Evaluation of Oxygen Stable-Isotope Fractionation Among Co-existed Carbonates in the Sediments of Lake Qinghai

Cheng Zeng

School of Social Development, Fuyang Teachers college, Fuyang, 236041, China
Zengcheng1975@sina.com.cn

Abstract

Mineralogical examination and stable isotope analyses for the Lake Qinghai sediments indicate that authigenic carbonate minerals are present either in the form of one type or several types co-existed in the sediments, and that large differences in $\delta^{18}O$ of up to 6.5‰ are shown for selected sediment samples. These $\delta^{18}O$ values are highly and positively correlated with total carbonate contents (TCC) and are not affected by shifts in carbonate mineral composition, indicating that oxygen stable-isotope fractionation among different carbonate minerals is minimum. The results suggest that marked changes in carbonate $\delta^{18}O$ are resulted predominantly from changes in isotopic composition of the lake water, and that differentiated $\delta^{18}O$ values resulted possibly from isotope fractionation among co-existed carbonates formed in natural environmental conditions are limited to 0-1‰. The $\delta^{18}O$ proved to be a useful environmental proxy for the study of the past changes in P-E budget of closed-basin lakes.

1. Introduction

Lake Qinghai, the closed-basin lake and the largest water body in China, lying in an intermontane basin on the northeast corner of the Tibet-Qinghai Plateau, is climatically influenced by both the Eastern-asian monsoon and the westerlies, and is sensitive to the climatic change such as regional precipitation. The history of the lake-level change is the important environmental archive for the study of regional monsoon evolution. For the changes in P-E budget of closed-basin lakes determining the changes of lake-
level and of the lake water $\delta^{18}O$ ($\delta^{18}O_w$), the carbonates $\delta^{18}O$ ($\delta^{18}O_c$) from such lakes is an important environmental proxy for the study of the lake water isotope chemistry and lake-level change [1-3]. Many study results suggest that $\delta^{18}O_c$ values from closed-basin lakes are parallel to those of $\delta^{18}O_w$. However, when the $\delta^{18}O_c$ is applied to study the environmental evolution, the differentiated $\delta^{18}O_c$ values resulted possibly from isotope fractionation among co-existed carbonates formed in natural environmental conditions needed to be given attention and to be clarified[4,5]. This paper discusses and evaluates the fractionation differences among co-existed carbonates, based on the mineralogical analysis and determined results of $\delta^{18}O_c$ values from Lake Qinghai.

2.Methods and results

Sediment core QH14 was extracted from the central sub-basin of Qinghai Lake using a Kullenberg corer and stored in cold room at 4°C. Core sections were split and photographed fresh. Total carbonate contents(TCC) were calculated from total inorganic carbon(TIC) determined by coulometer measurements. XRD analyses defined relative contribution of three carbonate minerals. Oxygen isotope composition of carbonate minerals ($\delta^{18}O_c$) was determined with a VG Micromass 903 mass spectrometer at the Geologisches Institut, ETH-Zurich.

As shown in table 1, TCC of sample No 1 is 31%, with the relative content of dolomite being 44%. Compared with sample No 1, $\delta^{18}O$ of sample No 2 and 3 is respectively 6.506‰ and 6.144‰ higher, and the relative contents of dolomite of which is up to 100%, companied with a rapid increase in TCC from 31-77%. Along with the sudden end of dolomite sediment at 399 cm of depth, TCC decrease speedily from 77-28%, as well as the synchronous fall of $\delta^{18}O$ which has dropped to -0.762‰ of sample No 4. Comparing sample No 5 and sample No 6, the relative contents of aragonite rises from 68% to 93%, and the $\delta^{18}O$ also rises from -0.034‰ to 1.466‰. Though the relative content of dolomite of sample No 7 is 36% higher than that of sample No 6, the $\delta^{18}O$ of which still drops 2.149‰ along with the fall of TCC from 78% to 54%.

TABLE. 1 Carbonate mineral composition and $\delta^{18}O$ data from core QH14

| Sample No | Depth (cm) | $\delta^{18}O$ (PDB, ‰) | Carbonates contents (%) | Relative contents of carbonates (%) |
|-----------|------------|--------------------------|-------------------------|-----------------------------------|
| 7#        | 383.1      | -0.683                   | 54.0                    | 38                  40              22          |
| 6#        | 383.9      | 1.466                    | 78.0                    | 93                  4               3           |
| 5#        | 385.5      | -0.034                   | 53.0                    | 68                  4               28          |
| 4#        | 389.6      | -0.762                   | 42.0                    | 47                  14              39          |
| 3#        | 400.8      | 5.108                    | 77.0                    | 0                   100             0           |
| 2#        | 404.0      | 5.470                    | 77.0                    | 0                   100             0           |
| 1#        | 415.5      | -1.036                   | 31.0                    | 18                  44              38          |
3. Discussion

The results above expressly indicate the high and positive correlation between δ¹⁸O and TCC (Fig. 1), which shows that oxygen stable-isotope fractionation among co-existed carbonates is not the main factor controlling the large range change of δ¹⁸O. The carbonates in the sediment from Lake Qinghai being autogenic, TCC mainly reflects the chemical status of lake water, especially the change of salinity and alkalinity of lake water which is commonly in synchronization with δ¹⁸O changing of lake water. So the large range of δ¹⁸O fluctuating of Qinghai lake sedimental profile reflects the marked change of δ¹⁸O of lake water.

Results from Lake Qinghai sediments indicate that the oxygen isotope fractionation among co-existing carbonates formed naturally in lake environments is minimum, and far less than the fractionation differences of 4‰-7‰ in δ¹⁸O between dolomite and calcite, obtained based on elevated-temperature
experiments and extrapolations to temperatures at 20°C -25°C[6-8]. The changes in δ18O with a magnitude up to 6.506‰ between sample No 1 and 2 from Lake Qinghai sediment are not the result of fractionation, for the reason that just like sample No2, dolomite is also the dominant carbonate mineral in sample No 1, the relative content of dolomite has reached to 44%. Results show that the relative content of dolomite in sample No 7 is 36 % higher than in sample No 6, while δ18O of sample No 7 does not rise accordingly due to the fractionation effect. Furthermore, the fall of δ18O up to 5.87‰ between sample No 3 and 4 is also not the result of oxygen isotope fractionation among co-existed carbonate minerals, but is caused by the abrupt rising of lake water, which results in the desalting of lake water and the termination of the playa lake environment[3]. The large range of negative shift in δ18O of lake water at this time is also suggested by the evidence of the drop of δ18O from lacustrine ostracodes [1].

Results from Qinghai Lake indicate that isotope fractionation between co-existing carbonates formed naturally in lake environments is far less than the extrapolated values based on elevated-temperature experiments. The result in this paper supports the conclusion that the differences caused by oxygen isotope fractionation between co-existing carbonate minerals formed in natural environment are limited to 0-1‰.

To explain such large difference of fractionation difference between extrapolated values obtained based on experiment and practical values formed in natural environment, O’Neil et al. [7] think that co-existed dolomite and calcite formed in natural environment do not reach the oxygen isotope equilibrium, while the equilibrium is achieved in elevated-temperature experiments. Some researchers hold the opinion that oxygen isotope equilibrium fractionation factor of dolomite is smaller than that of calcite[9], and the other researchers take the view that δ18O of proto-dolomite is 3‰ lower than of dolomite both formed in natural environment [10].

4.Conclusion

Authigenic carbonate minerals commonly in two or more types are present in the sediment column of many brackish lakes in the western China, either in different intervals of the column or in an annually-formed lamination. The magnitude of oxygen isotope fractionation between different carbonate minerals, that were used for isotope analysis, should be adequately evaluated and calibrated for the δ18Oc curve if the fractionation is substantial. The sediment interval of 380-450 cm from core Q14B was used for this study. The data of carbonate content and mineralogy, and δ18Oc indicate that changes in δ18Oc with a magnitude up to 6.51‰ are resulted from the rapid changes of precipitation-evaporation budget, rather than oxygen isotope fractionation between different carbonate minerals. δ18O of lacustrine authigenic carbonates is one of the important and sensitive environmental proxies for the study of lake water isotopic balance and of regional climatic evolution. Results from Lake Qinghai indicate that isotope fractionation between co-existed carbonates formed naturally in lake environments is minimum. The fractionation differences of 4-7‰ in δ18O between dolomite and calcite, obtained based on elevated-temperature experiments and extrapolations to temperatures at 20-25 ºC, are not applicable to the carbonates formed in natural environments. The fractionation differences of 0-1‰ are recommended for calibrating a possible disparity between co-existing carbonates in lacustrine isotopic records.

5.Acknowledgment

This work is partially supported by NSFC Grant # 40872114 to C. F. Fu, National Social Science Fund Grant # 10BZS052 to H. T. Wu, Youth Foundation of Humanities and Social Science Plan Authorized by China's Ministry of Education Grant # 10YJC770003 to C. Zeng, Humanities and Social Science Plan of An’hu Province College Grant # 2010sk337 to C. Zeng, Foundation for The Excellent Youth Scholars of An’hu Province College Grant # 2010SQRW113 to C. Zeng, Project on Educational
Sciences Planning of An‘hui Province Grant # JG09160 to C. Zeng, Scientific Research Project of Fu Yang Teachers’ College Grant # 2009FSKJ13 to C. Zeng, and Teaching Research Project of Fu Yang Teachers’ College Grant # 2010JYXM35 to C. Zeng.

Reference

[1] G. S. Lister, K. Kelts, K. Z. Chen, J. Q. Yu, and F. Niessen, “Lake Qinghai, China: closed-basin lake levels and the oxygen isotope record for ostracoda since the latest Pleistocene,” Palaeogeogr Palaeoclimatol Palaeoecol. Abbrev., vol. 84, pp.141-162, March 1991.

[2] J. Li and J. Q. Yu, “Oxygen stable isotope records for ostracodes from lake Huangqihai in Inner Mongolia,” Journal of Salt Lake Research, vol. 10, no. 4, pp.13-18, December 2002.

[3] J. Q. Yu and K. R. Kelts, “Abrupt changes in climatic conditions across the late glacial/Holocene transition on the N. E. Tibet-Qinghai Plateau: evidence from Lake Qinghai, China,” J. Paleolimno. Abbrev., vol. 28, pp.195-206, June 2002.

[4] S. H. Zheng, S. C. Zheng, and Z. Z. Mo, Analysis of stable isotope geochemistry, Beijing: Peking University Press, 1986, pp.81-464.

[5] Z. Y. Gu, et al, “Evolution of monsoon in Tibet-Qinghai Plateau since 12ka B.P.: geochemistry evidence from Selin Lake sediments,” Chinese Science Bulletin, Vol. 38, no 1, pp.61-64, January 1993.

[6] D. A. Northrop and R. N. Clayton, “Oxygen isotopic fractionation in systems containing dolomite,” J. Geol. Abbrev., vol. 74, pp.174-196, September 1966.

[7] J. R. O’Neil and S. Epstein, “Oxygen isotope fractionation in the system dolomite-calcite-carbon dioxide,” Science, vol. 152, pp.198-201, June 1966.

[8] S. M. F. Sheppard and H. P. Schwarcz, “Fractionation of carbon and oxygen isotopes and magnesium between coexisting metamorphic calcite and dolomite,” Contr Mineral Petrol. Abbrev., vol. 26, pp.161-198, June 1970.

[9] G. Faure, Principles of isotope geology, John Wiley & Sons, 1977, pp.368-369.

[10] P. Fritz P and D. G. W. Smith, “The isotopic composition of secondary dolomites,” Geochimica et Comochimica Acta, vol. 34, pp.1161-1173, July 1970.