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Paleoenvironment conditions across Late Cretaceous-Paleocene in Mahanadi offshore basin: proxies from a deep water well

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Abstract

The Cretaceous-Paleogene (K/Pg.) boundary event is one of the most well-known geological phenomena in the history of the earth and is marked by the sudden disappearance of numerous oceanic species, mostly the planktic group. The benthics comparatively appear to have coped better with this environmental upheaval and thus serve as proxies to the oceanic conditions during the K/Pg. transition. Benthic foraminifera are unparalleled as far as proxies to past environmental conditions are concerned. Smaller benthic foraminiferal assemblage in a 140m-thick section across Late Cretaceous (Campanian-Maastrichtian)-Paleocene is recorded in a deep water well (MX-O) drilled in the vicinity of the 85° E Ridge in Mahanadi offshore Basin. The recovered assemblage is utilised in an attempt to reconstruct paleoenvironmental/paleobathymetric conditions at the K/Pg. transition in the basin. At least thirty one genera and seven speciesof both arenaceous and calcareous benthic forams are identified in the well which includearenaceous forms*Ammodiscuscretaceus, Ammodiscus*sp., *Aragonia* sp., *Bathysiphon* sp., *Bolivinoidesdraco*, *Dorothia* sp., *Eggerella* sp., *Gaudryinapyramidata, Guadryina* sp., *Glomospiracharoides*, *Marssonellaoxycana, Marssonella* sp., *Neoflabellina* sp., *Reophax*sp. *Reusella*sp., *Textularia*sp., and calcareous forms*Allomorphina* sp., *Anomalinoides* sp., *Bolivina* sp., *Bulimina* sp., *Cibicidoides* sp., *Gavellinellabecariiformis*, *Guttulina* sp., *Gyroidinoides* sp., *Lagena* sp.,*Lenticulina* sp.,*Nodosaria* sp., *Nonion* sp., *Oridorsalis* sp., *Osangularia* sp., *Pulleniajarvisi,Stensioeina* sp., *Uvigerina* sp. These occur along with a rich assemblage of planktic foraminifera in the studied interval.

The K/Pg. boundary in the well is marked at the disappearance level of all typical Maastrichtianplanktic foraminifers, except *Guembelitria* sp., and some Heterohelicids, which persisted into Early Paleocene (Danian). Besides, latest Maastrichtian and earliest Danian planktic foraminifera are also recorded in this well. Amongst the smaller benthic foraminifera, several genera are observed to have made it across the boundary and continue into Paleocene. However, their diversity and population decreased from the lower part of the interval towards the K/Pg. transition suggesting that the boundary related stress conditions may also have affected the sea bottom conditions. Foraminiferal assemblage thus suggests a continuous marine set-up across K/Pg. transition in bathymetric conditions ranging from outer shelf to deeper Bathyal realm.

Introduction

The Cretaceous-Paleogene (K/Pg) boundary marks a period of major environmental upheaval on Earth. The sudden disappearance of both terrestrial and oceanic species has been commonly linked to the effects of a bolide impact Alvarez et al.(1), Smit and Hertogen(2). This catastrophe model of extinction at K/Pg is countered by other researchers, who suggest that the extinctions were more gradual and in phase manner (Eg. Keller (3) and (4)). In the marine realm, the planktic foraminifera extinctions are well known all over the earth. In contrast, the benthic foraminifera do not show significant extinction at the K/Pg boundary (Culver (5), Coccioni and Marsili(6),Alegret and Thomas (7), Alegret (8)). These changes were followed by gradual and phase-wise recovery in the Danian. Such temporary and local/regional changes have been attributed to the sudden collapse of the pelagic food web due to the disappearance of calcareous primary producers, and the consequent drop in the food supply to the sea bottom (Thomas (9), Culver(5)).

Benthic foraminfera are excellent indicators of environmental conditions at the ocean bottom (Van der Zwaan et al. (10)). Besides being good paleobathymetry indicators, the abundance of certain

species/assemblage allows us to infer changes in the paleodepth. Benthic foraminifers are thus an important tool in reconstructing paleoenvironmental changes at the K/Pg boundary.

The Mahanadi deep offshore area has seen exploratory efforts by E & P Companies like ONGC LTD in the recent past. These efforts have been mainly focussed on the Tertiary (Paleogene carbonates and Neogeneclastic) sequences and wells have rarely penetrated below Paleocene. The well MX-O (Fig. 1) was drilled in the vicinity of the 85° E Ridge and encountered Tertiary and Late Cretaceous sequences. Biostratigraphic study was carried out in the cuttings and side wall cores (SWC) recovered from the well. The Late Cretaceous (Campanian-Maastrichtian)-Paleoceneplanktic foraminifera are well-recorded in the well. The latest Maastrichtian- earliest Danian planktic zones are also recognised (Whisoet al.(11)). A fairly rich assemblage of associated smaller benthics recovered from this section are studied in an attempt to reconstruct the paleobathymetric conditions across the K/Pg boundary in the area.

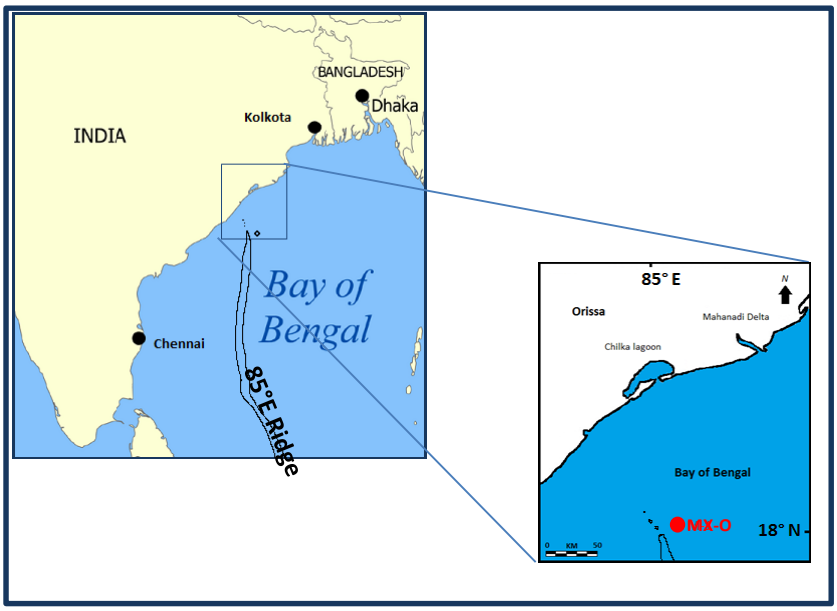


Fig. 1: Location of studied well, MX-O

Materials and methods

Approximately 20gm each of a total of 11 samples in a ~150m section of the well MX-O were processed and analysed for the present study. The sediments studied are made up of reddish brown to grey, soft, marls inter-bedded with calc marls. Samples, available at 5m intervals, were processed using standard micropaleontology technique. Some of the microfossils identified were illustrated using Scanning Electron Microscope (SEM). Generic classification of benthic foraminifera follows Loeblich and Tappan (12); identification both at generic and specific level followsBolli et al. (13), Widmark (14) and Jenkins and Murray (15). When possible, benthic foraminifera were identified to the specific level.An attempt is made to allocate all benthic foraminiferal taxa to morphogroups following Corliss (16) and bring out the infaunal:epifaunal and the agglutinated:calcareousratio. Since the samples are well cuttings and sampling intervals are large, we consider the general trends of fauna across the section rather than changes in each sample, for the interpretation of the data. The benthic foraminiferal distribution chart (Fig. 2) was created in the *StrataBugs* software v.1.8. All materials pertaining to this study are preserved in the repository of the Palaeontology Laboratory, KDMIPE, ONGC,Dehradun.

Foraminiferal assemblage and morphogroups

Benthic foraminifera, both the agglutinated and calcareous group were studied in the well section spanning the K/Pg transition. Recovered fauna include 31 genera out of which 7 have been identified to specific level. These are*Ammodiscuscretaceus*Reuss,*Ammodiscus*sp., *Aragonia* sp., *Bathysiphon* sp., *Bolivinoidesdraco*(Marsson),*Dorothia* sp., *Eggerella* sp., *Gaudryinapyramidata*(Cushman),*Guadryina* sp., *Glomospiracharoides*(Jones and Parker),*Marssonellaoxycana*(Reuss),*Marssonella* sp., *Neoflabellina* sp., *Reophax*sp. *Reusella*sp., *Textularia*sp., and calcareous forms*Allomorphina* sp., *Anomalinoides* sp., *Bolivina* sp., *Bulimina* sp., *Cibicidoides* sp., *Gavellinellabecariiformis*(White),*Guttulina* sp., *Gyroidinoides* sp., *Lagena* sp.,*Lenticulina* sp.,*Nodosaria* sp., *Nonion* sp., *Oridorsalis* sp., *Osangularia* sp., *Pulleniajarvisi*Cushman,*Stensioeina* sp., *Uvigerina* sp., *Nodosaria* sp., *Nonion* sp., *Osangularia* sp. and *Uvigerina* sp. Fig. 2 shows the distribution of benthic foraminifera, few of which are illustrated at Plate 1.

The relationship between the habitat and the test morphology of foraminifers is well known (Corliss (16)). Species that inhabit mainly the top of the sediment or within 0.5 cm are referred to as *epifaunal* and dominated by trochospiral test morphologies, whereas species found deeper in the sediments are referred to as *infaunal* and exhibit bi-, tri-, multi- and plani-spiral test morphologies. Generally higher frequencies of infaunalmorphotypes indicate eutrophic conditions with high organic-carbon flux and low oxygen levels. The absence or lower frequency of infaunal species generally indicates oligotrophic conditions- low food supply with well oxygenated conditions, which favours epifaunalmorphotypes.

In the Late Cretaceous (Campanian-Maastrichtian) of well MX-O, the infaunalmorphotypes dominate in the interval 4585 to 4505m (51-77%); however at depth 4490m (approx. K/Pg), the percentage of infaunal species drops to ~33%. This may be due to a drop in food supply to the sea floor, possibly linked to the destruction of the oceanic food-web at the K/Pg event. This would lead to a more oligotrophic (O_2-rich, food poor) conditions. In the interval 4480-4460m (Danian), however, the infaunal species dominates (52->75%) again, indicating a possible recovery of food supply to the bottom after the K/Pg event. Thus, it is suggested that the bottom conditions during the Late Cretaceous-Early Paleocene in the MX-O area remained largely eu- to mesotrophic with a short, possibly local oligotrophic state at the close of Maastrichtian.In terms of test composition, both the agglutinated and the calcareous forms are fairly equally distributed throughout the section, with the calcareous forms slightly dominating both in generic and population counts.

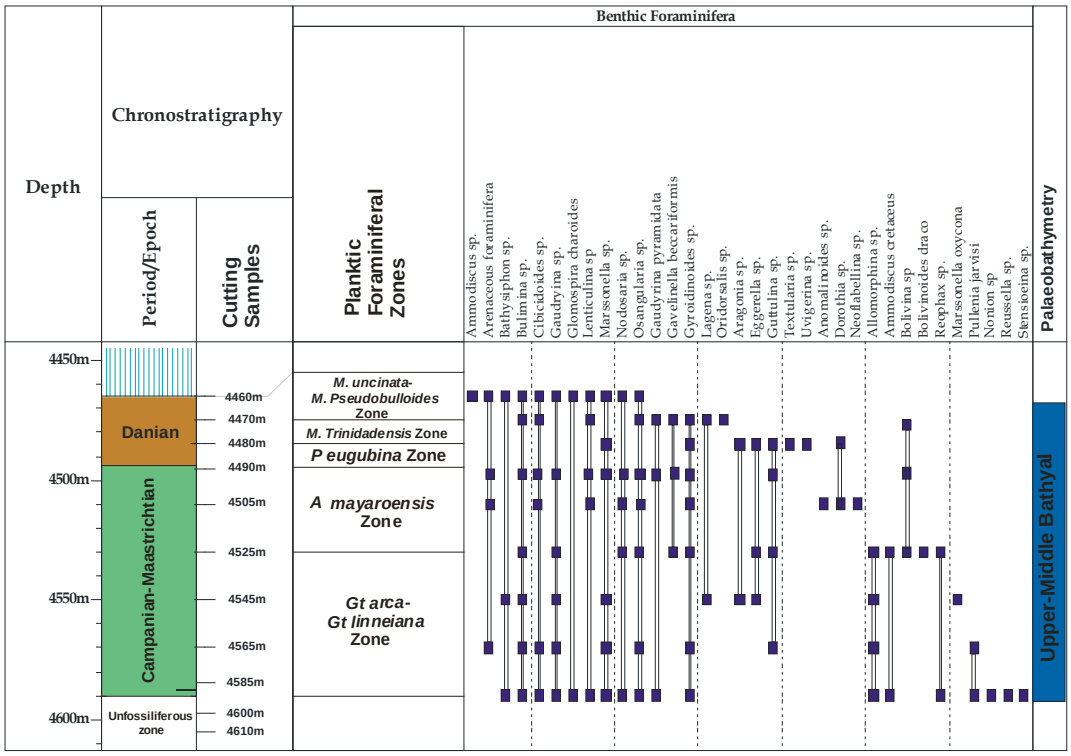
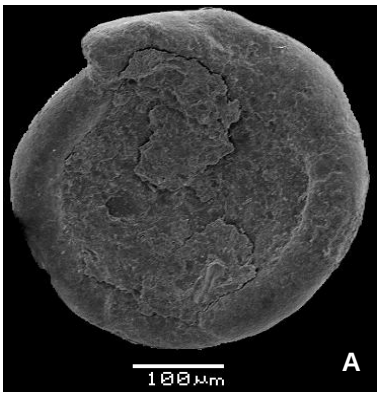
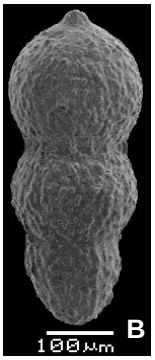


Fig. 2 Distribution of smaller benthic foraminifera in well MX-O

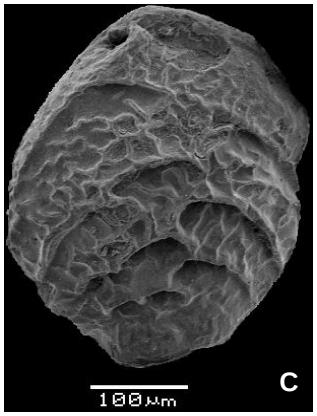
Plate 1



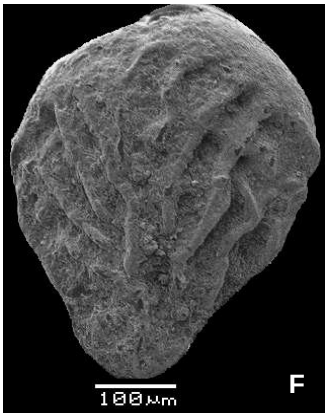
Ammodiscuscretaceus



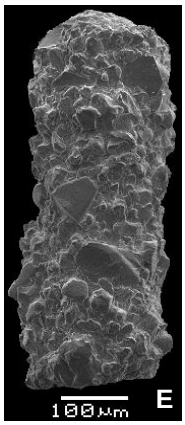
Nodosaria sp.



*Aragonia*sp.



Bolivinoidesdraco



Bathysiphon sp.

*Neoflabellina*sp.

Description of Plate 1

A. *Ammodiscus cretaceous*Reuss; dorsal view; sample 4490m (Maastrichtian)
B. *Nodosaria* sp.; side view; sample 4545m (Maastrichtian)
C. *Aragonia* sp.; front view; sample 4545m (Maastrictian)
D. *Neoflabellina* sp.; side view; samples 4505m (Maastrichtian)
E. *Bathysiphon* sp.; side view; sample 4460m (Early Paleocene)
F. *Bolivinoidesdraco* (Marsson); front view; sample 4525m (Maastrichtian)

Discussion

The K/Pg boundary event saw a large number of planktic foraminifera and calcareous nanno fossils become extinct. In contrast, deep-sea benthic foraminifera do not show significant extinctions in coincidence with the boundary events. However, change in the community structure, followed by a phase-wise recovery in the Danian is recorded worldwide (Eg. Culver, (5), Alegret and Thomas, (7)). The K/Pg boundary effects on benthic foraminifera have been variously analysed taking into consideration their test morphology vis-à-vis micro-habitat (Infaunal/Epifaunal), their test composition (Agglutinated vs. Calcareous). These have been useful in reconstructing the paleobathymetric conditions of the oceanin the MX-O area during the K/Pg event.

Conclusions

- At least 31 genera of well-preserved smaller benthic foraminifera are recovered from a deep water well (MX-O) drilled in the vicinity of the 85° E Ridge, Mahanadi offshore basin. A total of 7 species are also identified. These comprise of both the agglutinated as well as calcareous forms, straddling the Late Cretaceous-Early Paleocene.

- Bottom conditions remained largely Eu-Mesotrophic, with a short span of oligotrophic conditions close to the K/Pg. This is thought to be due to the destruction of the oceanic food web, resulting in a drop in food supply to the bottom. O_2-rich (Oligotrophic) condition is well-supported by the iron oxide-rich reddish brown- grey marls that characterise the lithology of the studied section.

- Extinction rates amongst the smaller benthic are found to be quite low; from the 30 genera and 7 species observed in Late Cretaceous, only 3 species, namely *Ammodiscuscretaceus*, *Bolivinoidesdraco* and *Pulleniajarvisi*do not cross into Danian.

- The benthic foraminfera are associated with very rich assemblage of planktic foraminifera, with a high P:B ratio. This, along with the record of deep water benthics indicates a upper-middle bathyalpaleobathymetric conditions at MX-O.

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