Inter-hemispheric appraisal of the role of the $C_{37:4}$ alkenone as a climate proxy: a new molecular index to determine the position of the Arctic front and sea surface temperature?

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The U^K_{37} and $U^K_{37}{}'$ index are used as proxies to reconstruct absolute sea surface temperature (SST) variations in the photic zone (Brassell *et al.*, 1986; Prahl *et al.*, 1988). These indices are derived from the relative abundance of methyl alkenones with 37 carbon atoms and 2, 3 or 4 double bonds (e.g. $C_{37:4}$ stands for C_{37} alkenone with 4 double bonds). Alkenones are biosynthesized by some algae of the Class Prymnesiophyceae, such as *Emiliania huxlevi* which is the most abundant and widespread coccolithophorid in the oceans, and most likely, the main producer of alkenones found in recent sediments. In comparison to other sedimentary organic components (i.e. biomarkers), alkenones are more resilient to degradation, abundant in sediments, and their presence is widespread in all oceans.

The purpose of this paper is to provide new insights into the value of $U^K_{37}/U^K_{37}{}'$ to estimate SST at low temperatures (<10°C), and to examine the information contained in $C_{37:4}$ for palaeoceanographic reconstruction. Alkenone sediment data from the Nordic Seas are compared to data for the Southern Ocean (Sikes *et al.*, 1997), to appraise the global significance of regional data from the North and South hemispheres.

Methods

The procedures employed to determine alkenone indices have been described in detail elsewhere (Rosell-Melé *et al.*, 1995). Briefly, sediment samples were freeze dried, weighed (1–2 g), solvent-extracted (dichloromethane/methanol, 3:1 × 3), and the total extracts cleaned up using solid phase extraction on silica. After derivatization with bis-(trimethyl-silyl)-trifluoro-acetamide (BSTFA), the C_{37} alkenones were quantified by gas chromatography (GC)-mass spectrometry with ammonia chemical ionization (CIMS).

The CIMS method allowed quantification of the $C_{37:4}$ alkenone with a similar precision to the other members of the U^K_{37} index, because each peak was integrated from its mass chromatogram and a comparable signal/noise ratio was obtained for each component. In this case, the relative errors of both U^K_{37} and $U^K_{37}{}'$ are comparable and any difference in the magnitude of the errors is not likely to be significant from a climatic standpoint (small temperature variation).

Results

We have found significant regional or inter-hemispheric differences in the temperature dependence of the relative abundance of sedimentary alkenone data, at the cold end of the temperature range. U^K_{37} can be used to estimate SST both in the Southern Ocean and the Nordic Seas, albeit with different calibration equations. In contrast, $U^K_{37}{}'$ in the Nordic seas below 10°C shows no correlation with SST, although $U^K_{37}{}'$ does correlate with SST in the Southern Ocean. Leaving practical or analytical considerations aside, the application of U^K_{37} *vs* $U^K_{37}{}'$ as a climate proxy is thus equally justified, but constrained by regional differences and temperature ranges.

Geographical variations are specially significant in relation to the relative abundance of the tetraunsaturated alkenone to the total of C_{37} alkenones (37:4%). In the Nordic seas, 37:4% correlates with SST when 37:4% < 5, and shows potential as a palaeoceanographic proxy applied to North Atlantic sediments. In the Nordic Seas, the alkenone indices dependence with SST ceases when 37:4% > 5. We propose to use the 37:4% index downhole a core to identify situations when $U^{K'}_{37}$ is not a reliable palaeothermometer.

In the Nordic Seas, we have related the sedimentary abundance of $C_{37:4}$ to two types of water masses. In locations affected by Atlantic water masses 37:4% values are <5%, whereas in Arctic type water masses these increase to >5%. We propose that this observation can be used as a modern analog to reconstruct the position of the Arctic front in North Atlantic Quaternary sediments. Reconstruction of the past extent of the Arctic domain will aid and provide constraints on modelling of the location and intensity of oceanic convection.

Conclusions

The relative abundance of $C_{37:4}$ to the total abundance of C_{37} alkenones (37:4%) can be used as a palaeothermometer or as a proxy to identify the position of the Arctic front in North Atlantic sediments. However, there are significant regional or inter-hemispheric differences in the temperature dependence of the relative abundance of sedimentary alkenone data, at the cold end of the temperature range. Future studies, or consideration of published investigations into the SST dependence of alkenones, should take into account that observations or recommendations based on regional databases cannot be extended beyond their geographical coverage, unless their global significance is proven. However, more regional studies are needed to understand the environmental variability of alkenone indices and constrain their application as effective palaeoceanographic proxies.

References

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