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Data report: Oligocene foraminifers and stable isotopes from IODP Hole U1435A

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Abstract

The foraminifer assemblage in samples from the Oligocene section in International Ocean Discovery Program Hole U1435A contains abundant specimens of planktonic foraminifers and frequent benthic foraminifers. Planktonic species indicate Zones P18 and P19 deposition in the early Oligocene, whereas benthic species imply outer-shelf to slope settings. Both planktonic and benthic δ18O show progressive enrichment upsection.

Introduction

International Ocean Discovery Program (IODP) Expedition 349 Site U1435 is located on a structural high at the transition between the extended continental crust and the oceanic crust in the northern South China Sea (SCS), at a water depth of 3757 m (Figure F1). As the shallowest of five sites drilled during the expedition, Site U1435 was designed to recover an older (possibly Mesozoic) sequence that may have formed the basement before break up and spreading of the SCS. Hole U1435A was drilled to 300 m below sea-floor (mbsf) and recovered three units. Unit I (0–77.65 mbsf) is a sequence of Oligocene–Pleistocene greenish gray nannofossil-rich clay and clayey nannofossil ooze and is divided into Subunits IA and IB. Subunit IA (0–36.04 mbsf) is Miocene to Pleistocene in age and consists of manganese nodules underlain by clayey nannofossil ooze. Subunit IB (36.04–77.65 mbsf) is Oligocene in age and consists of mostly greenish gray nannofossil-rich clay and lesser quantities of greenish gray clay, which is heavily bioturbated with trace fossils of the *Nereites* ichnofacies. Unit II (77.65–275.54 mbsf) is a 197.89 m thick sequence of pre-Oligocene thick-bedded and mostly medium-grained dark gray silty sandstone, with very little carbonatic and minor sandy siltstone and conglomerate and burrows typical of the *Cruziana* ichnofacies indicative of shallow-marine conditions. Unit III (275.54–300.00 mbsf) is a 24.46 m thick sequence of dark gray silty sandstone, silty mudstone, and minor conglomerate (see the Site U1435 chapter [Li et al., 2015b]).

We investigated planktonic and benthic foraminifers and measured their stable isotopes in samples from Subunit IB of Hole U1435A. The primary objective of this study was to record the distribution patterns of foraminifers and to provide information for interpreting Oligocene environmental changes during the early history of the SCS.

Materials and methods

Subunit IB of Hole U1435A is represented by 21 m of core with 51% recovery (see the Site U1435 chapter [Li et al., 2015b]). The lower section (especially between 58.6–71.6 mbsf) contains several dolomite-rich layers. Preliminary shipboard paleontological investigation indicated that the section represents full marine deposition during the Oligocene, likely immediately after the breakup of the SCS (see the Site U1435 chapter [Li et al., 2015b]).
For this study, we collected 43 samples (20 cm$^3$) from split sections and 4 samples from core catchers over Subunit IB, yielding a sampling resolution of mostly 30–60 cm. Samples were oven-dried at 60°C, weighed, and then washed through a 63 μm sieve. Dry residues were weighed again for the purpose of calculating the >63 μm coarse fraction. Planktonic and benthic foraminifers in the dry residues were analyzed under a binocular microscope. Relative abundances of species or species groups were estimated using the following categories: D = dominant (>30% of the assemblage), A = abundant (10%–30%), F = few (5%–10%), R = rare (1%–5%), and P = present (<1%). We referred to Bolli and Saundres (1985) and Kenney and Srivavasan (1983) for identification of planktonic foraminifer species, to Kuhnt et al. (2002) and Ortz and Thomas (2006) for benthic species, and to Wade et al. (2011) for zonation, and to Gradstein et al. (2012) for age of datums.

Specimens of planktonic species Chiloguembelina cubensis (40–60 specimens; 100–150 μm), Cassigerinella chiplenis (40–60 specimens; 100–150 μm), Globigerina ciperoensis (20–30 specimens; 150–250 μm), and Globoquadrina venezuelana (5–10 specimens; 300–400 μm), and benthic species Cibicidoides spp. (3–5 specimens; 400–450 μm) were picked for measuring stable isotopes. The picked specimens were washed with ethanol (~99.7%) in an ultrasonic bath, dried in an oven at 60°C, and reacted with orthophosphoric acid in an automated carbonate device (Kiel III) at 70°C to generate $^{13}$C, which was then transferred to a Finnigan MAT252 mass spectrometer for measuring stable isotopes. Because of their small test size, both C. cubensis and C. chiplenis often required repeat analyses on a new set of specimens for better results. Measurement precision was regularly checked with a Chinese national carbonate standard GBW04405; the standard deviation is 0.07‰ for $^{18}$O and 0.05‰ for $^{13}$C. Finally, an NBS19 standard was used to convert the results to the international PeeDee belemnite (PDB) scale. All analyses and measurements were performed in the State Key Laboratory of Marine Geology of Tongji University.

Results

The original planktonic foraminfer census data plus notes on the benthic species groups are shown in Table T1. In general, both planktonic and benthic foraminifers are extremely rare in the lowermost Sample 349-U1435A-9R-2, 125–129 cm (77.55–77.59 mbsf), which is characterized by fine sand similar to the lithology in underlying Unit II. Planktonic and benthic foraminifer abundance increases rapidly from Sample 9R-2, 60–64 cm (76.90–76.94 mbsf), uphole, with group abundance from common to abundant (40%–70% or more) over the rest of the studied interval. Planktonic/benthic ratio (P/B) also quickly reached 70:30 to 90:10 and stayed high with values of 80–90:20–10 except in samples between 58.6 and 71.6 mbsf, which are influenced by dolomite sand. Preservation is mostly good with no sign of obvious dissolution. The foraminifer assemblage is dominated by small specimens and only in several samples were some large tests observed, such as 8R-5, 11–15 cm (70.90–70.94 mbsf), as well as most samples from shallower than 58 mbsf (Table T1).

Planktonic foraminifers and zones

The most common planktonic foraminifer species include Chiloguembelina cubensis, Cassigerinella chiplenis, Tenuitella spp., and Pseudohastigerina naguewichiensis, all with a small test size of 100–150 μm. Species with a medium test size of ~200–250 μm, such as Globigerina praebulloides (and allied forms), Globigerina ciper-
in samples immediately above (Table T1). Although planktonic species are often represented by many individual specimens, most benthic species occur only with one or several specimens. Reworked specimens are largely filled or replaced with pyrite and show abrasive features and different colors. Reworked specimens are always rare.

Unlike the calcareous species–dominated assemblage in Hole U1435A, the benthic assemblage found in the lower Oligocene section of Site 1148, which is located ~50 km north of Site U1435 (Figure F1), is characterized by large, elongate, sometimes branching agglutinated forms (Kuhnt et al., 2002; Zhao et al., 2009). Instead, their late Oligocene–early Miocene assemblage contains abundant calcareous hyaline tests, similar to the assemblage found in the lower Oligocene Subunit IB of Hole U1435A.

The benthic foraminifer assemblage found in Subunit IB in Hole U1435A indicates upper- to middle-slope settings. The transition to slope from outer shelf is represented by Sample 9R-2, 60–64 cm (76.90–76.94 mbsf), with a benthic proportion of ~30% from the base of the subunit. This sample also contains more pyrite grains and small benthic forms with frequent Cibicides, Textularia, Bigerina, Karrieriella, Trifarina, Cassidulina, Bolivina, Livigerina, Fissurina, and Denticulina, which are characteristic of the benthic assemblage from ~150–500 m present-day water depths (Wang et al., 1985; Szarek et al., 2006, 2009).

**Stable isotopes**

Stable isotope results are shown in Table T2 and plotted in Figure F4. The results show that δ18O in Hole U1435A samples varies between ~5‰ and ~0.9‰ for planktonic species and between ~3‰ and 1.5‰ for benthic species, whereas δ13C varies between ~2.7‰ and 1.4‰ for planktonic species and between ~1‰ and 0.9‰ for benthic species. The lightest δ13C value (~2.7‰), recorded for C. chiplensis in Sample 349-U1435A-5R-1, 130–134 cm (37.30–37.34 mbsf), may be a measuring error because other planktonic species from the same sample register ~1‰ or heavier δ13C values.

Both benthic and planktonic δ18O show an enriched trend, and variations between the two groups become slightly enlarged up-section. The δ18O values are heaviest for Cibicides spp., followed by G. venezuelana, G. ciperoensis, C. chipolensis, and C. cubensis, although the δ18O differences between G. ciperoensis and C. chipolensis are minor. Our results support the δ18O patterns of these species as reported in early studies (e.g., Keller, 1985; Pearson et al., 1997).

Table T2. Benthic and planktonic foraminifer isotopic data in samples from Hole U1435A. Download table in .csv format.

Figure F4. Stable isotope variations of benthic (black squares) and planktonic (colored circles) foraminifers, Hole U1435A. PDB = Peedee belemnite.
Wider variations are displayed in the δ13C records. For the benthic δ13C, three negative shifts can be observed at about 69, 57, and 37 mbsf, respectively (Figure F4). Planktonic δ13C appears similar but shows minor positive shifts at 69 and 57 mbsf instead of the pronounced negative swings seen in the benthic record. Both benthic and planktonic δ13C records lack distinct heavy values characteristic of the global δ13C maximum across the Eocene/Oligocene boundary (Zachos et al., 2001). The absence of such a positive δ13C shift from the record is further evidence that the Subunit IB marine section in Hole U1435A was deposited after the boundary event, or younger than 33.89 Ma.

Summary

Planktonic foraminifer Zones P18 and P19 of early Oligocene age are recognized in samples from Subunit IB of IODP Hole U1435A. The sediment section is dated to between <33.89 and >30.72 Ma based on the occurrence of Cassidulinella chipolensis and T. ampliapertura and the absence of P. opima opima. The Zone P18/P19 boundary lies close to 46.8 mbsf, as evidenced by the top of P. nagewicheiensis.

The benthic foraminifer assemblage is dominated by calcareous hyaline species that live in upper- to middle-slope settings. Shallower water depths of 150–500 m are indicated by the benthic assemblage from the lowermost part of the section.

Benthic and planktonic δ18O values increase progressively up-section without any obvious sudden shifts. Their δ13C variations are larger, but larger positive swings matching the Oligocene δ13C maxima are lacking.

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References


