A method of quantitatively calculating amount of allochthonous organic carbon in lake sediments

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TOTAL organic matter(TOM) or total organic carbon(TOC) is often treated as an important indicator of lake environment. As a matter of fact, TOC is of multi-origin, and can simply be divided into two parts: autochthonous and allochthonous organic carbon. The autochthonous organic carbon is mainly controlled by the production of the plankton of lake itself; and the allochthonous one by climate and environment in the catchment area, e.g. more precipitation and runoff and densely developed vegetation will give rise to more allochthonous organic components in the lake sediments. Therefore, the amount of allochthonous organic carbon is a more effective proxy for climate and environment, and it can reflect the past precipitation to a certain degree. However, the amount of allochthonous organic carbon cannot be directly measured. Thus how to quantitatively calculate it has been a problem to be resolved.

1 Method

The past studies indicate that C/N ratio (TOC against total organic nitrogen) is different among the organic matter of different sources. The subaerial higher plant has a higher C/N value (14—23, even>30) than lake plankton (about 6—7)[1]. Based on this study, we use the following duality model to quantitatively calculate the amount of TOC of two origins, because there are a series of measuremental data of TON and TON(total organic nitrogen) along the lake sediment profile.

Assume that TOC and TON at the depth of i m in the profile are C(i) and N(i) respectively. Then

$$\begin{aligned} C(i) &= C_l(i) + C_s(i), \\ N(i) &= N_l(i) + N_s(i), \\ C_l(i)/N_l(i) &= R_l(i), \\ C_s(i)/N_s(i) &= R_s(i), \end{aligned} \tag{1}$$

where $C_l(i)$ and $N_l(i)$ are TOC and TON from subaerial organic input, and $C_s(i)$ and $N_s(i)$ from autochthonous organic matter. $R_l(i)$ and $R_s(i)$ are C/N ratio from the subaerial and autochthonous sources respectively. Eq. (2) can be deduced from eq. (1):

$$\begin{aligned} N_l(i) &= [C(i) - R_s(i)N(i)]/[R_l(i) - R_s(i)], \\ N_s(i) &= [C(i) - R_l(i)N(i)]/[R_s(i) - R_l(i)], \\ C_l(i) &= \{R_l(i)[C(i) - R_s(i)N(i)]\}/[R_l(i) - R_s(i)], \\ C_s(i) &= \{R_s(i)[C(i) - R_l(i)N(i)]\}/[R_s(i) - R_l(i)]. \end{aligned} \tag{2}$$

Therefore, choice of the value of $R_l(i)$ and $R_s(i)$ will directly change the result of eq. (2). The C/N ratios mentioned above are average value, then $R_l(i) = R_l = 23$ and $R_s(i) = R_s = 6$ by zero-order approximation. But this will lead to negative value in eq. (2). Therefore R_l and

R_s need to be regulated. According to the current report, $R_l > R_s$. So

$$R_s \leqslant C(i)/N(i), \qquad R_l \geqslant C(i)/N(i).$$

By zero-order approximation:

$$\begin{aligned} R_l &= \max[C(i)/N(i)] + \Delta l, \\ R_s &= \min[C(i)/N(i)] - \Delta s, \end{aligned} \tag{3}$$

where Δl and Δs are the parameters which can be regulated. They can be determined by the result from eq. (2) and other relative results.

2 Example

According to the above duality model, we have made a preliminary study on the allochthonous organic carbon components for the RM core of Zoigê Basin in northeastern Qinghai-Xizang Plateau. RM core (33°57′N, 102°21′E) is located in the depositional center. The land surface has an altitude of 3410 m a.s.l. The core has a depth of 310.46 m. TOC is determined by $K_2Cr_2O_7$ volumetric[2], because the inorganic nitrogen is very low in lake sediments and TON is approximately replaced by total nitrogen(TN). TN is measured by persulfate oxidation-ultraviolet spectrophotometry[3].

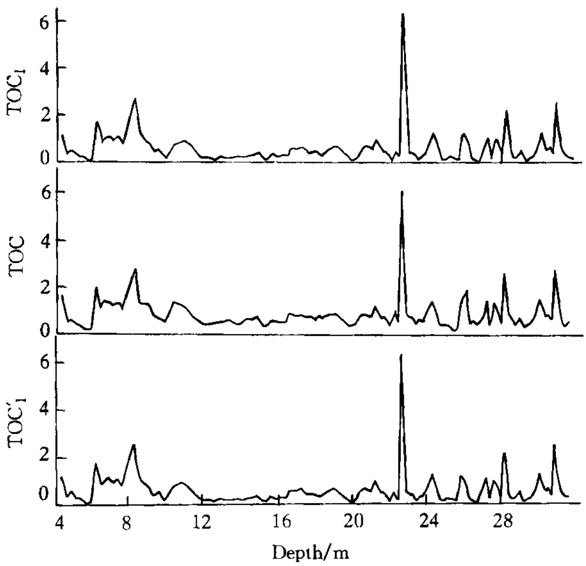

Fig. 1. Distribution of TOC(i)/TOC$_l$(i), TOC$_l'$(i) values.

The maximum and minimum values of 115 samples from the depth i of 4.3—31.71 m in RM core are 22.264 and 3.569. By assuming $R_l = 22.264$, $R_s = 3.569$ and $R_l = 23.0$, $R_s = 3.0$, the calculated results from eq. (2) are TOC$_l$(i) and TOC$'_l$(i) as shown in fig. 1. The comparalive study suggests that the results from the two assumptions are similar with an error of 4%.

In order to prove the effectiveness of this method, we have compared TOC(i)/TN(i), TOC$_l$(i)/TOC(i) and CD/TC ratio (fig. 2). CD/TC ratio is the ratio of the total amount of chlorophyll and its derivations against total carotenoids. CD/TC is one of an effective proxies to evaluate the balance of autochthonous and autochthonous organic matter. High CD/TC value corresponds to abundant allochthonous organic input and *vice versa*[4].

The values of TOC(i) and TOC(i)$_l$ have good positive trends, suggesting that the allochthonous organic carbon TOC$_l$(i) calculated from the model can be treated as an indicator for lake environment and the Zoigê palaeo-lake maintained a stable environment for a long time with a few changes of preservation condition[5].

The TOC$_l$(i)/TOC(i) ratio and CD/TC also have good positive correlation, suggesting that the model is right from another angle.

3 Conclusion

The lake sediments have registered the information of palaeoclimate and palaeoenvironment in the lake itself and the regional scale. This also leads to a complexity in study of the palaeolimnology by all kinds of proxies. How to purify these proxies to indicate the palaeoclimate has become a problem to be solved. Most of the proxies can qualitively identify the percentage of allochthonous and autochthonous organic components, e.g. $\delta^{13}C_{org}$, CD/TC. The model introduced in this note has provided a method of quantitatively calculating the amount of allochthonous organic carbon. As for determination of regulating parameters, i.e. Δl and Δs, further work is still in need.

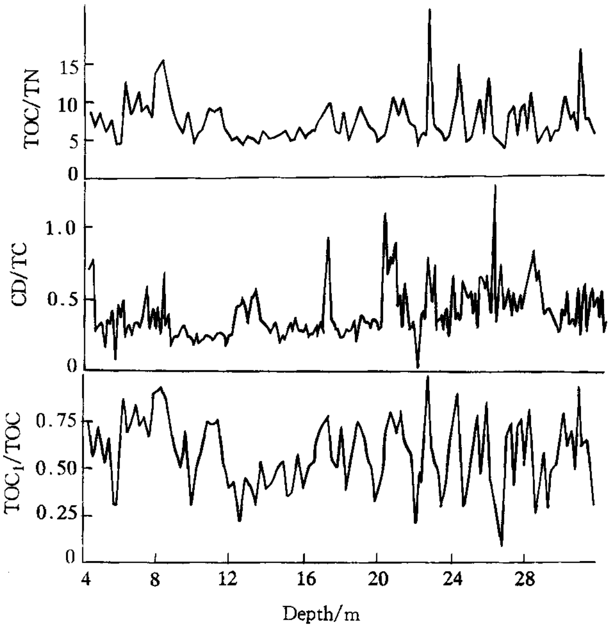

Fig. 2. Distribution of TOC(i)/TN(i), $TOC_1(i)$/TOC(i) and CD/TC ratio in RM core sediment.

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