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Miscellaneidae: A biostratigraphic tool for hydrocarbon exploration in Paleocene carbonate platform deposits of Tethys: An example from Upper Indus Basin, Pakistan

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Abstract

The family Miscellaneidae of larger foraminifera is restricted to the Paleocene and earliest Eocene of the Tethyan carbonate platforms.

The two species (*Miscellanea miscella* and *Miscellanea juliettae*) of this family are common in the Paleocene of the Indus Basin. Due to the small size, light ornamentation and thin walls, the *M. juliettae* can be easily distinguished from the *M. miscella*. The *M. juliettae* is restricted to the shallow benthic Zone 3 (SBZ3) and it is the diagnostic larger foraminifera of the hydrocarbon bearing Lockhart Formation in the Upper Indus Basin. However, *M. miscella* almost double of the size of *M. juliettae* and having dense ornamentation and thick walls representing shallow benthic zones 4 and 5 (i.e. SBZ 4 & 5). *M. miscella* commonly occurs in the limestone beds of the Patala Formation, Upper Indus Basin, Pakistan.

Keywords: Paleocene; Eocene; Miscellaneidae; Indus Basin; Lockhart Formation; Patala Formation.

1. Introduction

Production biostratigraphy is the applied aspect of biostratigraphy in hydrocarbon exploration and production. The dating of rock units through biostratigraphy is routinely employed in petroleum exploration. The reservoir-enveloping non-pay stratigraphic units during drilling are finger printed through biostratigraphy; this technique is known as bio-steering. The primary purpose of bio-steering is to maximize reservoir penetration. Some of the case studies utilizing bio-steering technique to resolve problems related to exploration and production are highlighted in Giwa et al. (2006). These include; 1. Determination of the case point in Gorm Field, North Sea, 2. Horizontal drilling through a thin reservoir in Andrew Formation, North Sea and 3. Identification of foraminifera peculiar to reservoir-enveloping shales in Niger Delta, Nigeria. This research is an example from the Indus Basin, Pakistan and the purpose is to emphasize the importance of bio-steering for enhancement of the hydrocarbon exploration and production.

In previous research a number of larger foraminifera are reported from the Paleocene carbonate successions of the Indus Basin (e.g., Haque, 1956; Adams, 1970; White, 1989; Butt, 1991; Afzal, 1997; Sameeni, 1998; Shafique, 2001 and Afzal et al., 2009, 2010). However, *Miscellaneidae* (family of the larger foraminifera), provides a group of index microfossils for Tethyan carbonate platforms (e.g., Serra-Kiel et al., 1998; Höttinger, 1998, 2001, 2009; Scheibner et al., 2005; Scheibner and Speijer, 2009). The *Miscellaneidae* is commonly occurring in the Paleocene of the Indus Basin and provide diagnostic criteria for the recognition of hydrocarbon bearing horizons. This study attempts to provide a biostratigraphic tool for the recognition of the Paleocene platform deposits on surface as well as in the subsurface by providing example from the Lockhart and overlying Patala formations from Upper Indus Basin, Pakistan.

2. Methods and material

In addition to a review of the existing literature (as given in introduction) on the Paleocene larger foraminifera, the Lockhart Formation was logged and sampled in the Western Salt Range. The Patala Formation in Kala Chitta Range contains more

frequent Limestone beds therefore; the limestone samples from the Patala Formation were collected from the Kala Chitta Range (Fig. 1).

This work follows the Miscellaneidae morphology of Höttinger (2009); the terminologies are adopted from the illustrated glossary of Höttinger (2006) that is available on the web.

3. Miscellaneidae family

The two species (i.e., *M. miscella* and *M. juliettae*) of this family of the larger foraminifera are commonly occurring in the Paleocene carbonate successions of the Indus Basin. The adult *M. juliettae* is significantly smaller in size and is about half of the adult *M. miscella* size (Table 1). The *M. juliettae* is diagnostic of the Lockhart Formation and represent the Shallow benthic Zone 3 (SBZ3) of the Serra-Kiel et al. (1998) and Höttinger (2009) (Table 2).

The appearance of *M. miscella* associated with *Discocyclina ranikotensis* and *Ranikothalia sindensis* (appearing in SBZ3) marks the boundary between SBZ3 and SBZ4 and represent SBZ4 and SBZ5. The SBZ4 starts in the top most part of the Lockhart Formation and occurs to the top most part of the Patala Formation (Table - 2). The *Miscellanea miscella* occurs both in SBZ4 and 5, however, Kuss and Leppig (1989) named a form of *Miscellanea miscella* as *M. rhomboidea* and reported that this form is restricted to SBZ4. According to Höttinger (2009), the number of microspheric specimens of *M. rhomboidea* is too small and the meglaospheric specimens exhibit a considerable variability. Therefore, the new name for the SBZ4 *miscella* is not accepted till date and for the time being both species are treated as synonyms with a range of SBZ4-5.

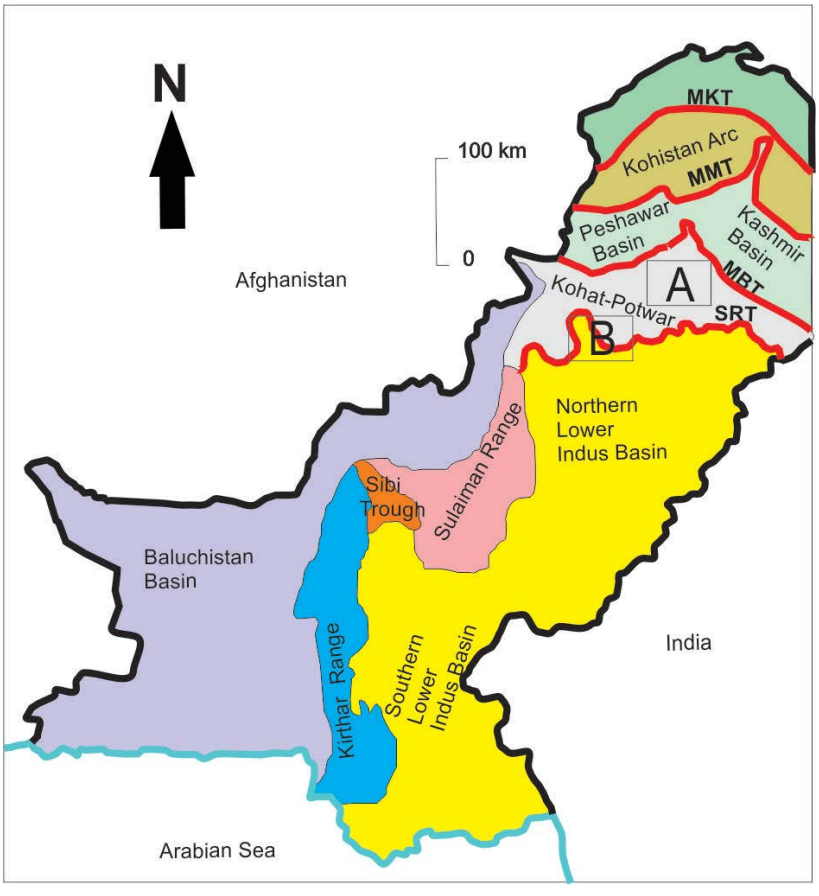

Fig. 1. Geological map of Pakistan showing sample locations (modified after Hanif et al. (in press), A- Kala Chitta Range and B- Western Salt Range, Upper Indus Basin, Pakistan, SRT-Salt Range Thrust, MBT- Main Boundary Thrust.

Table 1. Morphometric data for different specimens of *Miscellanea miscella* and *Miscellanea juliettae* in term of their lengths (L) and widths (W).

Plate references	Dimension	Species	Plate references	Dimension	Species
Plate 3 a	L=750 µm W=210 µm	*Miscellanea miscella*	Plate 4 a	L=450 µm W=180 µm	*Miscellanea juliettae*
Plate 3 b	L=700 µm W=300 µm		Plate 4 b	L=430 µm W=220 µm	
Plate 3 c	L=650 µm W=250 µm		Plate 4 c	L=700 µm W=200 µm	
Plate 3 d	L=1000µm W=400 µm		Plate 4 d	L=450 µm W=250 µm	
Plate 3 e	L=1200 µm W=450 µm		Plate 4 e	L=450 µm W=190 µm	
Plate 3 f	L=700 µm W=300 µm				
Plate 3 g	L=600 µm W=400 µm				
Plate 3 h	L=600 µm W=500 µm				
Plate 3 l	L=210 µm W=210 µm				

Table 2. Distribution of *M. juliettae* and *M. miscella* in Lockhart and Patala formations respectively in Upper Indus Basin, Pakistan (modified for Indus Basin after Höttinger (2009)).

Formation			Miscellaneidae
Lockhart Limestone	Patala Formation		
Shallow Benthic Zonation (SBZ)			
3	4	5	
			Miscellanea miscella
			Miscellanea yvettae
			Miscelanea juliettae

3.1. Miscellanea miscella (Plates 1 & 3)

The shell is lenticular and occurs in both forms (megalospheric and microspheric). Peripheries of the megalospheric form are sharp and unkeeled while those of microspheric form are rounded and covered by number of pustules. Group of heavy piles obscures the structure of the Polar Regions in the megalospheric forms, however in the microspheric forms the peripherial pustules are transformed into slender piles at the poles. The septa visible in the equatorial section are curved and backward inclined. The megalsphere is spherical and the deuteroconch embraces the protoconch in the axial section.

3.2. Miscellanea juliettae (Plates 2 & 4)

The lenticular shells of both microspheric and megalospheric forms of the species occurs in the Lockhart Formation. The megaloshperic embryo is biconch. Peripheries of both forms are sharp. Polar Regions in the megalospheric form are slightly convex while in the microspheric form is slightly depressed.

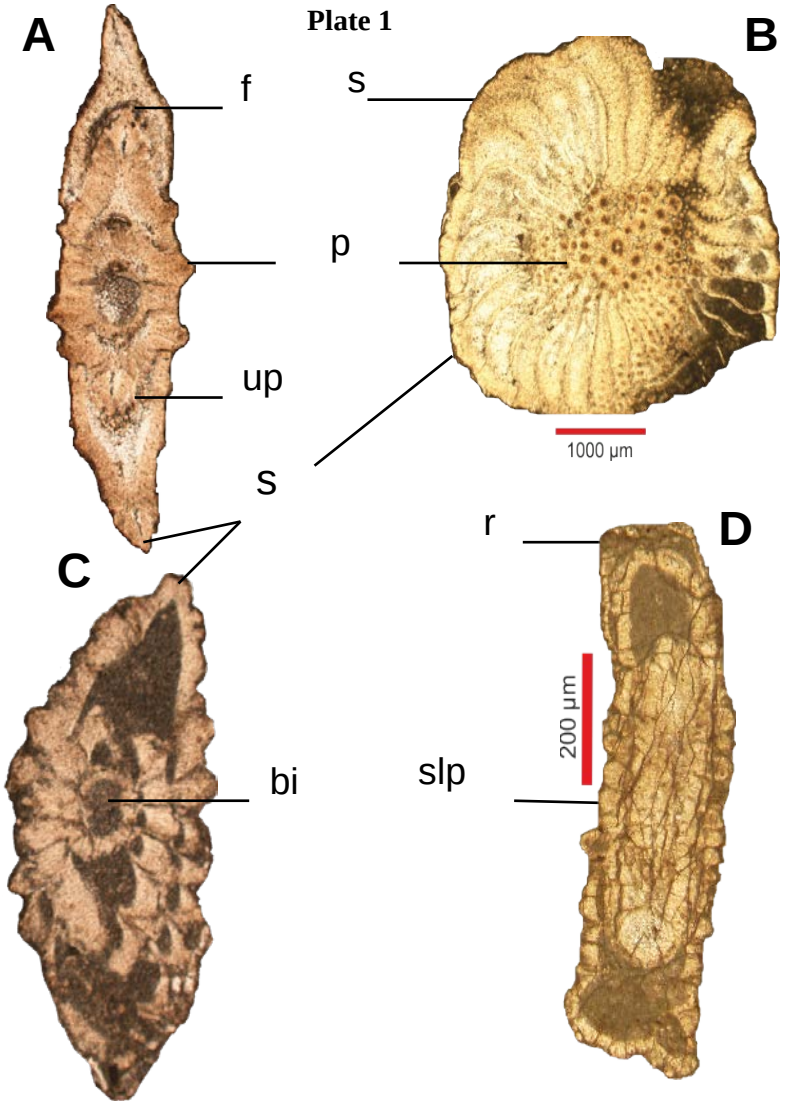

Plate 1. *Miscellanea miscella* (d' ARCHIAC & HAIME, 1853), SBZ4-5, Figs A-C: megalospheric form, Fig. D. microspheric form. Abbreviations: s: septum, f: foramen p: polar area, up: umbilical plate, sp: sharp peripheries, rp: rounded peripheries, slp: slender piles at poles, bic: biconch, wall separating protoconch and deuteroconch, deuteroconch embracing the proloculus (terminologies adopted from Höttinger, 2006), typical heavy ornamentation of *M. miscella* in Figure B.

Plate 2

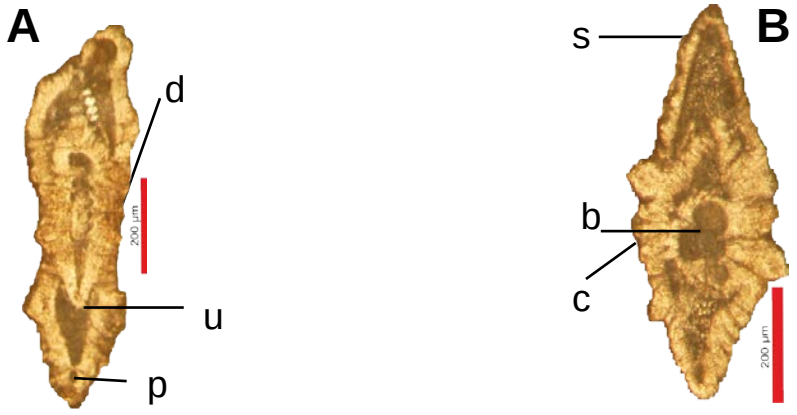

Plate 2. *Miscellanea juliettae* (Leppig, 1988), Fig. A. microspheric form, Fig. B. megalospheric form. Abbreviations: cp: convex poles, dp: depressed poles, up: umbilical plate, pct: peripheral chamber tip, sp: sharp peripheries, bic: biconch, wall separating protoconch and deuteroconch, (terminologies adopted from Höttinger, 2006), scales for figures A and C are the same as for figures B and D.

Plate 3

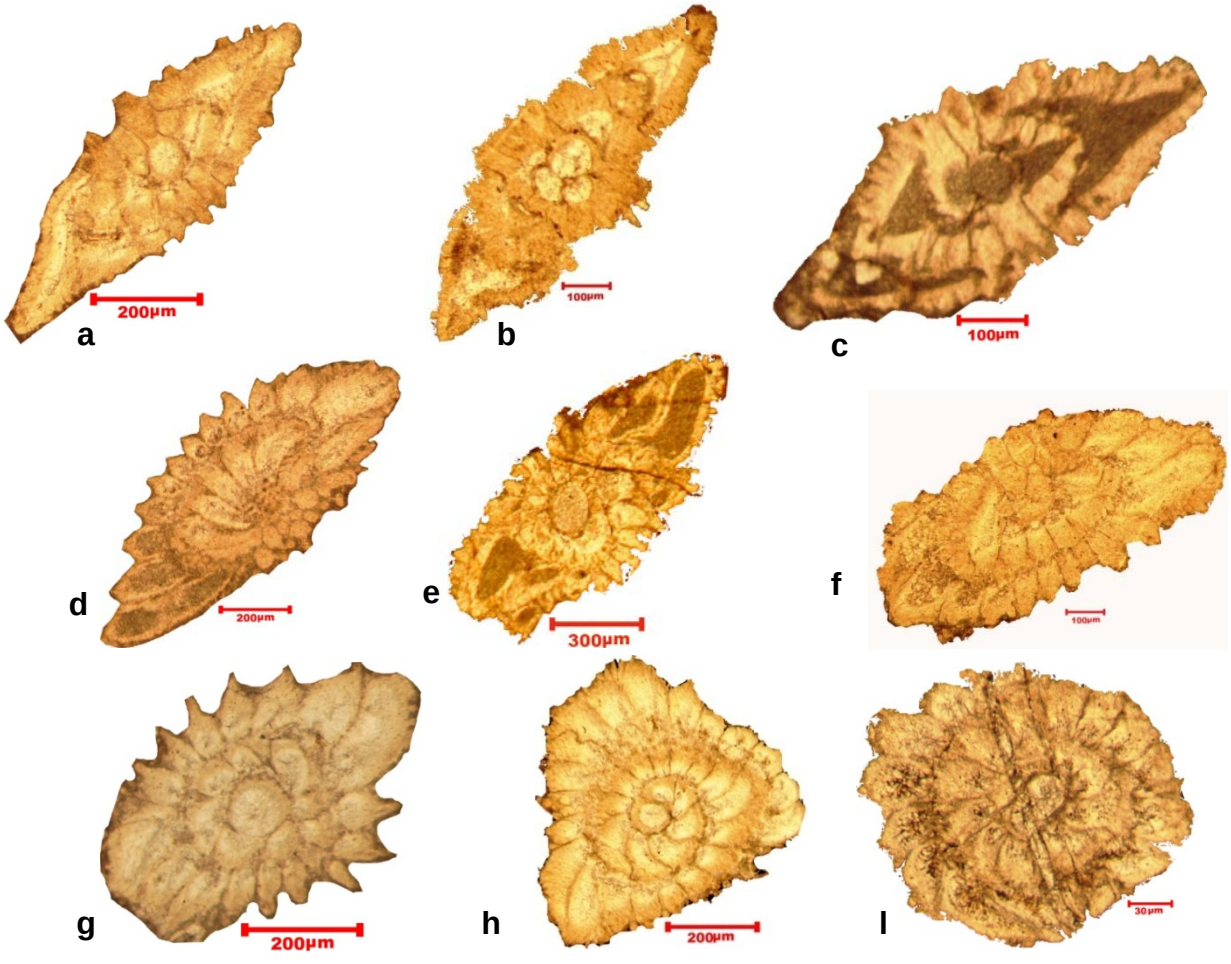

Plate 3. Different views of *Miscellanea miscella*.

Plate 4

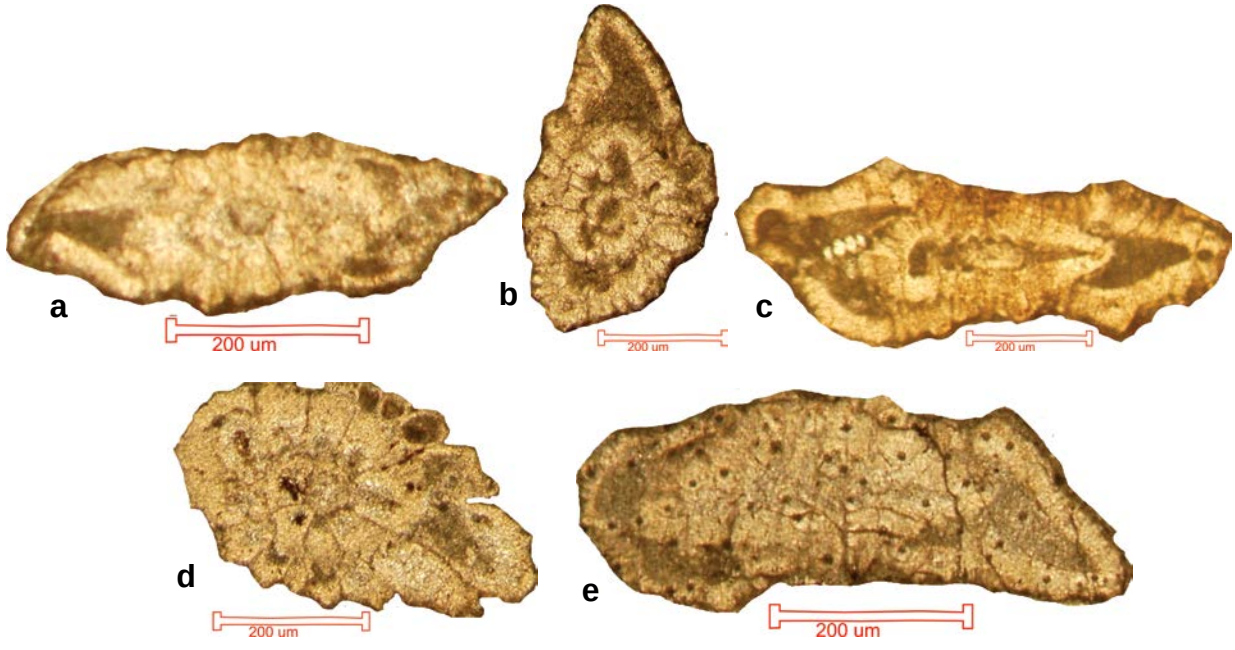

Plate 4. Different views of *Miscellanea juliettae.*

4. Conclusions

Most of the Lockhart Formation occurs within the zone SBZ3 and *M. juliettae* is the diagnostic larger foraminifera for the identification of Lockhart Formation both on surface and in the subsurface in Upper Indus Basin, Pakistan. The appearance of *M. miscella* marks the start of SBZ4 ranging upto SBZ5 and it occurs in the limestone beds of the overlying Patala Formation and is a biostratigraphic marker for Patala Formation both on surface and in subsurface in the Upper Indus Basin, Pakistan.

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