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MODERN CLIMATIC SIGNALS DEDUCED FROM STABLE ISOTOPE IN SHELLS IN XINGCUO LAKE SEDIMENTS, EAST TIBETAN PLATEAU, CHINA

WU Jing-lu[1], YU Hong[2], ANDREAS Luecke[3], WANG Su-min[1]

(1. Nanjing Institute of Geography and Limnology, the Chinese Academy of Sciences, Nanjing 210008, P. R. China; 2. Department of Atmospheric Observing Engineering, Institute of Meterology, PLA University of Science and Technology, Nanjing, 211101; 3. Forschungszentrum Juelich, ICG – 4, D – 52425 Juelich, Germany)

ABSTRACT: Xingcuo lake, a closed one, is situated in eastern Tibetan Plateau. There are abundant snail shells *Gyraulus sibirica* in its sediments. Here we display the determining results of $\delta^{13}C$, $\delta^{18}O$ in shell *Gyraulus sibirica* continuously preserved in Xincuo Lake sediments in the recent 50 years. And by coupling the indexes of $\delta^{13}C$, $\delta^{18}O$ and instrumental meteorological data in its basin to build relative function relations among them, we probe quantitatively climatic signals recorded in those indexes. The results show that there are remarkable relations between $\delta^{13}C$ proxy and precipitation, $\delta^{18}O$ proxy and air temperature, of which correlative coefficient was 0. 89 and 0. 71, respectively. Besides, we also demonstrated that average variation between $\delta^{13}C$ proxy and precipitation ($d\delta^{13}C/dP$) was 0. 027‰/mm and 1. 64‰/℃ for $\delta^{18}O$ and air temperature ($d\delta^{18}O/dT$).

KEY WORDS: Xingcuo Lake; $\delta^{13}C$, $\delta^{18}O$ proxies; climatic signals; eastern Tibetan Plateau

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It is one of the frontier focuses in the field of globle environmental changes to extract quantitatively past climatic signals from lake sediment records. In the recent decadcious years, a series of achievements on rebuilding the sequences of climatic and environmental evolutions at various scales by using the methods of lake sediments have been obtained, during which it also has shown great potential tool in the following quantitative study on past globe changes. However, it is extremely difficult to separate and extract climatic signals from lake sediments due to mixed signals contained in the lake sediments, especially the impact of human activities, which limited the further application of lake archives on PAGES. To obtain quantitatively high-resolvtion sequences of historic climatic evolution, therefore, it is a key to use statistic methods to select sensitive climatic proxies from mult-proxies of environment in lake sediments. The indexes of stable isotope in carbonates in lake sediments as climatic proxies, which have been explored, checked and applied in the study of quantitatively extracting past climatic signals, have been advocated by some international co-operation projects and have obtained better achievements (GRAFENSTEIN, 1999; ZHANG, 1994) . However,

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Biography: WU Jing-lu(1965 –), male, a native of Zhejiang Province, Ph. D. . His research interest includes isotope geochemistry.

stable isotope indexes in carbonates, as climatic proxies, still exist some uncertainty factors because lake carbonate formation is controlled by several factors (for instance, $\delta^{18}O$ values in lake carbonate are affected by that in lake water and in precipitation in its basin, the process of carbonate deposition and the ambient temperature when it is deposited, etc.). In order to concretely interpret climatic signals from environmental proxies in various regions, therefore, the study of modern lake sediment processes and environments should first be made to further understanding the background of applying these climatic proxies.

By coupling the variations of $\delta^{18}O$ and $\delta^{13}C$ values in shell *Gyraulus sibirica* in Xingcuo Lake sediments with instrumental climatic data, in this paper climatic signals recorded in recent sediments in Xincuo Lake have been quantitatively extracted, which provided a study base for reconstructing quantitatively long-scale climatic evolutionary sequences in this region.

1 INTRODUCTION

Xingcuo Lake (102°20′ – 102°24′E; 33°54′ – 33° 50′N), a fault small basin among hills, is situated in the northeastern part of the east Tibetan Plateau. The lake basin is encircled by a stretch of 3500 to 3600-meter-high hilly area in its three sides, leaving a relatively broad valley in its southwest. The area of Xingcuo Lake is 2.0km^2 with 3425m a. s. l. and 29km^2 basin area. The lake has a maximum depth of 1.5m. There exist two continuous terraces around the Xingcuo Lake. After the Huanghe (Yellow) River cut off the basin about 20 ka B. P. (WANG, 1995), the lake gradually became an independent and closed water body, which water supplement mainly relies on atmospheric precipitation in the drainage area and partially comes from groundwater. The Xingcuo Lake is an idea region to research recuperation of climatic environments in different historical periods in view of topographical and lake hydrological regime there.

2 EXPERIMENTAL ANALYSES

During the Tibeatn Plateau field investigation in July – August in 1998, samples of precipitation, lake water and present gastropod snails at different places of the Xingcuo Lake were collected. A core of 34cm thick (core SXC) was also drilled at a nearly central position at a water depth of 1.2m of the lake according to distribution characteristics of lake sediments using a piston sampler and, meanwhile, sampled in the interval of 1 cm. All these samples were used to analyze the following experiments in the laboratory.

2.1 ^{137}Cs and ^{210}Pb

Dating dried samples, weighed and calculated their qualitative depth, then to determine dating ^{137}Cs and ^{210}Pb with OTEC919 gamma spectrometer with high pure Ge and low background (and with an additional α probe) (OTEC Corp., USA).

2.2 Analyses for Stable Oxygen and Carbon Isotopes

The steps for determining stable isotopes in shells follows as: 1) Gastropod *Gyraulus sibirica* of continuous mono-species is chosen from identified gastropod snails, which are chosen at an interval of 1cm in the laboratory. Shells of *Gyraulus sibirica* are immersed into 1% hydrogen peroxide solution for 12 hrs, rinsed with distilled water and ultrasonic, baked dry, and mulled into fine powder (<100 mesh); 2) Weighed 100μg sample and put it into the pretreating system which is manufactured by Analytical Precision, U.K., after added 100% concentrated phosphoric acid, reacted at an isothermal condition of 70℃ for 12 hrs to decompose calcium phosphate in the powder and release CO_2 gas, in which isotopes oxygen and carbon are determined with a mass spectrograph instrument. PDB is adopted as a standard in the test, test error is below 0.1‰. The above experiments were finished in Juelich in Germany.

3 EXPERIMENTAL RESULTS

On the basis of dating ^{137}Cs, ^{210}Pb, core SXC was cabliated by its sediment rate (WU, 2000). Here the climatic signals recorded in stable isotope of shells *Gyraulus sibirica* in lithological core (10cm upper of core SXC) was detected by coupling $\delta^{13}C$, $\delta^{18}O$ proxies with instrumental meteorological data.

3.1 Composition of $\delta^{13}C$, $\delta^{18}O$ in Shells *Gyraulus sibirica* in the Recent 50 Years

It has been reported that snail forms its shell in an isotope balancing state with ambient water body, and $\delta^{13}C$ and $\delta^{18}O$ contents in the formed carbonate keep unchanged after settled (BOWEN, 1990). $\delta^{18}O$ composition in shell carbonate is mainly affected by temperature, salinity and $\delta^{18}O$ composition in its ambient water and so on, while the factors affecting carbon isotopes include hardness of the lake water, primary production of the lake, concentration of dissolved-in-water CO_2, and others, while $\delta^{13}C$ of shell carbonates are governed by the exchange between carbon dioxide in the atmosphere, aquatic carbon, hardness of the lake water and aquatic biological productivity etc. Besides, the processes of creature metabolism also affected its isotope composition, but, for the same species the affect can normally be neglected. Therefore, there is obvious correlation of climatic signals and stable isotope record in shell carbonate. Figure 1 shows that there is wide fluctuation of $\delta^{13}C$ and $\delta^{18}O$ values in shells Gyraulus sibirica in the recent 50 years, in which amplitude of $\delta^{18}O$ value is between $-5‰$ and $0.5‰$, average value is $-2.6‰$; for $\delta^{13}C$ values, between $-8‰$ and $8‰$, which average value is $-1.2‰$. At the beginning of 1950s, $\delta^{18}O$ value is higher, then gradually decrease to the lowest value at the end of 1950s; in the following about 20 years long, $\delta^{18}O$ value is generally lower, during which, however, there exists several obvious fluctuations. At around 1997 $\delta^{18}O$ value is the lowest in the whole profile. After that time, $\delta^{18}O$ value rises abruptly to the highest point in the whole section and keep that state about 10 years, then fall down quickly, but remain higher value till the present. $\delta^{13}C$ curve tendency keeps general pace with that of $\delta^{18}O$ value, however, except to obvious dales occurred in around 1954, 1977 and one peak in 1985, the fluctuations of $\delta^{13}C$ curve is relatively slower. Therefore, the composition of $\delta^{13}C$ and $\delta^{18}O$ in shells *Gyraulus sibirica* is affected not only by some their common factors but also by some respective special factors.

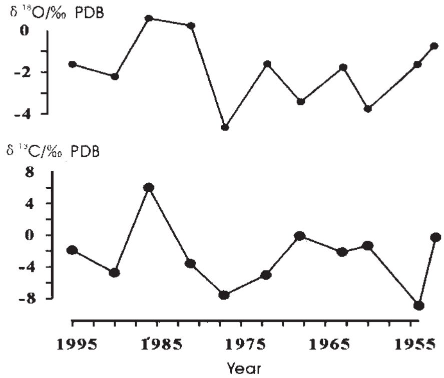

Fig. 1. $\delta^{13}C$, $\delta^{18}O$ values in shells of *Gyraulus sibirca* in the recent 50 years

3.2 Coupling Composition of $\delta^{13}C$, $\delta^{18}O$ with Instrumental Climatic Data

Comparative research between environmental proxies and instrumental data is an important step to recuperate past climatic environment quantitatively. With this, internal relationship of the proxy of climatic environment with climatic parameters may be more accurately established, so climatic proxy from lake sediments may be utilized to recuperate ancient climatic signals objectively. Taking the limination in sediment resolution of the core SXC (on an average, about 3–5a/cm) and the living period of *Gyraulus sibirica* into account, the author compares the data on 5-year running average temperature and annual precipitation measured at the Zoige Meteorological Station with the indices of $\delta^{13}C$, $\delta^{18}O$ in the shell of *Gyraulus sibirica*, finding a certain correlativity between $\delta^{18}O$ and the local temperature. This correlativity will be more notable if this comparison is carried out with the running average temperature in five months (April, May, June, July, and August) of warm seasons (Fig. 2), the index $\delta^{13}C$ is closely related to the precipitation in warm seasons (Fig. 3). This discovery further proves that the shell in the Xincuo lake mainly forms in warm seasons, what only recorded by the shell stable isotope proxies in the eastern region of the east Tibetan Plateau is the climatic signals of warm seasons, but that in the whole year.

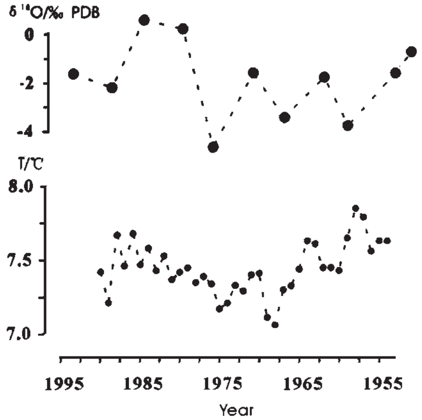

Fig. 2 Comparison of $\delta^{18}O$ values in *Gyraulus sibirica* shells and relative running average air in warm seasons in the recent 50 years

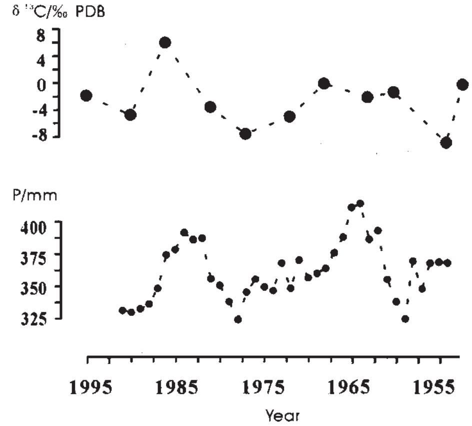

Fig. 3 Comparison of $\delta^{13}C$ values in *Gyraulus sibirica* shells and relative running average temperature precipitation in warm seasons in the recent 50 years

It is shown in Fig. 2 that the tendency of $\delta^{18}O$ curve not only is generally consistent with the fluctuation of local air temperature fluctuation, but also is comparable with the latter in their details. In the period from 1950s to the mid-1960s, the local air temperature reached a highest point in the last five decades, however, in around 1960 there existes an event of low temperature. Accordingly, a distinct negative offset of $\delta^{18}O$ value occurs in the same period; in the period of nearly 15 years from the mid-1960s to the end 1970s, the temperature curve takes on a bottom, including a rebound of temperature in around 1972 and two obvious drops in temperature in around 1969 and 1977, respectively, $\delta^{18}O$ value shows to be a higher value section in the corresponding higher temperature period on the temperature curve. The sections corresponding to 1980s, no matter on the temperature curve or on the $\delta^{18}O$ curve, all are peak value sections. At the early 1990s, temperature re-falls, decline of the $\delta^{18}O$ curve follows. The analysis above shows that variation of $\delta^{18}O$ in the shell of Gyraulus sibirica is mainly related to temperature, a higher temperature offset is corresponding to a positive offset of the $\delta^{18}O$ value. But the amplitude of fluctuation is different in $\delta^{18}O$ values and air temperature. In the last 50 years, the highest values of $\delta^{18}O$ occurred at the end of 1980s, instead of that in the 1950s, in which the air temperature was the highest; In the same way, the lowest values of $\delta^{18}O$ occurred in 1977, not corresponding to the stage of the lowest air temperature in 1969, showing that $\delta^{18}O$ values in shell *Gyraulus sibirica* are controlled by other factors besides main conection with air temperature.

Some differences exists between the $\delta^{13}C$ value in the shell of *Gyraulus sibirica* and the precipitation curve in detail variation, however, their general variation basically are coincident, the peak value of precipitation is corresponding to the higher peak of $\delta^{13}C$ value (Fig. 3). Two stages of low $\delta^{13}C$ values occurred in the 1960s and the 1980s in response to high precipitation in this period; in the 1970s, low precipitation vs negative $\delta^{13}C$ values. Because the variation of precipitation diectly controll hardness of lake water, lake primary production, concentration of dissolved-in-water CO_2, and aquatic biological productivity etc. which affect the variations of $\delta^{13}C$ values, there is clearly correlation between $\delta^{13}C$ vaiation and precipitation.

3. 3 Quantitatively Extracting Climatic Signals from $\delta^{13}C$ and $\delta^{18}O$ Proxies

As to a closed lake basin system, the main factors that affect its lake level fluctuation, lake physical, chemical and biological variations are precipitation and air temperature. The living, developing and dying of lake creatures have direct relation with variations of lake level, ambient temperature and water qualitative of their living lakes. Therefore, air temperature and precipitation control indirectly the composition of stable isotope in shells, which provide a theory base for obtaining quantitative climatic signals from these proxies by using mathmetical methods.

By using least square procedure to simulate the data of instrumental air temperature and $\delta^{18}O$ in shells in Xincuo Lake in the recent 50 years, the following linear regression equations was obtained: $\delta^{18}O = 1.64 * T - 14.36$, which coefficient is 0.89 and passes reliability test. From the regressive eqution, the average variable rate of proxy $\delta^{18}O$ and air temperature ($d\delta^{18}O/dT$) is 1.64‰/℃. The average values of $\delta^{18}O$ in shells *Gyraulus sibirica* in the recent 50 years is −2.1‰, and corresponding to warm seasons average air temperature is 7.4℃, so the ratio of $\delta^{18}O$ and air temperature is 0.28‰/℃. At the same a monadic linear-regression equations for the index $\delta^{13}C$ in the shell and the data of instrument-measured precipitation in warm seasons are also gotten, it is $\delta^{13}C = 0.027 * P - 8.047$, which correlation coefficient is 0.71, and passes confidence check.

4 CONCLUSIN AND DISCUSSION

Comparison of information from climatic proxies in lake sediments in instrumental period with meteorological data, verification of them, and acquisition of their functional relations is one of the most efficient ways to recuperate quantitatively historic climatic sequence. By comparing between the indices of $\delta^{13}C$, $\delta^{18}O$ in the shell of *Gyraulus sibirica* in the Xingcuo Lake in the eastern part of the Qingzang Plateau in the last five decades with the corresponding instrument-measured data of temperature and precipitation, the author quantitatively searched the climatic information contained in them. The results showed that proxies of $\delta^{18}O$, $\delta^{13}C$ in shells in a closed lake(e.g. the Xingcuo Lake) are effective climatic indexes to reveal the variation of temperature and precipitation during forming of the shell, this particularly is true for shallow lakes. It has been reported that stable oxygen isotope in lake carbonate is mainly controlled by temperature index, namely, high temperature is in favor of the enrichment of heavy stable oxygen isotope (GASSE, 1991; WU, 1997). However, in some environmental conditions, such factors as icy water with lighter oxygen isotope inflowing or changes in hydrological characteristics in lake catchment will affect composition of oxygen isotopes in the lake water, further may become the main factors affecting oxygen isotopes composition in carbonate(BOWEN, 1990; WEI, 1995). After 20ka B.P., when the Xingcuo Lake had gradually become a closed lake, its water environment has been relatively stable, the basin hydrological circumstances are simple, a positive correlativity between index $\delta^{18}O$ in the shell of *Gyraulus sibirica* and the running average air temperature in warm seasons shows that the main factor affecting oxygen isotope composition in the shell of *Gyraulus sibirica* is temperature. At least two meanings are contained in this statistical relation: one is variation of temperature directly affects equilibrating exchange of isotopes during forming of the living being shell; the second is that air temperature controls the living environment of lake creatures (for instance, the hardness of lake water, the composition of stable oxygen isotope in lake water, etc.), which indirectly affects that in shell. As to proxy of $\delta^{13}C$ in lake carbonates, it is mainly governed by the hardness of lake water, and it is enrich in heavy carbon isotope with respect to the high hardness of lake water (RUBINSON, 1969). For benthic lake creature *Gyraulus sibirica*, its living environments changes with the variations of the depth of lake water, for instance, the decrease of the amount of CO_2 in lake water, the weakness of exchanes of lake with atmosphere above it, which all possibly cause the enrichment of heavy carbon isotope in shells *Gyraulus sibirica* (STUIVER, 1970). By building functional relation between the proxy $\delta^{18}O$ in shells and instrumenatl air temperature, we found that the variable rate of $\delta^{18}O$ proxy and running average air tempearature in warm seasons is 1.64‰/℃, average value is 0.28‰/℃. So far the studies on the functional correlation between stable isotope in fresh snail shells and meteorological parameters is seldom reported, while the average variable rate of $\delta^{18}O$ in benthic foraminfera in deep ocean to sea water temperature is 0.2‰/℃, which is generally accepted (BOWEN, 1990). Besides this, there are relative lots of studies on the relation of $\delta^{18}O$ valeus in precipitation and air temperature, however, the ranges of the differences between them are greater from 0.18 ‰/℃ 0.98‰/℃, as a result of the differences of the sources of water vapor and the pattern of atmospheric circulations, the processes of precipitation formation in various regions, together with the affect of landform, height above sea level and so on(STUIVER, 1970; ABELL, 1985). Lake water temperature, especially in a shallow lake system, widely fluctuates with the variations of air temperature, it is thus normally accepted that the variable rate of $\delta^{18}O$ in lake carbonates to water temperature is greater than that in deep sea carbonates. With the development of further study on lakes located in difference regions, we will find that there are greater differences in the variable rate of d $\delta^{18}O/dT$ in various regions. Because of this, in the study of past climatic reconstruction, the modern evolutionary processes of lakes and their basins should be strengthen, and then climatic proxies in lake sediments may be marked with instrumental data. With this, the historic climates could be concretely rebuilt by using marked climatic proxies preserved in lake sediments.

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