Marine Micropaleontology 84-85 (2012) 74–86

Contents lists available at SciVerse ScienceDirect

Marine Micropaleontology

journal homepage: www.elsevier.com/locate/marmicro

Research paper

Geochemical assessment of the palaeoecology, ontogeny, morphotypic variability and palaeoceanographic utility of *"Dentoglobigerina" venezuelana*

Joseph A. Stewart [a,*], Paul A. Wilson [a], Kirsty M. Edgar [a,1], Pallavi Anand [b], Rachael H. James [a]

[a] National Oceanography Centre, Southampton, University of Southampton, SO14 3ZH, UK
[b] Department of Earth and Environmental Science, Walton Hall, The Open University, Milton Keynes, MK7 6AA, UK

ARTICLE INFO

Article history:
Received 17 May 2011
Received in revised form 9 November 2011
Accepted 16 November 2011

Keywords:
Planktic foraminifera
Dentoglobigerina venezuelana
Morphotype
Palaeoecology
Ontogeny
Mg/Ca

ABSTRACT

To better understand the links between the carbon cycle and changes in past climate over tectonic timescales we need new geochemical proxy records of secular change in silicate weathering rates. A number of proxies are under development, but some of the most promising (e.g. palaeoseawater records of Li and Nd isotope change) can only be employed on such large samples of mono-specific foraminifera that application to the deep sea sediment core archive becomes highly problematic. *"Dentoglobigerina" venezuelana* presents a potentially attractive target for circumventing this problem because it is a typically large (>355 μm diameter), abundant and cosmopolitan planktic foraminifer that ranges from the early Oligocene to early Pliocene. Yet considerable taxonomic and ecological uncertainties associated with this taxon must first be addressed. Here, we assess the taxonomy, palaeoecology, and ontogeny of *"D." venezuelana* using stable isotope (oxygen and carbon) and Mg/Ca data measured in tests of late Oligocene to early Miocene age from Ocean Drilling Program (ODP) Site 925, on Ceara Rise, in the western equatorial Atlantic. To help constrain the depth habitat of *"D." venezuelana* relative to other species we report the stable isotope composition of selected planktic foraminifera species within *Globigerina*, *Globigerinoides*, *Paragloborotalia* and *Catapsydrax*. We define three morphotypes of *"D." venezuelana* based on the morphology of the final chamber and aperture architecture. We determine the trace element and stable isotope composition of each morphotype for different size fractions, to test the validity of pooling these morphotypes for the purposes of generating geochemical proxy datasets and to assess any ontogenetic variations in depth habitat. Our data indicate that *"D." venezuelana* maintains a lower thermocline depth habitat at Ceara Rise between 24 and 21 Ma. Comparing our results to published datasets we conclude that this lower thermocline depth ecology for the Oligo-Miocene is part of an Eocene-to-Pliocene evolution of depth habitat from surface to sub-thermocline for *"D." venezuelana*. Our size fraction data advocate the absence of photosymbionts in *"D." venezuelana* and suggest that juveniles calcify higher in the water column, descending into slightly deeper water during the later stages of its life cycle. Our morphotype data show that $\delta^{18}O$ and $\delta^{13}C$ variation between morphotypes is no greater than within-morphotype variability. This finding will permit future pooling of morphotypes in the generation of the "sample hungry" palaeoceanographic records.

1. Introduction

There is a pressing need to improve our understanding of Oligo-Miocene (O/M) climate change and, in particular, the major perturbation of Cenozoic climate that occurred near the O/M boundary at around 23 Ma (Fig. 1). This climate shift is marked by a large increase in the benthic foraminifera $\delta^{18}O$ record (>1.5‰), classically termed the "Mi-1 event" (after the "Mi-1 zone" of Miller et al., 1991), that is now well dated cyclo- and magnotostratigraphically to "$58_{Ol\text{-}C6Cn}$" in the scheme of Wade and Pälike (2004) and Pälike et al. (2006b). The increase in benthic $\delta^{18}O$ is interpreted to represent major ice sheet expansion on Antarctica (Zachos et al., 2001) associated with a contemporaneous change in the carbon cycle as indicated by an increase in $\delta^{13}C$ of benthic foraminifera (Fig. 1).

While benthic foraminiferal $\delta^{18}O$ records provide insight into the timing and magnitude of glaciation, the causes and consequences of the Mi-1 event remain poorly understood. An increase in the ratio of organic carbon to carbonate burial has been invoked (Paul et al., 2000) to account for the $\delta^{13}C$ maximum shown in Fig. 1 however, there is little evidence of organic carbon-rich deposits of appropriate age (Lear et al., 2004). Changes in global silicate weathering have a profound effect on the global carbon cycle and climate change on multi-million year timescales (Walker et al., 1981; Berner, 1991; Raymo and Ruddiman, 1992), but relatively little is known about the links between short-term (<10^5 yrs) climatic aberrations and

---

* Corresponding author. Tel.: +44 2380599374.
E-mail address: Joseph.Stewart@noc.soton.ac.uk (J.A. Stewart).
[1] Now at: School of Earth and Ocean Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3AT, UK.

0377-8398/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.marmicro.2011.11.003

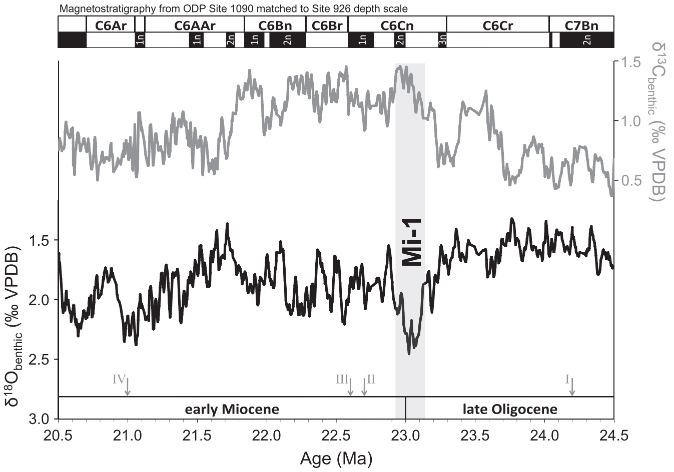

Fig. 1. Benthic foraminiferal stable isotope records across the Oligocene–Miocene boundary from ODP Site 926 (Pälike et al., 2006a). Solid black and grey lines show a 5-point moving average of $\delta^{18}O$ and $\delta^{13}C$, respectively. Vertical grey bar highlights the Mi-1 excursion (Miller et al., 1991; Zachos et al., 2001). Grey arrows denote stratigraphic position of samples investigated in this study (I–IV). Magnetostratigraphy from ODP Site 1090, South Atlantic (Billups et al., 2002; Channell et al., 2003), correlated to Site 926 depth scale (Liebrand et al., 2011), and matched through shipboard physical property data to Site 925 depth scale.

silicate weathering (Vance et al., 2009). Nevertheless, variations in chemical weathering rates (and therefore levels of atmospheric carbon dioxide), related to the degree of silicate rock exposure on Antarctica, are hypothesised to account for temperature anomalies observed across the O/M boundary (Lear et al., 2004; *cf.* Kump et al., 1999). A detailed assessment of silicate weathering across the O/M interval is therefore needed to help assess linkages between climate change and this major geological sink for atmospheric CO_2.

Silicate weathering is known to exert a control on the oceanic concentration and isotopic composition of many elements including Li, Os and Nd (Burton and Vance, 2000; Huh et al., 2001; Frank, 2002; Ravizza and Peucker-Ehrenbrink, 2003; Kisakürek et al., 2005). Arguably the most useful archive for reconstructing the palaeoceanographic record of silicate weathering through use of these elements is planktic foraminiferal calcite recovered from deep-sea sediment cores as exemplified by the pioneering work of Vance and Burton (1999), Hathorne and James (2006) and Burton et al. (2010). Unfortunately, all of these elements occur in extremely low abundance within foraminiferal calcite, hence the mass of carbonate required for isotopic analysis is so large (e.g., Nd ~30 mg; Vance and Burton, 1999) that these proxies cannot readily be applied using typical sample suites. One strategy to circumvent this problem is to target particularly large, abundant, long-ranging and cosmopolitan taxa. Such species are rare, but one clear candidate is *"D." venezuelana*, a species that ranges from the early Oligocene to early Pliocene (Stainforth et al., 1975; Kennett and Srinivasan, 1983; Bolli and Saunders, 1989; Olsson et al., 2006), typically possesses medium to large tests (usually 355–400 μm; Spezzaferri, 1994), has a wide geographical distribution (equator to ~50° latitude; Spezzaferri, 1994) and is found in high abundance in tropical O/M sections (Chaisson and Leckie, 1993; Leckie et al., 1993; Spezzaferri, 1994; Pearson and Chaisson, 1997). Yet considerable taxonomic and ecological uncertainties are associated with *"D." venezuelana* and these must be addressed before this taxon can be used for palaeoceanographic purposes with any degree of confidence.

The brief taxonomic description of the holotype specimen (Hedberg, 1937) has led to inclusion of multiple morphotypes under *"D." venezuelana* (Stainforth et al., 1975; Kennett and Srinivasan, 1983; Spezzaferri, 1994; Li et al., 2002), the geochemical validity of which has never been systematically explored. In addition, the depth ecology of *"D." venezuelana* is extremely unclear (Fig. 2). Most stable isotope studies of planktic foraminifera assign *"D." venezuelana* to a sub-thermocline habitat (Barrera et al., 1985; Keller, 1985; Hodell and Vayavananda, 1993; Norris et al., 1993; Pearson and Shackleton, 1995; Pearson et al., 2001; Smart and Thomas, 2006; Spezzaferri and Pearson, 2009). However, data generated on samples of O/M boundary age (~23 Ma), from Ceara Rise and Trinidad, imply that *"D." venezuelana* calcified higher in the water column, within the thermocline (Biolzi, 1983; Pearson et al., 1997; Pearson and Wade, 2009). Furthermore, results from analysis of Oligocene (~28 Ma) age samples from the Gulf of Mexico (Poore and Matthews, 1984) and the equatorial Pacific at ODP Site 1218 (Wade et al., 2007), imply that calcification took place within the mixed layer. Establishing the depth habitat of calcification for *"D." venezuelana* across the O/M boundary is a prerequisite for the generation of proxy records of silicate weathering because the concentration of neodymium, and its isotopic composition, vary with depth in the water column (Jeandel, 1993). Similarly, the Li/Ca of planktic foraminifera may be partly dependent on parameters that change with depth in seawater, such as carbonate ion saturation state (Hall and Chan, 2004).

Here, we present new $\delta^{18}O$, $\delta^{13}C$ and Mg/Ca data from planktic foraminiferal assemblages at ODP Site 925 (Ceara Rise, equatorial Atlantic Ocean) (Fig. 2) of O/M boundary age. We determine the effect of test size on $\delta^{18}O$, $\delta^{13}C$ and Mg/Ca, and use these data to explore the ontogenetic variation in the depth habitat of *"D." venezuelana*. We apply a narrow taxonomic concept to *"D." venezuelana*, by identifying three distinct morphotypes. The depth habitat of these morphotypes is inferred from $\delta^{18}O$ and $\delta^{13}C$ analyses, and the geochemical variation within and between morphotypes is established to assess the validity of pooling these intra-specific groups for the purpose of generating "sample hungry" palaeoceanographic records of silicate weathering (e.g., Nd and Li isotopes).

2. Materials and methods

2.1. Geological setting and chronology

Four samples (see Table 1), spanning the O/M boundary, were analysed from core sediments recovered from ODP Leg 154, Site 925, Hole A (4°12.249′N, 43°29.334′W, 3042.2 m present water depth; Shipboard Scientific Party, 1995a). Magnetostratigraphic age control is not available in ODP Leg 154 sediments, but a high quality magnetostratigraphy is available for ODP Site 1090, Agulhas Ridge (Billups et al., 2002; Channell et al., 2003) and it is correlated to ODP Site 926 (Liebrand et al., 2011), a close neighbour to our study site (ODP Site 925). We tie the ODP Site 925 depth scale to that of ODP Site 926 by peak-matching shipboard magnetic susceptibility and colour reflectance data from both sites. Depth correlation is aided by astronomically matched tie points on either side of the O/M boundary (work of Crowhurst and Shackleton; S. Crowhurst personal written communication[2], 2010) and two biostratigraphic tie points, the first occurrence of *Paragloborotalia kugleri* and the last occurrence of *Sphenolithus delphix* (Shipboard Scientific Party, 1995a; Shipboard Scientific Party, 1995b; Pearson and Chaisson, 1997; Weedon et al., 1997). Sample ages are reported relative to the astronomically tuned age model of ODP Site 926 (Pälike et al., 2006a).

2.2. Taxonomy and morphotypes

In some taxonomic descriptions, the final chamber of *"D." venezuelana* is described as flat, and often small and irregular relative to the penultimate chamber (Stainforth et al., 1975; Spezzaferri, 1994), whereas in other cases chambers in the final whorl are described as increasing

---

[2] S. Crowhurst, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, United Kingdom, sjc13@cam.ac.uk