DECIPHERING CHANGES IN ORGANIC MATTER SOURCE INPUTS ON LONG-TERM GEOLOGICAL TIMESCALES

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Introduction

The distribution of biomarkers in ancient sediments is a powerful tool for diagnosing the sources of organic matter and, within constraints and recognizing appropriate caveats, the climatic and environmental processes that governed the production, delivery and preservation of that organic matter. Although these approaches have been applied on glacial-interglacial timescales, i.e. to reconstruct aeolian processes via leaf wax abundances, or in deeper time contexts across transient events such as the Paleocene Eocene Thermal Maximum, there are relatively few studies of long-term organic matter (ca 10 Myr) source changes; those that have been done are largely from a basin-development and petroleum exploration perspective and therefore have focused on those classical biomarker classes (i.e. steranes and hopanes). Although interpretation will be complicated by the multiple evolutionary, tectonic and climatic controls operating on multimillion-year timescales, biomarker source indicators could have value in understanding the long-term evolution of an oceanographic regime, provide evidence for long term changes in Earth system processes and/or reveal constraints on the application of such proxies on shorter term timescales.

Here, we have developed a 20 Myr Eocene record of lipid biomarker changes within the Greenland region of the North Atlantic, Ocean Drilling Program (ODP) Site 913B (Myhre et al., 1995). This site represents one of the best long-term high-latitude records for Eocene environmental changes, with continuous deposition having occurred from the Early Eocene Climatic Optimum to the Eocene-Oligocene boundary. Biomarkers analysed include glycerol dialkyl glycerol tetraethers (GDGTs), *n*-alkyl lipids, higher plant derived triterpenoids, and hopanoids, from which we reconstruct potential changes in fluvial, aeolian and ice rafted debris inputs. From these, we infer the response of the hydrological cycle at high latitudes during this long-term decline in global temperatures.

Results and Discussion

Saturated hydrocarbon fractions are dominated by a homologous series of *n*-alkanes, highly variable concentrations of hopanoids of bacterial origin, and both intact and degraded di- and triterpenoids of a presumed higher plant origin. Many of the early Eocene samples are dominated by the di- and triterpenoids, whereas in the younger samples these are frequently absent, leading to remarkable differences in the overall biomarker assemblage, and inferred organic matter sources, between the older and younger sediments. Other biomarker classes such as steroids are generally rare throughout the section, although re-arranged diasteranes and aromaticized steranes occur in some of the early Eocene samples. These changes in distribution arise from both a long-term decrease in terpenoid concentrations and an increase in high molecular weight *n*-alkane concentrations. Similarly, *n*-alkane CPIs increase in younger sediments, as do various terrestrial to aquatic *n*-alkane ratios. This change in higher plant biomarkers could arise from a change in source vegetation but we instead attribute it to a decline in fluvial inputs and an increase in aeolian inputs, the former being consistent with sedimentological evidence.

Complicating these interpretations, however, is a long-term increase in BIT indices, suggesting an increase in soil inputs. Similarly, the apparent thermal maturity of hopanes is higher in younger sediments. We attribute the latter to an increase in ice-rafted debris, for which there is mineralogical evidence in Site 913 sediments. We speculate that this could also explain the increase in BIT indices (see also Schouten et al., 2008), with small Greenland ice sheets delivering both kerogen-derived and soil organic matter. Although our interpretations of these superficially divergent trends are somewhat ad hoc, they are climatically consistent. Long-term cooling (Site 913TEX_{86}-derived sea surface temperatures suggest cooling of up to 10 °C, Inglis et al., 2015) appears to have brought about the growth of small and perhaps transient ice sheets on Greenland which impacted the fluvial and IRD-associated delivery of organic matter. At the same time, growth of ice sheets and high latitude cooling could have caused increased wind strengths and greater aeolian inputs as observed on Plio-Pleistocene timescales in the North Atlantic (Naafs et al., 2012).

Finally, we have developed the first long-term, >1 Myr, leaf wax δ^2H record. Overall, there is little short-term variability, providing some confidence in previous work that has focussed on short-term events (typically without including a long-term context). However, leaf wax δ^2H values do exhibit long-term variations that are difficult to rationalise with simple climate dynamics: we expect δ^2H values to be high at high latitudes during times of global warmth due to efficient export of water vapour to Polar Regions, and this is not observed. Instead, we suggest that trends are governed by changes between local convective processes (i.e. water vapour sourced from local, semi-isolated basins) and large scale atmosphere dynamics.

Conclusions

Although there are many long-term biomarker records for those compounds that serve as quantitative climate proxies (i.e. sea surface temperature), there are relatively few that explore changes in organic matter source and more complex aspects of climate dynamics; and those that do are primarily focused on classical petroleum biomarkers and the evolution of basins. Here, we show that sediments in the Eocene North Atlantic are dominated by terrigenous organic matter inputs but that the nature of those sources and inferred transport mechanisms changed markedly during the long-term descent towards the late Cenozoic Icehouse. This illustrates that such qualitative biomarker data can yield important insights into changes in environmental or even climate dynamics on such timescales.

References

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