Data report: relative abundance of benthic foraminiferal morphotypes across the Eocene/Oligocene and Oligocene/Miocene boundaries (IODP Expedition 342 Site U1406, North Atlantic)[1]

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Chapter contents

Abstract

Relative abundances of five benthic foraminiferal morphotype groups (i.e., agglutinated, elongated, planispiral, tapered, and trochospiral) from the late Paleocene to early Miocene at Site U1406 (Integrated Ocean Drilling Program Expedition 342) are reported. Benthic foraminiferal tests from Site U1406 are generally very well preserved and occur abundantly from the late Eocene through middle Oligocene; they are less abundant for the remainder of the studied interval. Among the five morphotypes identified in this study, tapered and trochospiral forms are the dominant groups. Thereby, tapered morphotypes show increasing abundances at and above the Eocene/Oligocene and Oligocene/Miocene boundaries. Agglutinated and planispiral morphotypes are minor components throughout the studied interval. Relative abundances of the elongated morphotype abruptly increase during the lower Eocene. This increase can be correlated to a distinct decrease in carbonate content between lithostratigraphic Units III and IV.

Introduction

Because of the relatively stable and monotonous deep-sea environment, the stratigraphic range of benthic foraminiferal species is relatively long, and their usefulness for biostratigraphy is less advantageous compared to planktonic foraminifers (e.g., Boltovskoy, 1980; van Morkhoven et al., 1986; Thomas, 2007). On the other hand, benthic foraminiferal species provide useful indicators of environmental change, and significant changes in benthic foraminiferal assemblage composition usually imply severe climatic and/or paleoceanographic perturbations (e.g., in global ocean circulation). One of the most severe perturbations occurred across the Paleocene/Eocene boundary accompanied by a major redistribution of benthic foraminiferal faunas (e.g., Kennett and Stott, 1991; Thomas and Shackleton, 1996).

Following this major turnover across the Paleocene/Eocene boundary, three benthic foraminiferal faunas can be recognized: (1) Paleogene-like fauna during the Eocene, (2) transitional fauna in the late Oligocene to early Miocene, and (3) near-modern-like faunas that developed from the late Miocene onwards (Thomas, 1992, 2007). These three different faunas are separated by faunal turnovers associated with the global cooling event at the Eocene/

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Oligocene boundary and the middle Miocene climatic optimum.

Although morphotypes of benthic foraminifers do not exclusively represent ecology and/or habitat of a given species, it has been reported that changes in morphotype composition and/or the reaction of specific morphotypes are related to environmental perturbations (e.g., Rosoff and Corliss, 1992). One example for this pattern is the significant decrease of elongated morphotypes, such as pleurostomellids and stilostomellids, across the Eocene/Oligocene boundary and during the middle Miocene turnover (e.g., Thomas, 2007). This pattern suggests the response of a specific morphotype, and therefore a specific habitat, to climate perturbations. Relative changes in the abundances of benthic foraminiferal morphotypes may therefore represent faunal turnover and/or climate variation.

Integrated Ocean Drilling Program (IODP) Expedition 342 recovered semicontinuous sequences from the Lower Cretaceous to middle Miocene. Especially for the lower Eocene through lower Miocene interval, many continuous cores containing well-preserved microfossils were drilled at multiple sites (see the **"Expedition 342 summary"** chapter [Norris et al., 2014a]).

Among those sites, coring at Site U1406 recovered carbonate-rich sediments of late Paleocene through early Miocene age, including the Eocene/Oligocene and Oligocene/Miocene boundaries (see the **"Site U1406"** chapter [Norris et al., 2014c]).

In this data report, we present changes of benthic foraminiferal morphotype distribution across these cooling events at Site U1406.

Materials and methods

Site studied

Site U1406 (40°21.0′N, 51°39.0′W) was drilled at J-Anomaly Ridge, southeast of Newfoundland in the northern Atlantic (Fig. **F1**) in a present water depth of 3798.9 m (see the **"Expedition 342 summary"** chapter [Norris et al., 2014a]). Three holes were drilled at this site, recovering ~310 m of sedimentary sequences. The sequences were divided into lithostratigraphic Units I through IV. Units I and II are composed of foraminiferal sand and/or nannofossil ooze (see the **"Site U1406"** chapter [Norris et al., 2014c]). Units III and IV mainly consist of nannofossil chalk. The uppermost Unit I is correlated to the Pleistocene (0–2.61 m core composite depth below seafloor [CCSF] in Hole U1406A). Unit II (2.61–205.68 m CCSF in Hole U1406A) is Oligocene through Miocene in age, including the Oligocene/Miocene boundary (88.09 m CCSF). Unit III correlates to the middle Eocene through early Oligocene (206.68–273.84 m CCSF in Hole U1406A) and includes the Eocene/Oligocene boundary (~219 m CCSF). The deepest Unit IV (273.84–310.83 m CCSF in Hole U1406A) represents the Paleocene to middle Eocene time interval with a significant hiatus during the early Eocene. Carbonate content is generally more than 40 wt% in all units, indicating that the site was positioned above the carbonate compensation depth throughout it sedimentary history (Fig. **F2**) (see the **"Site U1406"** chapter [Norris et al., 2014c]).

Sedimentation rate at Site U1406 is somewhat higher than normal deep-sea sediments because of the site's position in a drift. Sedimentation rates are especially high within Unit II, where they are estimated to be ~2.8 cm/ky. Downhole, sedimentation rates gradually decrease and are ~0.6 cm/ky across the Eocene/Oligocene boundary, ~0.2 cm/ky in the early Eocene, and somewhat higher at ~0.8 cm/ky within the Paleocene. Mass accumulation rates are ~0.5–1.0 g/cm^2/ky in the early Miocene through late Eocene except for the late Oligocene and the Oligocene/Miocene boundary where they reach 1.5–2.0 g/cm^2/ky (see the **"Site U1406"** chapter [Norris et al., 2014c]).

Samples analyzed

Core composite depth of each core and sample was calculated based on the splice table published by Norris et al. (see Table **T21** in the "Site U1406" chapter [Norris et al., 2014c]). All samples analyzed in this study were taken from Hole U1406A. Top core composite depth of each core from Hole U1406A was also calculated and is graphically shown in Figure **F2.**

In addition to the core catcher samples taken on the catwalk, ~5 mL discrete section samples were examined. A list of all samples studied is shown in Table **T1.** Samples were taken, on average, every 3 m, and 102 samples were analyzed in total from Cores 342-U1406A-1H through 34X. For cores recovered with the extended core barrel, a relatively well preserved solid piece of sediment was chosen for the discrete sampling.

Samples were prepared following the procedure described in detail in the **"Methods"** chapter (Norris et al., 2014b). Sediments were washed with tap water over a 63 µm sieve. If necessary, samples were washed and dried repeatedly until the fine fraction was thoroughly removed. Subsequently, all washed samples were oven-dried at low temperature (~50°C) and examined under a binocular microscope. Benthic foraminifers were hand-picked from the >150 µm size fraction. Relative abundances of benthic foraminiferal morphotypes are based on counts of ~100 individuals from each sample (mean value; maximum 385 individuals, minimum 19 individuals; see Table T1). When the number of benthic foraminiferal specimens was <100 in a given sample, all individuals from the >150 µm size fraction were analyzed.

Five benthic foraminiferal morphotypes were identified in this study:

1. Agglutinated = all specimens with agglutinated tests.
2. Elongated = uniserial elongated morphology with calcareous tests.
3. Planispiral = planispiral morphology with calcareous tests.
4. Tapered = multiserial, unilocular, ovate, and quinqueloculine morphology with calcareous tests.
5. Trochospiral = trochospiral morphology with calcareous tests.

The dominant species for each morphotype are listed in Table T2. Please note that all specimens with an agglutinated test wall are assigned to the agglutinated morphotype.

Results

Abundance and preservation

Group abundance, preservation, and total number of benthic foraminiferal specimens examined in each sample are shown in Figure F2. Whereas total number of specimens examined is typically ~100–150 from Samples 342-U1406A-1H-CC (6.23 m CCSF) through 26X-CC (246.36 m CCSF), the number decreases downhole. The scarcity in benthic foraminifers is also seen in the group abundance (Fig. F2), which is due to the increasing abundance of planktonic foraminifers in carbonate-rich sediments of lithostratigraphic Units III and IV (Fig. F2) (see the **"Site U1406"** chapter [Norris et al., 2014c]). Carbonate content significantly decreases at ~270 m CCSF, and benthic foraminiferal group abundance increases uphole from ~260 m CCSF to the seafloor. Group abundance shows the highest values between 120 and 250 m CCSF. The preservation of benthic foraminifers seems to be affected by the carbonate content as well. Whereas moderate or poor preservation is occasionally found in samples deeper than 250 m CCSF, the preservation is predominantly very good in shallower samples. Because cores shallower than 250 m CCSF contain less carbonate and more clay minerals (see the **"Site U1406"** chapter [Norris et al., 2014c]), the preservation of benthic foraminifers seems to be enhanced in the less permeable clay-rich sediments. On the other hand, in carbonate-rich deeper cores, precipitation of secondary calcite overgrowth has often been found.

Relative abundance of benthic morphotypes

Among the five different benthic foraminiferal morphotypes identified, trochospiral is the dominant type throughout the studied interval (Fig. F2). In contrast, the planispiral morphotype is the least abundant, with values usually <10% (average = 5.9%). Agglutinated foraminifers are also a minor constituent of the investigated faunas, showing average and maximum abundances of 7.7% and 27.3%, respectively. Compared to the agglutinated and planispiral morphotypes, elongated and tapered forms are relatively abundant, and their abundance is characterized by large variability downhole (Fig. F2). Thereby, maximum abundances are 68.8% for the elongated morphotype and 57.8% for the tapered morphotype.

Deeper than 239 m CCSF (except for samples between 267 and 272 m CCSF), the trochospiral morphotype is especially abundant (>40%), whereas tapered morphotype abundance is low. In Samples 342-U1406A-28X-4, 100–102 cm (267.30 m CCSF), 28X-6, 100–102 cm (270.30 m CCSF), and 28X-CC (271.69 m CCSF), the elongated morphotype suddenly becomes very abundant and reaches 68.8% of the studied fauna, which is the highest value throughout the studied interval. In parallel, the trochospiral and tapered morphotypes decrease to <20%. This drastic change in relative abundances can be correlated to an abrupt decrease in carbonate content (Fig. F2). Whereas carbonate content between 280 and 310 m CCSF is usually >80 wt%, it decreases rapidly between 270 and 280 m CCSF, reaching ~50 wt% at 260 m CCSF. The observed increase of the elongated morphotype occurs parallel to this drop in carbonate content. However, whereas carbonate content stays low uphole (~40–60 wt%), the relative abundances of trochospiral and tapered morphotypes rapidly increase around ~260 m CCSF, adding to ~80% of the entire fauna.

At ~220 m CCSF, which is correlated to the Eocene/Oligocene boundary, abundance of the tapered morphotype significantly increases, mainly driven by the abundant occurrence of *Cassidulina* spp. (see the **"Site U1406"** chapter [Norris et al., 2014c]). High abundances of the tapered morphotype occur uphole to ~130 m CCSF, well into the late Oligocene. Across the Eocene/Oligocene boundary, the observed increase in the tapered morphotype is accompanied by a rapid increase in carbonate content ("carbonate overshot"; Coxall et al., 2005) followed by a drop in carbonate content to ~40 wt%. Although a significant increase of the elongated morphotype is identified across the carbonate decrease event at ~270 m CCSF, no significant increase of this morphotype is found across the Eocene/Oligocene boundary at Site U1406. In contrast, Ortiz and Kaminski (2012) reported an abrupt and short-lived increase of the elongated morphotype (mostly stilostomellids) at the Eocene/Oligocene boundary at Ocean Drilling Program Site 647 in the southern Labrador Sea. This apparent discrepancy may be related to the relatively lower sample resolution of this study. Shallower than ~130 m CCSF, the trochospiral morphotype becomes the dominant morphotype uphole to ~90 m CCSF, which can be correlated to the late Oligocene. The abundance of trochospiral forms decreases at ~90 m CCSF. Interestingly, the tapered morphotype also increases at ~90 m CCSF, which is correlated to the Oligocene/Miocene boundary. *Cassidulina* spp., which is the most significant component of the tapered morphotype (Table **T1**), becomes abundant again in the lower Miocene.

Although the relative abundances of each benthic foraminiferal morphotype vary with carbonate content, abundance seems to be independent of primary production. This is shown by the lack of response in morphotype abundances between 10 and 150 m CCSF, an interval characterized by high abundances of diatoms and radiolarians, probably indicating enhanced primary production (see the **"Site U1406"** chapter [Norris et al., 2014c]).

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Figure F1. A. Location of J-Anomaly Ridge and Site U1406. **B.** Black rectangle in A.

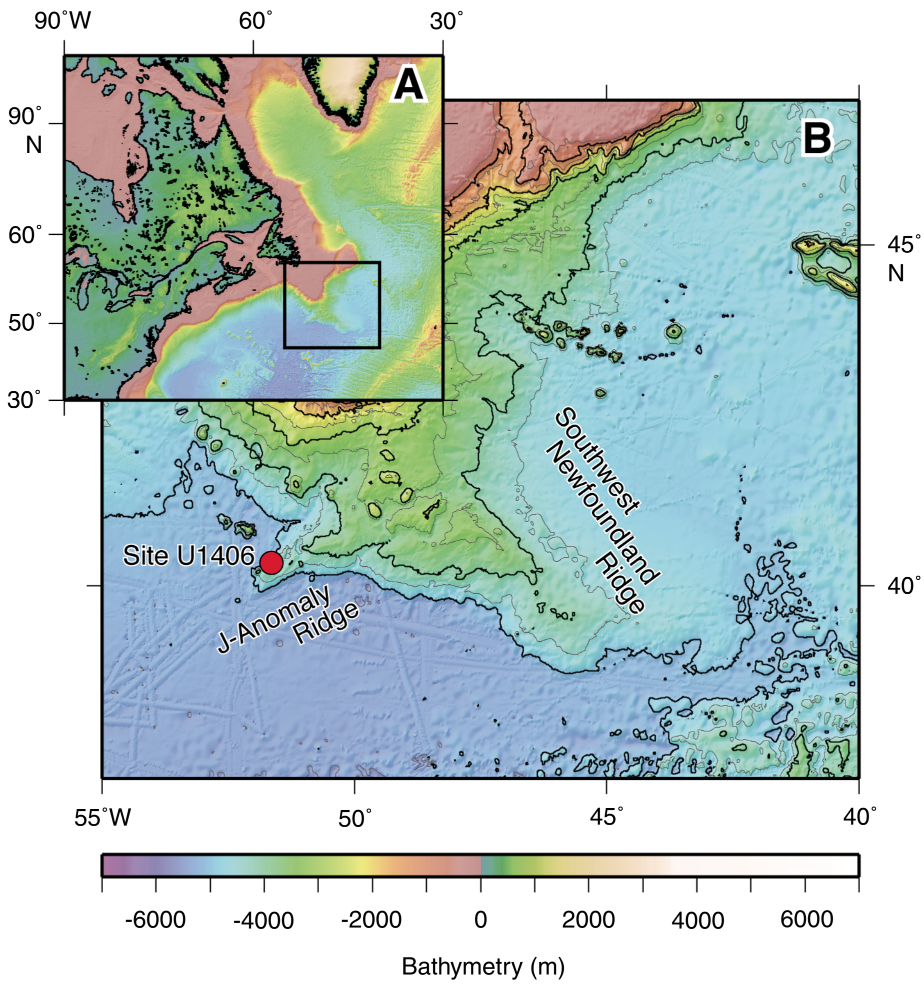

Figure F2. Stratigraphic distribution of preservation and group abundance of benthic foraminifers and relative abundance of each benthic foraminiferal morphotype shown with carbonate content and color reflectance (see the "Site U1406" chapter [Norris et al., 2014c]). Splice: green = Hole U1406A, pink = Hole U1406B, blue = Hole U1406C. Gray shading in the splice and the core distribution in Hole U1406A indicate unrecovered intervals. Green line = preservation, red shading = group abundance.

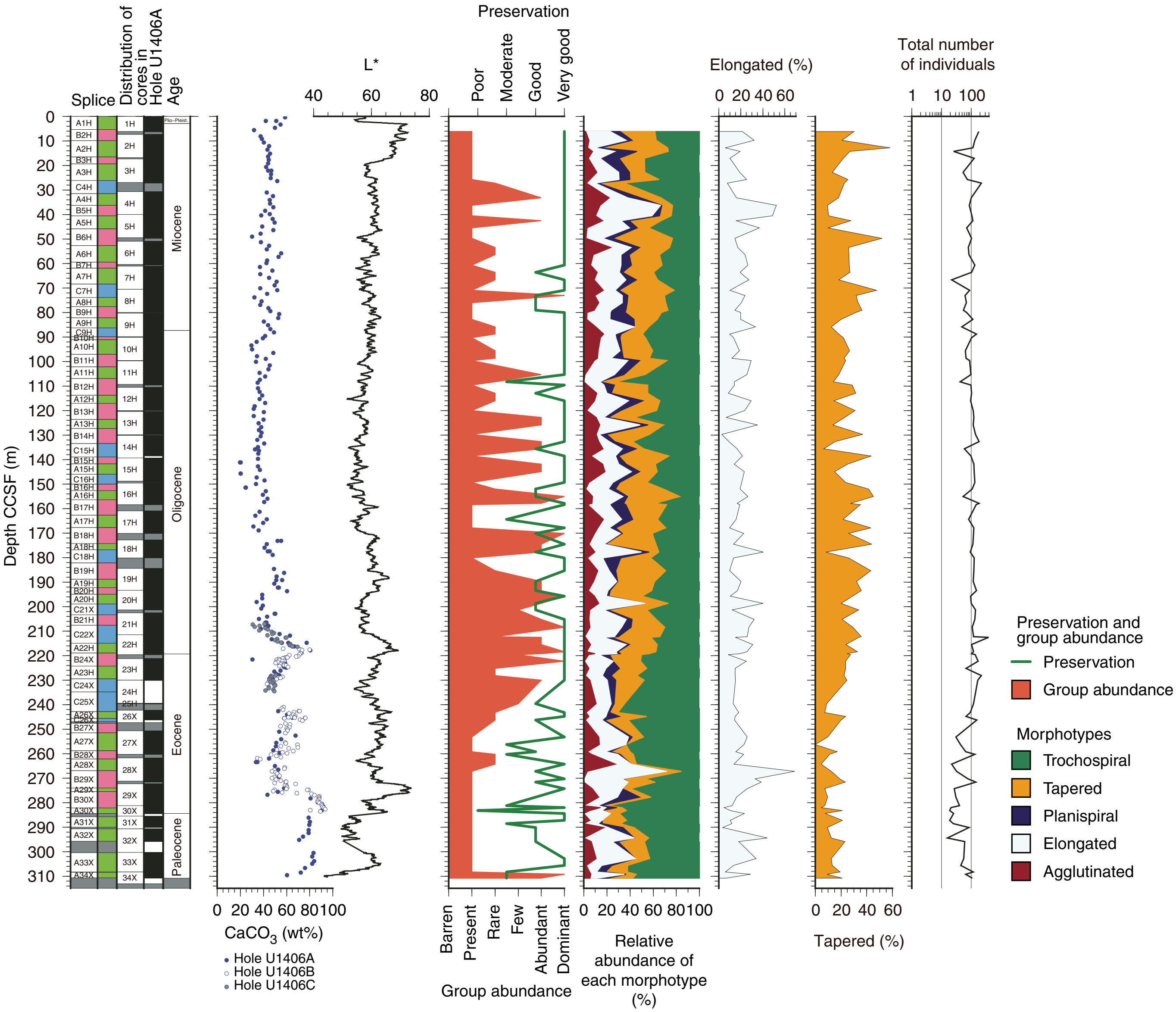

Table T1. Stratigraphic distribution of benthic foraminiferal morphotypes, Hole U1406A. This table is available as an **oversized PDF**.

Table T2. Main faunal components of the five benthic foraminiferal morphotypes identified in this study.

Morphotype	Main components
Agglutinated	*Dorothia* sp., *Gaudryina* sp., *Karreriella* sp.
Elongated	*Dentalina* sp., *Pleurostomella* spp., *Stilostomella* spp.*
Planispiral	*Lenticulina* spp., *Nonion* sp., *Pullenia* spp.*
Tapered	*Aragonia* spp., *Bulimina* spp. *Cassidulina* spp.*, *Fissurina* spp., *Lagena* sp.
Trochospiral	*Anomalina* sp., *Anomalinoides* spp., *Cibicidoides* spp., *Gyroidinoides* spp., *Oridorsalis* spp.

* = dominant species among species listed.