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Foraminiferal Biostratigraphy of the Eocene Kirthar Formation, western Sulaiman Fold-Thrust Belt, Balochistan, Pakistan

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Abstract

Kirthar Formation outcrops in the Quetta District in the western Sulaiman Fold-Thrust Belt has yielded rich and moderately diverse larger benthic foraminifera (LBF), comprising of thirty species from twenty-three different genera. On the basis of these identified assemblages, three Tethyan shallow benthic zones (SBZ 18- SBZ 20) spanning late Middle to Late Eocene are recognized. The SBZ 18 is characterized by the appearance of *Pellatispira madaraszi, Nummulites striatus, Borelis vonderschmitti* and species of *Alveolina* and *Heterostegina.* The boundary between Middle and Late Eocene is recognized by the appearance of *Nummulites fabianii* and *Spiroclypeus.* Fauna of the Kirthar Formation show some similarities to the West Tethys and other parts of eastern Tethys, facilitating a wide geographic stratigraphic correlation.

Keywords: Biostratigraphy; Larger benthic foraminifera; Biozone; Tethys; *Nummulites.*

1. Introduction

The Sulaiman Fold-Thrust Belt (SFTB) in the western Pakistan, consists of thick sedimentary succession from Triassic to Pleistocene (Figs 1, 2; Kassi et al., 2009; Afzal et al., 2009). The Triassic to Eocene rocks represents marine sedimentary strata, whereas the overlying younger rocks have been deposited in a fluvial depositional setting (Kassi et al., 2009). Among the marine sedimentary rocks, the Kirthar Formation represents the youngest marine sedimentary strata in the western SFTB (Fig. 2). The formation is named after Kirthar Range and the section near Gaj River in Dadu District is designated as its type section. The formation is outcropped throughout the Kirthar Fold-Thrust Belt (KFTB) and a greater part of the SFTB (Shah, 2009; Jones, 1961; Oldham, 1890). The formation dominantly comprises of limestone but also has some shales in some areas in the uppermost part. Limestone is chalky white, cream, medium to thick bedded, massive and nodular in some places whereas the shales are greenish grey, orange yellow, grey and olive in color (Shah, 2009). The thickest outcrops of the Kirthar Formation are documented from the Kalat Plateau where its maximum thickness is about 1829 m, whereas it is 1270 m thick in the type section and 300 m in the Spintangi area of the Harnai District (Shah, 2009). The Kirthar Formation has a conformable lower contact either with the Ghazij Formation or Laki Formation. The upper contact is unconformable either with the overlying Nagri Formation of the Siwaliks Group in the SFTB or with the Nari Formation in the KFTB (Shah, 2009).

Kirthar Formation is documented to contain rich and diverse fossil assemblages including molluscs, echinoids, algae and planktonic and benthic foraminifera (Jones, 1961; Cheema et al., 1977; Afzal et al., 1997; Warraich and Natori, 1997; Shah, 2009). Foraminifera represents rich and diverse faunal assemblages of the Kirthar Formation but only few studies have been conducted in the western part of the Sulaiman Belt despite its thick and widely extended outcrops in both the Sulaiman and Kirthar belts (Jones, 1961; Usmani et al., 2008; Shah, 2009). The earliest records of foraminifera of the Kirthar Formation dates back to late nineteenth and early twentieth century but later only few pilot studies have documented foraminifera (Blanford, 1876; Noetling, 1903; Vredenburg, 1906). A reconnaissance Survey Report of the Hunting Survey Corporation (HSC) has considered the

Kirthar Formation as Early Eocene-Oligocene in the KFTB and some parts of southern Balochistan. However, the section in the Spintangai Gorge of the SFTB has been dated Early to Middle Eocene (Jones, 1961). The Eocene assemblage the HSC comprises of species of *Actinocyclina alticostata, Assilina irregularis, A. cancellata, A. rota, A. laminosa, Nummulites beaumonti, N. gizhensis, Dictyoconoides cooki, D. vredenburgi,* and *Coskinlina balsilliei* etc., whereas the Oligocene assemblage comprises of some index species such as *Nummulites fichteli, N. intermedius* and *Lepidocyclina dilatala* etc. Recently Usmani et al., (2008) has documented forty-three species of benthic and planktic foraminifera from southern Sindh and has dated the formation as Middle Eocene to Lower Oligocene. However, in the western SFTB foraminifera of the Kirthar Formation has not been studied for more than fifty years after the initial pilot studies of Blanford (1876), Noetling (1903) and Jones (1961). Here, in this paper we aim to (a) document larger foraminifera of the Kirthar Formation in the study area, (b) establish biostratigraphic zonation, and (c) to compare our foraminiferal assemblages with the contemporaneous assemblages from other parts of the Tethys.

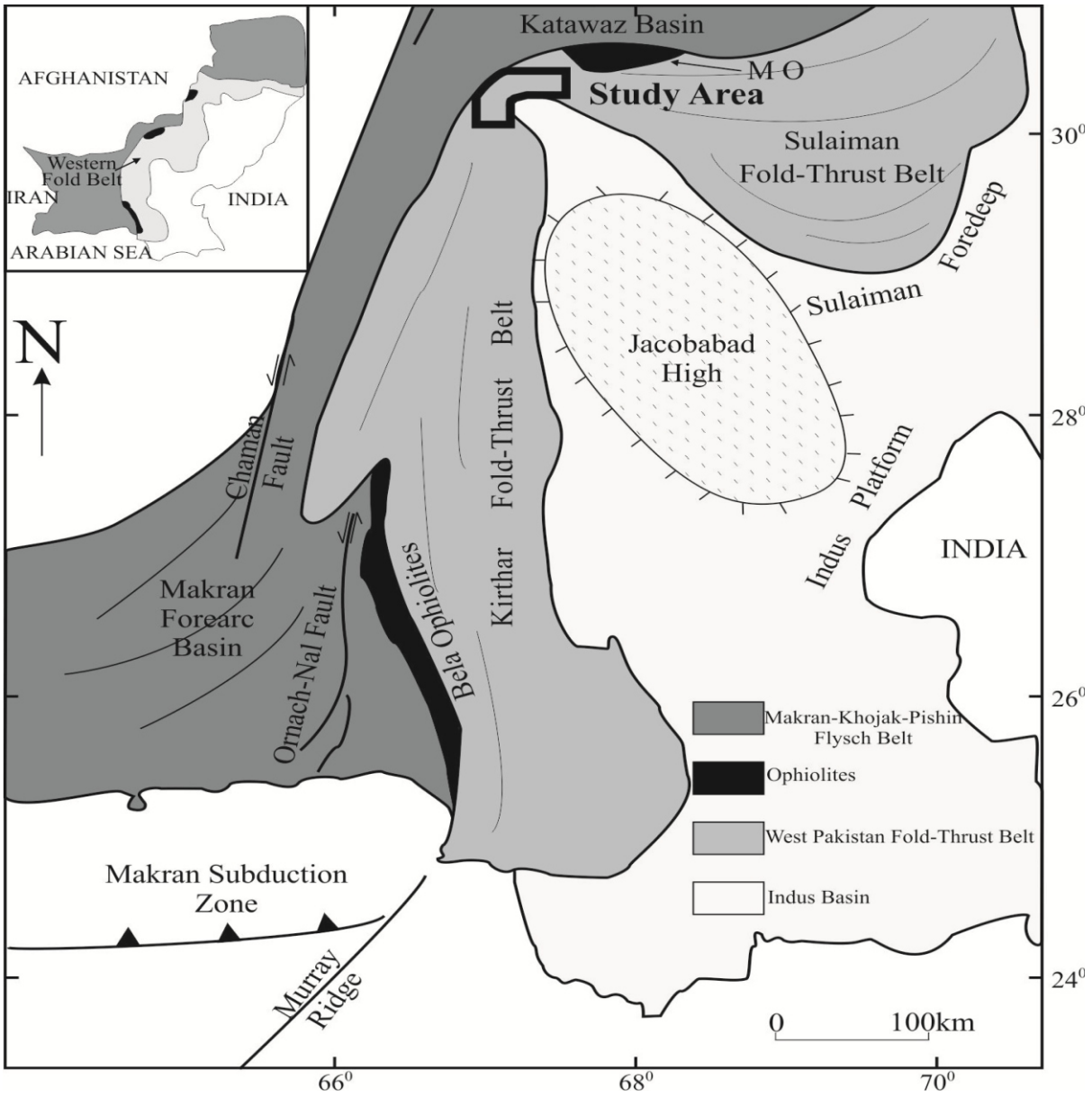

Fig. 1. Map of the Sulaiman-Kirthar fold-thrust belts and surrounding areas showing major tectonic elements of the region. MO represents Muslim Bagh Ophiolite (after Kasi et al., 2012).

2. Geological Setting

The Sulaiman Fold–Thrust Belt (SFTB) is a part of the western Pakistan fold and thrust belt and occupies the northwestern edge of Pakistan. It is the south-southwest extension of the Himalayan Belt of Pakistan (Bannert et al., 1992; Jadoon et al., 1994a; Bender and Raza, 1995; Jadoon and Khurshid, 1996; Kazmi and Jan, 1997). In the west, it is bounded by the Zhob Valley ophiolites and Pishin Belt, which are ultimately bounded by Chaman-Nushki Fault, the western transform boundary of the Indian Plate (Kasi et al., 2012; Ambraseys and Bilham, 2014; Ul-Hadi et al., 2013; Crupa et al., 2017), and in the east the belt is bounded by Sulaiman foredeep and Indus plain (Fig. 1). The study area lies in the western part of the SFTB, which consists of sedimentary and volcanogenic succession from Triassic to Pleistocene (Kassi et al., 2009) exposed in a chain of EW and ENE–WSW trending folds and thrusts (Jadoon et al., 1994b). The tectonic history and stratigraphic framework of the region are greatly influenced by collision of the Indo-Pakistan and Asian plates (Powell, 1979; Beck et al., 1995; Butler, 1995; Hodges, 2000). The marine sediments of SFTB started depositing in Neo-Tethys on the western passive margin of the Indian Plate before and after its separation from the Afro–Arabian plate in early Late Jurassic (Durrani et al., 2012). During the pre-rift, rift and drift phases of this margin, about 10 km thick sediments had been deposited on passive margin of the Indian Plate (Jones, 1961; Hemphill and Kidwai, 1973).

3. Methodology

For lithostratigraphic nomenclature of Mesozoic and Cenozoic we have used the terminology of Afzal et al., (2009) and Shah (2009). Two widely spaced outcrops of the Kirthar Formation in the Quetta area were measured and 53 rock samples were collected. Rock samples were made into thin sections (2.5 x 5 cm) and the larger benthic foraminifera (LBF) were photographed with a digital camera C-35AD-2 attached to Olympus Microscope BH-2 in the Centre of Excellence in Mineralogy, University of Balochistan, Quetta. This study is based on random sections of larger foraminifera as the solid specimens could not be obtained from hard indurated limestones. For biostratigraphy, the Shallow Benthic Zonation (SBZ) scheme of Serra-Kiel et al. (1998) are followed.

Studied Sections

Shingloona Kach Section

This section is located near Shingloona Village (N 30° 16′ 022″ E 67° 08′ 812″), about 30 km north of Quetta City (Fig. 2). The exposed sedimentary succession in this area ranges from Early Eocene to Pleisteonce. The Eocene Kirthar Formation in this section is 116 m thick, consisting of medium to thick bedded limestone, having wackestone to packstone. A total of 33 samples at about 1-3 m interval were collected.

Sarangzai Tangai Section

The Sarangzai Tangai section is located near Urak Village (N30° 16′ 16″ E67° 09′ 05″), about 25 km northeast of Quetta City (Fig. 2). The outcrops in this area range from Jurassic to Recent. Here, the Eocene Kirthar Formation is 99 m thick, consisting of medium to thick bedded limestone. The limestone has a packstone to wackestone texture. A total of 20 rock samples have been collected at about 1-3 m interval except the middle part of the section which is inaccessible (Fig. 4).

4. Biostratigraphy

Three Larger Benthonic Foraminiferal Biozones SBZ18–SBZ20 of Middle–Late Eocene are recognized. These biozones are recognized on the basis of one or more fundamental biostratigraphic markers and their first and last occurrences (Figs 3-4).

The SBZ 18 is identified by the first appearance of *Pellatispira madaraszi, Nummulites striatus, Borelis vonderschmitti* and species of Heterostegina, Pellatispira and *Alveolina* sp. (Figs 3-5). Other associated species in this zone include *Asterigerina rotula, Linderina, Medocia blayensis, Meghalayana indica* and species of *Peneroplis, Pyrgo, Quinqueloculina, Sphaerogypsina, Calcarina, Linderina, Operculina, Silvestriella tetraedra, Asterocyclina, Orbitolites, Glomalveolina, Nummulites, Discocyclina* and some rotalids (Fig. 5).

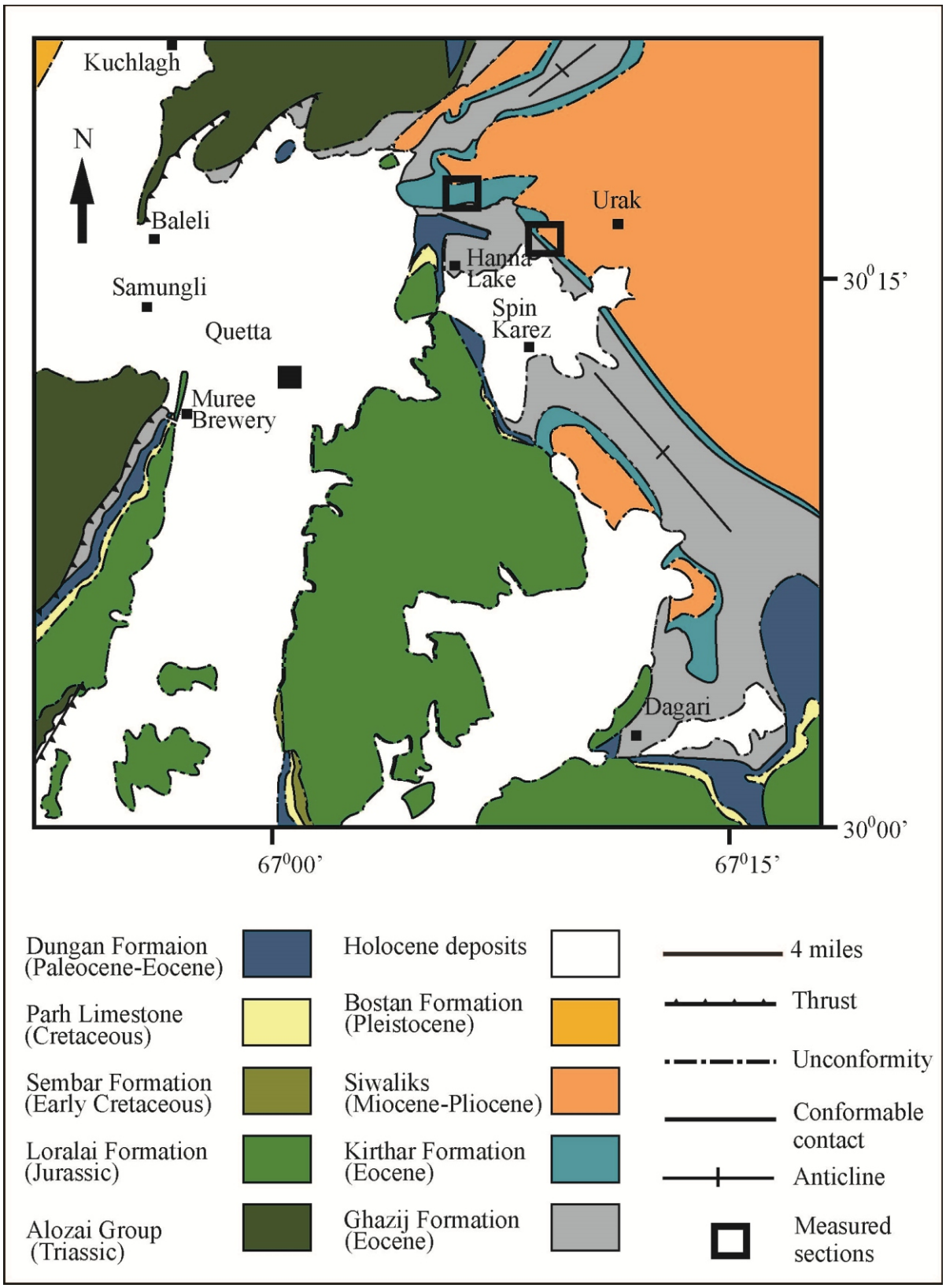

Fig. 2. Geological map of the study area showing location of the study area (modified after Jones, 1961).

The SBZ 19 is defined by the first appearance of *Nummulites fabianii* and *Spiroclypeus* (Figs 3-4). Other associated species include *Nummuites chavannesi, Triloculina, Medocia blayensis, Meghalayana indica* and species of *Discocyclina, Nummulites, Operculina Heterostegina, Pyrgo, Silvestriella tetraedra, Asterocyclina, Orbitolites, Quinqueloculina, Sphaerogypsina, Calcarina* and *Pellatispira.* The boundary between SBZ 19 and SBZ 20 cannot be recognized due to lack of key biostratigraphic markers.

Tethys Wide Comparison of LBF ranges

LBF are abundant in the Tertiary marine deposits and their rapid evolution and global distribution has made them important biostratigraphic markers (Hottinger, 1960, 1964; Schaub, 1981; Hottinger and Drobne, 1988; Ahmad et al., 2016). Serra-Kiel et al., (1998) erected twenty standard shallow benthonic biozones for Tethyan Palaeocene-Eocene, mainly based on the larger foraminifera of the western Tethys and partly from the eastern Tethyan regions such as Pakistan and India. These standard biozones provide a good base for comparison of newly reported LBF ranges with those documented by Serra-Kiel et al., (1998). Here, ranges of some key LBF of Kirthar Formation have been compared with those reported by Serra-Kiel et al., (1998) and others from various parts of Tethys.

Middle Eocene (SBZ 18)

Pellatispira madaraszi and *Borelis vonderschmidti* appear within SBZ 18 and ranges to SBZ 20 in the western Tethys (Serra-Kiel et al., 1998). *Pellatispira madaraszi* is the most widespread species, reported from almost the same horizon of late SBZ 18-SBZ 20 from various Tethyan and the Indopacific regions such as such as Oman, Aremenia, Turkey, Italy, Pakistan, India and Eua Tonga (Eames, 1952; Cole, 1970; Jones, 1961; Banerji, 1981; Serra-Kiel et al., 1998; Bassi, 1998; Özcan et al., 2010; Matsumaru and Sarma, 2010; Less and Özcan, 2012; Cotton et al., 2016). N*ummulites striatus* appear first in SBZ 18 and ranges to lower part of SBZ 19, whereas later it was also recorded from SBZ 17 of Turkey and Romania (Rusu et al., 2004; Özcan et al., 2010). However, in our succession its occurrence with taxa such as *Pellatispira, Heterostegina* and *Alveolina* confirms its range from SBZ 18 to Late Eocene.

Heterostegina appear first in SBZ 18 in Tethys and ranges to Holocene (Serra-Kiel et al., 1998; Less et al., 2008). In Kirthar Formation its first occurrence with *Alveolina* and *pellatispira* confirms its first appearance in SBZ 18. Speices of *Alveolina* are common in the Early and Middle Eocene and so far there is no report of their occurrence in the Late Eocene (Serra-Kiel et al., 1998; Afzal et al., 2011; Zhang et al., 2013). Here, their occurrence along with the first appearance of *Pellatispira* and *Nummulites striatus* confirms their last occurrence in SBZ 18. *Meghalayana indica* is reported only from the Late Eocene (Priabonian) of India (Matsumaru and Sarma, 2010) where as in Kirthar Formation it appears first in SBZ 18 and ranges to Late Eocene, thus extends its range downwards. *Silvestriella tetraedra, Medocia blayensis* and *Asterigerina rotula* have their first appearances prior to SBZ 18 and ranges to Late Eocene. Here, their presence throughout Kirthar Formation confirms their last occurrences in Late Eocene (Samanta, 1965; Banerji, 1981; Serra-Kiel et al., 1998; Caglar (Kaya), 2009; Özcan et al., 2010; Afzal et al., 2011; Huang et al., 2013; Bukhari et al., 2016; Sirel and Deveciler, 2017).

Late Eocene SBZ 19- SBZ 20

Nummulites fabianii and *Spiroclypeus* appear first in SBZ 19 (Late Eocene) and the later ranges to Miocene (Serra-Kiel et al., 1998; BouDagher-Fadel, 2008; Cotton and Pearson, 2012; Bukhari et al., 2016). *N. fabianii* is restricted to Late Eocene SBZ 19-SBZ 20 and is reported from many Tethyan regions including Pakistan, India and Bangladesh and there is no report of its existence in the younger or older strata (Samanta, 1968; Banerji, 1981; Özcan et al., 2010). *Nummulites chavannesi* appears within SBZ 18 and ranges to SBZ 20 and is documented from various parts of Tethys such as Turkey, Armenia, Spain, Austria and India (Banerji, 1981; Serra-Kiel et al., 1998; Rasser et al., 1999; Özcan et al., 2010; Less and Özcan, 2012; Costa et al., 2013; Cotton et al., 2016). However, in Kirthar Formation it is restricted to SBZ 19-SBZ 20.

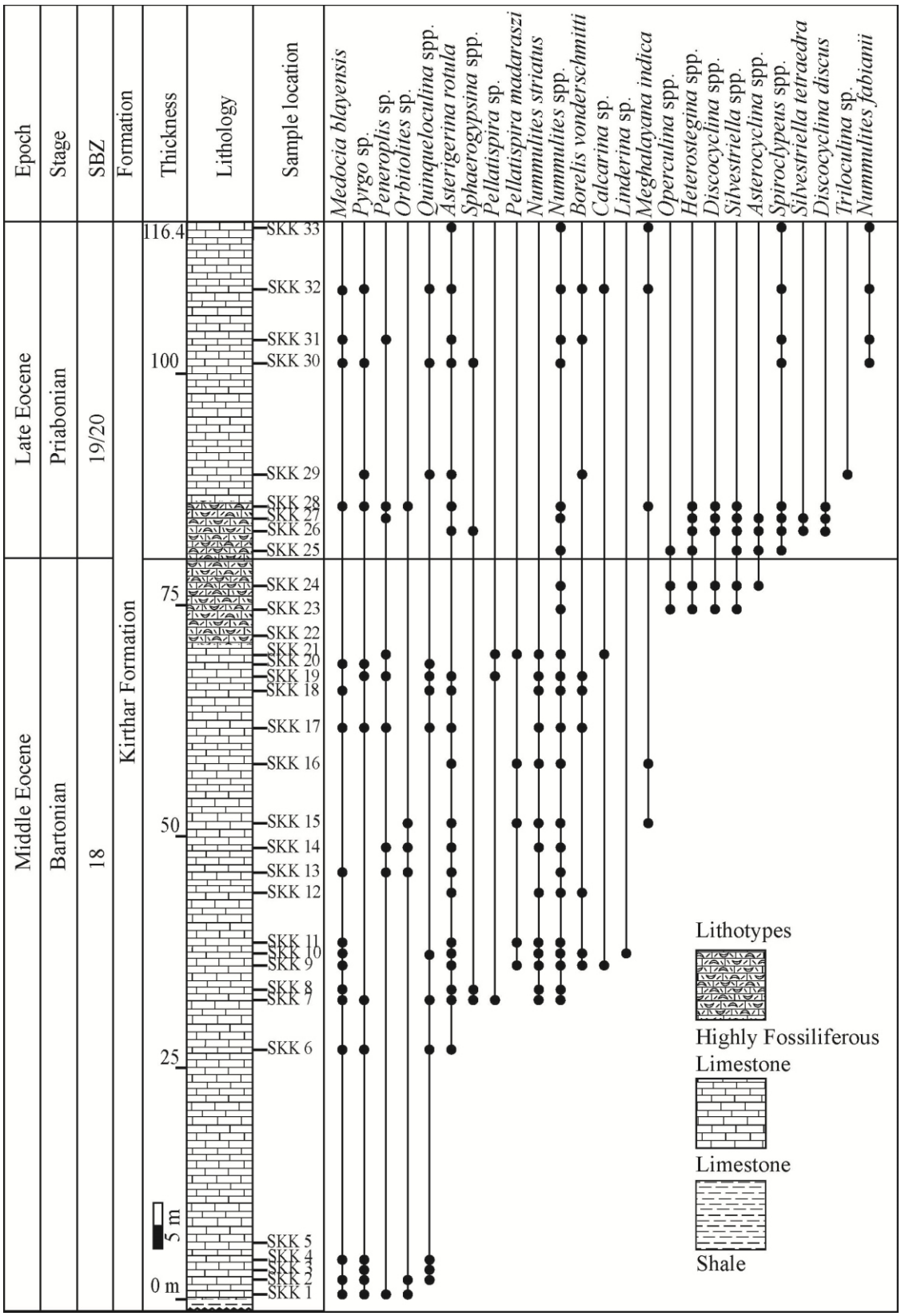

Fig. 3. Biostratigraphic column and species stratigraphic range of LBF of the Kirthar Formation of the Shingloona Section, Quetta.

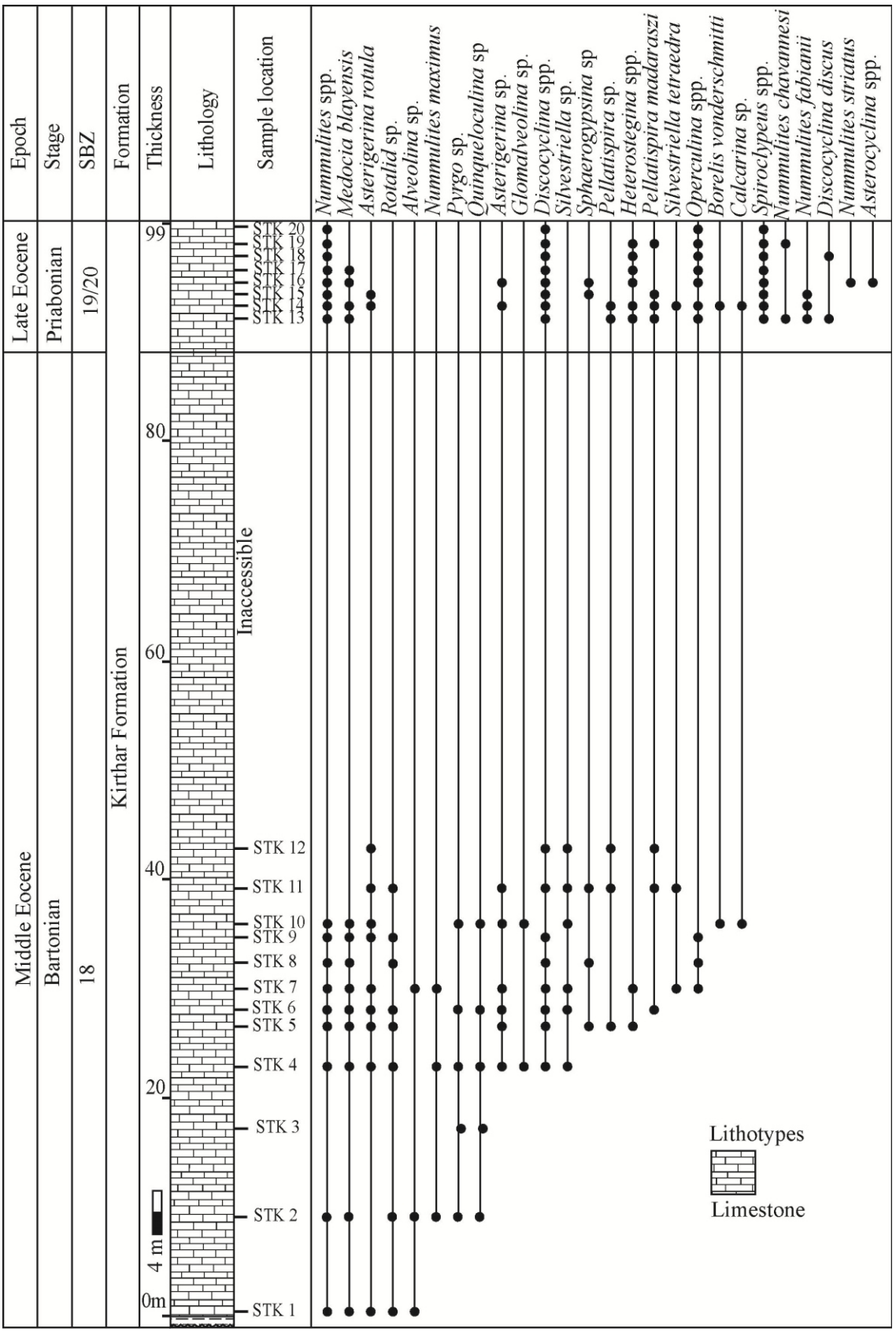

Fig. 4. Biostratigraphic column and species stratigraphic range of LBF of the Kirthar Formation of the Sarangzai Tangai Section, Quetta.

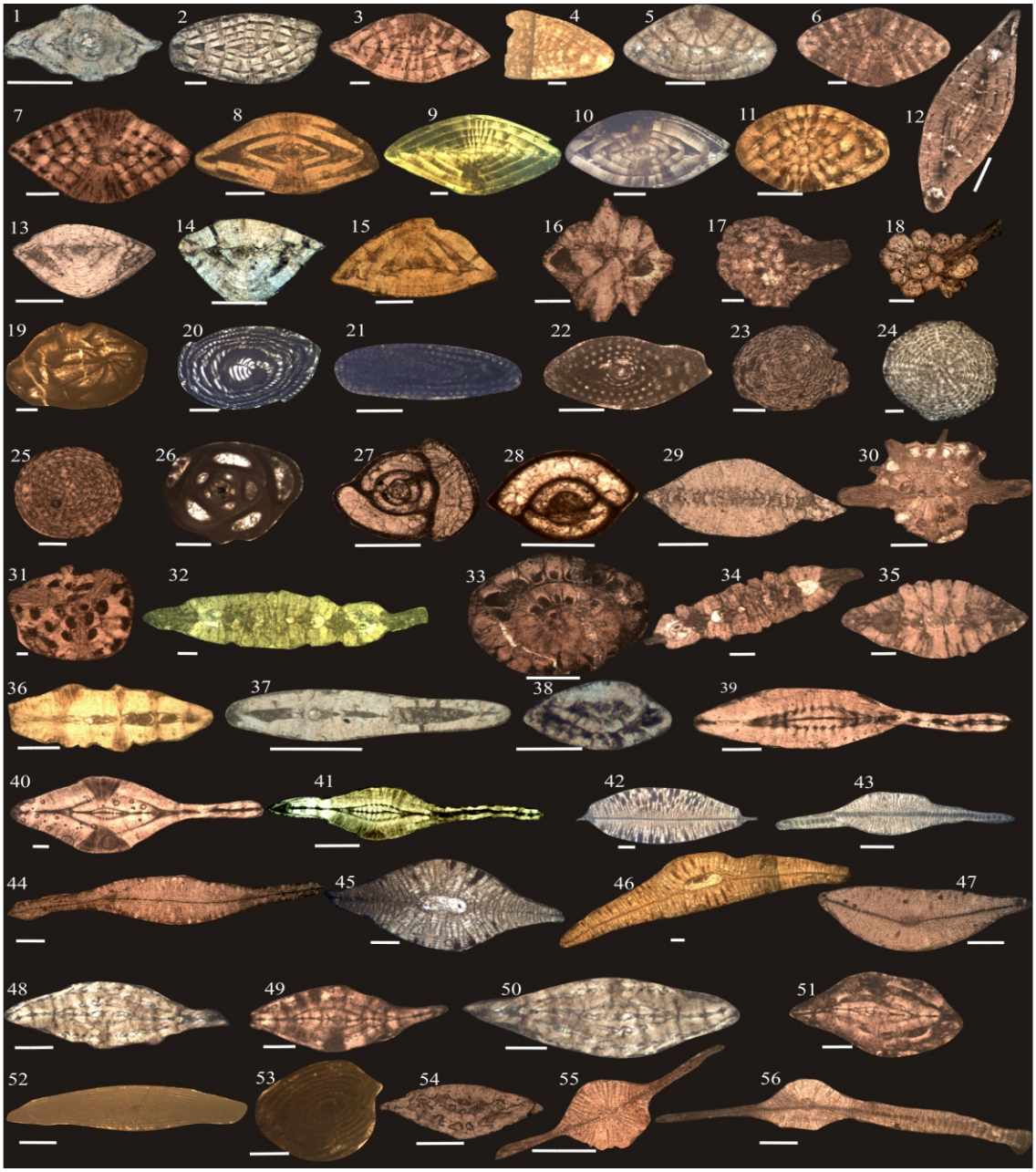

Fig. 5. Photomicrographs of LBF of the Kirthar Formation Middle- Late Eocene Larger Benthic Foraminifera. 1, *Nummulites maximus,* STK-2. 2-3, *Nummulites striatus,* 2, STK-16; 3, SKK-7. 4-7, *Nummulites fabianii,* 4, STK-15; 5, STK-16; 6-7, SKK-30. 8, *Nummulites chavannesi,* STK-13. 9-12, *Nummulites* spp., 9, STK-16; 10, STK-5; 11, STK-8; 12, SKK-15. 13-15, *Asterigerina rotula,* 13, SKK-7; 14, STK-16; 15, STK-13. 16, *Silvestriella* sp., SKK-23. 17-18, *Silvestriella tetraedra,* 17, STK-14; 18, SKK-27. 19-20, *Alveolina elliptica,* 19, STK-7; 20, STK-7. 21, 53, *Borelis* sp., STK-10. 22, *Borelis vonderschmitti,* SKK-29. 23-25, *Sphaerogypsina* spp., 23, SKK-8; 24, STK-5; 25, STK-11. 26, *Quinqueloculina* sp., SKK-4. 27, *Triloculina* sp., SKK-29. 28, *Pyrgo* sp., SKK-1. 29, *Linderina* sp., SKK-10. 30-31, *Meghalayana indica,* 30, SKK-28; 31, SKK-33. 32-35, *Pellatispira madraszi,* 32, STK-6; 33, STK-11; 34, SKK-9; 35, SKK-11. 36-37, *Operculina* spp., 36, STK-9; 37, STK-19. 38, 54, *Medocia blayensis,* 38, STK-6; 54, SKK-9. 39-41, *Heterostegina* spp., 39, SKK-27; 40, 41, SKK-26. 42-44. 47, *Discocyclina* spp., 42, STK-18; 43, STK-16; 44, SKK-28; 47, SKK-26. 45-46, *Discocyclina discus*, 45, STK-18; 46, STK-15. 48-51, *Spiroclypeus* spp., 48, STK-13; 49, STK-14; 50-STK-16; 51, SKK-33. 52, *Glomalveolina* sp., 52, STK-10. 55-56, *Asterocyclina* spp., SKK-25. (1-4, 6-8, 13-18, 21-29, 31, 32, 34-39, 41-45, 48-51, 53, 54) Scale bar 200 µm; (5, 9, 10, 11, 12, 19, 20, 30, 33, 40, 46, 47, 52, 55, 56) Scale bar 500 µm.

5. Conclusions

The Middle-Late Eocene fauna of Kirthar Formation in western Sulaiman Fold-Thrust Belt has yielded rich and diverse larger benthonic foraminiferal assemblages. These assemblages include stratigraphically important taxa suggesting late Middle Eocene to Late Eocene (SBZ 18-SBZ 20). The SBZ 18 is recognized by the co-occurrence of *Nummulites striatus* and representatives of *Alveolina, Pellatispira, Heterostegina* and *Borelis*. The SBZ 19-20 (Late Eocene) is defined by the extinction of *Alveolina* and the appearance of *Nummulites fabianii* and *Spiroclypeus*.

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