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Foraminiferal Biostratigraphy of the Dungan Formation, Harnai area, western Sulaiman Fold-Thrust Belt, Pakistan

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Abstract

The Dungan Formation at Mehrab Tangai of the Harnai district in the western Sulaiman Fold-Thrust Belt was studied for larger benthic foraminifera. A total of twenty-two species from fourteen different genera were identified suggesting Late Palaeocene SBZ 3-SBZ 4 biozones. The Dungan Formation contains many short ranging taxa with a wide geographic distribution, facilitating correlation across the east to west Tethys. Species that characterize the Late Palaeocene SBZ 3 are *Miscellanea juliettae, Rotalia implumis, Vania anatolica, Glomalveolina primaeva* and *Lockhartia retiata.* Late Palaeocene SBZ 4 is identified by the first appearance of *Miscellanea miscella, Daviesina langhami* and *Discocyclina ranikotensis.* Furthermore, there are many taxa such as *Discocyclina ranikotensis, Rotalia implumis* and *Rotaliconus arachosiae* which are endemic to the eastern Tethys such as India and Pakistan, supporting the non-synchronous evolution taking place in some parts of the eastern Tethys.

Keywords: Foraminifera, Palaeocene, Biostratigraphy, Biozone, Tethys.

1. Introduction

The Sulaiman Fold-Thrust Belt (SFTB) preserves a thick sedimentary succession consisting of marine Triassic to continental Recent rocks (Figs 1, 2; Shah, 2009; Kassi et al., 2009; Afzal et al., 2009). The Triassic to Late Eocene rocks are of marine origin and the overlying younger sedimentary strata have been deposited in a fluvial system, owing to the cessation of marine depositional system due to the closure of the Tethys Sea (Afzal et al., 2009). The Palaeogene strata of the SFTB represent shallow marine carbonates, shallow and deep marine clastics, providing remarkable opportunities for accurate biostratigraphic correlation (Dungan Formation, Ghazij Formation, Kirthar Formation) (Warraich and Natori, 1997; Warraich and Nishi, 2003; Afzal et al., 2009; Ali et al., 2018). Its basal unit is marked by the Palaeocene-Early Eocene Dungan Formation, named after Dungan Hills, situated about 48 km to the southeast of Harnai town (Jones, 1961). The Dungan Formation is represents thick outcrops in both the eastern and western SFTB (Afzal et al., 2009; Shah, 2009). The formation mainly consists of limestone and shales with subordinate marl, siltstone and sandstone. The limestone is light to dark grey in color, medium to thick bedded, massive and nodular in some areas, while shales are olive, dark grey and black (Afzal, 1996; Warraich and Natori, 1997; Afzal et al., 2009, 2011a). In the western SFTB such as Quetta, Ziarat and Marri-Bugti areas, the formation dominantly comprises of limestone, whereas in some parts of the eastern SFTB, such as Rakhi Nala and Zindapir, it is dominantly composed of clastic rocks such as shale, siltstone, and subordinate sandstone and pelagic limestone (Warraich et al., 2000; Kassi et al., 2009; Afzal et al., 2009; Hanif et al., 2014). The Dungan Formation forms an unconformable contact represented by a laterite bed with the underlying Fort Munro Formation in the Quetta and Ziarat areas, whereas in the Mughal Kot, Sanjawi and Siazgi sections the lower contact transitional with the underlying Pab Sandstone (Shah, 2009; Kassi et al., 2009; Afzal et al., 2009). However, in Zindapir and Rakhi Nala the lower contact of the formation is reported to be unconformable with the underlying Pab Sandstone (Warraich and Natori, 1997; Afzal et al., 2011a, 2011b).

The Dungan Formation contains abundant and diverse fossil assemblages such as

molluscs, echinoderms, calcareous algae, dinoflagellates and benthic and planktonic foraminifera (Jones, 1961; Hanif et al., 2014). Among these benthic and planktonic foraminifera are the most diverse, biostratigraphically important and comparatively well studied (Jones, 1961; Afzal, 1996; Warraich et al., 2000). The earliest records of foraminiferal studies from the Dungan Formation dates back to the late nineteenth century and was named as the Alveolina limestone owing to occurrence of the foraminiferal genus *Alveolina* (Griesbach, 1881). Later, many studies reported rich planktonic and benthic foraminiferal assemblages in the eastern and western parts of the Sulaiman Belt, reflecting a wide variation in depositional settings (Williams, 1959; Jones, 1961; Latif, 1964; Samanta, 1973; Afzal, 1996; Warraich et al. 2000; Afzal et al., 2011b; Hanif et al., 2014). In most parts of the eastern SFTB like Zindapir and Rakhi Nala where the formation dominantly consists of clastics, has yielded abundant planktic foraminiferal assemblages and has been dated as Palaeocene to Early Eocene (P3-P7; Latif, 1961, 1964; Samanta, 1973; Afzal, 1996; Warraich et al., 2000). In the western Sulaiman Fold-Thrust Belt (SFTB), sections of Ziarat and Quetta and in some northeastern regions such as Mughal Kot, the dominant lithology of limestone has yielded abundant and diverse larger benthic foraminifera (LBF) (Afzal et al., 2009; 2011a, b). Recently, Afzal et al. (2011a) have studied larger benthic foraminifera (LBF) of the Dungan Formation and have dated the Mughal Kot section as Palaeocene (SBZ 1-SBZ 3), the Zranda section at Ziarat as Late Paleocene to Early Eocene (SBZ 3- SBZ 5/6), whereas the Hanna Lake and Brewery sections at Quetta have yielded fauna of Early Eocene biozones (SBZ 5/6-SBZ8). However, the type section of the Dungan Formation which represents the thickest exposure still lacks a modern biostratigraphic framework after the initial studies mentioned in a preliminary survey report of the Hunting Survey Corporation (Jones, 1961). The aim of this study is to (a) document LBF of the Dungan Formation in the study area (b) establish biostratratigraphic zonation on the basis recovered LBF assemblage.

2. Geological setting

The Sulaiman Fold–Thrust Belt (SFTB) is the north-north eastern part of the Western Pakistan Fold-Thrust Belt (WPFTB) which rims the northwestern edge of Pakistan. In the west it is bounded by the Muslim Bagh-Zhob Ophiolite and Pishin Belt, which are ultimately bounded by the left lateral Chaman Fault, the western most boundary of the Indian Plate (Kasi et al., 2012; Ambraseys and Bilham, 2014; Ul-Hadi et al., 2013, Crupa et al., 2017). In the east the belt is bounded by Sulaiman foredeeps and Indus plain (Fig. 1). The western Sulaiman Fold–Thrust Belt, comprises more than 10 km sedimentary and volcaniclastic succession from Triassic to Pleistocene (Kassi et al., 2009). The tectonics and stratigraphy of the WPFTB are strongly influenced by the collision of the Indian and Eurasian plates (Powell, 1979; Beck et al., 1995; Butler, 1995; Hodges, 2000). The Indian Plate started colliding with the Afghan Block (Eurasian Plate) along its northwestern margin at 65 Ma (Searle et al., 1987; Dewey et al., 1989; Le Pichon et al., 1992; Beck et al., 1995; Rowley, 1996). Since the Palaeocene time, uplift and compression has been episodic, nonetheless, the main phase of deformation and uplift is of Miocene–Pleistocene age and is related to the final collision of the western margin of the Indian Plate with the Afghan Block along the Chaman Fault (Mohadjer et al., 2010; Furuya and Satyabal, 2008).

3. Methodology

The studied section Mehrab Tangai is located about 8 km northeast of Harnai Town (Fig. 2). The formation in this section consists of dark grey color medium to thick bedded limestone. The section was measured and a total of ninety-six limestone samples were collected (Fig. 3). The samples were thin sectioned and the LBF were photographed with a digital camera attached to Olympus microscope (BH-2) in the petrography Lab of the Centre of Excellence in Mineralogy, University of Balochistan, Quetta. The isolation of individual specimens of LBF was not possible due to the hard and indurated nature of limestones.

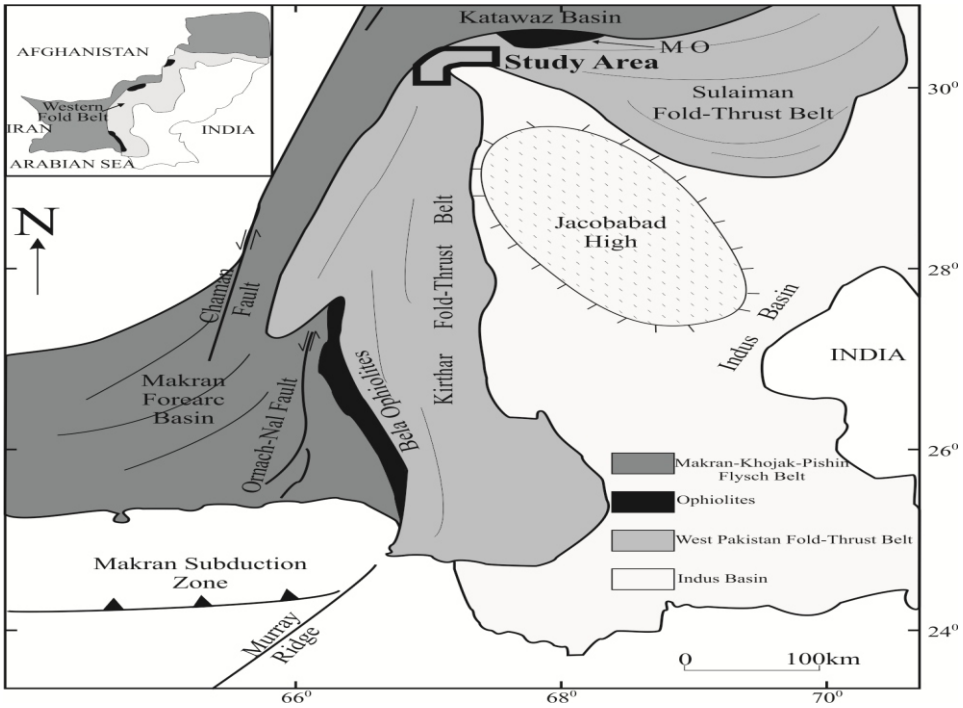

Fig. 1. Map of the Sulaiman-Kirthar Fold-Thrust Belts and surrounding areas showing major tectonic elements of the region. MO represents the Muslim Bagh Ophiolite (after Kasi et al., 2012.)

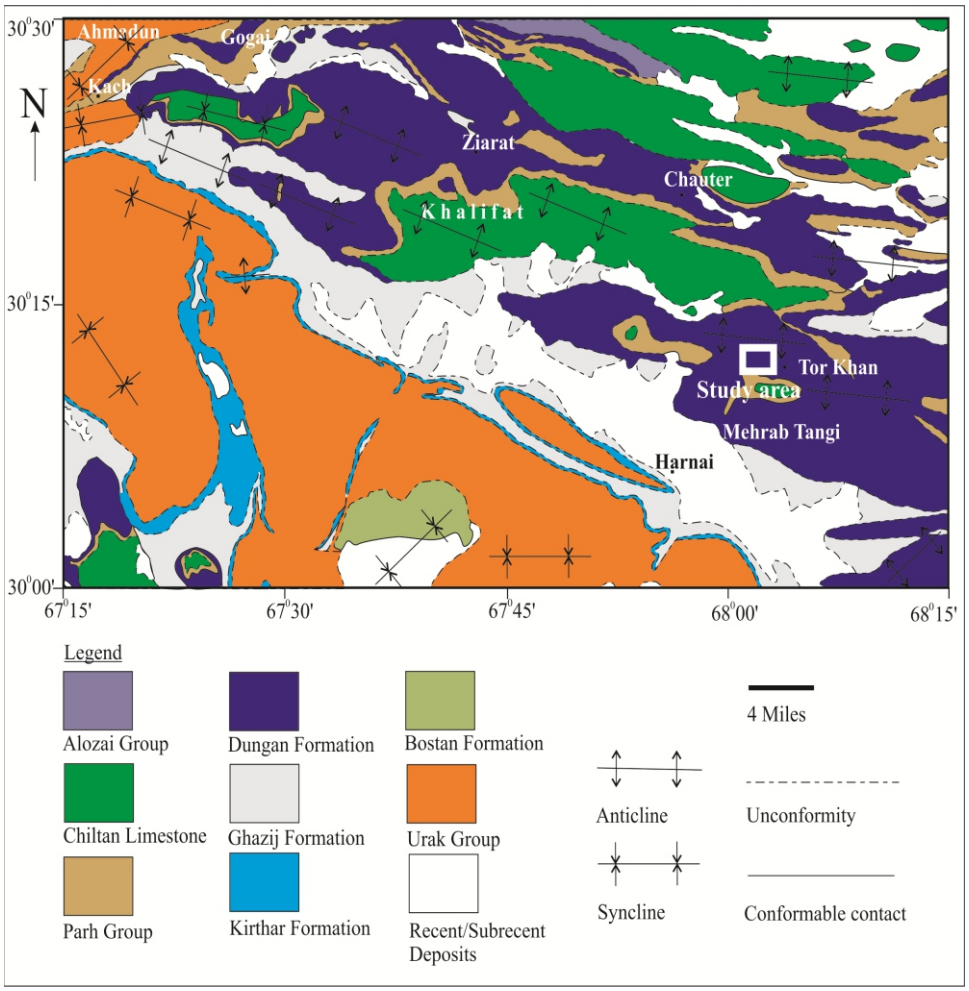

Fig. 2. Geological map of the study area and location of the study area (modified after Jones, 1961).

4. Biostratigraphy

We recognize the Palaeocene LBF biozones SBZ 3-SBZ 4 (Fig. 3). These biostratigraphic zones are recognized on the basis of key biostratigraphic markers and their first and last occurrences. The summary of biostratigraphic markers that demarcate these biozones are given below and the biostrtatigraphic ranges of all taxa are given in figure 3.

SBZ 3 is defined by the stratigraphic ranges of *Miscellanea juliettae, Rotalia implumis, Vania anatolica, Glomalveolina primaeva* and *Lockhartia retiata.* Other associated species which appears first in this zone include *Lockhartia haimei, Lockhartia conditi, Kathina selveri, Rotalia trochidiformis* and *Rotaliconus arachosiae* (see Serra-Kiel et al., 1998; Hottinger, 2009; Hottinger, 2014b, 2014c for stratigraphic ranges). SBZ 4 is identified by the first appearance of *Miscellanea miscella, Discocyclina ranikotensis* and *Daviesina langhami* (see Serra-Kiel et al., 1998; Afzal et al., 2011a; Hottinger, 2009; Hottinger, 2014b, 2014c for stratigraphic ranges).

Tethys-Wide Comparison

Cenozoic Larger Benthic Foraminifera (LBF) are widely used in dating shallow marine sediments owing to their high diversity, abundance, broad geographic and short stratigraphic ranges (Cahuzac and Poignat, 1997; Serra-Kiel et al., 1998; Zhang et al., 2013; Hottinger, 2014a). Extensive studies on LBF in the European and Mediterranean realm and in some parts of the eastern Tethys (Pakistan and India) in the second half of twentieth century has generated enough data for the recognition of twenty standard Shallow Benthic Zones (SBZ) for the Palaeocene-Eocene (Hottinger, 1960; Hottinger et al., 1964; Schaub, 1981; Hottinger and Drobne, 1988; Serra-Kiel et al., 1998). Although these zonation schemes are mainly based on faunal ranges of the western Tethys, they still provide an excellent base for the correlation of larger foraminifera across the Tethys, as these standard zones are in turn correlated with the planktonic (P1-P18) and nanofossil zones (NP-NP21; Martini, 1971; Berggren et al., 1995). The most recent studies in the last three decades in various parts of eastern Tethys have revealed faunal differences with the western Tethys, particularly in the Late Palaeocene to Early Eocene interval indicating the non-synchronous evolution of LBF in different parts of Tethys (Butt, 1991; Weiss, 1993; Jauhri, 1998; Afzal et al., 2009, 2011a, b; Zhang et al., 2013). However, there are still many common taxa which can be used to correlate strata across the whole Tethyan region (Afzal et al., 2011a). Here, we have compared the LBF of the Dungan Formation of the SFTB, Harnai area with those documented from different Tethyan regions.

Some species in the recovered assemblage such *Miscellanea juliettae* and *Glomalveolina primaeva* that characterize the SBZ 3 Biozone have a wide geographic distribution in both the eastern and western Tethys (Figs 3, 4). *Miscellanea juliettae* is documented from the SBZ 3 horizon of northwestern Spain, Pakistan, Iran, eastern Oman and Turkey (Bizon et al., 1972; Leppig, 1988; Sirel, 1998; Akhtar and Butt, 1999; Özcan et al., 2001; Hottinger. 2009; Afzal et al., 2011a; Serra-Kiel et al., 2016). *Glomalveolina primaeva* is found in association with other characteristic species of the SBZ 3 Biozone which is a similar stratigraphic range given by Hottinger (1960), Serra-Kiel et al. (1998), Özcan et al., 2001; Pignatti et al., (2008), Scheibner and Speijer (2009) and Zamagni et al., (2012). However, Afzal et al., (2011a) has extended its range to the lower part of SBZ 4. *Lockhartia retiata* is considered by Hottinger (2014b) to be restricted to SBZ 3 and is documented from Saudi Arabia, Qatar, northern Iran and southern France (Smout, 1954; Sander, 1962; 2012; Rahaghi, 1978, 1983; Hottinger, 2014b). However, Serra-Kiel et al., (2016), Zhang et al., (2013) and Kahsnitz et al., (2016) have extended their range downward to SBZ 2. *Vania anatolica* is documented from Turkey, Algeria and Pakistan and so far no study has documented its occurrence in any strata younger or older than SBZ 3 (Sirel and Gunduz, 1985; Özcan et al., 2001; Belkhodja and Bignot, 2004; Afzal et al., 2011a). Rotalia implumis is previously documented from the SBZ 3 interval of the Hangu Formation from

Pakistan but Zhang et al., (2013) has plotted its range from SBZ 2-SBZ 4 in the Tibetan region (Hottinger, 2014c). Idalina sinjarica is a cosmopolitan species, reported from SBZ 2 of the Indopacific and Carribean region and SBZ 2 to SBZ 6 of the Tethyan region (Drobne et al., 2002; Afzal et al., 2011a) but in studied section it is found only in SBZ 3. *Lockhartia haimei, Lockhartia* conditi and *Kathina selveri* are found in SBZ 3-SBZ 4 in the studied section which is coincident with the stratigraphic ranges documented by various authors (Figs 3, 4; Serra-Kiel et al., 1998; Afzal et al., 2011a; Serra-Kiel et al., 2016; Kahsnitz et al., 2016; Hottinger et al., 2014b, d). *L. haimei* and *L. conditi* are common in the Eastern and Central Tethys and the most recent studies have plotted their stratigraphic range as SBZ 3-SBZ 5 (Afzal et al., 2011a; Kahsnitz et al., 2016). *Rotalia trochidiformis* appears first in SBZ 3 and is a long-ranging species, documented from the Early and Middle Eocene (Afzal et al., 2011a; Bukhari et al., 2016). *Rotaliconus arachosiae* is documented from the SBZ 4 horizon of the Zhob Valley in Pakistan (Hottinger, 2014e), whereas in the studied section it is also found in SBZ 3, in association with the typical SBZ 3 species such as *Glomalveolina primaeva* and *Vania anatolica. Daviesina langhami* appears first in SBZ 4 and ranges to SBZ 8 and is documented from Saudi Arabia, Qatar, Iran, Pakistan and south Tibet, China (Smout, 1954; Rahaghi, 1983; Hasson, 1985; Hottinger, 2009, 2014f). *Miscellanea miscellea* ranges to SBZ 7 and is documented from Pakistan, India, Afghanistan, Iran, Egypt, France and Turkey (Rahaghi, 1983; Sirel, 1998; Jauhri, 1998; Jauhri and Agarwal, 2001; Jauhri et al., 2006; Hottinger, 2009; Afzal et al., 2011a).

Discocyclina ranikotensis appears first in SBZ 4, continues into the Early Eocene and is endemic to the Indian subcontinent (Samanta, 1969; Afzal et al., 2011a).

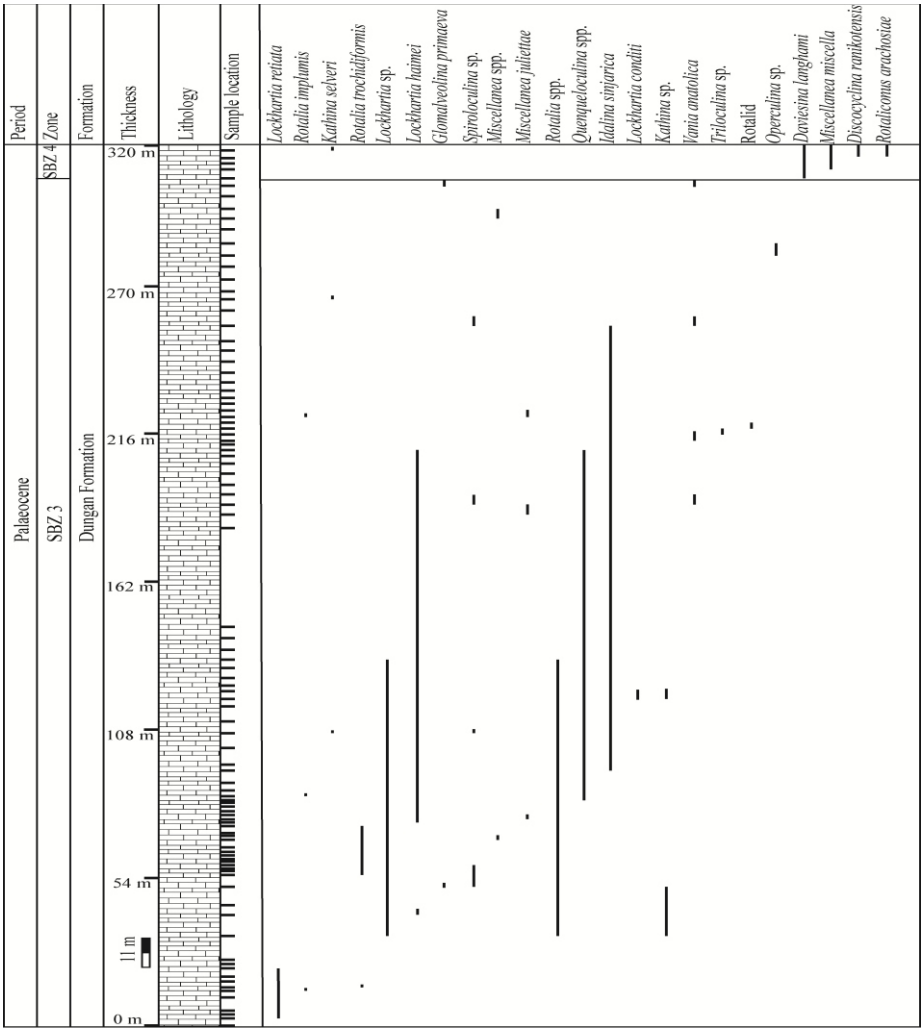

Fig. 3. Biostratigraphic column and species stratigraphic ranges of LBF of the Dungan Formation, Mehrab Tangai, Harnai.

Fig. 1. Fig. 4. Photomicrographs of Larger Benthic Foraminifera of the Dungan Formation at Mehrab Tangai, Harnai. 1-2: *Daviesina langhami,* 1; sample HD-92, 2; sample HD-96. 3: *Discoycylina ranikotensis,* sample HD-95. 4: *Operculina* sp., sample HD-85. 5: *Miscellanea* sp., sample HD-26. 6-7: *Glomalveolina primaeva,* 6; sample HD-91, 7; sample HD-16. 8-9: *Idalina sinjarica,* 8; sample HD-6, 9; sample HD-40. 10-11: *Kathina* sp., 10; sample HD-13, 11; sample HD-16. 12-13: *Kathina selveri,* 12; sample HD-7, 13; sample HD-96. 14-15: *Lockhartia retiata,* 14; sample HD- 5, 15; sample HD-10. 16-17: *Lockhartia haimei,* 16; sample HD-30, 17; sample HD-46. 18-19: *Lockhartia* sp., 18; sample HD-29, 19; sample HD-54. 20-21: *Rotaliconus arachoisae,* 20; sample HD-95, 21; sample HD-96. 22-23: *Miscellanea miscellea,* 22; sample HD-96, 23; sample HD-93. 24-25: *Miscellanea julittae,* 24; sample HD-56, 25; sample HD-60. 26-27: *Spiroloculina* sp., 26; sample HD-16, 27; sample HD-57. 28-29: *Quinqueloculina* sp., 28; sample HD-43, 29; sample HD-55. 30-31: *Rotalia implumis,* 30; sample HD-6, 31; sample HD-37. 32-33: *Rotalia* sp., 32; sample HD-50, 33; sample HD-31. 34-35: *Rotallia trochidiformis,* 34; sample HD-29, 35; sample HD-17. 36: Rotalid, sample HD-67. 37: *Triloculina* sp., 37; sample HD-66. 38-39: *Vania anatolica,* 38; sample HD-57, 39; sample HD-91. Scale bar for all images is 200 μm.

5. Conclusions

The Dungan Formation at Mehrab Tangai of the Harnai district has yielded rich larger benthic foraminiferal assemblages suggesting a Late Palaocene (SBZ 3-SBZ 4) age. SBZ 3 is recognized by the stratigraphic ranges of *Miscellanea juliettae, Vania anatolica, Glomalveolina primaeva, Rotalia implumis* and *Lockhartia retiata.* The boundary between SBZ 3 and SBZ 4 is marked by the first appearance of *Daviesina langhami, Miscellanea miscella* and *Discocyclina ranikotensis*. The Dungan Formation assemblage contains many taxa such as *Discocyclina ranikotensis, Rotalia implumis* and *Rotaliconus arachosiae* which are restricted to eastern Tethyan region suggesting a non-synchronous evolution in this part of the Tethyan Ocean.

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