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Endemic vs cosmopolitan tethyan benthic foraminifera from the lower Eocene Panoba Formation, Kohat sub basin, Pakistan: implications for early Eocene warming

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Abstract

The Panoba Formation in Kohat sub-basin of the Indus Basin, Pakistan exposes excellent early Eocene tethyan section. In this study a preliminary work on the paleontology of the forty four early Eocene smaller benthic foraminiferal species as well as their potential for paleoclimatological research from the Panoba Formation is carried out. A systematic treatment of the species is based on the diagnostic morphology. These species belongs to two suborders, twenty super families, twenty five families, thirteen subfamilies and twenty seven different genera. Among these foraminifera twenty seven species are agglutinated and seventeen are non agglutinated (calcareous). The biostratigraphic analysis of the Panoba Formation based on benthic foraminifera suggests that the Formation was deposited in basal Ilerdian time, equivalent to larger benthic zones SBZ 5 & 6 and planktic foraminiferal zones E1 and E2 (part). The biofacies analysis suggests that Panoba Formation was deposited in a variety of settings ranging from middle neritic zone to upper bathyal zone environments. The time period of deposition and wide spectrum of depositional depth of the Panoba Formation offers potential material for future paleoclimatological research pertaining to the Paleocene Eocene Thermal Maximum (PETM) or post PETM scenarios.

Keywords: Benthic foraminifera; Tethys; Pakistan; Paleogene; Thermal Maximum.

1. Introduction

The Kohat sub basin is located between latitude 32˚- 34˚N and longitude 70˚-74˚E (Fig. 1). It is bounded to the north by the Main Boundary Thrust (MBT) and to the south by the Surghar Range Thrust, which is separated from the Salt Range Thrust by Kalabagh Strike-Slip Fault. The western boundary is marked by the Kurram-Parachinar Range and the River Indus separates the Kohat-Potwar Plateau into the Potwar area on the east and the Kohat area on the west. The Paleogene rocks of the Kohat Basin include Patala Formation, Panoba Formation, the Bahadur Khel Salt Facies, the Jatta Gypsum Facies, Sheikhan Formation, Kuldana Formation and Kohat Formation in a younging up sequence. The marine rock units contain well preserved benthic foraminifera. Earlier research has reported variable nature of the benthic foraminiferal community e.g. endemic nature from the Upper Indus Basin by Afzal, (1997) and cosmopolitan nature from Lower Indus Basin by Hanif et al. (2014). This variation in benthic community proposes that the Indus Basin was not a uniform basin during late Paleocene-early Eocene times and this is because of the local tectonic effects (see Beck et al., 1995). At places the bottom of shelf was connected with the main Tethyan Ocean while in other places the connectivity was lacking. Therefore, there is a need to identify sections that are well connected to the Tethyan Ocean for studying the global climatic trends. Although this study is of primary nature but it will assess endemism effects on the benthic foraminiferal community, to use benthic foraminifera for determining the age of the interval studied as well as the paleobathymetry and paleoenvironment and to evaluate the suitability of the sedimentary material for future paleoclimatological research on the early Eocene hyperthermals.

Early Paleogene (60-50Ma) was the warmest period on earth during Cenozoic (Zachos et al., 2008). A number of short lived extreme global warming event 'hyperthermals' are superimposed on the overall warming trend of the Paleogene. The most documented

'PETM', smaller hyperthermals are also reported from the early Eocene deposits worldwide e.g. Eocene Thermal Maximum 2 (ETM2; ~53.7Ma) or Early Eocene Climatic Optimum (EECO). Such climatic events left significant signatures on the past biogeosphere evolution leading to flourishing as well as elimination of floral and faunal communities in a number of realms ranging from deep sea benthics to mammals on land (e.g., Wing et al., 2005; Gingerich, 2006). Benthic foraminiferal community suffered maximum extinction during PETM (i.e. ~ 50% after Thomas (2007). The PETM or post PETM climatic events are least studied in terms of their effect on life in this particular region. Therefore, this study is a preliminary attempt to assess the benthic foraminifera for any such study from the lower Eocene Panoba Formation of the Kohat Sub-basin, Pakistan.

2. Material and Methods

About 150 rock samples of Panoba Formation were collected from three field sections, which are Sheikhan, Panoba and Tarkhobi Nala sections of the Kohat sub-basin, Indus Basin, Pakistan (Fig. 1). All outcrop samples were weighed and 300gram clay/marl from each sample was collected for sieving. 25 and 63 micron mesh size sieves were used to separate smaller benthic foraminifera from the rock sample. All those rock samples with high siliceous content were treated with 30% aqueous solution of hydrogen peroxide for the separation of foraminifera. A reasonable quantity of foraminifera from each sample was sieved and collected in a bottle for microscopic investigation. Using binocular microscope most of the smaller benthic foraminifera were picked with a zero size paint brush from the picking tray with rectangular subdivisions. Afterwards all picked foraminifera were mounted on a carbon coated stub and treated for gold plating and subsequently used for Scanning Electron Microscopy (SEM) for photomicrography. All SEM photographs were compared with published literature and the early Eocene smaller benthic foraminifera are identified and presented in Plates 1-2. The smaller benthic foraminifera was compared with the assemblages of Berggren and Miller, (1989), Afzal, (1997) and was correlated with the larger benthic foraminiferal zones of Serra-Kiel et al. (1998) and Ahmad (Jr.) et al. (2011) for biostratigraphy. The work of Afzal, (1997) from Upper Indus Basin and of Hanif et al. (2014) from Lower Indus Basin has been used for intra-basinal correlation.

3. Results and Discussions

3.2. Benthic foraminiferal biostratigraphy and intra-basinal correlation

The Panoba Formation is straddled between the limestone beds of underlying Patala and overlying Sheikhan Formation. These limestone beds indicate larger benthic zones BFZK1 (B) and BFZK 2 of Ahmad (Jr.) et al. (2011), respectively (Figs. 2-5). Zones BFZK 1 (B) and BFZK 2 are equivalent to Shallow Benthic Zones (SBZ) i.e. SBZ 4 & 5 and SBZ 6 & 7 of Serra-Kiel et al. (1998) respectively. Therefore, based on the indirect inferences drawn from the above biostratigraphic information, the Panoba Formation either belongs to SBZ 5 or SBZ6 or both. According to Scheibner and Speijer, (2009) the bottom of SBZ 5 corresponds to the Larger Foraminiferal Turnover, Paleocene Eocene Thermal Maximum (PETM), Carbon Isotopic Excursion and ultimately to the Paleocene-Eocene boundary. SBZ 5 & 6 are equivalent to the planktic foraminiferal zones E1 and E2 (lowermost portion) of Berggren and Pearson, (2005) and representing basal Ilerdian age.

Smaller benthic foraminifera are also widely applied as biostratigraphic tool in the Tethyan Paleocene and Eocene deposits of the bathyal and abyssal environments. The major extinction of smaller benthic foraminifera associated with PETM is called benthic extinction event 'BEE'. This BEE is used by Berggren and Miller, (1989) to define a zonal boundary between the Paleocene bathyal zone BB1 and Eocene bathyal zone BB2. The disappearance of *Gavelinella beccariiformis* and associated smaller benthics in Tethyan sections mark the BEE and the boundary between BB1 and BB2 (Speijer, 1994; Speijer et al., 1995, 1997; Scheibner and Speijer, 2009). *G. beccarriiformis* is a common smaller benthic foraminiferal species in the latest Paleocene of Tethyan sections. Occurrence of *Gavelinella* species and absence of *G. becccariiformis* in

the Panoba Formation most probably points towards the fact that the BEE may be in the underlying Paleocene Patala Formation. Absence of typical Tethyan smaller benthic foraminifera in Panoba Formation may be an indication of the endemism effect and the same is reported from other sections in the Upper Indus Basin, Pakistan (e.g. Afzal, 1997). Due to this possible endemism effect, the Tethyan smaller benthic zonation e.g. of Berggren and Miller, (1989) cannot be adopted completely and therefore the local available zonal scheme of Afzal, (1997) is followed in this study. The presence of *Cibicides alleni* and *Valvulineria patalaensis* represent SRX-3 and SRX-4 biozones of Afzal, (1997), these zones are equivalent to SBZ 5 and SBZ 6 zones of Serra-Kiel et al. (1998).

By using the larger and smaller benthic foraminifera, the age of the Panoba Formation is confirmed as Early Eocene (basal Ilerdian represented by SBZ 5 and SBZ6). Therefore, the Panoba Formation is age equivalent to the top most parts of the Patala Formation (Upper Indus Basin) of Afzal, (1997) and the Dungan Formation (Lower Indus Basin) of Hanif et al. (2014).

3.3. Paleobathymatery and paleoenvironment

Smaller benthic foraminiferal assemblages are widely applied for determination of the paleodepths (e.g. Gibson and Buzas, 1973; Olsson and Wise, 1987; Olsson, 1991; Nagy et al., 2000). Following the paleobathymatric ranges of Van Morkhoven et al. (1986) and Speijer, (1994), the overall paleodepth for the Panoba Formation is interpreted to be neritic to upper bathyal as represented by the occurrence of *Loxostomum applinae.* Important benthic foraminifera of the Early Eocene Panoba Formation include the following assemblages;

Middle - outer neritic facies

This foraminiferal assemblage has low to high biodiversity represented by agglutinated and calcareous forms. Dominant agglutinated species includes *Textularia barrettii* Jones & Parker, *Textularia martini* Pijpers while other common species include *Textularia dibollensis var humblei* Cushman & Applin, *Textularia cuyleri* Davis, *Textularia hannai* Davis, *Textularia gertrudeana* Davis.

Calcareous foraminiferal assemblage is characterized by *Bolivina gracilis* Cushman & Applin, *Bolivina acerosa* Cushman, *Bulimina stokesi* Cushman and Renz, *Cibicidoides tuxpamensis tuxpamensis* Cole, *Praeglobobulimina ovata* D, Orbigny, B*ulimina gracilis* and *Uvigerina rustica* Cushman & Edwards, *polymorphinids, cibicides.* This foraminiferal assemblage is compared with the *Bulimina* and *Uvigerina biofacies* of Miller et al. (1997).

The *Bulimina* biofacies was defined by Miller at al. (1997) as the *Bulimina gracilis* biofacies. It characterizes middle neritic (50-80 m) paleodepths. In this study 1m to 3m outcrop sample interval of Panoba Formation have *Bolivina gracilis* Cushman, *Bolivina* acerosa Cushman and varieties of *Textularids* that marks the shallower end of the *Bulimina* biofacies indicating middle neritic environment, while 3m to 9m outcrop samples of Panoba Formation show increase in biodiversity and abundance of *Cibicides* and polymorphinids that marks the deeper end of the Bulimina biofacies. The *Uvigerina* biofacies was defined by Miller et al. (1997) which characterizes middle to outer neritic paleodepths (>75 m). It includes *Uvigerina modeloensis* and *Uvigerina* juncea, and in this study 10-14m sample interval includes *Uvigerina gallowayi basicordata* Cushman and Renz along with increasing *Cibicides* and calcareous forms indicating water depth reached up to 75m or more indicating middle to outer neritic environment.

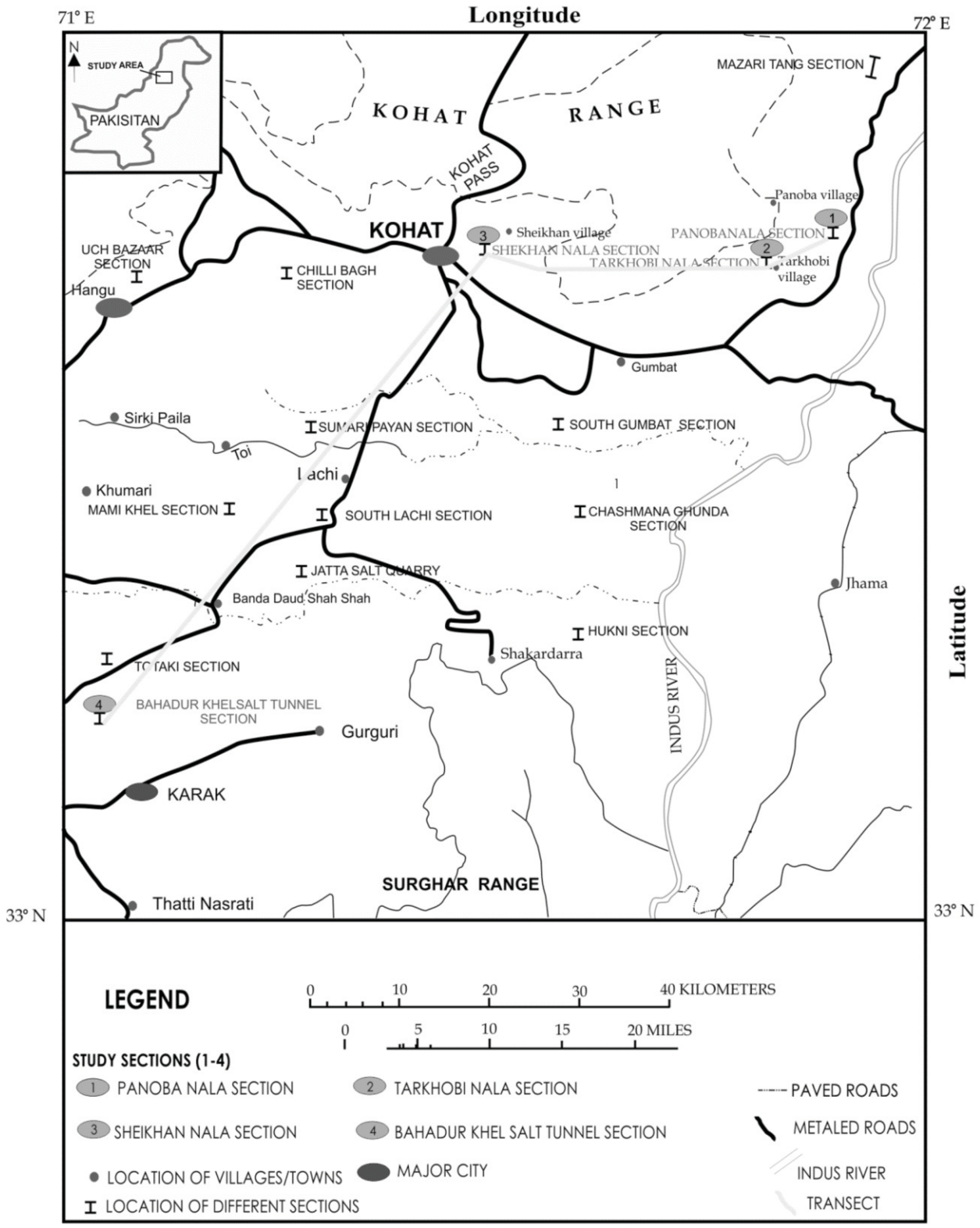

Fig.1. Generalized geological map showing location of the studied sections (after Kazmi and Rana, 1986).

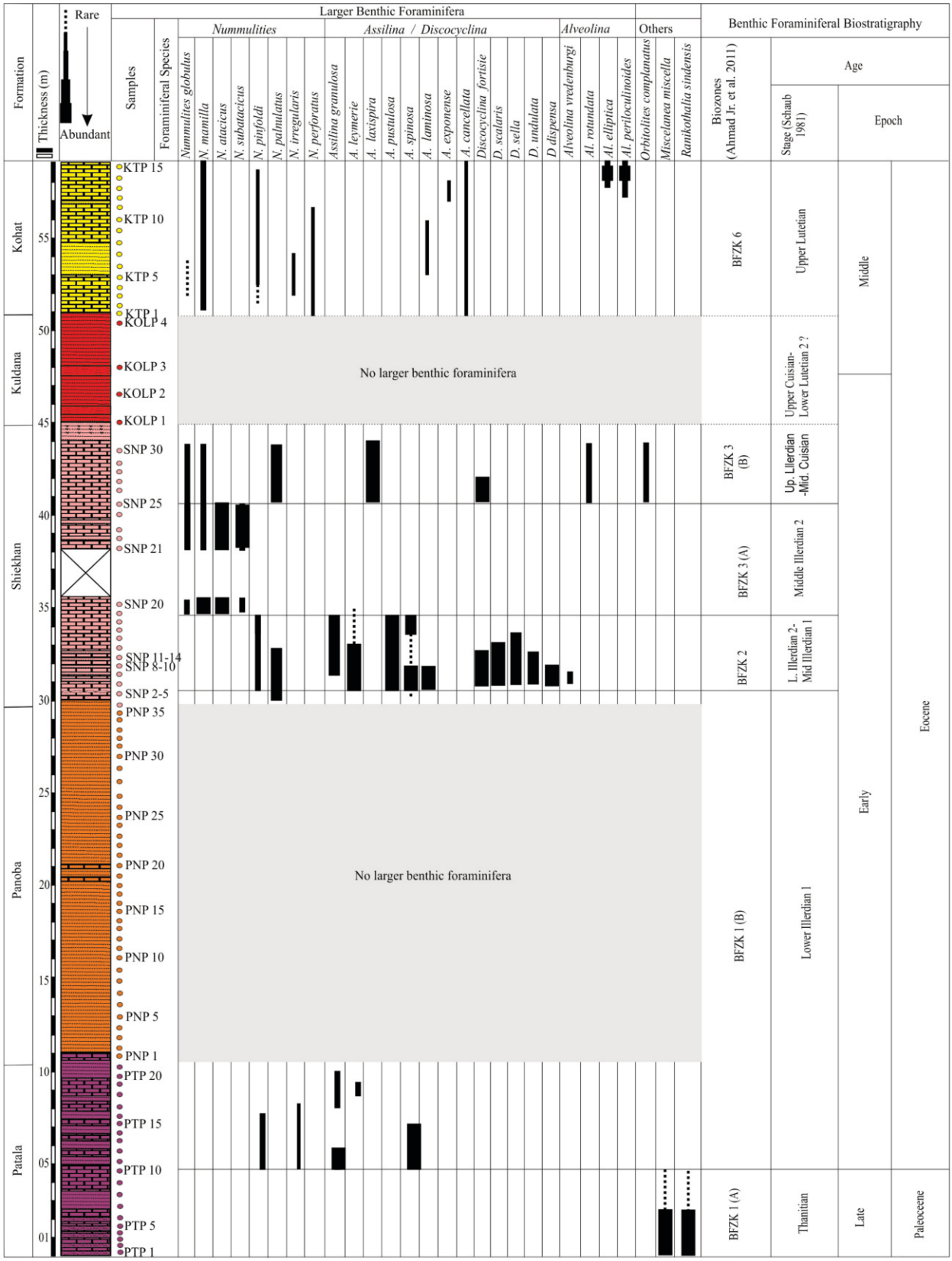

Fig. 2. Range distribution, abundance and larger benthic foraminiferal biostratigraphy of the Eocene succession of the Panoba Nala Section, Kohat Sub-basin, northwest Pakistan.

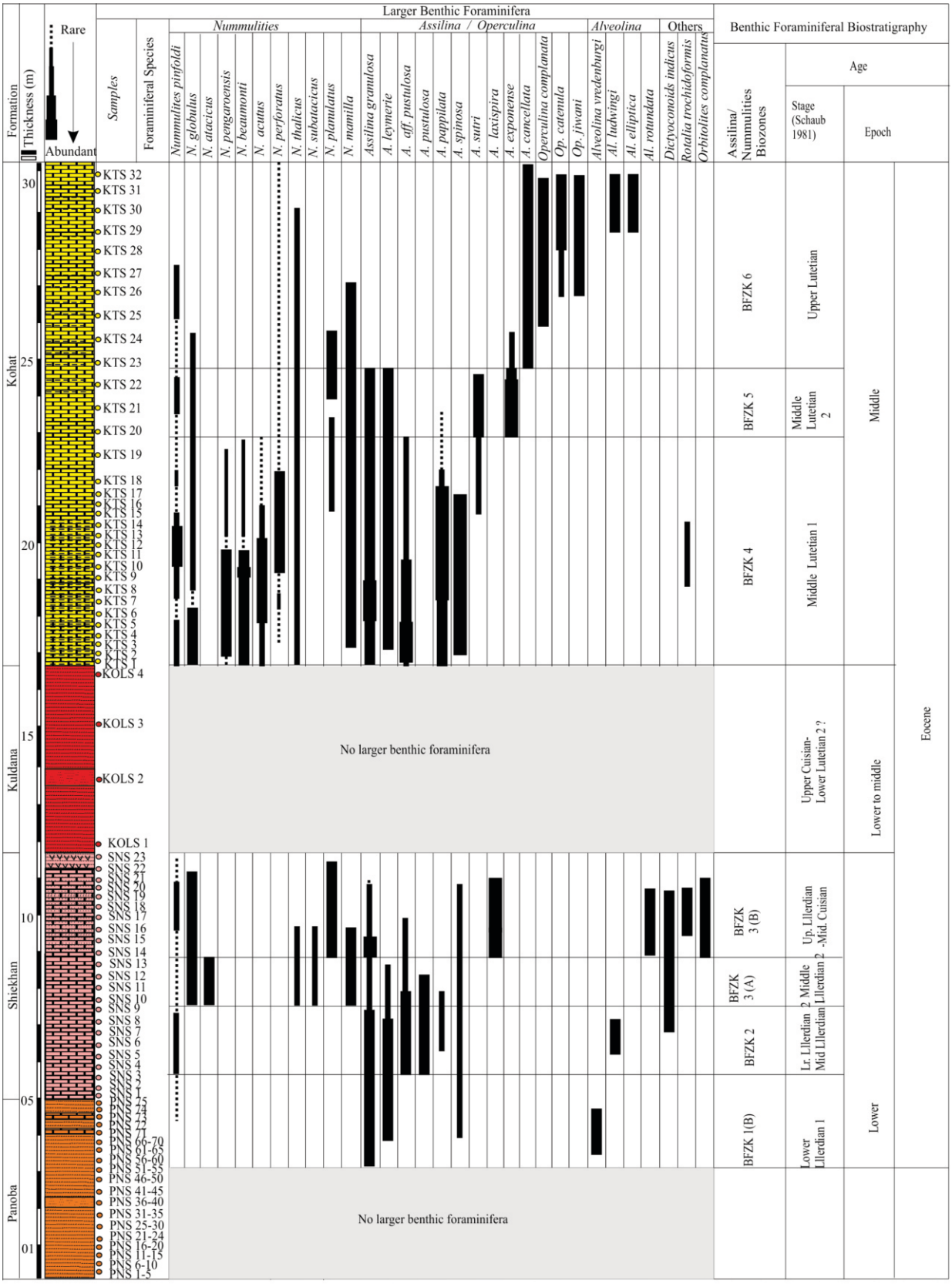

Fig. 3. Range distribution, abundance and larger benthic foraminiferal biostratigraphy of the Eocene succession of the Sheikhan Nala Section, Kohat Sub-basin, northwest Pakistan.

Upper bathyal facies

Important agglutinated foraminifera that characterizes the upper bathyal zone (200-500m) are reported by several workers i.e. Panama Basin (Kaminski et al., 1988), south Caribbean region (Bolli et al., 1994), North Sea (Gradstein and Berggren, 1981; Miller et al., 1982; King, 1983), Polish Carpathians (Unrug, 1979; Koszarski, 1985) and Tromsø Basin southwestern Barents Sea (Nagy et al., 2000). The agglutinated assemblage of *Rhizammina, Bathysiphon* and *Hypermania* are interpreted as reflecting upper to middle bathyal conditions (Nagy et al., 2000). Upper slope (bathyal Zone) assemblages in California were found to be dominated by calcareous genera with the most common agglutinated genera of *Gaudryina, Dorothia, Cribrostomoides, Bathysiphon* and *Spiroplectammina* (Sliter and Baker, 1972).

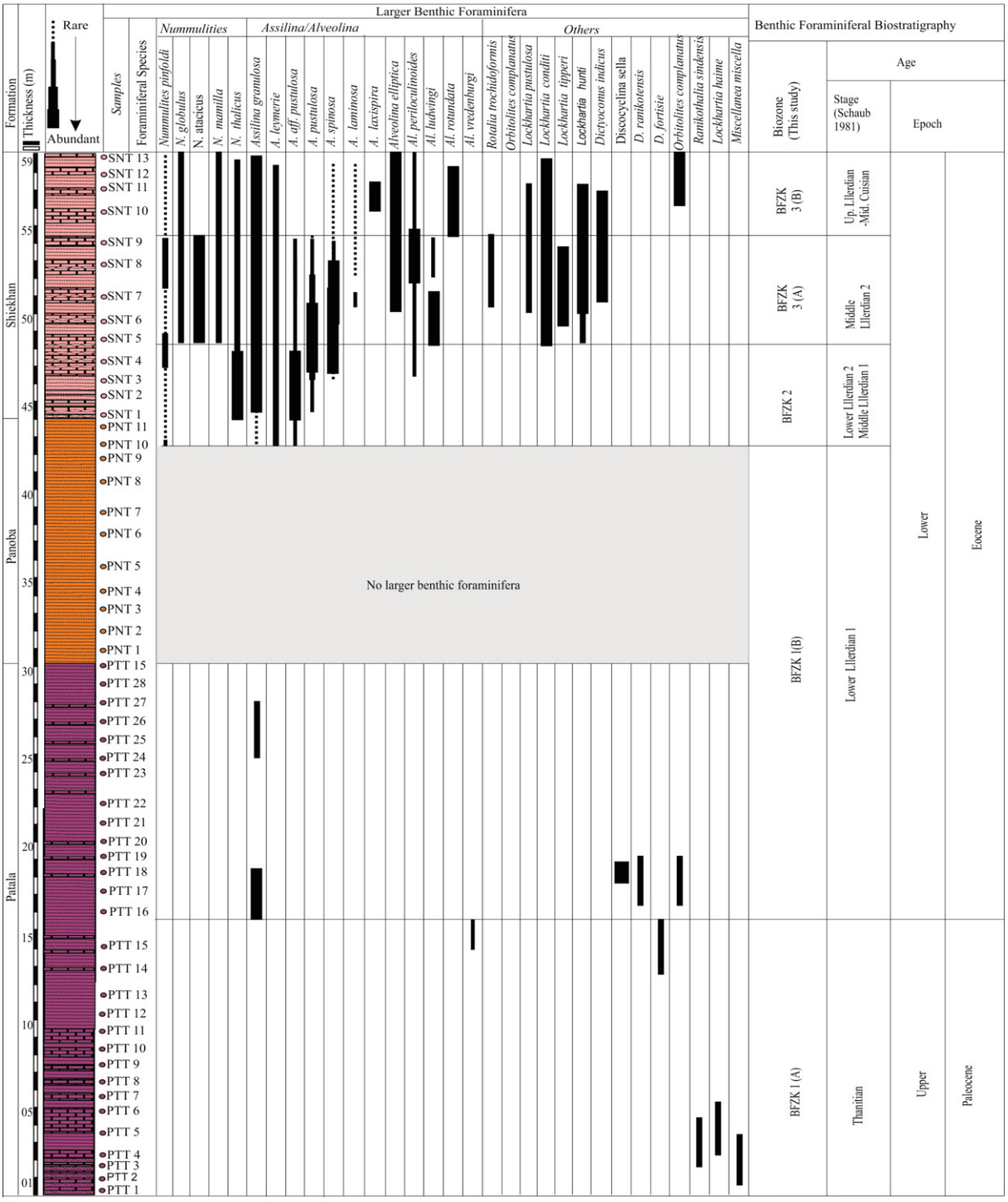

Fig. 4. Range distribution, abundance and larger benthic foraminiferal biostratigraphy of the Eocene succession of the Tarkhobi Nala Section, Kohat Sub-basin, northwest Pakistan.

In this study the upper 12-16m outcrop sample of the Panoba Formation showed a rich variety of flysch type agglutinated foraminifera that include species of *Astrorhizids, Hyperamminids, Verneulinids, Bathysiphonids,* and *Trochamminids.* Redeposited benthic foraminifera of middle to outer neritic environment were also common in the upper bathyal zone that includes species of *Textularids, Bolivinids, Buliminids* and *Polymorphinids.*

The important agglutinated benthic foraminiferal species that characterize the upper bathyal environment include *Bathysiphon eocenicus* Cushman & Hanna, Dendrophyra excelsa Grzybowski, *Gaudryina pyramidata* Cushman, *Trochomania* sp., *Guadryinella pussilla* Magneiz-Jannin, *Hyperammina elongata* Brady and *Conotrochammina cf dispersa* Finaly.

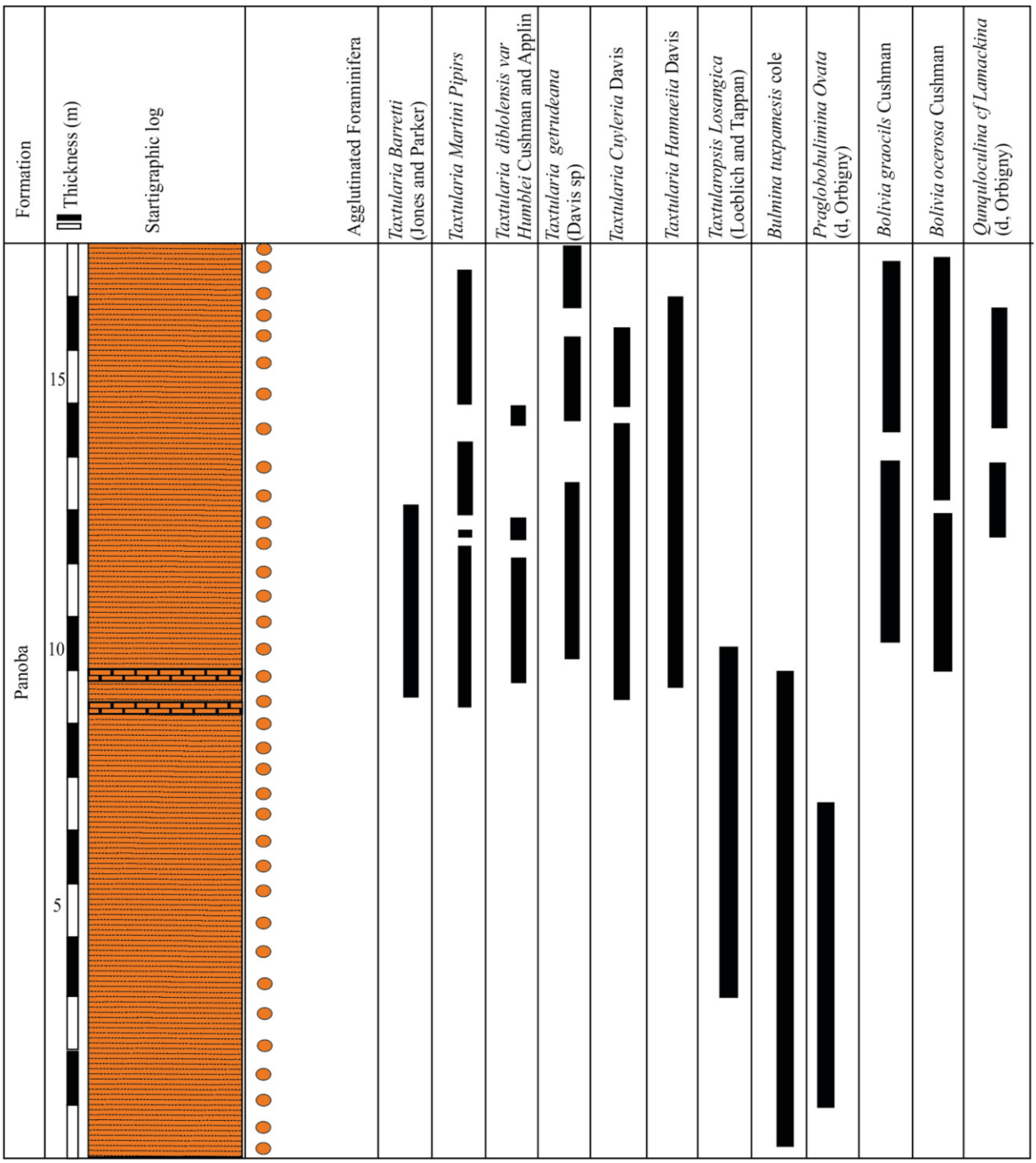

Fig. 4. Range distribution, abundance and larger benthic foraminiferal biostratigraphy of the Eocene succession of the Tarkhobi Nala Section, Kohat Sub-basin, northwest Pakistan.

The upper 2m sample interval from 16-18m again showed decrease in faunal diversity, increase in *Bolivinids, Textularids* and presence of some reworked shallow water larger benthic foraminifera i.e. *Nummulites* and *Milliolids,* representing middle neritic environment of deposition.

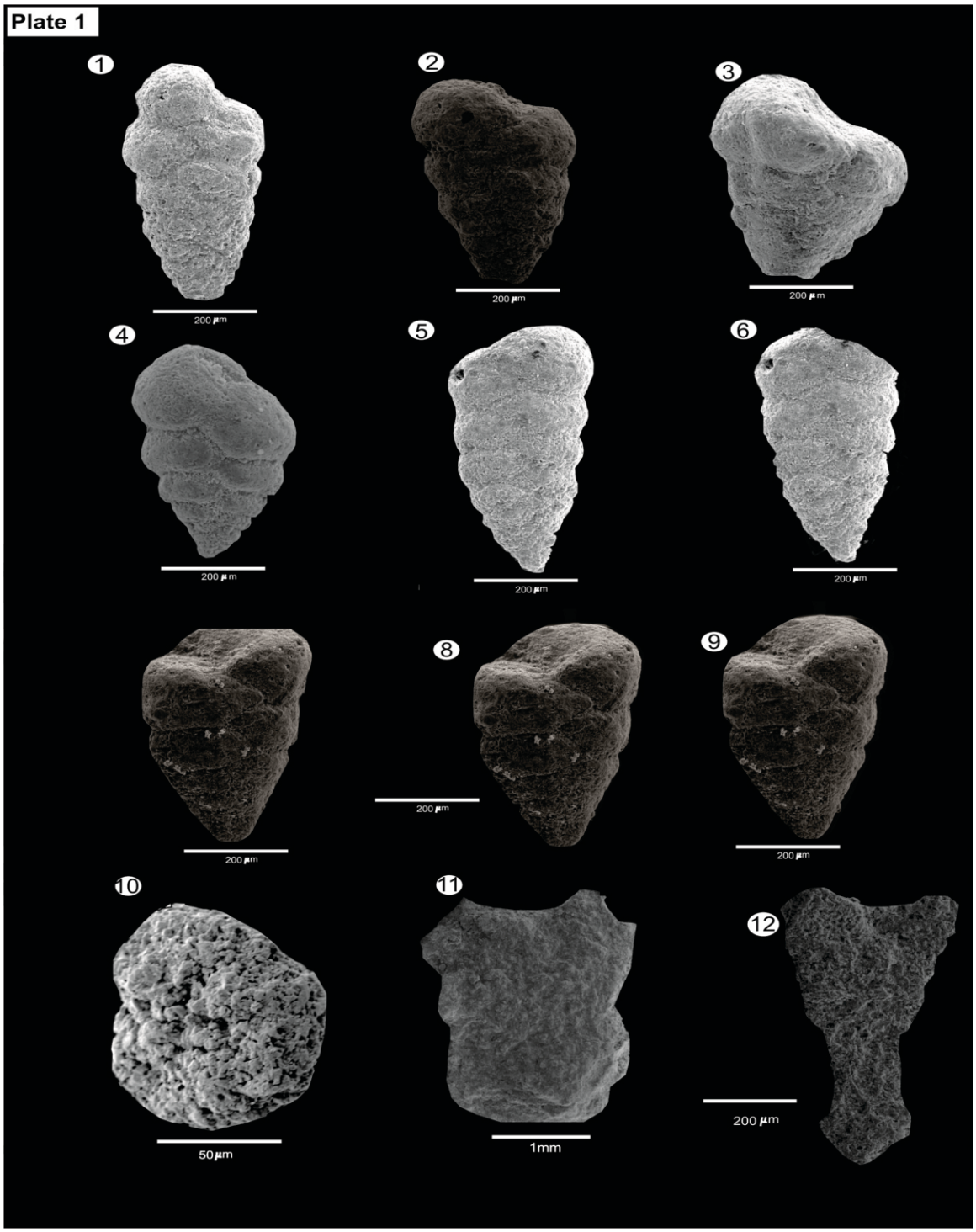

Plate 1. 1:*Textularia dibollensis var humblei* Cushman & Applin (Side view). 2: *Textularia hannai* Davies (Side view). 3:*Textularia cuyleri* Davies (Side view). 4:*Textularia martini* Pijpers (Side view) . 5, 6 :*Textularia gertrudeana* Davies (Side view). 7, 8 and 9:*Textularia barrettii* Jones and Parker (Side view) (1-9, recorded from the Panoba Formation in the Sheikhan Nala Section, north-eastern Kohat Basin, Pakistan). 10:*Conotrochammina cf dispersa* Finlay (recorded from the Panoba Formation in the Panoba Nala Section, north-eastern Kohat Basin, Pakistan). 11:*Bathysiphon eocenicus* Cushman & Hanna (Side view). 12:*Dendrophyra excelsa* Grzybowski) (11-12. recorded from the Panoba Formation in the Sheikhan Nala Section, north-eastern Kohat Basin, Pakistan).

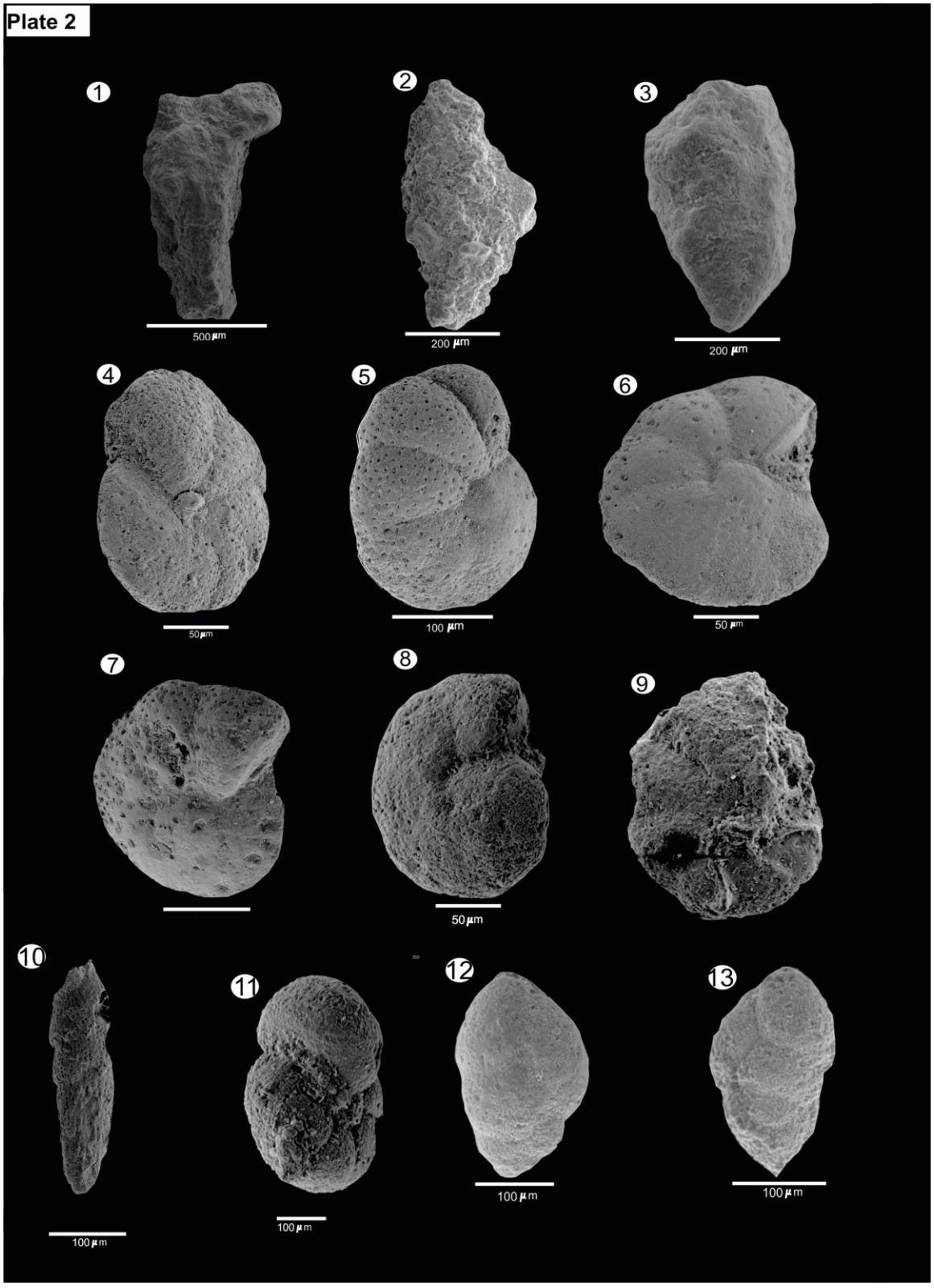

Plate 2. 1:*Hyperammina elongata* Brady. 2:*Guadryinella pussilla* Magneiz-Jannin (1 and 2 recorded from the Panoba Formation in the Panoba Nala Section, north-eastern Kohat Basin, Pakistan) 3:*Gaudryina pyramidata* Cushman. 4:*Cibicides cf simplex* Brotzen. 5:*Cibicides alleni* Plumer. 6:*Cibicides mensilla* (Schwager) var. nammalensis 7:*Cibicides tuxpamensis laxispiralis* Beckmann. 8:*Cibicidoides tuxpamensis tuxpamensis* Cole (3-8, recorded from the Panoba Formation in the Sheikhan Nala Section, north-eastern Kohat Basin, Pakistan). 9:*Gavelinella schloenbachi* Reuss. 10:*Loxostomum applinae* Plumer. 11:*Valvulineria patalaensis.* 12:*Bulimina stokesi* Cushman and Renz. 13:*Uvigerina gallowayi basicordata* Cushman and Renz (9-13, It is recorded from the Panoba Formation in the Panoba Nala Section, north-eastern Kohat Basin).

4. Conclusions

The Panoba Formation from Kohat sub-basin, Indus Basin, Pakistan yield significant smaller benthic foraminifera of the basal Ilerdian age (early Eocene) equivalent to larger benthic foraminiferal zones SBZ 5 & 6 and planktic foraminiferal zones E1 and E2. The foraminiferal assemblage proposes middle neritic to outer bathyal settings for the deposition of Panoba Formation. The time span and depositional depth suggests that the Panoba Formation offers potential sedimentary material for paleoclimatological research on the Paleocene Eocene Thermal Maximum (PETM) or post PETM scenario and on the early Eocene short hyperthermals e.g. EECO. The sedimentary material of the Panoba Formation may yield significant data on events mentioned earlier if evaluated by utilizing an integrated approach (e.g. organic geochemical and stable isotope analysis, abundance data on foraminifera). Though, the material shows some endemism effect which points to a restricted or partially restricted bottom conditions, however information on the surface water circulation may be gained by utilizing either planktic foraminifera or organic walled dinoflagellates.

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