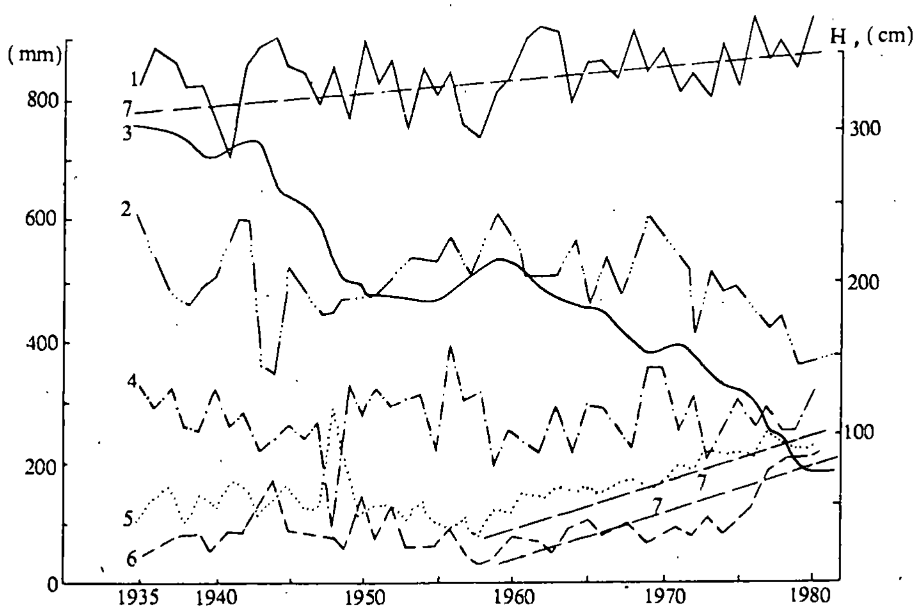

Fig.4 The changes of water level of Issyk-kul Lake and hydrological elements (from Д.В. (ЕВАСТЬ НОВ)[6-8]

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