Relationship between the Expansion of Mountain Lakes and Their Catchment Mountains on the Qinghai-Tibet Plateau

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Inland closed lakes are good indicators of changes of regional climate and hydrology [1, 2]. Based on the 1:500,000 topography map (1976 edition), the authors chose 5 typical regions and respectively summarized many characteristics of 12~15 lakes and their basins, and in conjunction with the 1:100,000 topography map (1970 edition) the author also investigated rivers, snow lines, glaciers and the climate characteristics in these basins, and researched the relationship between mountains and lakes in different regions, also tried understanding the difference mechanism of expansion scope of mountain lakes during the warm-wet period.

Hydrological balance of mountain lakes in a plateau

Generally, water balance equation of closed lake basins is shown as the following:

$$P_BS_B+P_LS_L+G_W=E_LS_L+E_BS_B \qquad (1)$$

Among which, P_B and P_L respectively denote the basin land (excluding glacier, the same below) and the lake-level average precipitation, S_B and S_L respectively denote the basin land area and lake area, G_W denote the glacial meltwater, E_L and E_B respectively denote the lake-level evaporation and basin land-level evaporation.

If the equation is:

$$P_BS_B- E_BS_B +G_W= (E_L- P_L)S_L \qquad (2)$$

And $(E_L- P_L)S_L$ of which can be shown as <RS>, <RS> denotes basin mountain runoff at different heights:

$$\langle RS\rangle=R_1S_1+R_2S_2+\cdots+R_nS_n \qquad (3)$$

Among which, R denotes runoff depth, S denotes the mountain area at different heights. So, Lake area and mountain area at different heights have the following relationship:

$$(E_L- P_L)S_L= R_1S_1+ R_2S_2+\cdots+R_nS_n \qquad (4)$$

Introducing into lake supply coefficient $K=S_B/S_L$ [3], we can elicit the following linear relationship between K and the mountain area at different heights:

$$(E_L- P_L)\, K= R_1S_1/S_B+ R_2S_2/S_B +\cdots+R_nS_n/S_B \qquad (5)$$

While the reciprocal of lake supply coefficient $K_V=1/K= S_L/S_B$ can denotes the static water maintained by unit basin land surface.

Therefore, from the relationship between the lake area and the mountain area at different heights we can analyze the characteristics of hydrological flow & store and lake expansion of closed lake basins.

Relationship between lakes and the hydrological characteristics of basins of typical regions in the Plateau

Based on temperature and precipitation, we divided the plateau into 5 typical regions (Fig.1): A) NamCo-Zige-tang Co Region, B) Zhari Namco –Angzi Co Region, C) Akesaiqin Lake-Guozha Co Region, D) Maerguochaka-Duogerenco QiangCo Region, E) Kusai Lake-Wulan Wula Region; and summarized many characteristics of 12~15 closed basins with similar climate in various regions (Table 1).

These basins are basically classified into two types: 1) lowland basins type (remarked as L type), in the basins with meek and open valley lowlands, the mountains with the height of more than 1,000 m （above the present lake level, except special instruction, the same below） take up less than 1‰, such as Zigetang Co, Yong Co and Gouren Co. 2) Mountain basins type (remarked as M type), in this kind of basins, the mountains with the height of more than 1,000 m take up above 1‰. According to that the mountains have slope break or not, and the height of slope break, basins can be subdivided into four types: (1) Ma type, with 500~750m height of slope break, namely, the lowlands with the height of less than 500~750m are meek while the mountains with the height more than 500~1000m are much steeper, such as Zhabu Yechaka Lake, Jiasa Co, Anggu Co, Guozha Co and Peigu Co, etc. The mountain area with the height of 500~1000m in the basins is larger. (2) MB type, with 1000~1500m height of breach, namely, middle-low mountains with the height less than 1000~1500m are meek while the high mountains with the height of more than 1000~1500m are much steeper, such as Dangqiong Co, Muco Bingni Lake, Dangreyong Co, Dongbu Co and Bangda Co, etc. The mountain area with the height of 1000~1500m in the basins is larger. (3) Mc type, there are slop breaks with the above two heights, such as Suona Lake, Taiyang Lake, Longmu Co, Kekexili Lake, etc. And (4) Md type, there is no obvious slope breaks, and some lakeshore plains are narrow such as Bangong Co; some are opener such as Nam Co, Zhari Namco, Akesaiqin Lake, Zeco and Jiezechaka Lake. In other words, some basin mountains have a plateau surface of relative meek gurgitation, such as Ma, Mb, Mc-type basins, while Md-type basin has no obvious plateau surface.

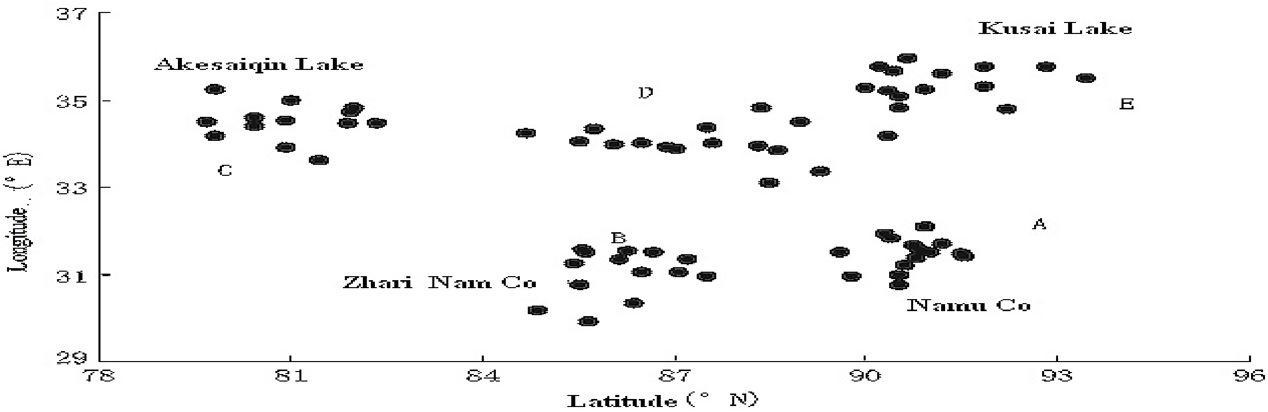

Figure 1, Distribution of Lakes mentioned in this paper on the Qinghai-Tibet Plateau

Table 1 Information of various typical closed lake basins on the Qinghai-Tibet Plateau

Region	Temperature	Annual Precipitation	Height of Snow Lines	Lake-level Height	Generation Height of Perennial River	Disappeared River (Initial Height)
A	0~-2?	400~450mm	5500~5750m	4500~4750m	5200~5500m	N/A
B	0~-2?	140~200mm	5800~6000m	4500~5200m	5200~5700m	N/A
C	<-4?	140~200mm	5800~6000m	4800~5100m	5700~6000m	5300~4800m
D	<-4?	<75mm	5800~6000m	5000~5200m	5800~6000m	5300~5000m
E	<-2?	120~160mm	5400~5500m	4800~5200m	5200~5500m	5000~4800m

These basins are basically classified into two types: 1) lowland basins type (remarked as L type), in the basins with meek and open valley lowlands, the mountains with the height of more than 1,000 m （above the present lake level, except special instruction, the same below）take up less than 1‰, such as Zigetang Co, Yong Co and Gouren Co. 2) Mountain basins type (remarked as M type), in this kind of basins, the mountains with the height of more than 1,000 m take up above 1‰. According to that the mountains have slope break or not, and the height of slope break, basins can be subdivided into four types: (1) Ma type, with 500~750m height of slope break; (2) MB type, with 1000~1500m height of breach; (3) Mc type, there are slop breaks with the above two heights; And (4) Md type. Md-type basin has no obvious plateau surface. while some basin mountains have a plateau surface of relative meek gurgitation, such as Ma, Mb, Mc-type basins.

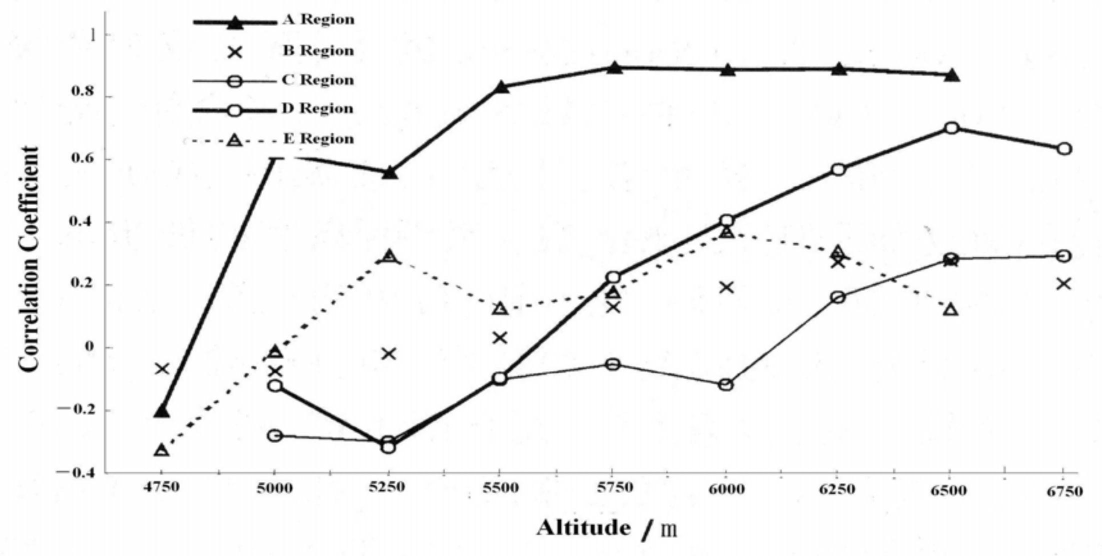

Figure 2 Correlation coefficients of 1/k and mountain area at various heights in various regions at the 0.01 confidence level

The correlation (shown as Drawing 2) between Kv and the mountain area at different heights in various basins is approximately the same. With the heightening of mountains, related coefficient is bigger and bigger, but the related coefficient of the mountain with the height of more than 6,250m and perennially covered by ice and snow is smaller.

Change of mountain lakes of the plateau during the global warm-wet period since 40 ka B.P

According to marine（deep-sea） oxygen isotope records, since 40 ka B.P, the world has undergone three typical climate stages: the interstadial of the last glacial---the last glacial maximum stage---Holocene (interglacial stage)[4]. Through the comprehensive analysis of existing information [5-21], the closed lakes during the warm-wet period in the interglacial stage of Qinghai-Tibet Plateau have the following expansion characteristics (shown as Table 2 and 3, ellipsis).

At interglacial stage of 40~23 ka B.P, mountain lakes significantly expanded, and at the glacial maximum stage, paleolake area was several times even dozens of times [21, 22] of present area or the paleolake became exorheic lake [20].

At Holocene （8.0~5.0 ka B.P）, lakes in the plateau entered into another expansion period, but totally, the expansion range was far less than that at 40~23 ka B.P.

Discussions

Based on most of lakes in Qinghai-Tibet Plateau since 40 ka B.P and Hydrological Effects of lake expansion under the orbital-cycle global-warming period (especially at 40~23 ka B.P), scholars have deep researches[14,19-22] on the expansion scope, change and mechanism of regional climate environment, etc.

However, based on basin type, lake status quo and expansion scope, precipitation increase of the plateau in warm-wet period was more likely to happen in the middle and high mountains, instead of hill and lowland. Especially, middle and the high mountains (with the height>500~750m) have larger area, and their lake expansion scope is greater. So, L-type basin has biggest modern lake supply coefficient (in comparison with others in the same region, the same below), while the lake expansion scope is very little. For basins of the highest mountain (with the height>1500~2000m), middle and high mountains with the height>500~750m have greater area (absolute area and the proportion), smaller modern lake supply coefficient and very obvious lake expansion.

The above situation shows that the precipitation of middle and high mountains is more that hill and lowland, which also may be caused by the following three factors:1) The higher the mountain is, the lower its temperature is, and the fainter the evaporation is; after flowing to and storing in a lake, the cold runoff will cool the lake in certain degree, and also reduce the lake evaporation, which makes the lake shrinkage caused by lake evaporation slowly.2) The mountain’s runoff depth value is bigger than hill’s and lowland’s under the same other conditions, which makes hydrographic flow and store of lake increased. And 3) When the climate changes to the warm-wet period making the regional precipitation increased, the lake expansion scope of middle and high mountains' basins is more obvious than hill's and lowland's. So, when rebuilding paleo-hydrography through exploiting paleolakes site, the regional wet degree of ancient climatic environment will be amplified artificially to some extent.

Conclusions

1) There is close relation between the mountain lakes area on the plateau and the basin mountain (the height in the east of the plateau >25m, and in the central and the west of the plateau >500~750m). The mountain's precipitation is the main source of lake-water, and the quality (low temperature) and quantity are the main factors for sustaining the existence of a lake which keeps a certain scope steadily.

2) In Qinghai-Tibet Plateau, the lake expansion scope at middle and high mountain basins is more obvious than hill's and lowland's in global warm-wet period and under the climate changing from cold to warm period.

3) At 40~23 ka B.P, the mountain lakes on the plateau had unusually expansion, which may be caused by a mass of low-temperature water formed by increased monsoon precipitation flowed to and stored in the lake during warm period. And the water increase is more obvious at mountain areas.

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