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Biostratigraphy of the Eocene Nisai Formation in Pishin Belt, Western Pakistan

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Abstract

In this study the Eocene Nisai Formation at its type section, (Kazha Mirzai, Qilla Saifullah) in western Balochistan, Pakistan, is investigated for larger benthonic foraminiferal biostratigraphy. Thirty-four species belonging to twenty-five different genera have been identified from the limestone at lower and uppermost of this stratigraphic unit, whereas the middle argillaceous part is devoid of larger benthonic foraminifera. The lower part consist of an assemblage of *Asterigerina rotula, Sphaerogypsina globula, Austrotrillina eocenica, Rotalia trochidoformis, Ranikothalia nuttalli, Lockhartia hunti, Assilina sublaminosa, Assilina leymeriei* and *Assilina subspinosa, Eorupertia* spp., *Pellatispira* spp., *Linderina* spp. and *Asterigerina* spp., which suggests Middle Eocene age spanning between zone SBZ-13 and SBZ-18. The upper part has yielded an assemblage that consist of *Nummulites fabianii* and species of *Heterostegina, Calcarina, Pellistella, Asterocyclina, Austrotrillina, Amphistegina, Discocyclina* and *Operculina* which suggests a Late Eocene (Priabonian) age.

Keywords: Biostratigraphy; Larger benthonic foraminifera; Eocene; Nisai Formation; Pishin Belt.

1. Introduction

Foraminifera are marine protozoans with their fossil record extending back to the Early Cambrian (Culver, 1991). Their earlier forms in the Paleozoic and Triassic were benthonic, whereas planktonic forms appeared in early Jurassic (Hart et al., 2003). The modern foraminifera are widespread in contemporary oceans from tropics to higher latitudes, inhabiting near shore to deep oceanic trenches, ocean surface to sea floor (Korsun et al., 1995; Armstrong and Brasier, 2005; Panieri and Sen Gupta, 2008; Gooday et al., 2008). The foraminiferal diversity was subsided during most of the Palaeozoic which was elevated by the Late Carboniferous and Permian. The number of foraminiferal species has significantly declined during the Late Palaeozoic due to extinction which wiped about 90% of their genera, resulting in low diversities in the Triassic and Jurassic, and regained their peak by Cretaceous (Loeblich and Tappan, 1988; Kaiho et al., 2001; BouDagher-Fadel, 2008, 2013). Both the planktonic and benthonic foraminifera have recorded rapid evolution, making one of the favorite fossil group for biostratigraphic dating of marine sediments (Berggren et al., 1995; Berggren and Miller, 1998; Serra-Kiel et al., 1998). Benthonic foraminifera are further classified into two major subgroups smaller benthonic and larger benthonic. Larger benthonic foraminifera (LBF) differ from their smaller benthonic counterparts in having complex internal morphologies and relatively large sizes. Some of the taxa amongst LBF may attain sizes up to 180 mm (Armstrong and Brasier, 2005; BouDagher-Fadel, 2008). Most of the LBF are found in shallow, warm, tropical water, associated with oligotrophic reefs and are important carbonate producers (BouDagher-Fadel, 2008). This group is widely used in the biostratigraphy of Permian, Late Cretaceous, and Cenozoic shallow marine carbonates where plankton are either absent or rarely found (Cahuzac and Poignant, 1997; Serra-Kiel et al., 1998; BouDagher-Fadel, 2008). The Cenozoic marine sediments especially the Palaeocene and Eocene rocks are widespread in Pakistan and have attracted attention of various biostratigraphers. Most of these studies are conducted on the geographically widespread Indus Basin (Afzal et al., 2005, 2009, 2010, 2011; Hanif et al., 2013; Ahmad et al., 2015; Özcan et al. 2015). The Nisai Formation which represents the oldest marine strata in the Pishin Belt (Katawaz Basin) is rarely studied and its poorly documented fauna lack high resolution biostratigraphic framework (Jones, 1961; Alleman, 1979; Qayyum, 1997). The Kazha Mirzai section is an integral part of the Pishin Belt and is a type section of the Nisai Formation. This stratigraphic unit is dated Middle Eocene to Late Eocene (SBZ 13 to SBZ 20) by Ahmad and Afzal (2012), however faunal details are missing in their studies. In this paper an attempt is made to (1) document LBF of the Nisai Formation at its type section and (2) and to establish a reliable biostratigraphic framework based on larger benthonic foraminifera with subsequent comparison of LBF taxa of other Tethys sections.

2. Geological setting

The Pishin Belt is a 700 km long and 200 km wide sedimentary basin in western Pakistan. This northeast-southwest belt is bounded by Chaman Fault in the west and Zhob thrust in the east. Broadly the Pishin Belt is northern part of the Makran-Khojak-Pishin Flysch Belt (Fig. 1). This belt was first named and mapped by Jones (1961) while Qayyum et al., (1997a, b, 2001) made a detail study of the Palaeogene marine sedimentary succession of the area. Kasi, (2012) and Kasi et al., (2012) carried out detail study of the Neogene continental succession of the Pishin belt.

Depositionally the Pishin Belt is part of very large Katawaz Basin. It evolved since Late Paleocene-Early Eocene time, following the collision between Indian Plate and Eurasian plate, resulting in the closure of the northern part of the Neo-Tethys and opening of the Katawaz remnant ocean (Molnar and Tapponnier, 1975; Tapponnier et al., 1986; Harrison et al., 1992; Qayyum et al., 1997a; Zhu et al., 2005; Ding et al., 2005; Najman et al., 2010). The basin was ultimately closed by the end of Middle Miocene time (Qayyum et al., 1997a, 2001). The basin fill consists of thick sedimentary successions of dominant siliciclastic and subordinate carbonate discrete depositional packages of Eocene-Oligocene marine deposits and Neogene molasse deposits. The Late Cretaceous-Palaeocene Muslim Bagh-Zhob Ophiolite makes the base of the Pishin Belt. The Eocene-Oligocene Nisai and Oligocene-Miocene Khojak formations are carbonate and siliciclastic marine depositional units exposed in this belt respectively. The Miocene-Pliocene Dasht Murgha Group, Pliocene Malthanai and Pleistocene Bostan are fluvial dominated successions exposed in the belt (Fig. 2).

3. Methodology

The type section of the Nisai Formation at Kazha Mirzai, Qilla Saifullah (N305549.4; E680411.8) is located at about 12 km north of the Nisai Railway Station. The stratigraphic unit in its type section offers about 930 m thick outcrops of limestones and shales (Fig. 3).
These outcrops were measured and sampled for LBF. Forty-five limestone samples were collected which were thin sectioned and microphotographed in plane polarized light in the Centre of Excellence in Mineralogy, University of Balochistan, Quetta.

4. Biostratigraphy

The Nisai Formation is reported to contain rich fossil fauna including foraminifera, however work on its biostratigraphic significance is still far from over. In this paper a first ever attempt is made to document the detail investigation of larger benthonic foraminifera from the type section of the Nisai Formation. In the current study thirty-four species from 25 different genera have been identified in the studied section (Fig. 3-6). Most of the LBF are recovered from the grey colored (Fig. 3) medium to thin bedded limestones in the lower part (Fig. 3), and thick bedded cliffs forming reefoidal limestone in the upper most part (Fig. 3), whereas the thin bedded micritic limestones interbedded with shales in the middle part are barren of larger benthonic foraminifera (Fig. 3). The lower part represents Middle Eocene assemblage whereas the upper part represents a Late Eocene (Priabonian) assemblage. Detailed discussion of biostratigraphy is given below.

4.1. Middle Eocene (SBZ 13-SBZ 18)

The co-occurrence of *Asterigerina rotula, Sphaerogypsina globula, Austrotrillina eocenica, Eorupertia* spp., *Pellatispira* spp., and *Linderina* spp. with *Rotalia trochidoformis, Ranikothalia nuttalli, Lockhartia hunti, Assilina sublaminosa, Assilina leymeriei* and *Assilina subspinosa* are considered to indicate a Middle Eocene (Lutetian-Barthonian) age. Other associated species include Discocyclina dispansa, and species of *Austrotrillina, Nummulites, Fabiania, Alveolina, Amphistegina, Asterigerina, Operculina, Smoutina, Assilina, Dictyoconus, Orbitolites, Elphidium* and *Planorbulina* (Figs. 4-5). Further subdivision of Middle Eocene into shallow benthonic zones (SBZ) is difficult due to lack of index taxa of alvelolinds, nummulitids and orthophragminids in our samples which are the key zonal markers for the Eocene sediments of Tethys.

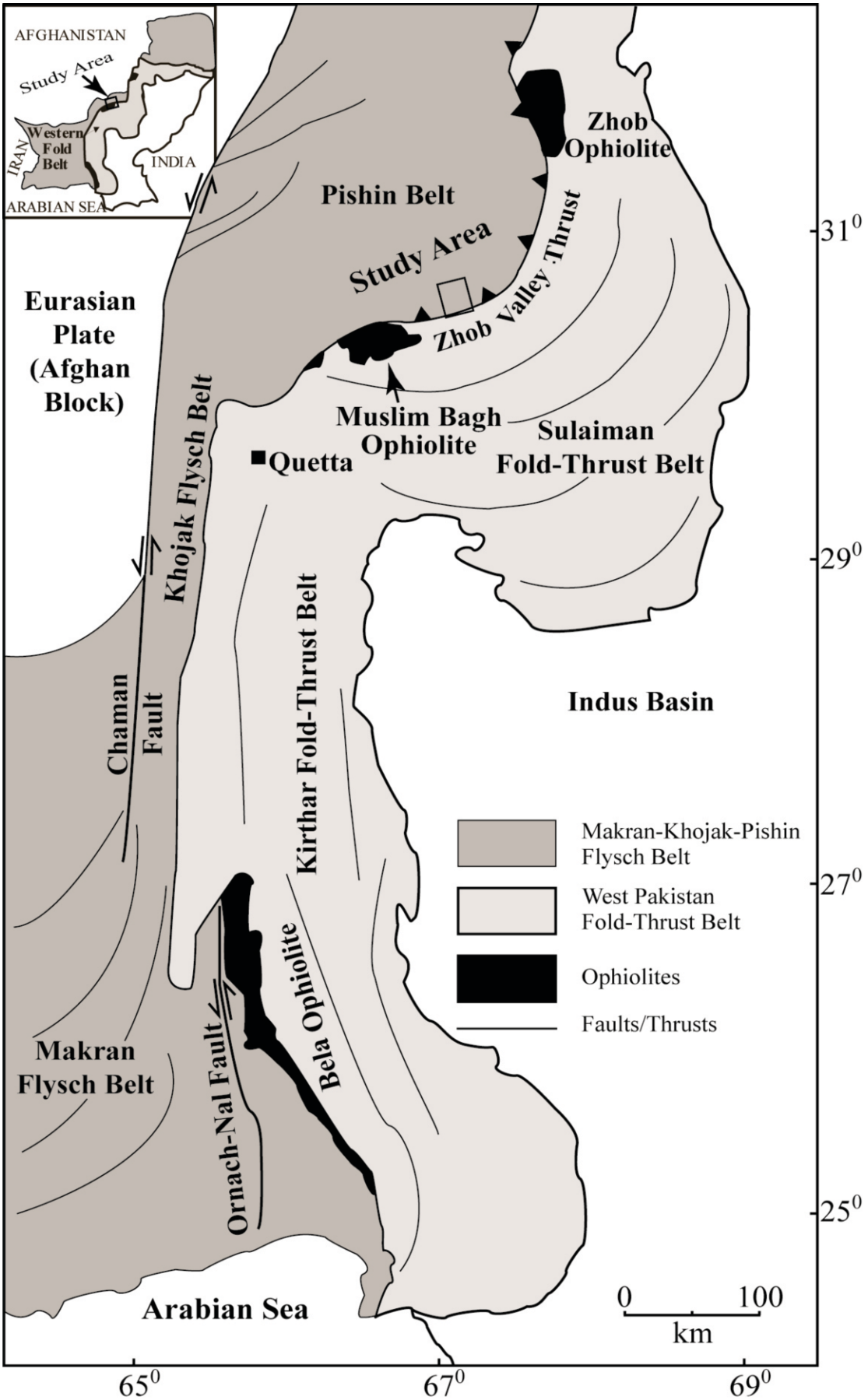

Fig. 1. Generalized geological map of the western part of Pakistan showing the position of Pishin Belt and the study area (after Kasi et al., 2012).

Age	Group	Formation/Member		Lithology	Tectono-stratigraphic Zones
Holocene	-	Zhob Valley deposits		Conglomerate, sandstone and shale/siltstone	Zone VI
Thrust/Angular Unconformity					
Pleistocene	-	Bostan Formation		Red colored shale/siltstone, conglomerate and sandstone	Zone V
Thurst/Angular Unconformity					
Late Miocene-Pliocene	-	*Malthanai formation		Sandstone and conglomerate interbedded with red colored mudstone/siltstone	Zone IV
Thurst/Angular Unconformity					
Early-Middle Miocene	**Dasht Murgha group	Sra Khula formation		Dark red mudstone dominated by cyclic alteration of mudstone, siltstone and sandstone	Zone III
		Bahlol Nika formation		Dominantly greyish green sandstone, with subordinate mudstone and occasional conglomerate	
		Khuzhobai formation		Dominantly maroon mudstone with subordinate reddish brown sandstone	
Thrust/Angular Unconformity					
Oligocene-Early Miocene	-	Khojak Formation	Shaigalu Member	Dominantly sandstone with subordinate shale	Zone II
			Murgha Faqirzai Member	Dominantly shale with subordinate sandstone	
Middle Eocene to Late Oligocene	-	Nisai Formation		Highly fossiliferous to reefoidal limestone interbedded with marl and thick marine (fossiliferous) shale with occasional thin limestone horizons	
Nonconformity					
Cretaceous-Palaeocene	-	Muslim Bagh-Zhob Ophiolite		Mostly ultrabasic and basic igneous rocks	Zone I

Fig. 2. Tectono-stratigraphic zones and lithostratigraphy of the Pishin Belt and surrounding areas (modified after Kasi et al., 2012).

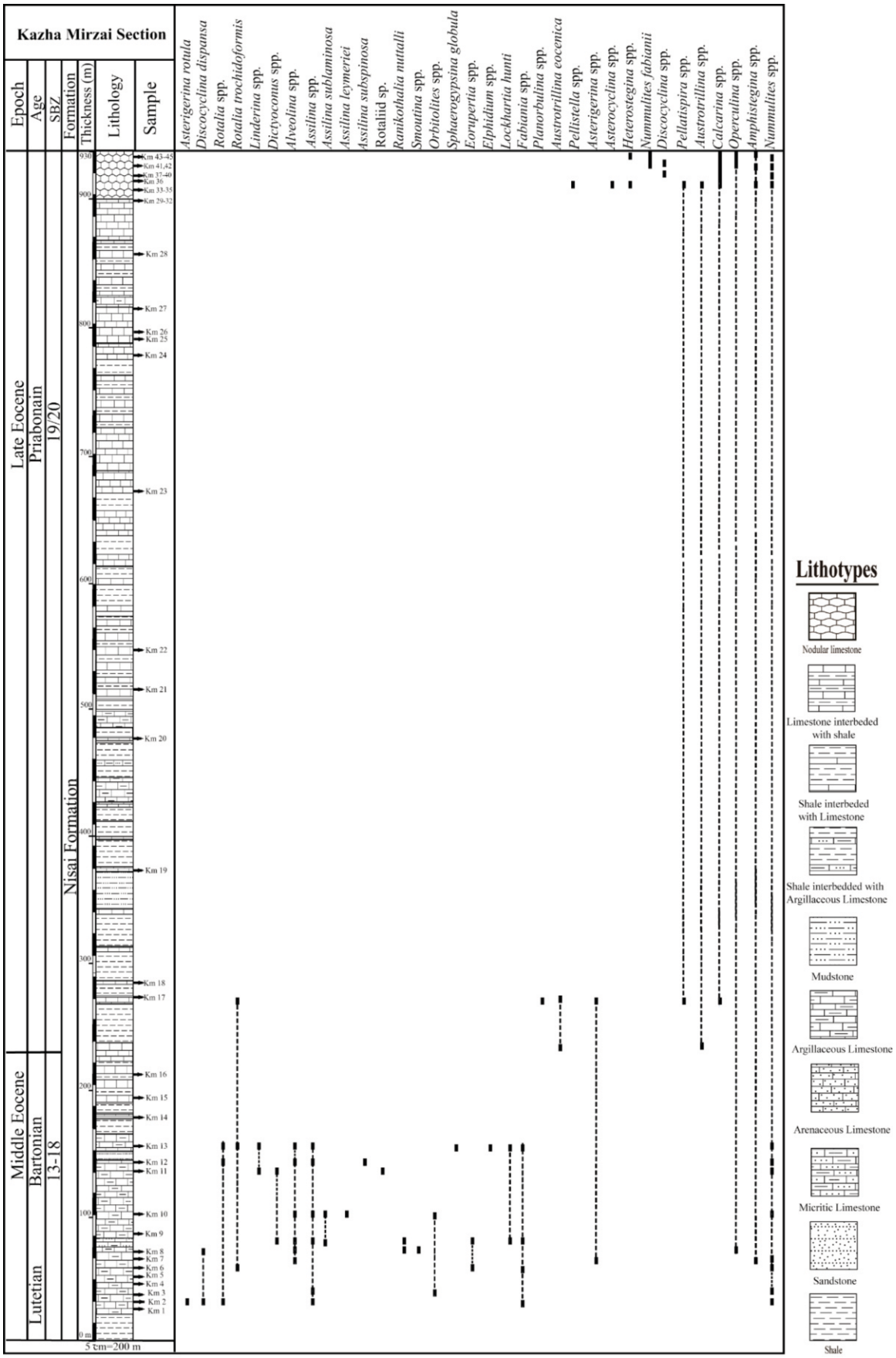

Fig. 3. Biostratigraphic column of the Nisai Formation at Kazha Mirzai, near the Nisai Railway Station, Pishin Belt, showing range of Larger Benthic Foraminifera (LBF).

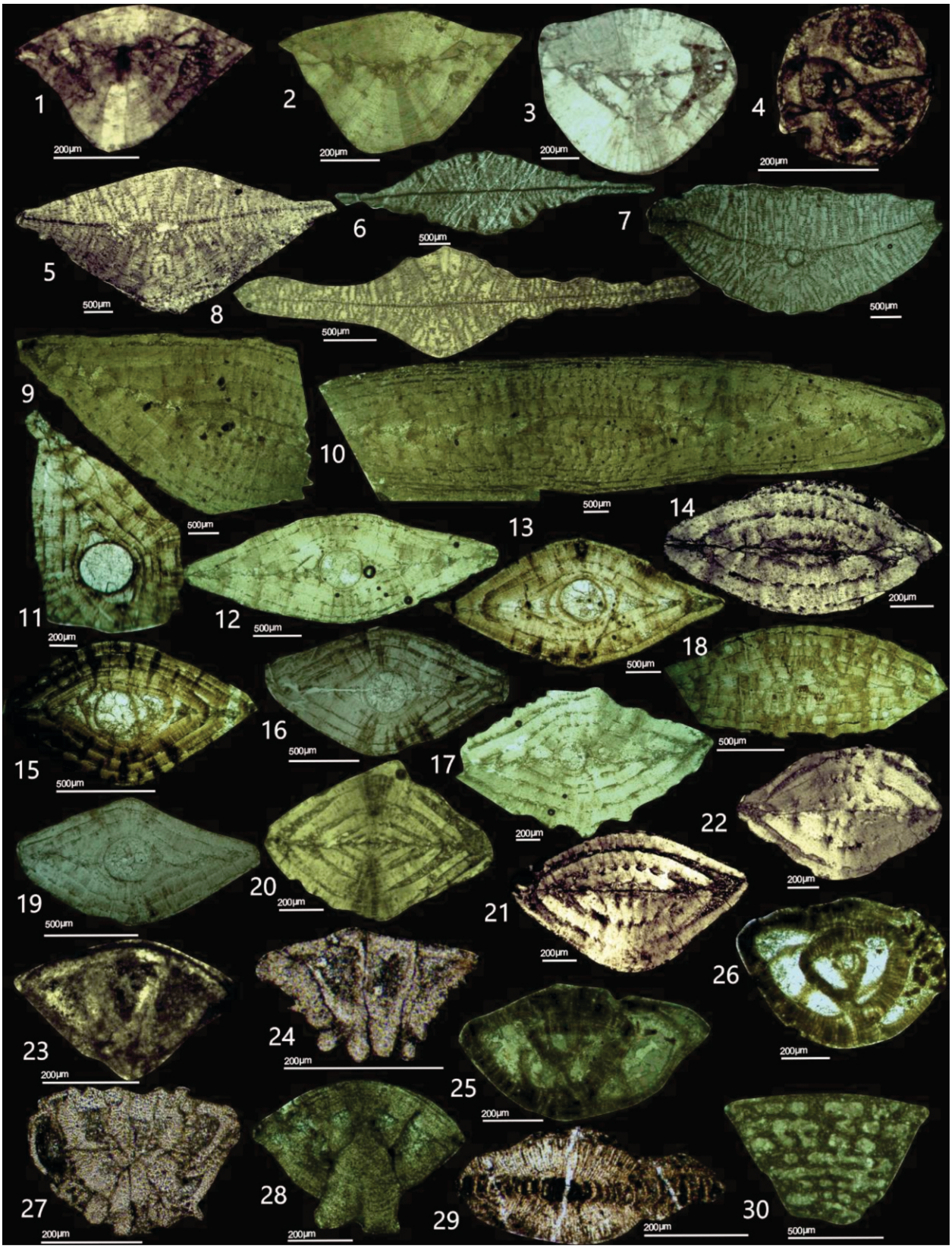

Fig. 4. Photomicrographs of the Middle Eocene Larger Benthic Foraminifera assemblage; 1: *Asterigerina rotula* 2-3: *Asterigerina* spp. 4: Bryozoan fragment 5-6: *Discocyclina dispansa* 7-8: *Discocyclina* spp. 9-22: *Nummulites* spp. 23-24, 26: *Rotalia* spp. 25: *Rotaliid* sp. 27-28: *Rotalia trochidoformis* 29: *Linderina* spp. 30: *Dictyoconus* sp.

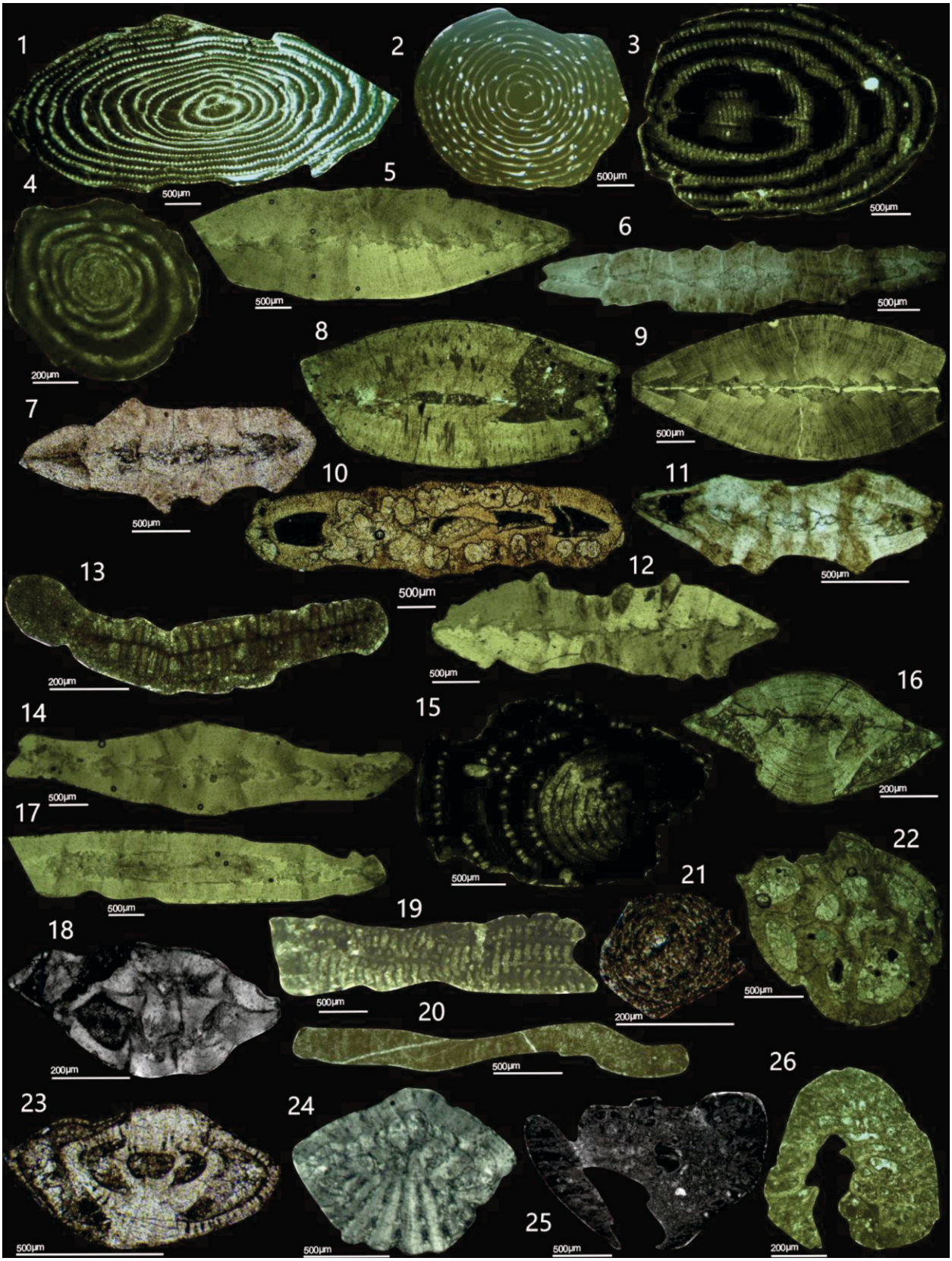

Fig. 5. Photomicrographs of the Middle Eocene Larger Benthic Foraminifera assemblage; 1-4: Alveolina spp. 5-7 and 9-10: *Assilina* spp. 8: *Assilina sublaminosa* 12: *Assilina leymeriei* 11: *Assilina subspinosa* 13: *Distichoplax biserialis* 14: *Operculina* sp. 15: Coralline red algae 16: *Amphistegina* sp. 17: *Ranikothalia nuttalli* 18: *Smoutina* sp. 19-20: *Orbitolites* spp. 21: *Sphaerogypsina globula* 22: *Eorupertia* spp. 23: *Elphidium* sp. 24: *Lockhartia hunti* 25-26: *Fabiania* spp.

4.2. Late Eocene (Priabonian; SBZ 19-SBZ 20)

The Late Eocene (Priabonian) is marked by the appearance of *Heterostegina* spp., and *Nummulites fabianii.* Other associated species include *Calcarina* spp., *Asterigerina* spp., *Pellistella, Asterocyclina* spp., *Austrotrillina* spp. *Amphistegina* spp., and *Operculina* spp. Like the Middle Eocene assemblage, this assemblage also cannot be further subdivided into SBZ 19 and SBZ 20 due to low diversity (Fig. 6).

4.2. Comparison of LBF ranges

Larger benthonic foraminifera are widely used for the biostratigraphy of Cenozoic age shallow marine carbonates and so far twenty-six standard biozones based on lager foraminifera are erected for Palaeocene to Miocene epochs of the Tethys (Serra-Kiel, 1998; Cahuzac and Poignat, 1997). Here, a comparison of the larger benthonic foraminifera of the Nisai Formation at Kazha Mirzai is discussed with those reported from other parts of the Tethys.

4.3.1. Middle Eocene

Asterigerina rotula, Eorupertia spp., *Linderina* spp. and *Sphaerogypsina globula* have their First Appearance Datums (FADs) in the early Middle Eocene (Lutetian) and ranges to Late Eocene (Priabonian) and there is no evidence of their occurrence in the older or younger strata except *Sphaerogypsina globula* which ranges in to Oligocene and Miocene (Nyírő Budapest, 1970; BouDagher-Fadel, 2008; Ozce et al., 2013). *Asterigerina rotula* is documented from the Middle and Late Eocene of Turkey and Hungary (Nyírő Budapest, 1970; Özce et al., 2013). Species of *Austrotrillina* are documented from the late Middle Eocene to Miocene from various parts of Tethys (Adams, 1968; Yazdi-Moghadam, 2011; Saleh, 2014; Zoeram et al., 2014; Hottinger, 2007). The oldest species of the genus *Austrotrillina* i.e. *Austrotrillina eocenica* has its FAD in late Middle Eocene (?SBZ 16), which ranges to Late Eocene (Priabonian) and is only documented from Iran (?SBZ 16, SBZ 17-SBZ 20; Hottinger, 2007). In our studied section this taxon is found in association with first appearance of *Pellatispira* which is also reported elsewhere to appear first in the late Middle Eocene (SBZ 17), hence, its co-occurrence with *Pellatispira* confirms its earliest occurrence in the late Middle Eocene and may prove as a stratigraphically important taxon for the late Middle Eocene (SBZ 17) of Tethys. The *Ranikothalia nuttalli* is documented from the Late Palaeocene SBZ 4 of Egypt and Early Eocene SBZ 5-SBZ 6 of Pakistan and India (Jauhri, 1998; Jauhri and Agarwal, 2001; Jauhri et al., 2006; Scheibner and Speijer, 2009; Afzal et al., 2009, 2010). In this study the stratigraphic range of this taxon in the Nisai Formation extends to Middle Eocene due to its occurrence with typical Middle Eocene taxa such as *Eorupertia* spp. and *Asterigerina rotula.* Species such as *Rotalia trochidoformis, Lockhartia hunti, Assilina sublaminosa, Assilina subspinosa* found in current study in association with Middle Eocene taxa have their FADs either in the Late Palaeocene or Early Eocene and extend to Middle Eocene (Serra-Kiel et al., 1998; Afzal et al., 2010; Ahmad, 2010; Ahmad et al., 2015). Among these taxa *Rotalia trochidiformis* appears first in the Late Palaeocene (Thanetian) SBZ 3 and disappears in the Middle Eocene (late Lutetian) SBZ 16, as documented from various Tethyan regions such as Pakistan, India, Qatar and northeast Turkey (Weiss, 1993; Akhtar and Butt, 1999; Inan et al., 2005; Özgen-Erdem et al., 2005; Mathur et al., 2009; Afzal et al., 2010). *Lockhartia hunti* ranges from Late Palaeocene SBZ 5 to Middle Eocene SBZ 16 and is documented from Tibet and Indus Basin of Pakistan (Ahmad, 2010; Zhang et al., 2013). *Assilina leymeriei* occur throughout Eocene ranging from Early to Late Eocene (Ypresian to Priabonian; SBZ 8-SBZ 20), documented from Early Eocene of Tibet (Ypresian; SBZ 8-SBZ 9), Early to Middle Eocene of Pakistan, India, France and Middle to Late Eocene (upper Lutetian to Priabonian) of Indonesia (Serra-Kiel et al., 1998; Less et al., 2007; Less and Kovćs, 2009; Afzal et al., 2010; Ahmad 2010; Zhang et al., 2013; Ahmad et al., 2015). The oldest occurrence of *Discocyclina dispansa* is recorded from the Late Palaeocene (late Thanetian) and ranges to Late Eocene (Priabonian) SBZ 20 (Jauhari et al.,, 2006; Serra-Kiel et al., 1998; Afzal et al., 2010; Ahmad, 2010; Babazadeh, 2011; Ahmad et al., 2015). Assilina subspinosa and Assilina sublaminosa ranges from Early to Middle Eocene (Ypresian to Lutetian; SBZ 8-SBZ 15) and are documented from some parts of eastern Tethys such as Tibet and Pakistan (Zhang et al., 2013; Ahmad et al., 2015).

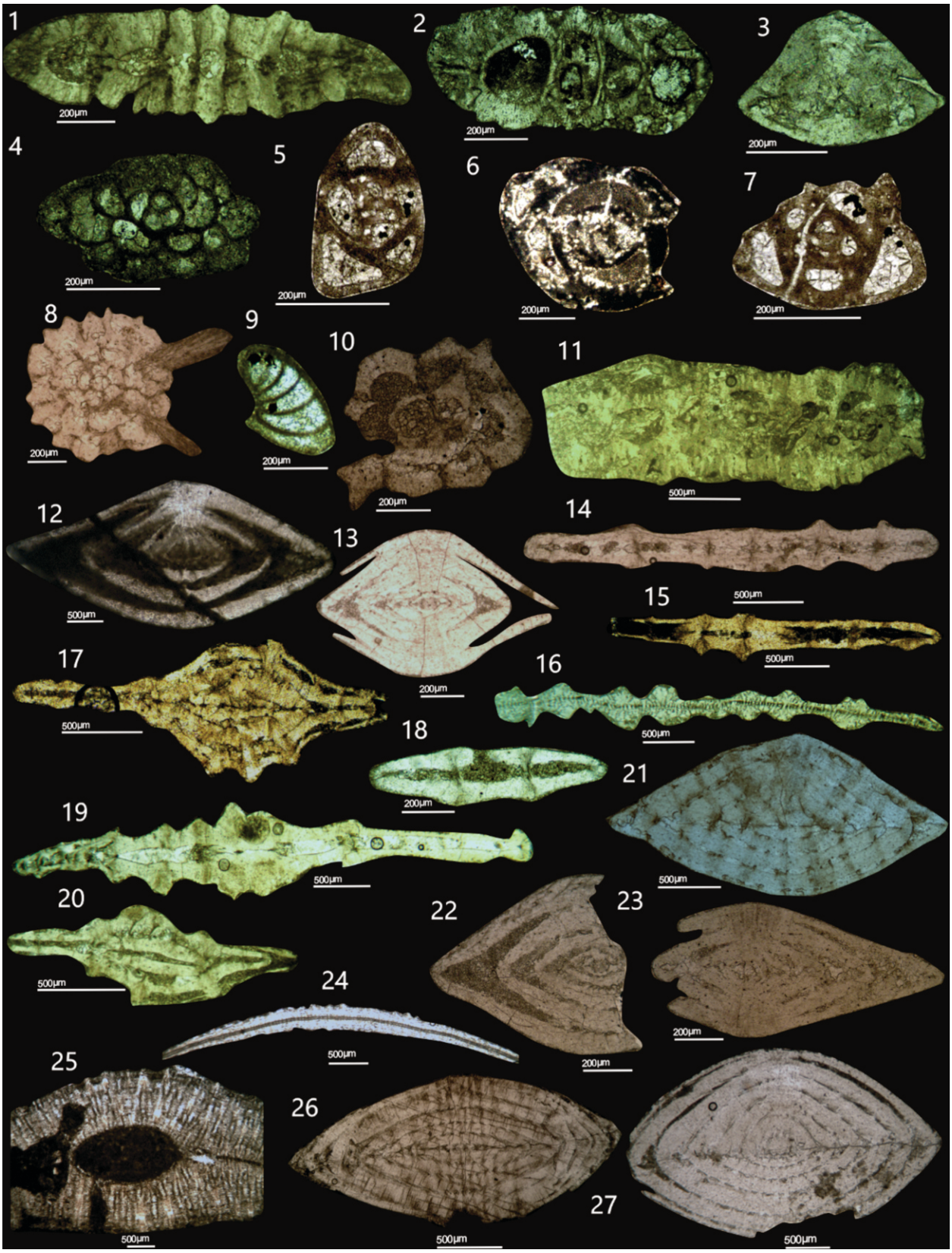

Fig. 6. Photomicrographs of the Late Eocene Larger Benthic Foraminifera assemblage; 1-2: *Pellatispira* sp. 3: *Asterigerina* sp. 4: *Planorbulina* spp. 6-7: *Austrotrillina eocenica* 5: *Austrotrillina* sp. 8-10: *Calcarina* spp. 11: *Pellistella* sp. 12-13: *Amphistegina* spp. 14-15: *Operculina* spp. 16: *Asterocyclina* sp. 17-20: *Heterostegina* spp. 21-23: *Nummulites fabianii.* 24-25: *Discocyclina* spp. 26-27: *Nummulites* spp.

4.3.2. Late Eocene

According to Serra-Kiel et al., (1998) *Nummulites fabianii* appears first in the Late Eocene (Priabonian) SBZ 19, and has been documented by various workers to range extending to SBZ 20 and there is no evidence of its occurrence in the older or younger strata (Matsumaru and Sarma, 2010; Less et al., 2011). It is a cosmopolitan species, documented from the Late Eocene (Priabonian) of various Tethyan and Indo-pacific regions such as Italy, Turkey, Libya, India and Tanzania (AbdulSamad, 2000; Matsumaru and Sarma, 2010; Cotton and Pearson, 2011; Less et al., 2011; Less and Özcan, 2012). Species of *Heterostegina* also appear first in the Late Eocene (Priabonian) SBZ 19 but it ranges to Holocene (Serra-Kiel et al., 1998; BouDagher-Fadel, 2008). Here, the first appearance of *Heterostegina* spp. with *Nummulites fabianii* confirms the Late Eocene (Priabonian) age for the uppermost cliffs forming limestone of the Nisai Formation, which is in agreement with the previous records in the Tethys (Serra-Kiel et al. 1998; Less and Özcan, 2012). The associated taxa such as species of *Calcarina, Pellistella, Asterocyclina, Austrotrillina, Amphistegina* and *Operculina* are long ranging, documented from the younger as well as older strata from various regions of Tethys, hence these cannot be used for biostratigraphic constraints (BouDagher-Fadel, 2008).

5. Conclusion

The Nisai Formation at Kazha Mirzai, Qilla Saifullah has yielded a moderate diversity of larger benthonic foraminiferal fauna comprising of some thirty-four species from twenty-five different genera. These assemblages suggest Middle to Late Eocene (Lutetian to Priabonian; SBZ 13-SBZ 20) age for the Nisai Formation in the Kazha Mirzai. The Middle Eocene (Lutetian to Bartonian) assemblage is chararcterized by *Asterigerina rotula, Sphaerogypsina globula, Austrotrillina eocenica Eorupertia* spp., *Pellatispira* spp., and *Linderina* spp., *Rotalia trochidoformis, Ranikothalia nutalli, Lockhartia hunti, Assilina sublaminosa, Assilina leymeriei* and *Assilina subspinosa.* The Late Eocene assemblage (Priabonian) is characterized by the association of *Heterostegina* spp., *Nummulites fabianii, Calcarina* spp., *Asterigerina* spp., *Pellistella, Asterocyclina* spp., *Austrotrillina* spp. *Amphistegina* spp., and *Operculina* spp.

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