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Research paper

Sea-level and surface-water change in the western North Atlantic across the Oligocene–Miocene Transition: A palynological perspective from IODP Site U1406 (Newfoundland margin)

Lisa M. Egger[a,*], André Bahr[a], Oliver Friedrich[a], Paul A. Wilson[b], Richard D. Norris[c], Tim E. van Peer[b], Peter C. Lippert[d], Diederik Liebrand[b], Jörg Pross[a]

[a] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234-236, D-69120 Heidelberg, Germany
[b] National Oceanography Centre, University of Southampton, Waterfront Campus, European Way, Southampton SO14 3ZH, UK
[c] Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0244, USA
[d] Department of Geology and Geophysics, University of Utah, Frederick A. Sutton Building, 115 S 1460 E, Salt Lake City, UT 84112, USA

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ABSTRACT

The Oligocene–Miocene transition (OMT; ~23.1 Ma) terminates the late Oligocene warming trend and is marked by a transient, large-amplitude expansion of Antarctic ice sheets. The associated glacial maximum, which is expressed by a ~1‰ positive shift in benthic foraminiferal oxygen-isotope values, is commonly referred to as the 'Mi-1 isotope event'. Whereas the causes for the glacial maximum at the OMT are intrinsically connected to Southern Hemisphere ice-sheet dynamics, the behavior of the surface ocean in the Northern Hemisphere during this time is poorly known. To contribute to a better understanding of the paleoceanographic evolution during the OMT in the higher-latitude North Atlantic, we have analysed both marine and terrestrial palynomorphs from Integrated Ocean Drilling Program (IODP) Site U1406 offshore Newfoundland; this site has yielded a complete OMT section and exhibits a high-quality magnetostratigraphy that provides precise age control and allows reliable correlation to other records beyond Newfoundland. Our palynological data, which span the interval from 23.3 to 22.5 Ma and have a mean gtemporal resolution of 11.9 kyrs, show strong ~110-kyr eccentricity-paced oscillations during the earliest Miocene; these oscillations are in phase with similar cyclicity identified in previously published benthic foraminiferal oxygen-isotope records. More specifically, a pronounced sea-level variability is documented by the abundances of neritic dinoflagellate cysts (dinocysts) and terrigenous palynomorphs, which both reach maxima during peak glacial intervals as inferred from previously published South Atlantic benthic oxygen-isotope data. A decline in the abundance of warmer-water dinocysts suggests a surface-water cooling offshore Newfoundland from the latest Oligocene onwards. Surface-water productivity (as derived from the ratio between heterotrophic and autotrophic dinocysts) remained generally low throughout the studied interval. Notably, this ratio does not exhibit any correlation with changes in surface-water temperature, which is estimated from the ratio of warm-water over cold-water dinocysts. Together with the consistently low surface-water productivity, the lack of a correlation between surface-water productivity and temperature makes it highly unlikely that the observed paleoceanographic change was caused by a southward migration of the Arctic Front. Instead, we argue that our data may document an enhanced influence of the (Proto-) Labrador Current on surface waters offshore Newfoundland during the earliest Miocene that suppressed the influence of the Gulf Stream in this region of the Northwest Atlantic. We speculate that the enhanced influence of the (Proto-) Labrador Current was triggered by cooling of the northern hemisphere and possibly modulated by high-latitude sea-ice expansion.

1. Introduction

Separating the Paleogene and Neogene periods, the Oligocene-Miocene Transition (OMT, 23.03 Ma; Gradstein et al., 2012) represents a prominent transition in Cenozoic paleoceanography and paleoclimatology. It divides a relatively warm late Oligocene world characterized by a reduced Antarctic ice volume and higher sea level from a generally cooler early Miocene world that was subject to substantial variability in

* Corresponding author.
E-mail address: lisa.egger@geow.uni-heidelberg.de (L.M. Egger).

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temperature, ice volume, and sea level (Miller et al., 1991; Zachos et al., 2001, 2008; L`ear et al., 2004; Liebrand et al., 2011, 2016, 2017).

Much of the information on the sequence of events across the OMT comes from benthic foraminiferal stable-isotope records. Published high-resolution oxygen isotope data from benthic foraminiferal calcite show a ~1‰ positive excursion within the OMT interval that represents a transient expansion of the Antarctic cryosphere in concert with high-latitude and deep-ocean cooling (Naish et al., 2001; Zachos et al., 2001; Lear et al., 2004; Mawbey and Lear, 2013). Ice-sheet expansion started at ~23.4 Ma and ended at ~22.6 Ma (Liebrand et al., 2011, 2016, 2017). This large-amplitude glacial maximum, named the ‘Mi-1 event’ in earlier, lower-resolution work (e.g., Miller et al., 1991), probably represents a change from half to full present-day Antarctic ice-sheet configuration (Liebrand et al., 2011, 2017). The ice build-up on Antarctica during the OMT resulted in a substantial sea-level drop of 50 m (Naish et al., 2001; Beddow et al., 2016) or even 90 m (Miller et al., 1991). It was followed by a series of recurrent glaciations none of which reached the magnitudes of the glaciations marking the Eocene–Oligocene boundary interval or the ‘mid’-Oligocene (Zachos et al., 1997, 2008).

The glacial expansion across the OMT has been connected to low-amplitude variability of Earth's obliquity cycle during a ~1.2-My obliquity node concurring with a 405-kyr minimum in the eccentricity cycle. This astronomical configuration resulted in a suppressed seasonality (i.e., prolonged avoidance of ‘extreme’ summer-insolation maxima), which would have favoured ice-sheet expansion on the Antarctic continent (Zachos et al., 2001; Wilson et al., 2009, and references therein). A ~110 kyr cyclicity in benthic oxygen-isotope records is particularly pronounced during the recovery phase of the OMT and continued well into the early Miocene. This indicates that eccentricity modulation of precession was the dominant forcing factor controlling the volume of the Antarctic ice sheet during that time (Beddow et al., 2016; Liebrand et al., 2017).

While the causes for the glaciation at the OMT are intrinsically connected to Southern Hemisphere ice-sheet dynamics, its effects on the Northern Hemisphere beyond what is inferred from the signals obtained through deep-sea proxies (notably stable-isotope records from benthic foraminifera) are poorly known. This holds particularly true for surface-water conditions in the higher northern latitudes. Based on inverse modeling, Liebrand et al. (2011) have suggested shifts in mean annual air temperature in the Northern Hemisphere of up to 15 °C; this is, however, difficult to reconcile with the scarce planktic foraminiferal oxygen-isotope information from the North Atlantic (e.g., Wright et al., 1992; Pearson and Wade, 2009). Hence, more observations and quantitative data on surface-water characteristics across the OMT are needed to better understand the paleoclimatic effects of the Mi-1 glaciation in the higher northern latitudes.

Over the past several decades, the organic-walled cysts of dinoflagellates (dinocysts) have increasingly been recognized as sensitive paleoenvironmental indicators of surface-water conditions during the Cenozoic (e.g., Wall et al., 1977; Brinkhuis, 1994; Versteegh and Zonneveld, 1994; De Vernal et al., 2001; Pross and Schmiedl, 2002, Harding et al., 2011, Frieling et al., 2017). Studies of these cysts allow us to decipher trends in surface-water temperatures, productivity, and salinity, as well as proximal-distal trends, with the latter aspect making dinocysts a useful tool for reconstructing changes in local relative sea-level (see reviews by Dale, 1996 and Sluijs et al., 2005 and references therein). The significance of a dinocyst-based approach towards deciphering past environmental conditions can be further enhanced through the analysis of terrestrial palynomorphs (i.e., pollen and spores) that are contained in the same samples. These terrestrial palynomorphs can yield a first-order land-sea correlation and thus form the basis for an integrated picture of environmental change (e.g., Heusser and Shackleton, 1979; Traverse, 1994; Pross et al., 2012).

In 2012, Integrated Ocean Drilling Program (IODP) Expedition 342 set out to recover clay-rich Paleogene sequences from the high northern latitudes with well-preserved microfossils. The expedition aimed to recover sedimentary sequences with exceptionally high sedimentation rates in order to reconstruct paleoceanographic changes in the northern hemisphere during critical intervals of the Paleogene (Norris et al., 2014a). At Site U1406, the expedition cored a complete late Oligocene to early Miocene section that is characterized by relatively high deposition rates (Norris et al., 2014b), has high-quality bio- and magnetostratigraphic age control (Norris et al., 2014b; van Peer et al., 2017a), and yields abundant organic-walled microfossils with excellent preservation (Egger et al., 2016; Bijl et al., 2017).

Here, we describe our results concerning the palynomorph assemblages across the OMT from IODP Expedition 342 Site U1406, with the goal of contributing to a better understanding of the effects of the Mi-1 event on surface-water conditions in the high-latitude North Atlantic.

2. Integrated Ocean Drilling Program Site U1406

Site U1406 (coordinates: 40°21.0′N, 51°39.0′W; present-day water depth: 3813 m) has been cored from drift-sediment deposits c. 700 km east-southeast of Newfoundland (Fig. 1). It has yielded a sedimentary succession that spans the Paleogene to Quaternary. Lithologically, the OMT interval at Site U1406 consists of greenish grey nannofossil ooze (Norris et al., 2014b) with carbonate and total organic carbon contents of 30–50% and 0.96–1.38%, respectively (Norris et al., 2014b). Based on the available bio- and magnetostratigraphic data (Norris et al., 2014b; van Peer et al., 2017a), sedimentation rates across the OMT interval are between 1.4 and 2.8 cm/kyrs.

During the latest Oligocene and earliest Miocene, the region offshore Newfoundland was situated at a paleo-latitude of ~40°N (Norris et al., 2014a). Deposition took place in a deep-water sediment drift setting, with paleo-water depths between c. 2800 and 4000 m. The drift sediments are likely derived from the Labrador margin and the Labrador Sea (Norris et al., 2014a; Boyle et al., 2017).

Because of its position in the Northwest Atlantic Ocean offshore the Newfoundland margin, Site U1406 provides information on different surface-water regimes, such as the cool Labrador Current and the Arctic Front in the north and the warm Gulf Stream in the south (Fig. 1). Conclusive evidence about North Atlantic surface-water patterns is not yet available for late Oligocene and early Miocene times. While available data suggest that the Gulf Stream was established from at least the early Miocene onwards (Pinet et al., 1981; Wade et al., 2001), the timing of the onset of the Labrador Current is a matter of ongoing debate; suggested dates for the initiation of this important oceanographic current range from the Maastrichtian (Nederbragt, 1992) to the middle Miocene (Via and Thomas, 2006; Kender and Kaminski, 2013). The occurrence of ice-rafted debris in the Arctic Sea since c. 46 Myr (St. John, 2008; Stickley et al., 2009) indicates seasonal sea-ice formation that could have exported high-latitude freshwater to the lower latitudes via the (Proto-)Labrador Current, which could suggest that this current had been established by that time. Because of its paleoceanographically highly sensitive setting, Site U1406 allows us to assess the interplay between cold surface waters derived from the Labrador Sea and warm surface waters derived from the (sub-) tropical Atlantic.

3. Material and methods

3.1. Sampling strategy

The investigated samples from Site U1406 comprise the OMT interval from magnetochrons C6Cr to C6Br (c. 23.3–22.5 Myrs; Norris et al., 2014b, van Peer et al., 2017a; Fig. 2). The Site U1406 splice has been developed based on shipboard magnetostratigraphic and biostratigraphic (planktic foraminifera, calcareous nannoplankton and radiolaria) data (Norris et al., 2014b) in combination with post-cruise XRF-scanning (van Peer et al., 2017b). For our study, Site U1406 cores were sampled from Sections U1411A-8H-4W-56 cm to U1411B-10H-