Revista Brasileira de Paleontologia, 27(1):e20240385, 2024
A Journal of the Brazilian Society of Paleontology

doi:10.4072/rbp.2024.1.0385

DISTRIBUTION OF THE THANETHIAN–ILERDIAN BIOZONES IN THE LORESTAN ZONE, WEST OF IRAN

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ABSTRACT – The Taleh Zang Formation is a carbonate sequence of the late Paleocene–early Eocene age in the Lorestan zone, west of Iran. This Formation overlays siliciclastic rocks of the Amiran Formation and is overlain by red sandstone of the Kashkan Formation. A biostratigraphic scheme, based on the larger benthic foraminifera, is proposed for the Thanetian–Ilerdian deposits in Lorestan Zone. We compare our results with the available data from other parts of Tethys and the zonation of shallow-marine Paleocene–Eocene of Mediterranean Tethys is made. In total, 367 samples were collected from the six sections. From a biochronostratigraphic point of view, three biozones and one indeterminate zone are identified. The zones are shallow benthic zone 3 (early Thanetian), shallow benthic zone 4 (late Thanetian), and shallow benthic zone 6 (early Ilerdian). In the northern part of the Lorestan Zone (Kabutar Bula and Psht-e Jangal sections), the Taleh Zang Formation contains poor fauna. Due to the stratigraphic position, an early Thanetian age can be considered. Our data showed that the late Paleocene and Eocene biozones in Lorestan Zone developed parallel to the axis of the folding, in a northwest-southeast trend. They get younger from the northeast to the southwest.

Keywords: biostratigraphy, Eocene, Foraminifera, Lorestan Zone, Paleocene.

RESUMO – A Formação Taleh Zang é uma sequência de carbonato do final do Paleoceno e Eoeoceno na zona de Lorestan, a oeste do Irã. Esta formação está sobreposta às rochas siliciclásticas da Formação Amiran e é coberta por arenitos vermelhos da Formação Kashkan. Um esquema bioestratigráfico, baseado em foraminíferos bentônicos maiores, é proposto para os depósitos do Tanetiano–Ilerdiano na zona de Lorestan. Comparamos nossos resultados com dados disponíveis de outras regiões do Tétis, o que permitiu a zonação do Paleoceno–Eoceno em ambientes marinhos rasos no Tétis Mediterrâneo. No total, foram coletadas 367 amostras em seis seções. Do ponto de vista biocronoestratigráfico, identificamos três biozonas e uma zona indeterminada: a zona bentônica rasa 3 (início do Tanetiano), a zona bentônica rasa 4 (final do Tanetiano) e a zona bentônica rasa 6 (início do Ilerdiano). Na parte norte da zona de Lorestan (seções Kabutar Bula e Psht-e Jangal), a Formação Taleh Zang apresenta baixa abundância de fósseis. Com base na posição estratigráfica, é possível atribuir uma idade do início do Tanetiano a estas camadas. Nossos dados indicam que as biozonas do Paleoceno e do Eoeoceno na zona de Lorestan se desenvolveram paralelamente ao eixo de dobra, seguindo uma tendência noroeste-sudeste, tornando-se progressivamente mais jovens do nordeste para o sudoeste.

Palavras-chave: bioestratigrafia, Eoceno, foraminíferos, Zona Lorestan, Paleoceno.

INTRODUCTION

The Taleh Zang Formation, a shallow marine carbonate succession of the upper Paleocene–lower Eocene, stretches from the Iraq border to the eastern edge of the Lorestan zone (James & Wynd, 1965). The Lorestan Zone is located west of Iran in the western Zagros Basin. Numerous authors have studied the Taleh Zang Formation's stratigraphy and sedimentary environments (*e.g.*, Maghfouri Moghaddam & Jalali, 2004; Adabi *et al*., 2008; Maghfouri Moghaddam *et al*., 2008; Zohdi & Adabi, 2008; Bagherpour & Vaziri, 2011; Shalavand *et al*., 2020). Despite these studies, the timing of the deposition remains of Taleh Zang Formation poorly constrained due to the lack of extensive data regarding the shallow benthic zone.

Wynd (1965) designed two assemblage zones for the Taleh Zang Formation: The *Miscellanea-Kathina* assemblage Zone (Paleocene) and the *Opertorbitolites* subzone (lower Eocene). Wynd was the first to study the biostratigraphy of Paleogene carbonates in the Zagros Basin.

Aside from work on the Zagros Basin, considerable effort has been expended over the past four decades to establish larger benthic foraminifera as indicators of geological time in Paleogene platform carbonates worldwide. Höttinger (1960) and Schaub (1981) published a preliminary assessment of the Early Paleogene alveolinids and nummulitids in the Mediterranean region. Serra Kiel *et al*. (1998) established the Paleocene and Eocene Shallow Benthic Zones for the Paleocene and Eocene interval in the Neo-Tethyan realm, which was later reviewed by Scheibner *et al*. (2005) and

Papazzoni *et al*. (2017). These Shallow Benthic Zones have been successfully used to construct high-resolution biostratigraphy in shallow-water environments, where the benthic foraminifera once dominated in the Paleocene and Eocene, by stratigraphic revision of the most diverse groups of Paleogene larger benthic foraminifera (particularly nummulitids, alveolinids, and orthophragmines) (Zhang *et al*., 2013).

In the past decade, several studies on the Paleocene–Eocene benthic foraminifera (such as alveolinids and nummulitids) with more precise stratigraphic data from various regions of Iran have been conducted (*e.g*., Hadi *et al*., 2015, 2016, 2019a, 2019b; Amirshahkarami & Zebarjadi, 2018). The primary objective of this study is to analyze biostratigraphy distributions of the Paleocene-Eocene benthic foraminifera from the Lorestan Zone and compare these data to known occurrences in other regions of the Tethys.

GEOLOGICAL SETTING

In the Late Cretaceous, the collision of the western Iranian and Afro-Arabian plates and the overloading of continental crust by ophiolite obduction led to the formation of the Lorestan Zone (Motiei, 1998). The Lorestan zone is bounded by the High Zagros Fault in the northeast, the Mountain Front Fault in the southwest, and the Bala Rud Fault in the south (Figure 1A).

The Taleh Zang, Shahbazan and Kashkan formations were deposited during the Paleogene, in the coastal and shallow carbonate parts of the Lorestan Basin (Motiei, 1993). Basin wards, shallow carbonate platforms pass into the hemipelagic Pabdeh Formation, as the rhythmic alternations of marlstone, marl and limestone. The Taleh Zang Formation consists of massive limestone, medium-bedded limestone, argillaceous limestone, dolostone and sandstone. Bagherpour & Vaziri (2012), by scrutinizing two stratigraphic sections of the late Paleocene–early Eocene deposits in the southern Lorestan Zone, suggested a ramp carbonate platform with depositional settings including tidal flats (including stromatolitic boundstone, sandy lime mudstone, dolostone, and lime mudstone), lagoon (including miliolid gastropod wackestone, alveolinid orbitolites packstone–wackestone, miliolid peloidal grainstone, *Alveolina* bioclastic grainstone), shoals (including foraminifera algal packstone and foraminifera packstone) and a variety of reef and open marine facies (including algal boundstone and coralgal boundstone) for the Taleh Zang Formation.

The Taleh Zand Formation was deposited in the Lorestan Zone, Zagros Basin, west of Iran (Setudehnia, 1972), and was bounded by two regionally significant unconformities. Its lower boundary with the Amiran Formation marks the end of a period of major Cretaceous collisional tectonics and ophiolite obduction on the northern and northeastern Arabian plate margins (Sharland *et al*., 2001), which coincided with the formation of an NW–SE-trending foreland basin in the Zagros Basin (Sherkati & Letouzey, 2004).

The shallow-marine sedimentation of the Taleh Zang Formation was replaced by the Kashkan Formation, which consists of polymictic conglomerate (containing ophiolite) grading progressively toward the southwest to sandstone, siltstone, and shale; and a cyclicity-developed, upward-coursing fluvial siliciclastic wedge (with growth strata locally) derived from the northeast (Ghazban, 2007). The continental deposits of the Kashkan Formation are gradually replaced by dolomitic Shahbazan Formation. The Shahbazan Formation is most developed in central and northeastern Lorestan, towards the southwest and west it becomes thin bedded and argillaceous, and ultimately succeeded by the Pabdeh Formation. The southwest limit of this formation is located on the southern flank of Chenareh anticline in the southeast Lorestan Zone.

MATERIAL AND METHODS

For this study, six biostratigraphical stratigraphy sections were measured in the field, bed by bed. A total of 367 hard rock and thin sections were prepared to analyze foraminiferal content of the Thanetian–Ilerdian succession in the Loresten Zone (Kabutar Bala, 142 m; Psht-e Jangal, 80 m; Ferdows, 141 m; Darreh Baneh, 118 m; Sarkan, 60 m; and Maleh Kuh, 121 m-thick) (Figure 1B). Sampling intervals were generally between 1.55 and 2 m. The selection of samples was primarily based on changes in color, lithology, and other sedimentary parameters. The most important features for choosing biostratigraphical sections are having a suitable outcrop, not covered, as well as to specify their upper and lower boundaries. The composition of the thin sections (28 × 48 mm) was microscopically investigated in transmitted light. Benthic foraminifera are abundant in the studied sections, so they are used for biostratigraphical interpretation.

Identification of benthic foraminifera was based on Höttinger (1960, 1973), Drobne (1977), and Sirel & Acar (2008), and the identified species are distributed according to the biostratigraphic scheme of Serra-Kiel *et al.* (1998), updated by Papazzoni *et al*. (2017).

BIOSTRATIGRAPHY

According to biostratigraphic data from the Taleh Zang Formation, 36 genera and 22 species of foraminifera (Figure 2) were identified in four biozones during the late Paleocene to early Eocene (Figures 3–7).

Indeterminate Zone

In the Kabutar Bula and Psht-e Jangal sections, only a few benthic foraminifera have been identified: *Dictyoconus* sp., *Glomalveolina* sp., *Haymanella* sp., *Kathina* sp., *Massilina* sp., *Miscellannea* sp., *Olssonina* sp., *Sacksaria* sp., Miliolid, *Cymopolia* sp., and *Neomeris* sp. (Dasyclad green algae).

Since no index microfossils were found in this interval, we labeled it the Indeterminate Zone. The Thanetian Age

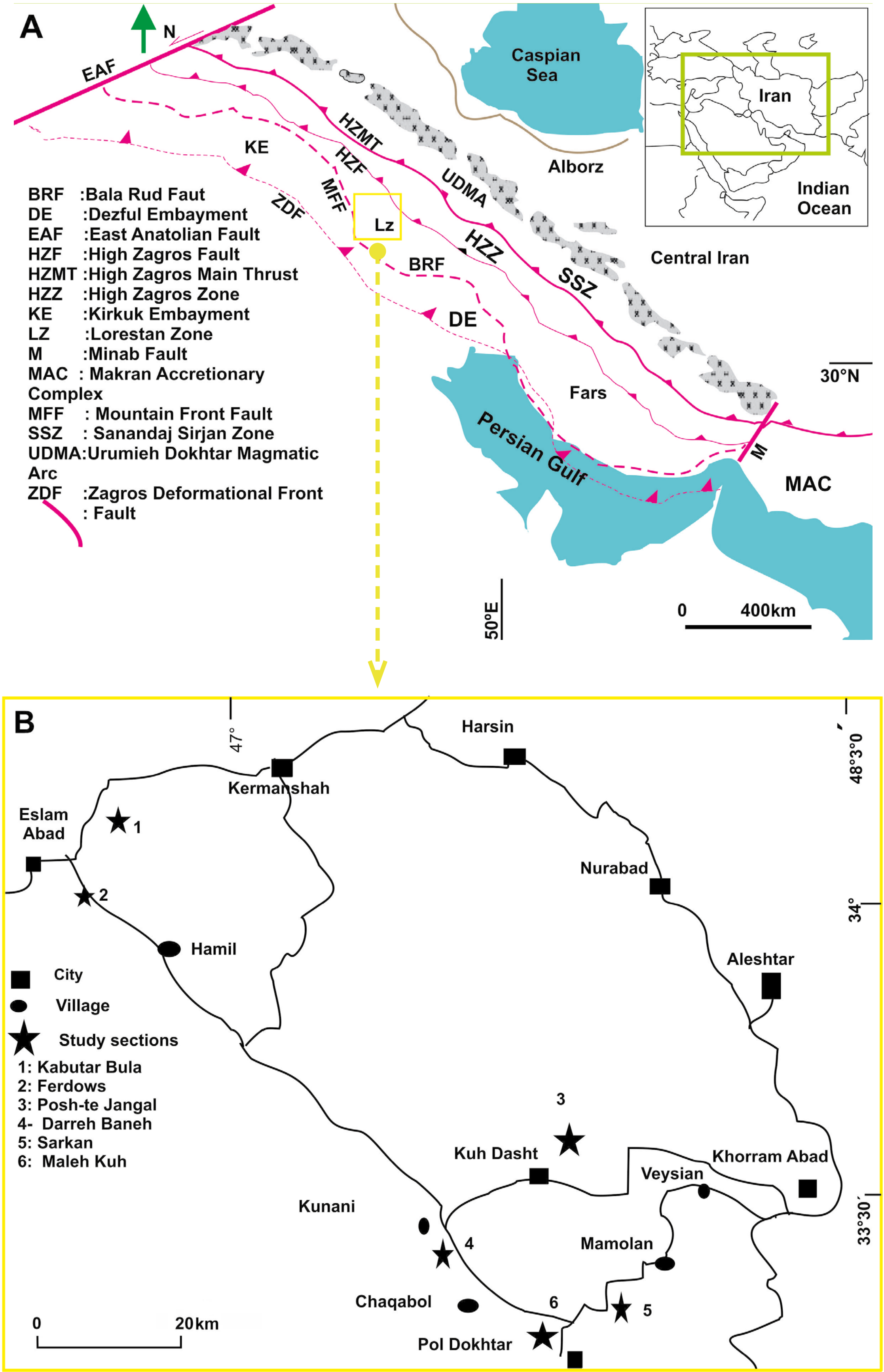

Figure 1. A, the position of Lorestan Zone in the Zagros Basin (Alavi, 2007), yellow box is zoom out on B. **B**, location map of the study sections.

attributed to these deposits derived primarily from their stratigraphic position and comparison to the Tale Zang Formation age in adjacent sections.

Shallow Benthic Zone 3

Shallow Benthic Zone 3 is characterized in the Taleh Zang Formation of the Darreh Baneh Section and the lower part

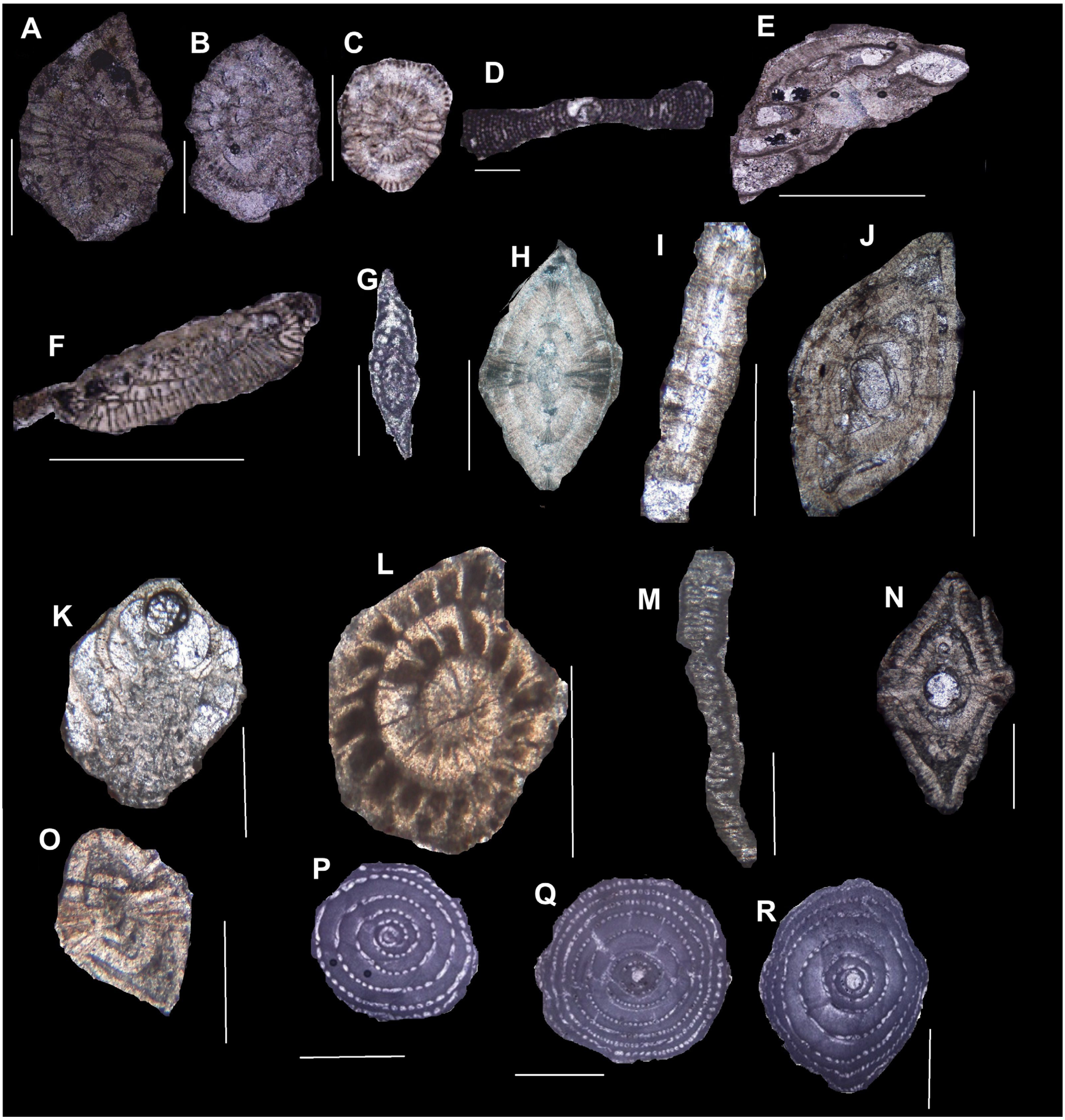

Figure 2. A, *Miscellanites minutus* (Rahaghi, 1983), Ferdows Section, sample no. 25; **B**, *Miscellanites primitivus* (Rahaghi, 1983), Ferdows Section, sample no. 62; **C**, *Miscellanites iranicus* (Rahaghi, 1983), Ferdows Section, sample no. 35; **D**, *Mardinella daviesi* (Henson, 1950), Ferdows Section, sample no. 84; **E**, *Sistanites iranica* (Rahaghi, 1983), Ferdows Section, sample no. 12; **F**, *Dictyokathina simplex* (Smout, 1954), sample no. 64; **G**, *Hottingerina anatolica* Sirel, 1999, Ferdows Section, sample no. 56; **H**, *Paleonummulites* sp., Maleh Kuh Section, sample no. 16; **I**, *Assilina yvettae* (Schaub, 1981), Darreh Baneh Section, sample no. 4; **J**, *Chordoperculinoides* sp., Darreh Baneh Section, sample no. 19; **K,** *Sakesaria somalica* (Ruggieri, 1951), Darreh Baneh Section, sample no. 30; **L**, *Nummulitoides inaequilateralis* (Carter, 1853), Darreh Baneh Section, sample no. 33; **M**, *Vania* sp., Darreh Baneh Section, sample no. 33; **N**, *Miscellanea dukhani* (Smout, 1954), Darreh Baneh Section, sample no. 23; **O**, *Miscellanea miscella* (d'Archiac & Haime 1853), Darreh Baneh Section, sample no. 27; **P**, *Alveolina globosa* (Leymeriew, 1846), Sarkan Section, sample no. 34; **Q**, *Alveolina pisiformis* (Höttinger, 1960), Sarkan Section, sample no. 24; **R**, *Alveolina pasticillata* (Schwager, 1883), Sarkan Section, sample no. 15. Scale bars = 1 mm.

of the Ferdows section. Based on the vertical distribution of identified microfossils in this section, dasyclad green algae and corallinacean are abundant. It contains both gray and argillaceous limestone. According to microscopic studies, bioclast wackestone is the predominant lithofacies of this section of the Taleh Zang Formation in this section. This biozone is marked by the appearance of *Dorotia* sp., *Fallotella* sp., *Hottingerina anatolica* Sirel, 1999, *Idalina antiqua* (Schlumberger & Munier-Chalmas, 1884), *Idalina sinjarica* (Grimsdale, 1952), *Mardinella daviesi* (Henson, 1950), *Miscellanites iranicus* (Rahaghi, 1983), *Miscellanites minutus* (Rahaghi, 1983), *Miscellanites primitivus* (Rahaghi, 1983), *Pseudolitunella* sp., *Quinqueloculina* sp., *Setia* sp., *Stomatorbina binkhorsti* (Reuss, 1862), *Textularia* sp., *Triloculina trigonula* (Lamarck, 1804), *Valvulina* sp., and *Cymopolia* sp.

The early Thanetian corresponds to a significant biological evolution, especially for benthic foraminifera. Höttinger (1960) introduced Shallow Benthic Zone 3 by the total range of *Glomalveolina primaeva* (Reichel, 1936). Serra-Kiel *et al.* (1998) identified *Glomalveolina primaeva* as the index taxa for the Late Selandin to mid-Thanetian. The Shallow Benthic

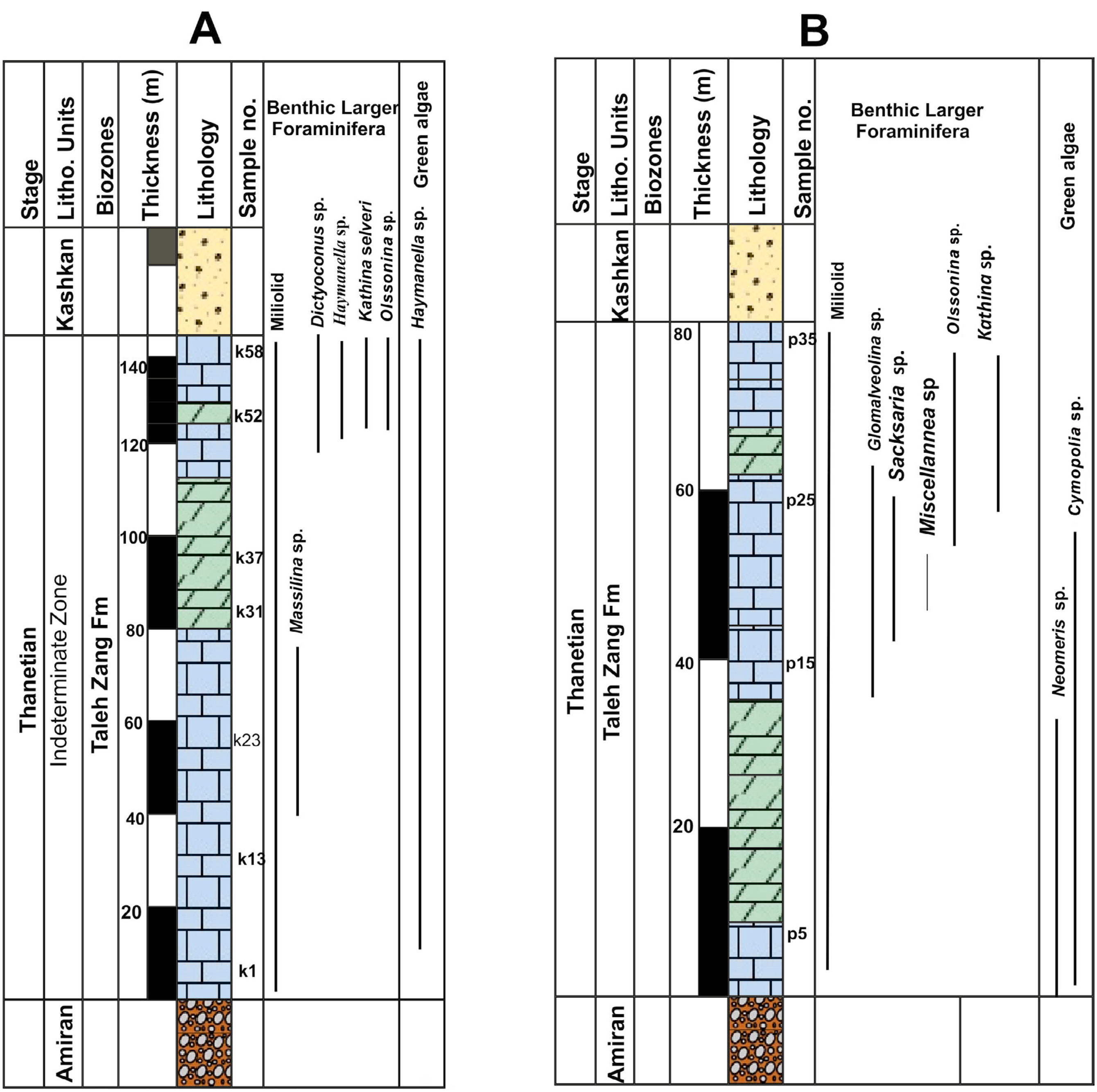

Figure 3. Distribution of benthic foraminifera and biostratigraphic zonation of the Kabutar Bala (**A**) and Psht-e Jangal (**B**) sections.

Zone 3 index taxa *Hottingerina anatolica* Sirel, 1999 and *Miscellanites iranicus* (Rahaghi, 1983) were documented by Sirel (1999). Contrary to the western Tethys and some Upper Paleocene outcrops in eastern Iran (Gorgij & Shahraki Mirzaei, 2019), the species *Glomalveolina primaeva* has not been observed in the Ferdows section. Homke *et al*. (2009) identified the Thanetian benthic foraminifera to southeast in the Amiran anticline and concluded that it corresponds to the Shallow Benthic Zone 3 of Serra Kiel *et al*. (1998).

Shallow Benthic Zone 4

According to the vertical distribution of identified foraminifers, Shallow Benthic Zone 4 is found in the Taleh Zang Formation of the Sarkan and upper-most of the Ferdows. A lithological aspect consists of gray massive limestone. The associated foraminifera taxa consist of *Alveolona* sp., *Assilina yvettae* (Schaub, 1981), *Chordoperculinoides* sp., *Discocyclina* sp., *Haymanella* sp., *Idalina sinjarica*, *Kathina pernavuti* (Sirel, 1972), *Miscellanea dukhani* (Smout, 1954), *Miscellanea miscella* (d'Archiac & Haime, 1853), *Nummulitoides inaequilateralis* (Carter, 1853), *Operculina* sp., *Opertorbitolites* sp., *Palaeonummulites* sp., *Quinqueloculina* sp., *Ranikothalia nuttalli* (Davies, 1927), *Redmondina henningtoni* (Hasson, 1985), *Sakesaria somalica* (Ruggieri, 1951), *Textularia* sp. and *Vania* sp.

Schaub (1981) believed the presence of *Assilina yvettae* (Schaub) indicated Shallow Benthic Zone 4. This assemblage is considered to be late Thanetian in age.

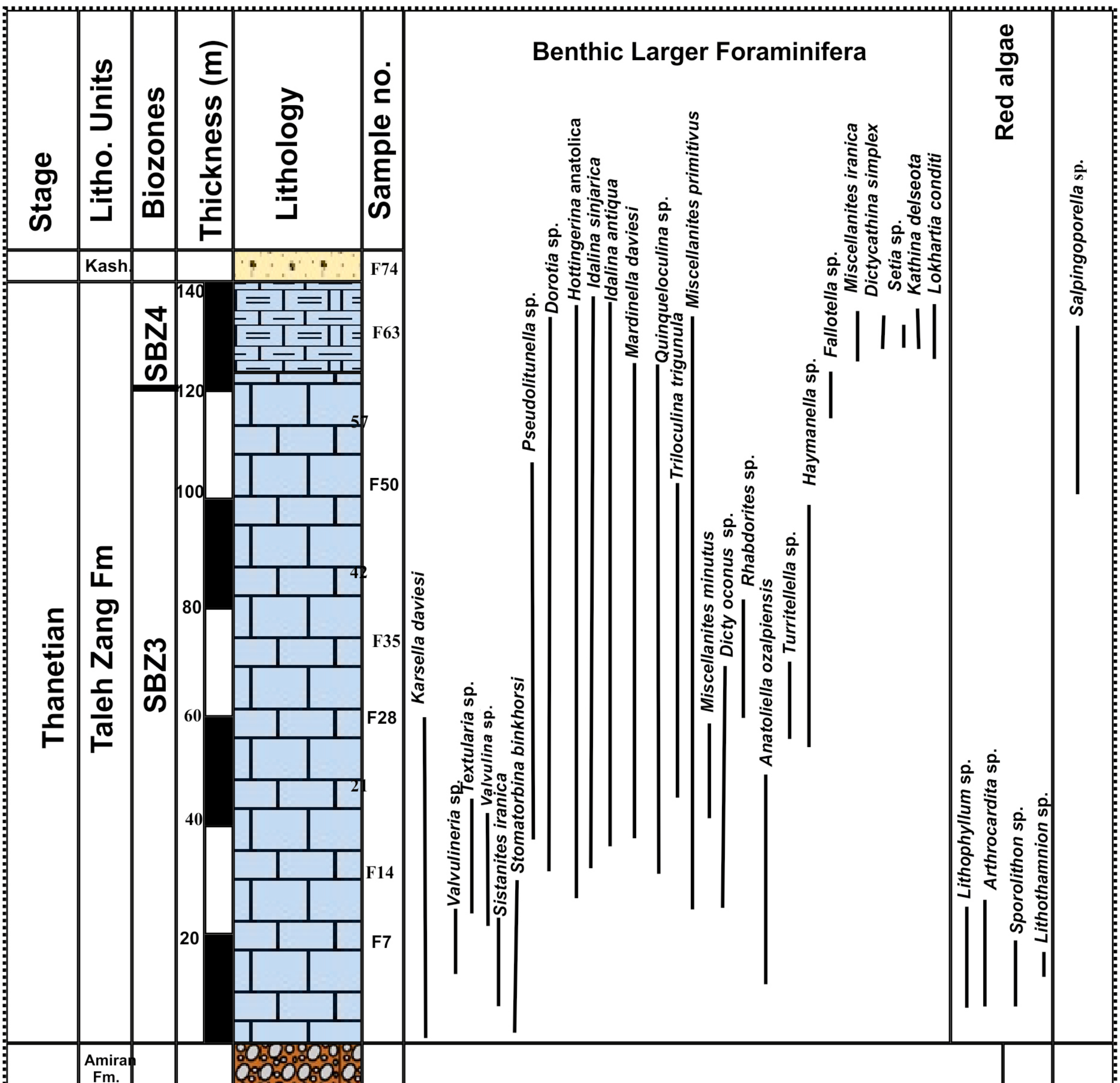

Figure 4. Distribution of benthic foraminiferaand biostratigraphic zonation of the Ferdows Section.

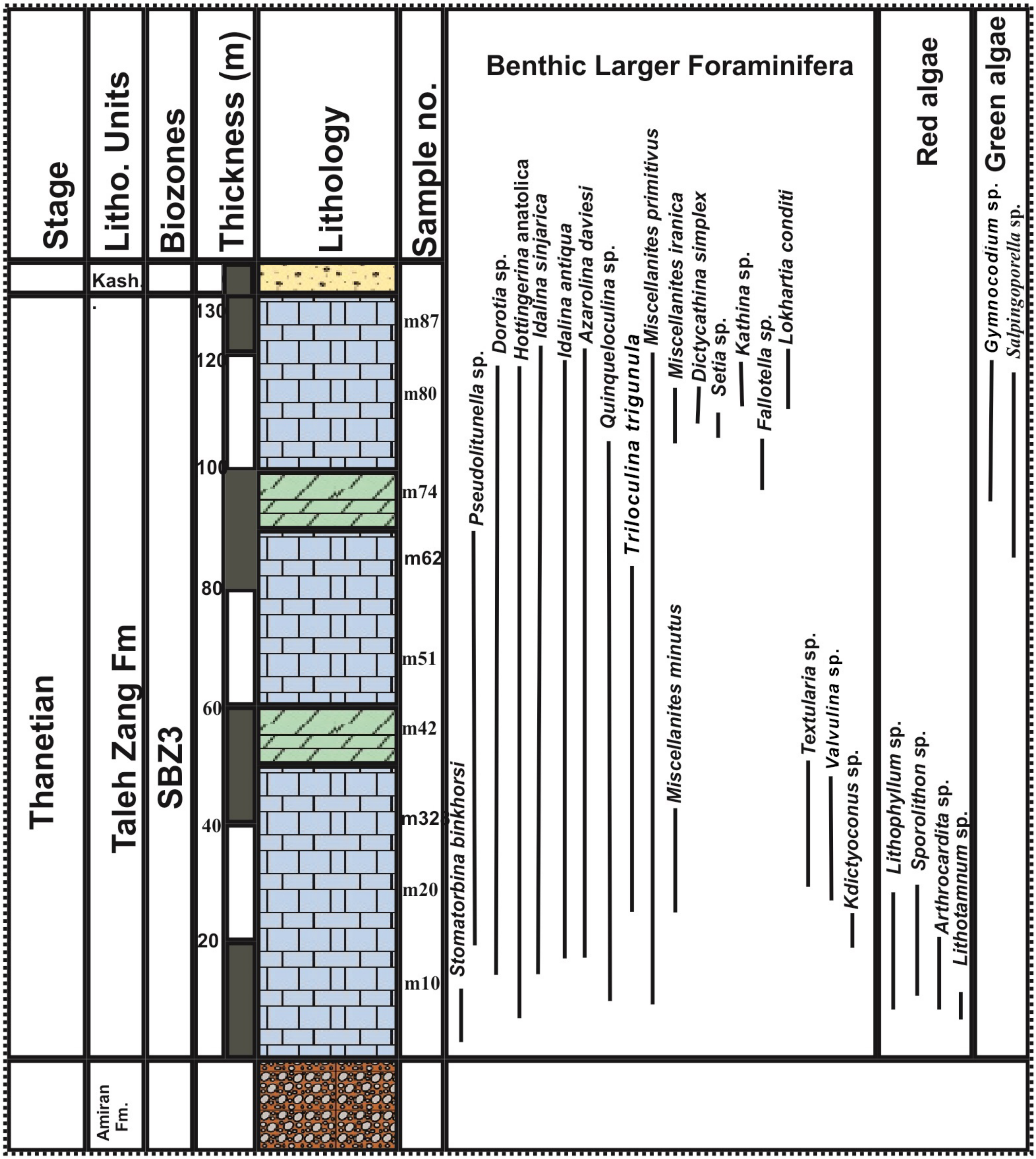

Figure 5. Distribution of benthic foraminifera and biostratigraphic zonation of the Darreh Baneh Section.

Shallow Benthic Zone 6

Shallow Benthic Zone 6 is described in the Maleh Kuh section. The lithological aspect consists of massive to medium-bedded and argillaceous limestone. Based on microscopic studies, the predominant lithofacies of these sections of the Taleh Zang Formation is bioclast wackestone with foraminifera fossils. This biozone is characterized by the first appearance of *Alveolina pasticillata* (Schwager, 1883), *Alveolina pisiformis* (Höttinger, 1960) and is indicative of the Ilerdian in age. The other foraminifera content also consisted of: *Alveolina ellipsoidalis*, *Alveolina globosa* (Leymeriew, 1846), *Alveolina pasticillata* (Schwager, 1883), *Alveolina pisiformis* Hottinger, 1960), *Davisina* sp., *Discocyclina* sp., *Idalina* sp., *Mardinella daviesi* (Henson, 1950) and *Miscellanea miscella*, *Nummulites minervensis*, *Operculina* sp., *Operturbitolites* sp., *Orbitolites* sp., *Paleonummulites* sp.,

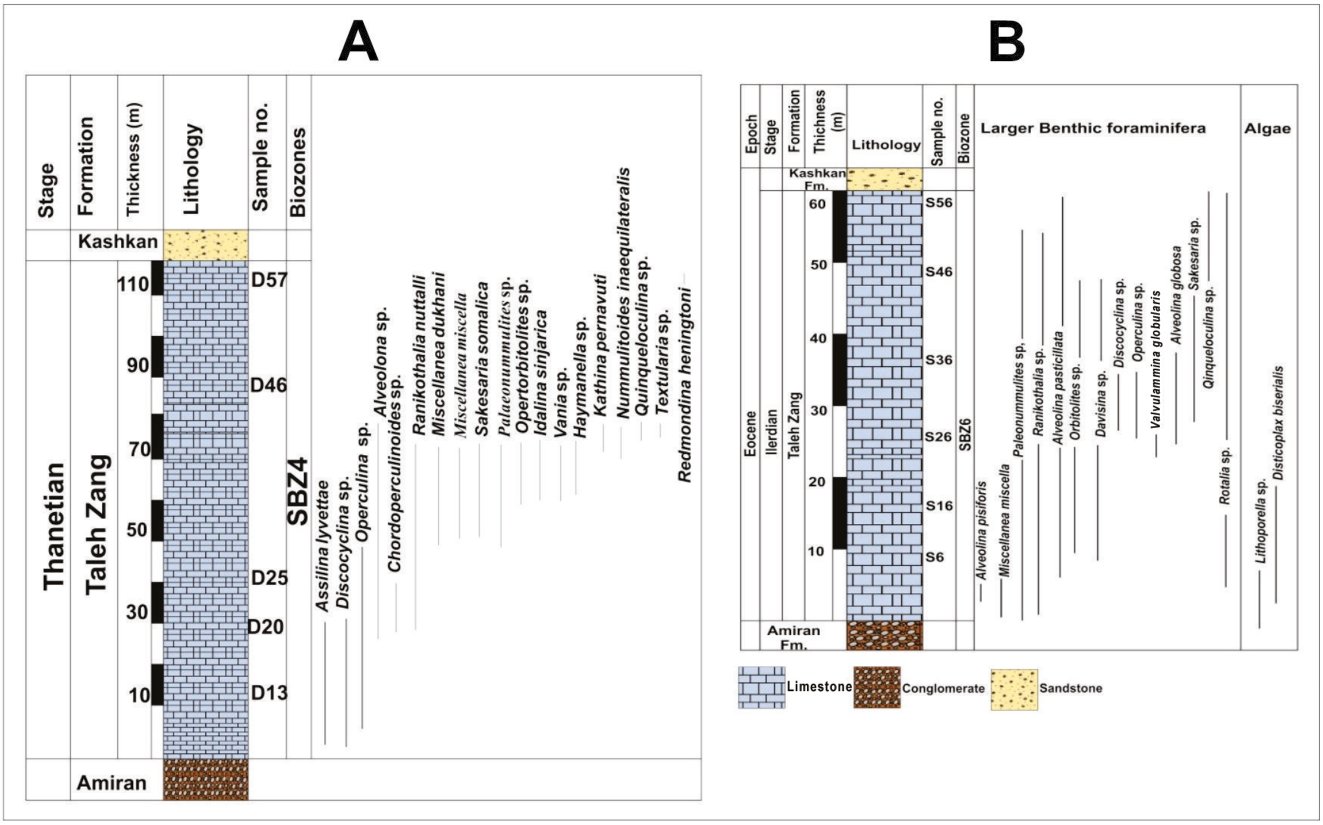

Figure 6. Distribution of benthic foraminifera and biostratigraphic zonation of the Sarkan (**A**) and Maleh Kuh (**B**) sections.

Quinqueloculina sp., *Ranikothalia* sp., *Rotalia* sp., *Sakesaria* sp., *Valvulina* sp., *Valvulammina globularis* (D'Orbigny, 1850), *Disticoplax biserialis* (Dietrich) (green algae), *Lithoporella* sp. (red algae).

DISCUSSION

The Lorestan Zone is a foreland basin along the northern Arabian margin (Alavi, 2007). The evolution of the Paleocene–Eocene carbonate platform margin and the variation in biotic content along the Lorestan Zone depend on the regional tectonic activity and global factors. Maastrichtian and Danian sediments were absent from most of the Arabian Plate due to an upper Cretaceous hiatus (Sharland *et al*., 2001).

Most of the southern and southwestern sides of the High Zagros zone and the northern side of the Sepid Kuh Fault lack Paleocene marine sediments. During the Paleocene, this zone was part of the wedge-top of the Lorestan Zone. Here the Paleocene–Eocene rocks, known as the Kashkan Formation, consist of approximately 100 m of red sandstone and conglomerate. The conglomerate is composed of radiolarite fragments of Late Cretaceous age.

At the end of the Selandian or the start of the Thanetian, significant paleogeographic shifts occurred throughout the Northern Lorestan Zone. These may be related to global eustatic sea-level rises that cause major transgressions. According to our research, the Taleh Zang Formation deposits are younger from the northeast to the southwest of the Lorestan Zone, and their distribution is parallel to the axis of the folds (Figure 7).

As orogenic movements continued in the late Paleocene–early Eocene, the wedge-top of the Lorestan Zone shifted from the northeast to the southwest. This caused the age of the Kashkan Formation in this direction to become younger. In northern Lorestan, therefore, the Thanetian deposits of the Taleh Zang Formation are located beneath the Kashkan Formation, whereas in the Sarkan anticline, the Taleh Zang Formation is early Eocene in age.

Scheibner *et al*. (2005) demonstrated that the sedimentary effects of primarily paleoclimatic changes associated with the evolution of larger foraminifera allowed for the subdivision of the upper Paleocene to lower Eocene carbonate platform into three stages of biotic platform development.

Stage I: It is distinguished by the expansion of coral into all latitudes except north-eastern India, while larger foraminifera have just begun to recover from their decline at the Cretaceous/Paleogene boundary (Scheibner & Speijer, 2008). This stage corresponds to Shallow Benthic Zone 3 and is dated to the Selandian–early Thanetian time (Figure 8). Following the K–Pg event, larger benthic foraminifera began to recover in platform stage (Boudagher-Fadel, 2008). They thrived on shallow, oligotrophic, carbonate platforms Circum-Tethyan (Buxton & Pedley, 1989).

The extremely shallow water limestone in the Kabutar Bula and Psht-e Jangal sections yielded rare *Kathina*,

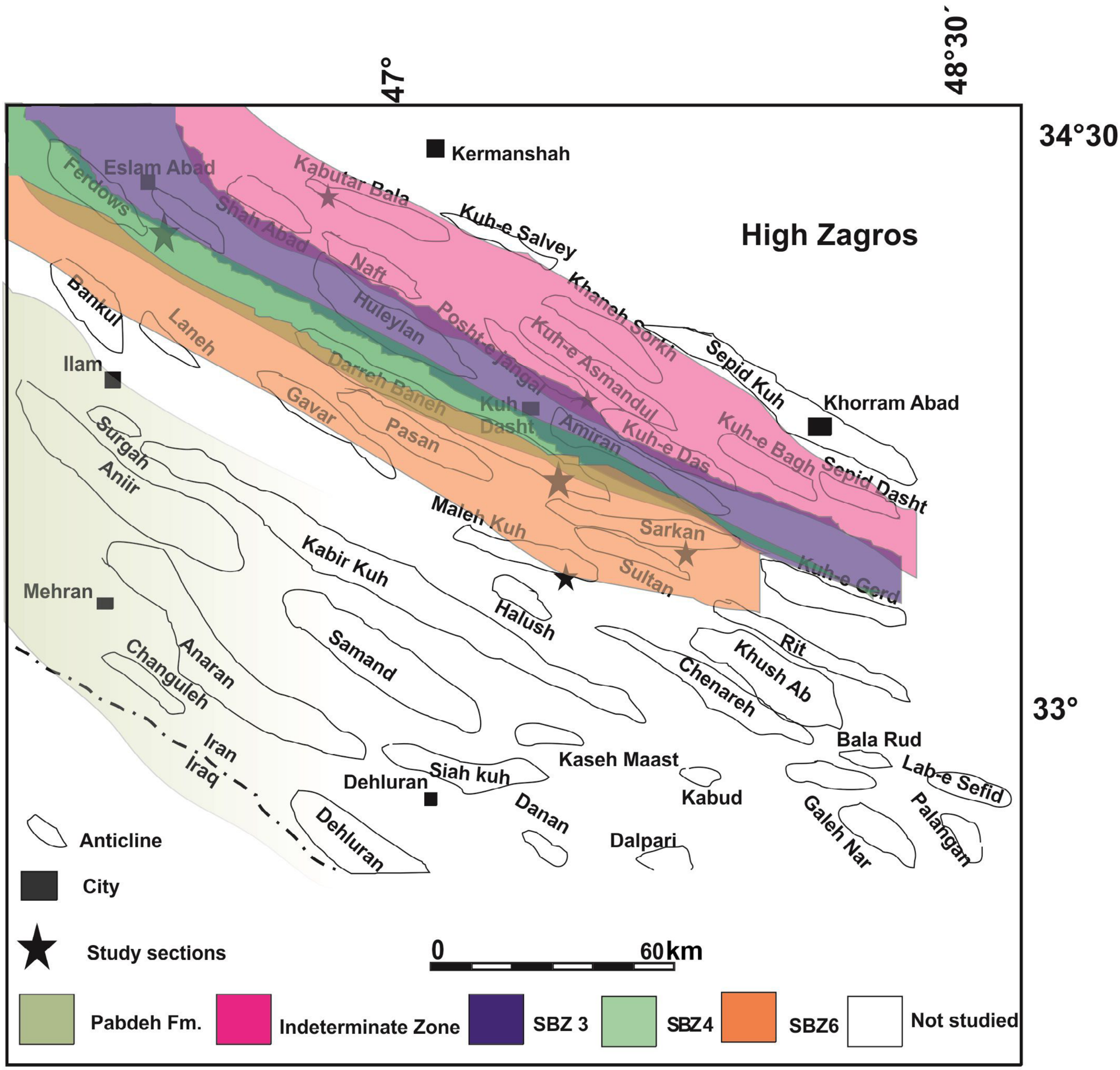

Figure 7. Map showing Thanetian–Ilerdian shallow benthic zone and Pabdeh Formation in the Lorestan Zone.

alveolinid, miliolid, and green algae, as well as very fine to fine crystalline dolomite and grey limestone composed of detrital quartz grains, gypsum, and fenestrate structures. These sediments indicate low-energy conditions, possibly a tidal environment with a flat seabed (Adabi, 2004). Southwest of the Ferdows and Darreh Baneh anticlines, the sedimentary basin becomes deeper and no longer contains dolomite and evaporative minerals. In contrast, both the quantity and diversity of foraminifera increase. Comparable to the upper Paleocene deposits of north-eastern India, corals are not common in the studied sections.

Stage II: The distribution of coral reefs exhibits a latitudinal gradient during the second stage. Coral reefs were still present at middle latitudes, whereas they were virtually non-existent at low latitudes, which were dominated by a suite of larger foraminifera. In the western Tethys, these foraminifera (including *Miscellanea* and *Ranikothalia*) are characteristic of the second platform stage, whereas, in the eastern Tethys (India), they are also present in platform stage III (Scheibner *et al*., 2008). The Larger Foraminifera Turnover, first described from the Pyrenees by Höttinger & Schaub (1960), is an additional significant event that occurred during stage II. The Larger Foraminifera Turnover is characterized by the beginning of adult dimorphism and large shell size in larger foraminifera, particularly nummulitids and alveolinids, and marks the base of the Ilerdian, which is located between Shallow Benthic Zone 4 and Shallow Benthic Zone 5 (Höttinger & Schaub, 1960).

According to Serra Kiel *et al*. (1998), *Alveolina cucumiformis* is the precursor biozone of Shallow Benthic

<table>
<tr><th rowspan="2">Serie</th><th rowspan="2">Age</th><th rowspan="2">Kabutar Bala and Psht-e Jangal</th><th rowspan="2">Darreh Baneh</th><th rowspan="2">Ferdows</th><th rowspan="2">Sarkan</th><th rowspan="2">Maleh Kuh</th><th colspan="2">SB Zones</th><th rowspan="2">Platform stage Scheibner & Speijer (2008)</th></tr>
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<tr><td rowspan="4">Upper Paleocene</td><td rowspan="3">Thanetian</td><td rowspan="3">Taleh Zang Fm.</td><td rowspan="2">Taleh Zang Fm.</td><td rowspan="4">Amiran Fm.</td><td>SBZ 5</td><td rowspan="2">SBZ 4</td><td rowspan="2">Stage II</td></tr>
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Figure 8. Correlations between Paleocene–and Eocene biostratigraphic schemes and platform stages in the Lorestan zone of Zagros basin. Our research focuses on the interval Shallow Benthic Zone 3–Shallow Benthic Zone 5/6.

Zone 5 (junior synonym of *A. vredenburgi* Höttinger *et al*., 1998). In the studied sections, no Shallow Benthic Zone 5 index species were found. Additional research on the presence or absence of this zone in Lorestan is required. Due to the inability to identify the Shallow Benthic Zone 5, which marks the beginning of the Eocene, it is impossible to trace the effects of the late Thanetian events, such as the rising temperatures, in the Lorestan zone's shallow sediments.

Nonetheless, it appears that the increase of hyaline foraminifera to the south of the Lorestan Basin, such as the Sarkan anticline, indicates an increase in depth.

Stage III: It is characterized by the decline of coral reefs and the presence of the most extreme K-strategist among larger foraminifera that once thrived on carbonate platforms (Scheibner *et al*., 2008). After the spread of oligotrophic conditions, nummulitids and alveolinids occupied the vacated niches, resulting in a larger foraminiferal turnover, and larger foraminifera thrived until the middle Eocene, when coral reefs became more abundant once more (Scheibner *et al*., 2008).

During the early Eocene, red algae and coral colonies dominate the lower portion of the Sarkan Section and facies with restricted environment properties, while the upper section is characterized by an abundance of larger foraminifera (*Ranikothalia*, *Miscellanea*, and *Nummulites*) and the absence of corals (Bagherpour & Vaziri, 2012).

In the north-eastern India and the Salt Range in Pakistan, the platform underwent retrogradation, and nummulitids, alveolinids, and discocyclinids predominate over miscellanids and ranikothalids as a result of the short-term effects of the Palaeocene–Eocene Thermal Maximum (temperature increase, eutrophication) during the platform stage III of Tethyan realm (Ghazi *et al*., 2020).

Near the end of the Maleh Kuh Section, *Ranikothalia*, *Miscellanea*, and *Nummulites* can be observed, indicating that the Tale Zang Formation is early Ilerdian in age.

CONCLUSIONS

Thanetian-Ilerdian Taleh Zang Formation of the Lorestan zone, of the Zagros Basin, a rich association of larger benthic foraminifera, has been identified. There are four biostratigraphic zones: The Indeterminate Zone (probably Thanetian), Shallow Benthic Zone 3 and 4 (Thanetian), and Shallow Benthic Zone 6 (Ilerdian). These biozones extend parallel to the axis of the folds and age from northeast to southwest. Their distribution pattern demonstrates that the axis of the folds was the southern edge of the Taleh Zang Formation's shallow platform, which migrated to the southwest during the evolution of the Lorestan foreland zone. Shallow Benthic Zone 5 was not observed in any of the examined sections. Nonetheless, if this biozone is present in the Lorestan foreland zone, it is likely to be found north of Sarkan and south of the Darreh Baneh anticline.

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Received: 10 January 2023. Accepted: 29 April 2024.

Associated editor: Cristianini Trescastro Bergue
Editor-in-chief: Matias do Nascimento Ritter