Clemens, S.C., Kuhnt, W., LeVay, L.J., and the Expedition 353 Scientists
Proceedings of the International Ocean Discovery Program Volume 353
publications.iodp.org

https://doi.org/10.14379/iodp.proc.353.201.2018

Check for updates

Data report: late Pliocene planktonic foraminifer assemblages from IODP Holes U1443B, U1443C, and U1445A[1]

Marci M. Robinson[2] and Harry J. Dowsett[2]

Keywords: International Ocean Discovery Program, IODP, *JOIDES Resolution*, Expedition 353, Site U1443, Site U1445, Indian monsoon rainfall, Bay of Bengal, Pliocene, foraminifer

Contents

Abstract

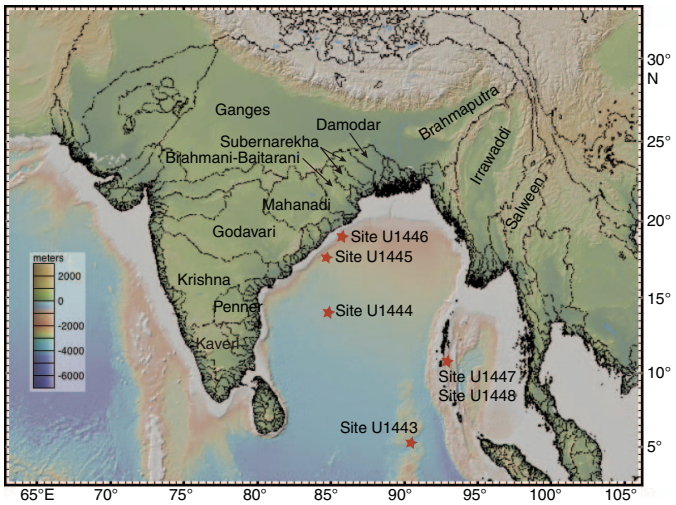
Planktonic foraminifers are key to reconstructing the paleoceanography and monsoon history of the Bay of Bengal. We examined foraminifers from International Ocean Discovery Program Site U1443 on the Ninetyeast Ridge and Site U1445 in the northwest Bay of Bengal, documented the planktonic assemblages, and compared four measures of sample preservation. These samples contain typical late Pliocene assemblages, although the upper stratigraphic limits of *Sphaeroidinellopsis seminulina* and *Dentoglobigerina altispira* are more similar to those of the Atlantic Ocean than of the Pacific Ocean. Observations of sample fragmentation and test preservation are more useful than numerical calculations based on foraminifer abundances in describing sample dissolution and offer a consistent means to compare samples from different sites in the Bay of Bengal.

Introduction

During International Ocean Discovery Program (IODP) Expedition 353, six sites were drilled in the Bay of Bengal with the overall goal of better understanding the response of monsoon systems to climate forcing (see the **Expedition 353 summary** chapter [Clemens et al., 2016]). Late Pliocene material was collected from five of these sites with the potential to explore the evolution of the Indian monsoon from the mid-Piacenzian warm period (~3.3–3.0 Ma) to the initiation of Northern Hemisphere glaciation (~2.7 Ma), an interval characterized by a reorganization of northern Indian Ocean paleoceanography (e.g. Gupta and Thomas, 2003; Clemens et al., 2008; Herbert et al., 2010).

We examined foraminifers from Site U1443 (5°23.01′N, 90°21.1′E; 2935 meters below sea level [mbsl]) on the Ninetyeast Ridge in the southern reaches of the Bay of Bengal and Site U1445 (14°00.01′N, 84°49.74′E; 2503 mbsl) in the northwest Bay of Bengal ~94 km offshore the eastern margin of India. Site U1443 (redrill of Ocean Drilling Program Site 758) is removed from the influence of seasonal precipitation runoff, whereas Site U1445 is in the fresh East Indian Coastal Current, which carries Mahanadi River outflow, and is likely to record a seasonal signal (Figure **F1**). Of the Expedition 353 sites containing Pliocene sediments, the range in salinity and other paleoceanographic parameters related to seasonal monsoon activity should be the least at Site U1443 and the greatest at Site U1445. Data from these two sites should provide the means to reconstruct seasonality and salinity gradients across the Bay of Bengal.

Figure F1. Bay of Bengal region showing main river basins and locations of Expedition 353 sites. Map was generated using GeoMapApp (**http://www.geomapapp.org**), using topography and bathymetry from Ryan et al. (2009).



[1] Robinson, M.M., Dowsett, H.J., 2018. Data report: late Pliocene planktonic foraminifer assemblages from IODP Holes U1443B, U1443C, and U1445A. *In* Clemens, S.C., Kuhnt, W., LeVay, L.J., and the Expedition 353 Scientists, *Indian Monsoon Rainfall*. Proceedings of the International Ocean Discovery Program, 353: College Station, TX (International Ocean Discovery Program). https://doi.org/10.14379/iodp.proc.353.201.2018

[2] US Geological Survey, Eastern Geology and Paleoclimate Science Center, USA. Correspondence author: **mmrobinson@usgs.gov**

MS 353-201: Received 23 April 2018 · Accepted 7 August 2018 · Published 8 November 2018

Here we present planktonic foraminiferal assemblage data and four measures of sample dissolution from 156 late Pliocene samples collected from Holes U1443B, U1443C, and U1445A. The primary objective of this research is to record the species distributions and to determine the most useful measure of sample dissolution for these Bay of Bengal samples for use in future paleoceanographic studies.

Methods and materials

For this study, ~10 cm^3 samples were collected at a sampling resolution of ~6 cm from Holes U1443B and U1443C and ~17 cm^3 samples were collected at a sampling resolution of ~40 cm from Hole U1445A. Samples from Holes U1443B and U1443C (N = 82) and Hole U1445A (N = 74) were freeze-dried and placed on an orbital shaker for ~1 h in a hexametaphosphate solution for sediment disaggregation. Samples were then washed through a 63 µm sieve to remove the mud fraction and oven dried at ~45°C. A split of ~300 specimens was collected from the >150 µm size fraction of most samples; in samples where specimens were less abundant, all foraminifers were collected. Samples were examined under a light microscope to determine preservation, and planktonic foraminifer species were transferred to a micropaleontologic slide where they were identified to the species level and counted. Sample slides and residues are archived in the PRISM laboratory at the U.S. Geological Survey National Center in Reston, Virginia.

We used four methods to describe foraminifer preservation and to estimate sample dissolution. First, we calculated the planktonic to benthic ratio (%P), defined as the percentage of planktonic foraminifers of all foraminifers in a sample. This ratio can be useful as a measure of dissolution because benthic species are generally more robust and dissolution resistant than planktonic species (e.g. Boltovskoy and Totah, 1992). This method is more problematic, however, because coastal processes and nutrient fluxes are known to affect the size of the benthic population (e.g., Berger and Diester-Haass, 1988).

Second, we calculated the ratio of dissolution-resistant species (RSP%). RSP% is defined by Cullen and Prell (1984) as the sum of the percentages of the following dissolution-resistant species and varieties: *Globorotalia crassaformis, Globorotalia inflata, Globorotalia menardii, Globorotalia truncatulinoides, Globorotalia tumida, Neogloboquadrina dutertrei, Neogloboquadrina pachyderma, Neogloboquadrina "dupac," Pulleniatina obliquiloculata, Sphaeroidinella dehiscens*, and *Turborotalita humilis*. We adapted the RSP% to our Pliocene samples by including the following late Pliocene ancestor species in the calculation: *Globorotalia tosaensis, Globorotalia puncticulata*, and all *Sphaeroidinellopsis* spp.

A quantitative fragmentation index is not suitable for most Site U1443 samples because of the vast quantity of fragments, often exceeding many times the number of whole specimens. Instead, as a third measure of dissolution, we performed a qualitative analysis of fragmentation on all Site U1443 and U1445 samples by assigning the degree of fragmentation in each sample to one of the following categories:

- O = overwhelming; fragments compose >67% in relation to total residue.
- D = dominant; fragments compose >50%–67% in relation to total residue.
- A = abundant; fragments compose >33%–50% in relation to total residue.
- C = common; fragments compose >20%–33% in relation to total residue.
- S = several; fragments compose >10%–20% in relation to total residue.
- F = few; fragments compose 5%–10% in relation to total residue.
- R = rare; fragments compose <5% in relation to total residue.

Finally, we described the dissolution characteristics of the tests of *P. obliquiloculata* specimens based on their appearance under a light microscope following Regenberg and Beil (2016). We assigned one of the following preservation states to each sample:

- Gentle = smooth and shiny translucent test surface damaged by fissures.
- Moderate = translucent test surface showing decayed or removed surface veneer.
- Severe = white tests with holes and broken chambers.

We added an intermediate preservation state of "moderate-severe" to describe *P. obliquiloculata* specimens with white (etched) tests but without holes in the tests or broken chambers.

Results

Planktonic foraminifer assemblage data for late Pliocene samples from Holes U1443B, U1443C, and U1445A are shown in Tables **T1** and **T2**. The most common planktonic foraminifer species in Site U1443 samples include *Globigerinoides sacculifer, Dentoglobigerina altispira, Sphaeroidinellopsis* spp., *G. menardii, Globigerinita glutinata*, and *Globigerinoides obliquus*. The most common planktonic foraminifer species in Site U1445 samples include *G. glutinata, N. dutertrei, G. sacculifer, Globigerinoides ruber, G. obliquus*, and *Globigerina decoraperta*. When present, *D. altispira* is one of the most common species.

These species represent a typical late Pliocene (Zone PL5) assemblage. All Site U1445 samples fall in Zone PL5. It is difficult to determine, however, if all Site U1443 samples fall in Zone PL5 because the Zone PL4/PL5 marker species *G. tosaensis* is rare. Because the position of the zonal boundary is unclear at Site U1443, we include all samples below the lowest occurrence of *G. tosaensis* at 42.92 m core depth below seafloor (CSF-A) in Zone PL4/PL5.

Interestingly, at both sites the upper stratigraphic limits of *Sphaeroidinellopsis seminulina* and *D. altispira* are higher than the lower limit of *Globigerinoides fistulosus*, indicating that the positioning of the stratigraphic ranges of these three species in the Bay of Bengal is more similar to their published ranges in the Atlantic Ocean than in the Pacific Ocean (e.g. Wade et al., 2011).

Because *G. decoraperta* occurs in most Site U1445 samples and we find *G. tosaensis* in the lowermost Site U1445 sample, we assign a biochronologic age range of 2.75–3.35 Ma (using Wade et al., 2011) to these samples. Our Site U1443 samples are also older than 2.75 Ma because of the presence of *G. decoraperta* and likely older than 2.98 Ma because of the presence of *Globorotalia multicamerata* at 39.43 m CSF-A. We find no evidence of early Pliocene taxa (Zone PL3) in these samples and conservatively estimate an age

Table T1. Planktonic foraminifer census data, Holes U1443B and U1443C. **Download table in CSV format.**

Table T2. Planktonic foraminifer census data, Hole U1445A. **Download table in CSV format.**

Figure F2. Four dissolution measures applied to late Pliocene foraminifer samples. %P = planktonic:benthic ratio, RSP% = dissolution-resistant species ratio. Qualitative fragmentation analysis and *P. obliquiloculata* test preservation also shown. A. Site U1443. B. Site U1445.

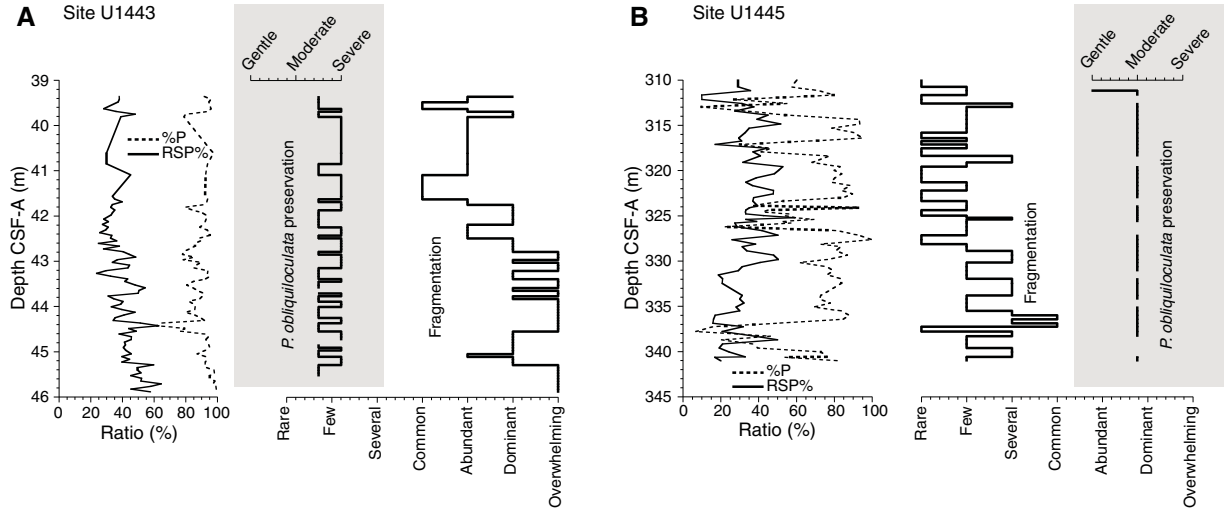
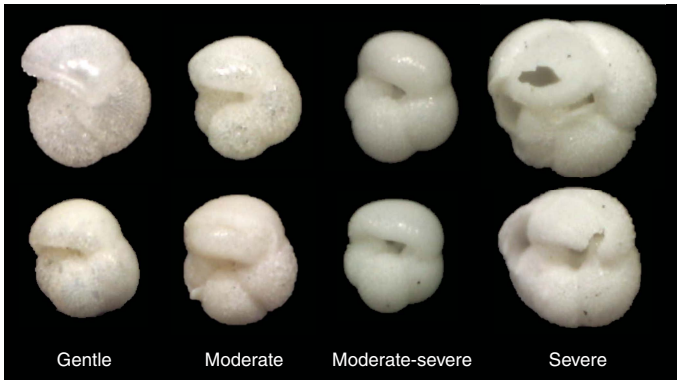


Figure F3. Specimens of *P. obliquiloculata* (×245 magnification) from samples demonstrating gentle (353-U1445A-34X-1, 47–49 cm), moderate (34X-2, 48–50 cm), moderate-severe (353-U1443B-5H-4, 19–21 cm), and severe (5H-4, 31–33 cm) dissolution.



for the lowermost Site U1443 samples of no more than 3.66 Ma to coincide with Zone PL3/PL4.

Two Hole U1445A samples show evidence of reworking. Samples 37X-3, 83–85 cm, and 37X-3, 135–137 cm (337.27 and 337.79 m CSF-A), both show a mixture of preservation states that range from well- to poorly preserved specimens. In addition, both samples also contain a few Miocene age species and show a dramatic increase in the number of benthic specimens as compared with the surrounding samples.

Dissolution indexes for late Pliocene samples from Holes U1443B, U1443C, and U1445A are shown in Tables **T1** and **T2**, and a summary of the four dissolution measures associated with each sample is illustrated in Figure **F2**. In Site U1443 samples, %P stays high (>75%) for all but two samples at 44.38 and 44.44 m CSF-A. These samples are coincident with a positive spike in RSP%, but not all positive RSP% spikes correlate with low %P. Overall, RSP% shows a decreasing trend upcore from ~50% to ~30%. Both numerically calculated measures of dissolution are highly variable in Site U1445 samples, with %P ranging from 10% to 100% and RSP% ranging from 10% to 66%, with no obvious correlation between the two measures.

Site U1443 samples are highly fragmented with moderate-severe and severe dissolution, whereas Site U1445 samples are lightly fragmented with evidence of only gentle or moderate dissolution. Examples of specimens from samples recorded as gentle, moderate, moderate-severe, and severe are illustrated in Figure **F3**. Samples from both cores become less fragmented upcore.

In these Bay of Bengal samples, where robust species of planktonic foraminifers are common and benthic foraminifer abundance is affected by coastal zone processes, fragmentation and test preservation yield an alternate representation of sample dissolution to numerical calculations based on dissolution-resistant foraminifer abundances. Fragmentation and test preservation offer a consistent means for comparing samples across time and among Expedition 353 sites without the bias of coastal zone processes that could influence both benthic foraminiferal abundance and the relative abundance of planktonic species.

Acknowledgments

This research is based on samples and data provided by the International Ocean Discovery Program (IODP), which is funded by the National Science Foundation and international partners. The science party, crew, and technicians aboard the R/V *JOIDES Resolution* are acknowledged for their work during IODP Expedition 353. Many thanks to Lyndsey Fox for a very helpful review of this report. Funding was provided by the U.S. Geological Survey (USGS) Land Change Science Program. The authors would like to acknowledge USGS technicians Whittney Spivey and Kristen Steele for their assistance with species identifications and students at Brown University for their help processing Site U1445 samples.

References

Berger, W.H., and Diester-Haass, L., 1988. Paleoproductivity: the benthic/planktonic ratio in foraminifera as a productivity index. *Marine Geology,* 81(1–4):15–25. **https://doi.org/10.1016/0025-3227(88)90014-X**

Boltovskoy, E., and Totah, V.I., 1992. Preservation index and preservation potential of some foraminiferal species. *Journal of Foraminiferal Research,* 22(3):267–273. **https://doi.org/10.2113/gsjfr.22.3.267**

Clemens, S.C., Kuhnt, W., LeVay, L.J., Anand, P., Ando, T., Bartol, M., Bolton, C.T., Ding, X., Gariboldi, K., Giosan, L., Hathorne, E.C., Huang, Y., Jaiswal, P., Kim, S., Kirkpatrick, J.B., Littler, K., Marino, G., Martinez, P., Naik, D., Peketi, A., Phillips, S.C., Robinson, M.M., Romero, O.E., Sagar, N., Taladay, K.B., Taylor, S.N., Thirumalai, K., Uramoto, G., Usui, Y., Wang, J., Yamamoto, M., and Zhou, L., 2016. Expedition 353 summary. *In* Clemens, S.C., Kuhnt, W., LeVay, L.J., and the Expedition 353 Scientists, *Indian Monsoon Rainfall*. Proceedings of the International Ocean Discovery Program, 353: College Station, TX (International Ocean Discovery Program). **https://doi.org/10.14379/iodp.proc.353.101.2016**

Clemens, S.C., Prell, W.L., Sun, Y., Liu, Z., and Chen, G., 2008. Southern Hemisphere forcing of Pliocene $\delta^{18}O$ and the evolution of Indo-Asian monsoons. *Paleoceanography,* 23(4):PA4210. **https://doi.org/10.1029/2008PA001638**

Cullen, J.L., and Prell, W.L., 1984. Planktonic foraminifera of the northern Indian Ocean: distribution and preservation in surface sediments. *Marine Micropaleontology,* 9(1):1–52. **https://doi.org/10.1016/0377-8398(84)90022-7**

Gupta, A.K., and Thomas, E., 2003. Initiation of Northern Hemisphere glaciation and strengthening of the northeast Indian monsoon: Ocean Drilling Program Site 758, eastern equatorial Indian Ocean. *Geology,* 31(1):47–50. **https://doi.org/10.1130/0091-7613(2003)031<0047:IONHGA>2.0.CO;2**

Herbert, T.D., Peterson, L.C., Lawrence, K.T., and Liu, Z., 2010. Tropical ocean temperatures over the past 3.5 million years. *Science,* 328(5985):1530–1534. **https://doi.org/10.1126/science.1185435**

Regenberg, M., and Beil, S., 2016. Test appearance of the planktonic foraminifer *Pulleniatina obliquiloculata* as an indicator of calcite dissolution in deep-sea sediments. *Journal of Foraminiferal Research*, 46(3):224-236. **https://doi.org/10.2113/gsjfr.46.3.224**

Ryan, W.B.F., Carbotte, S.M., Coplan, J.O., O'Hara, S., Melkonian, A., Arko, R., Weissel, R.A., Ferrini, V., Goodwillie, A., Nitsche, F., Bonczkowski, J., and Zemsky, R., 2009. Global multi-resolution topography synthesis. *Geochemistry, Geophysics, Geosystems,* 10(3):Q03014. **https://doi.org/10.1029/2008GC002332**

Wade, B.S., Pearson, P.N., Berggren, W.A., and Pälike, H., 2011. Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. *Earth-Science Reviews,* 104(1–3):111–142. **https://doi.org/10.1016/j.earscirev.2010.09.003**