Impact of oxic degradation and deep water column production on GDGT abundance and distribution in surface sediments in the Arabian Sea: Implications for the TEX₈₆ paleothermometer

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INTRODUCTION

In order to improve the application of the TEX₈₆ as a proxy for sea surface temperature, the impacts of oxic degradation and deep water column production need to be constrained. Here, we examined the distributions of core lipid (CL)- and intact polar lipid (IPL)-GDGTs in surface sediments deposited at a range of depths (900 to 3000 m) and exposed to different oxygen bottom water concentrations (<3 to 83 $\mu\text{mol} \cdot \text{L}^{-1}$), on a sea mount (Murray Ridge) whose summit protrudes into the oxygen minimum zone of the Arabian Sea (Fig. 1, 2). This allowed the sampling of sediment core tops which were exposed to different oxygen bottom water concentrations and for different amounts of time, due to the variations in sedimentation rates.

Figure 1. Location and topography of the Murray Ridge in the Arabian Sea.

Figure 2. Depositional environment and sampling stations along the Murray Ridge: a Bottom water oxygen concentration, b average exposure to oxygen, c sediment organic carbon content and d depth of sampling stations.

METHODS

CL- and IPL-GDGTs were extracted using a Bligh Dyer extraction, and separated according to Lengger et al. (2012a), as well as ASE-extracted, from sediment of the 10 stations across the Murray Ridge (Fig. 1, 2), and the TEX₈₆ was determined (Fig. 3). The IPL-GDGTs of stations P900, P1300 and P3000 were separated by preparatory HPLC and hydrolysed and the TEX₈₆ values of monohexose (MH)-GDGTs, dihexose (DH)-GDGTs and hexose, phosphohexose (HPH)-GDGTs were determined.

RESULTS

GDGT concentrations and TEX₈₆

Similar to the total organic carbon, all GDGT concentrations with the exception of IPL-GDGT-0 decreased with water depth (Fig. 3 b,c) and thus oxygen bottom water concentrations (or time of exposure to oxygen). This could indicate that their concentrations are predominantly dependent on the extent of oxic degradation. Surprisingly, TEX₈₆ values decreased with water depth by 0.08 units, which corresponds to 3°C. This reason for this observed bias could be sedimentary in situ production, differential degradation and a contribution of deep water production, all of which are explored below (Fig. 4, 5, 6).

Figure 3. TEX₈₆ and GDGT concentrations across the Murray Ridge. a TEX₈₆ values of core top sediment vs. water depth, b CL-GDGT and c IPL-GDGT concentrations with the water depth where the sediment was sampled.

EFFECT OF OXIC DEGRADATION

Figure 4. The effect of exposure to oxygen to organic carbon and GDGTs. a % TOC, b TEX₈₆, c CL-GDGTs and d IPL-GDGTs vs. average exposure time to oxygen, which was calculated from the oxygen penetration depths and the sedimentation rates.

CONCLUSIONS

The reasons for the TEX₈₆ increase are most likely a combination of deep water production and differential degradation. This is supported by the correlation of TEX₈₆ and GDGT concentrations with oxygen exposure and the observation of a similar decrease in TEX₈₆ values in suspended particulate matter, as well as a similar TEX₈₆ decrease seen in individual types of IPL-GDGTs.

COMPARISON WITH SPM VALUES

Figure 5. TEX₈₆ of suspended particulate matter in the Arabian Sea water column as shown by Schouten et al. (2012).

IPL-GDGTs BY HEADGROUP

Figure 6. TEX₈₆ and IPL-GDGT concentrations by headgroup. a TEX₈₆ values and b concentrations of IPL-GDGTs isolated of sediment at P900, P1300 and P3000 at 0-2 and 20-24 cm water depth.

The TEX₈₆ of individual IPL-GDGTs differs strongly (Fig. 6), as also observed in culture material. HPH-GDGTs show a low TEX₈₆, DH-GDGTs show a high TEX₈₆ and MH-GDGTs show an intermediate TEX₈₆. HPH-GDGTs are only present in high amounts at stations P1300 and P3000. However, TEX₈₆ of every IPL-type also decreases with water depth, but not with sediment depth. This strongly indicates that there is negligible contribution from sedimentary in situ production. Thus, not only differential degradation of GDGTs per headgroup is responsible for the trend in TEX₈₆, but also probably deep water production. This is supported by the fact that archaeal lipids show very slow turnover times (e.g. Lengger et al. 2013), and by the TEX₈₆ decrease observed in suspended particulate matter in the overlying water column (Fig. 5, Schouten et al., 2012).