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# Biostratigraphy of Late Eocene-Oligocene deposits based on planktonic and larger benthic foraminifera in the Sabzevaran and Sad sections, NW Jiroft (Iran)

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**Abstract**
In this paper, to study biostratigraphy of Paleogene deposits based on foraminifera fauna in NW of Jiroft located in the Central Iran zone, two stratigraphic sections, namely Sabzevaran (354 m) and Sad (132 m) sections were selected. Planktonic foraminifera and large benthic foraminifera were identified in both sections. Faunal assemblages and vertical distribution of identified species support presence of 5 planktonic foraminiferal and 2 large benthic foraminiferal biozones in the Sabzevaran section showing Middle Eocene to Chattian age. In addition, presence of planktonic foraminiferal assemblage along with 2 large benthic foraminiferal biozones confirms the Late Eocene to Chattian age for the Sad section.

**Keywords**
Eocene, Oligocene, Planktonic Foraminifera, Larger Benthic Foraminifera, Jiroft, Central Iran.

## 1. INTRODUCTION

In marine environment, foraminifers are of great importance because of their assemblages and distribution, and they are used as geological standard tools for biostratigraphic studies (e.g. Hendy *et al.*, 2004; Field *et al.*, 2006). In the meantime, regardless of small benthic foraminifera, planktonic and larger benthic foraminifera are a valuable tool more preferred to other fossil groups due to their high frequency, wide geographical distribution, and rapid evolution, making them ideal for biostratigraphic studies at the global level. Among these organisms, planktonic foraminifera were the first group investigated as biostratigraphic targets (Bolli & Krasheninnikov, 1977).

Marine sediments of Qom Formation (Oligo-Miocene) were deposited at northeastern coast of the Tethyan Seaway (Reuter *et al.*, 2009). Study on Qom Formation deposits in the Central Iran zone is essential and significant because of economic value of this Formation. Qom Formation is the main objective for oil and gas exploration projects in the Central Iran, and traditionally it has a great importance.

Formation of Qom basin is attributed to subduction of Neotethys oceanic crust beneath the Central Iran, which formed a back-arc opening, deposition of the Qom Formation, and alkaline volcanic processes (Berberian, 1983). Closure of this basin occurred probably because of eustatic falling of sea level (Rahimzadeh, 1994) and orogenic movement, or collision of the African-Arabian and Eurasia plates (Reuter *et al.*, 2008). Although, stratigraphic relationship between Eocene and Oligo-Miocene deposits of the Central Iran is not clearly known.

## 2. MATERIAL AND METHODS

To establish biozones of the Eocene and Oligocene deposits, sampling was done systematically at regular intervals as along with examination of facies changes. Ninety-six and 320 samples were collected from Sabzevaran and Sad sections (Fig. 1), respectively. Considering the variation of samples involving both hard rocky and loose marly ones, sample preparation was done using thin sections, and washed samples in 70, 120 and 230 mesh sieves. The foraminifers were identified according to the literature (Boudaugher-Fadel, 2018; Ferràndez-Cañadell & Bover-Arnal, 2017; Jones, 2014; Hamdan *et al.*, 2011; Hohenegger, 2011; Özcan *et al.*, 2010; Boukhary *et al.*, 2008; Wade & Pearson, 2008; Pearson

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*et al.*, 2006; Sexton *et al.*, 2006; Myftari *et al.,* 2001). After microscopic studies and identification, a number of samples were selected to provide photomicrographs using the SEM device.

## 3. RESULTS AND DISCUSSION

### 3.1. Lithostratigraphy

Several outcrops of sediments in studied area can be seen attributed to the Eocene and Oligocene deposits. In this area, Sad section deposits consist of marl, sandstone, conglomerate, limestone, and shaly limestone. Thickness of this section is approximately 132 meters. The top of the section is marked by an erosional surface (Fig. 2).
In addition, Sabzevaran section consists of alternation of conglomerate, sandstone, limestone, and shale. This section is extended about 354 meters. The lowermost part of the Sabzevaran section is distinguished by alternation of conglomerate and sandstone. Similar to Sad section, upper lithostratigraphic limit is recognized as an erosional surface (Fig. 3).

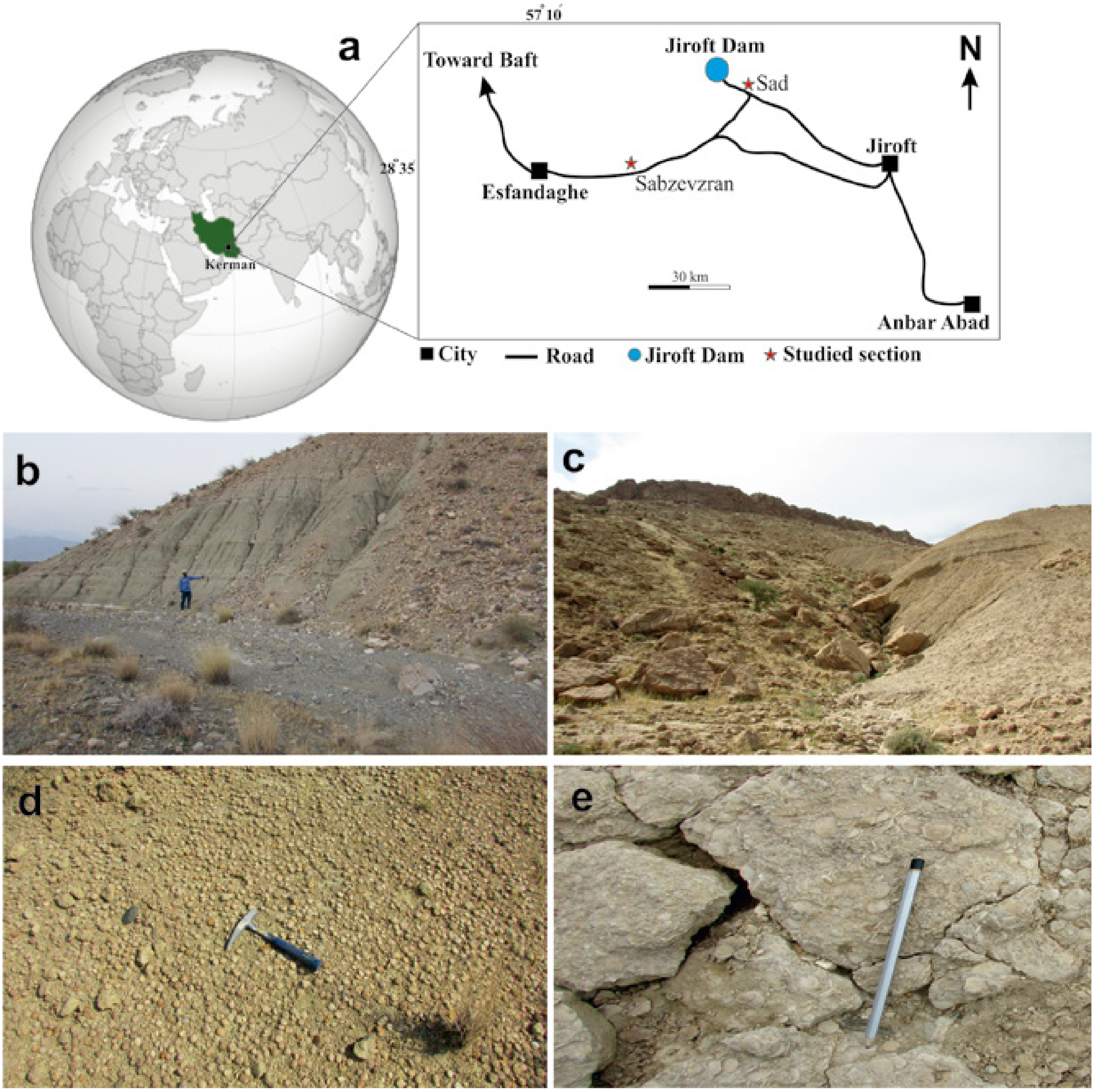


Fig. 1: Location of studied area (a), marly sequence of lower part of Sabzevaran section (b) and Sad section (c), more occurrence of larger benthic foraminifera in upper part of Sabzevaran section (d) and Sad section (e).

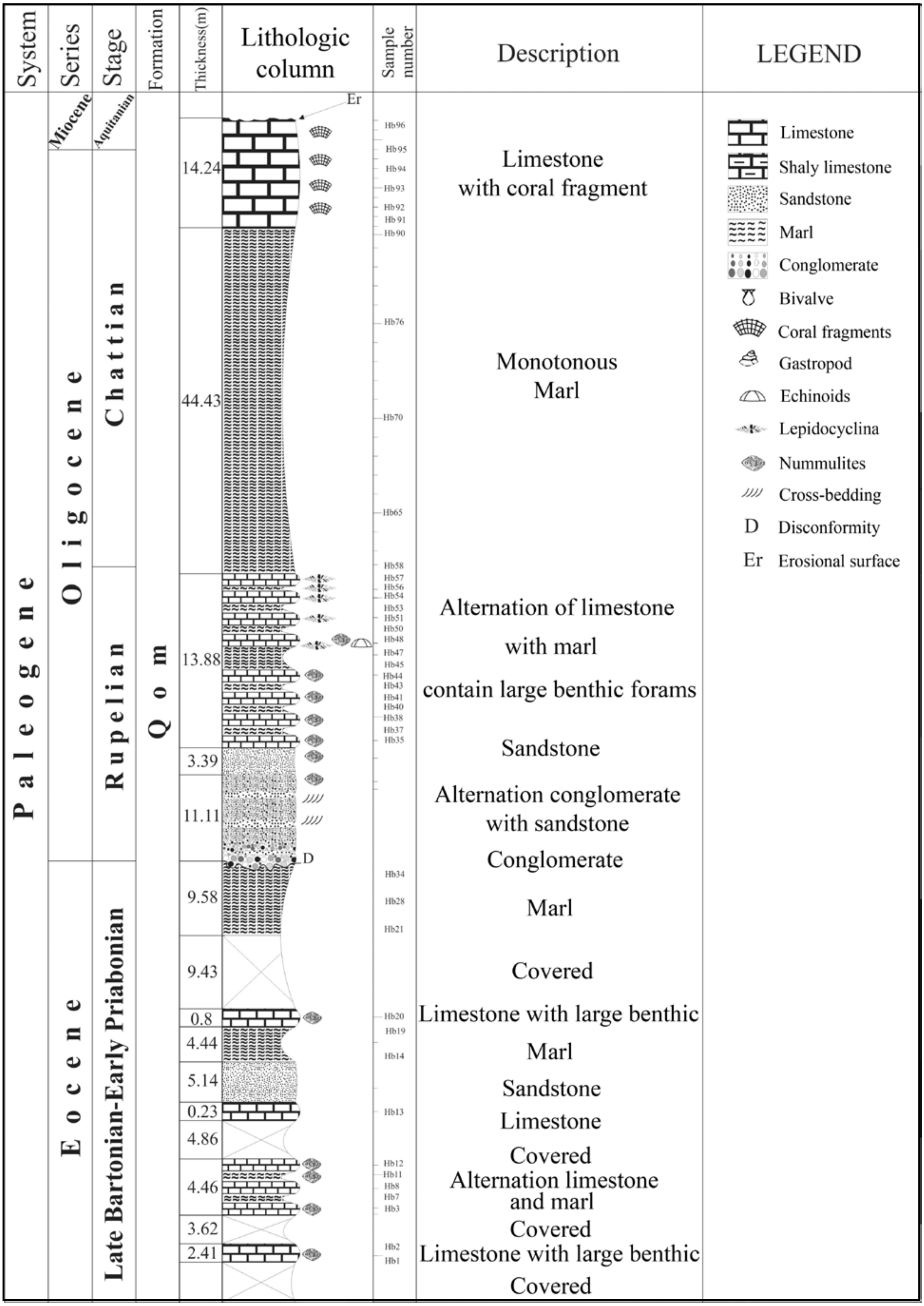


Fig. 2: Eocene-Oligocene section in the Sad field section.

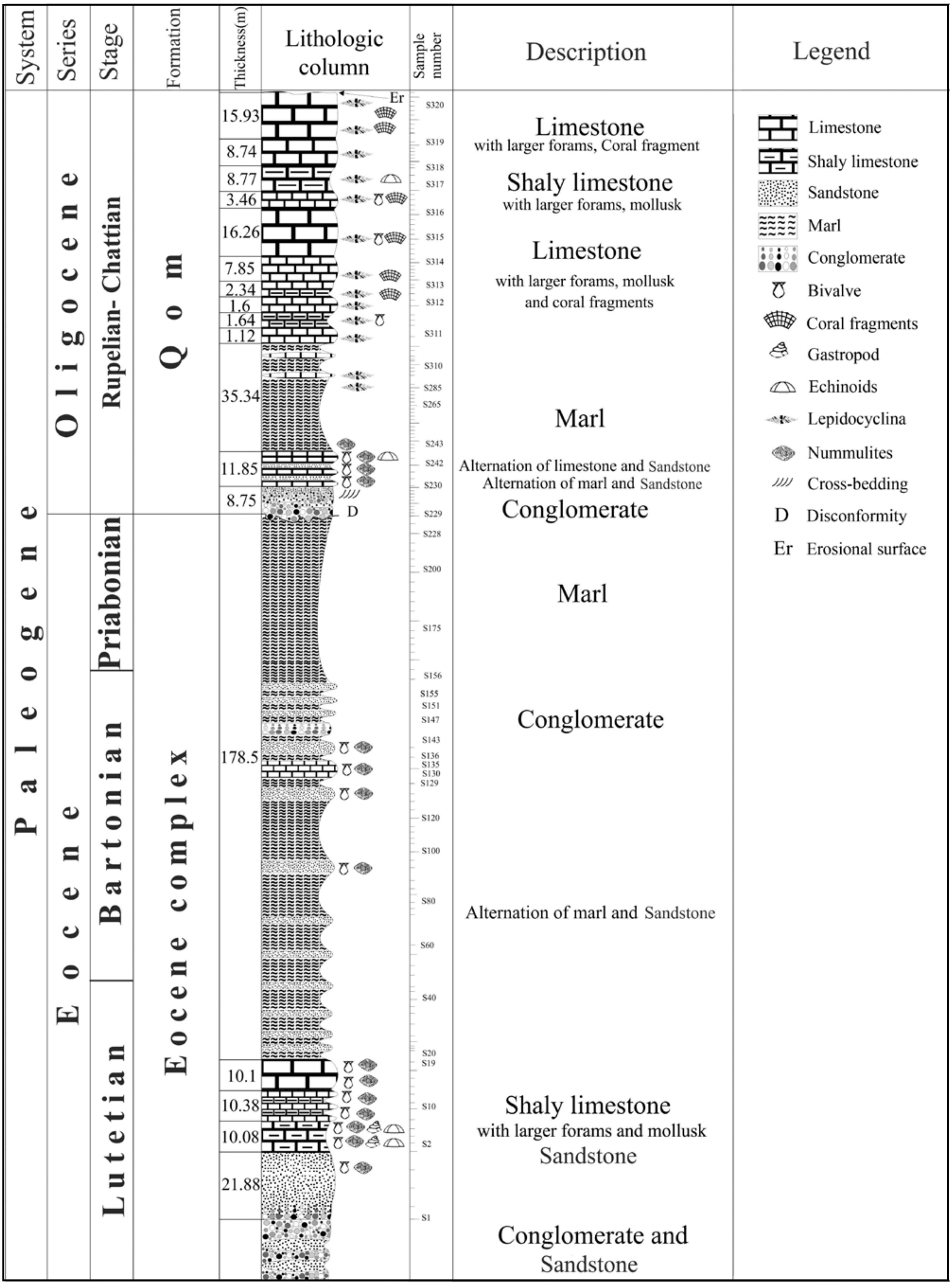


Fig. 3: Eocene-Oligocene section in the Sabzevaran field section. Some of the Foraminifera are illustrated in Plates I-III.

### 3.2. Biostratigraphy

In this study, planktonic foraminifera were identified in the Late Eocene marly deposits. Larger benthic foraminifera were also identified in the studied sections, especially in their upper part where they are significant. Large Benthic Foraminifera (LBF) are widely recognized during the Paleogene and the Neogene in shallow carbonate environments. Toward the top of the studied sections, a large benthic foraminiferal assemblage is distinguished, which is assigned to the lowermost Oligocene. No formal biozonation has been provided for the Qom Formation deposits so far (Oligocene-Miocene boundary). According to studied sections, faunal assemblages have many similarities with the deposits of Zagros region (Adams & Bourgeois, 1967; Wynd, 1965; Laursen *et al.*, 2009) (see Fig. 4). There is a conspicuous similarity between the Qom Formation foraminifera and those of the Asmari Formation in Zagros region (Bozorgnia, 1966).

### 3.3. Biozonation of Studied Sections

#### *3.3.1. Sad Section (Fig. 5)*

**Biozone 1:** In the Sad section, two species assigning two genera of planktonic foraminifera were identified and their interval presence was determined (Caron & Homewood, 1983; Loeblich & Tappan, 1988; Berggren *et al.*, 1995; Premoli-Silva *et al.*, 2003; Pearson *et al.*, 2006).
*Subbotina gortanii* (Borsetti, 1959) and *Turborotalia* aff. *altispiroides* Bermudez, 1961 were identified from the base of Sad section toward the beginning of conglomerate horizon (0-45 meters, samples Hb1 to Hb34). Based on their occurrence (Berggren & Pearson, 2005), Middle to Late Eocene age is proposed for this part of Sad section. Above this 45 meter at the base part in the Sad section dated as Eocene, the age was determined by larger benthic foraminifera.

**Biozone 2: *Nummulites* Assemblage Zone**
The last occurrence of *Nummulites* is coeval with the end of Rupelian (Racey, 1994; BouDagher-Fadel, 2018; Laursen *et al.*, 2009). Rupelian stage in Qom formation is characterized by presence of *Nummulites intermedius* (d'Archiac) (Rahaghi, 1980) and also contains *Nephrolepidina* sp., and *Eulepidina* aff. *dilatata* (Michelotti). Based on occurrence of some species of *Nummulites*, such as *Nummulites fichteli* Michelotti and *Nummulites vascus* Joly & Leymerie in the sample No. Hb 58, a Rupelian age is proposed for this part of section [45 m - 73 m (28 meters), samples Hb35 to Hb58]. Lepidocyclinids are present in the upper part of Sad stratigraphic section in the biozone 3 (Rupelian) (Fig. 5).

**Biozone 3: *Nepherolepidina* aff. *tournoueri-Operculina complanata* Assemblage Zone**
Because of faunal similarity of the Asmari and the Qom Formations, we used the species recognized by Adams & Bourgeois (1967), Wynd (1965) and Laursen *et al.* (2009) to establish the biozones in the section studied here. Biostratigraphically, *Nummulites* and Lepidocyclinids are the most important index fossils for age dating of Rupelian and Chattian deposits in the Qom and Asmari Formations, respectively in the Central Iran and Zagros zones. The base of this biozone is marked by the last occurrence of *Nummulites* in sample No. Hb 58. The upper part of the Sad section, with *Eulepidina*, *Heterstegina*, *Nephrolepidina*, and *Operculina* but without *Nummulites* is dated to the Late Oligocene-Early Miocene [73 m - 131 m (58 meters), samples Hb35 to Hb96].

#### *3.3.2. Sabzevaran Section*

In this section, planktonic foraminifera were identified and their interval presence was determined in the studied section. Based on stratigraphic distribution of identified taxa, 4 planktonic foraminiferal biozones were identified in the Eocene interval of this section.

**Biozone 1: *Subbotina angiporoides* Interval Range Zone**
Definition: It is included between the first occurrence of *Subbotina jacksonensi* (Bandy) and the first occurrence of *Subbotina angiporoides* (Hornibrook), and corresponds to a Middle Eocene (late Lutetian) age.
This stratigraphic biozone equivalent to upper part of the planktonic foraminifera E9 and E10 biozones mentioned in Berggren & Pearson (2005). This biozone can also be correlated with the upper part of the P11 and the basal part of the P12 biozone in Berggren *et al.* (1995). This zone is represented by about 28 meters of conglomerate and sandstones in the basal part of the section. It contains *Subbotina* aff. *corpulenta* (Subbotina), *Catapsydrax unicavus* Bolli, Loeblich & Tappan, *Subbotina* aff. *jacksonensis* (Bandy), *Globoturborotalita martini* (Blow & Banner), *Turborotalia possagnoensis* (Toumarkine & Bolli).

**Biozone 2: *Subbotina angiporoides-Hantkenina alabamensis* Interval Range Zone**
Definition: It is included between the first occurrence of *Subbotina angiporoides* and the first occurrence of *Hantkenina alabamensis* Cushman. The studied interval is referred to a Middle Eocene (late Lutetian-Early Bartonian) age.
This stratigraphic zone is equivalent to the planktonic foraminifera E11 and basal part of E13 biozones mentioned in Berggren & Pearson (2005). This biozone can also be correlated with the upper part of P12 towards

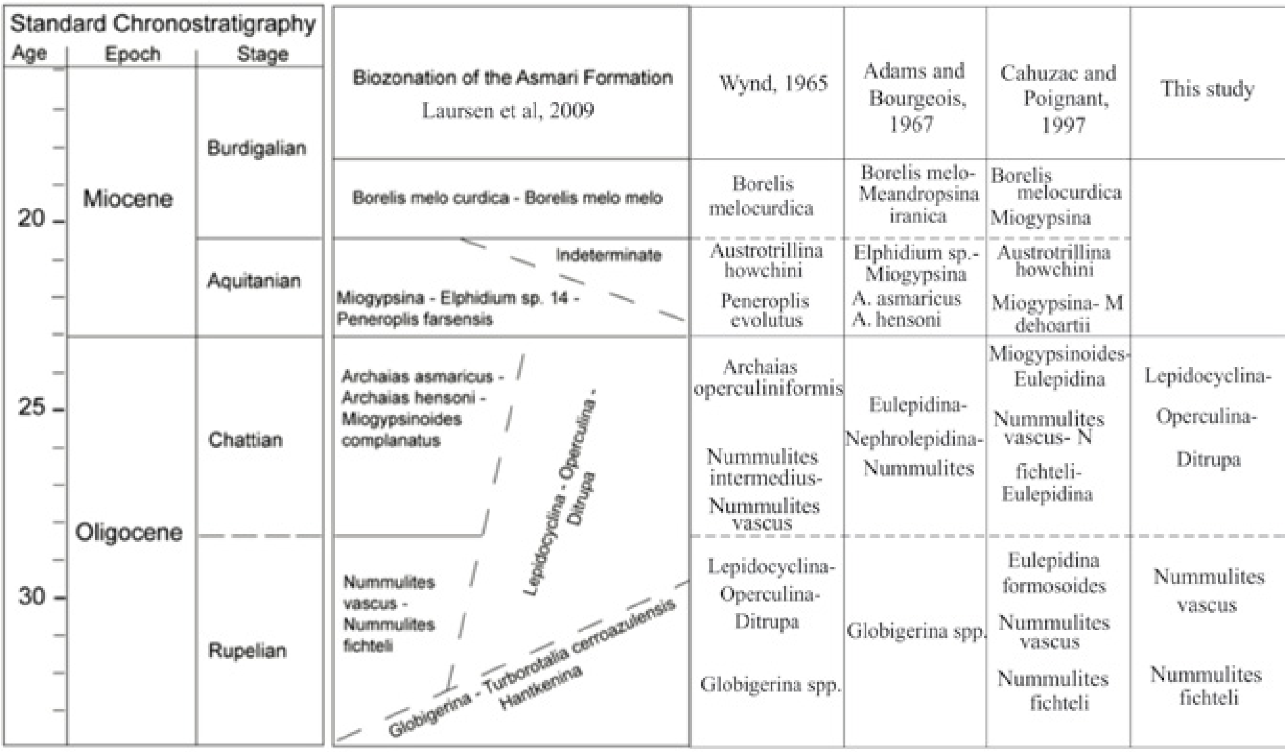


Fig. 4: Biozonations of Wynd (1965), Adams & Bourgeois (1967), Cahuzac & Poignant (1997), Laursen *et al.* (2009), and this study.

lower part of P14 of the biozones in Berggren *et al.* (1995). This zone is about 50 meters in thickness. The faunal assemblages is composed of *Subbotina corpulenta*, *Catapsydrax unicavus, Subbotina jacksonensis, Globoturborotalita martini, Turborotalia possagnoensis, Subbotina angiporoides, Catapsydrax* sp.*, Hantkenina compressa* Parr*, Turborotalia cerroazulensis* (Cole)*, Turborotalia altispiroides, Catapsydrax globiformis* (Blow & Banner)*, Subbotina* sp. 3.

**Biozone 3: *Hantkenina alabamensis-Catapsydrax globiformis* Interval Range Zone**

This zone is included between the first occurrence of *Hantkenina alabamensis* and the last occurrence of *Catapsydrax globiformis*. The age of this biozone is assigned to the Middle-Late Eocene (late Bartonian-Priabonian).

This zone is equivalent to the planktonic foraminifera E13-E15 biozones in Berggren & Pearson (2005). Moreover, this zone correlates with the upper part of P14 to P16 biozones in Berggren *et al.* (1995). This zone is 55 meters in thickness. The faunal assemblages of this biozone comprise *Subbotina corpulenta, Catapsydrax unicavus*, *Subbotina jacksonensis, Globoturborotalita martini, Subbotina angiporoides, Catapsydrax* sp., *Hantkenina compressa, Turborotalia cerroazulensis, Turborotalia altispiroides, Catapsydrax globiformis, Subbotina* sp3., *Turborotalia* sp., *Hantkenina alabamensis, Subbotina* sp. 4*, Turborotalia increbescens* Bandy*, Subbotina* sp. 1., *Subbotina* sp. 2., *Turborotalia ampliapertura* Bolli.

**Biozone 4: *Hantkenina compressa* Interval Range Zone**

This zone is included between the last occurrence of *Catapsydrax globiformis* and the last occurrence of *Hantkenina compressa*. According to stratigraphic range of the mentioned taxa, the age of this biozone is assigned to the Late Eocene (late Priabonian).

The *Hantkenina compressa* interval range Zone corresponds to the planktonic foraminifera E16 biozone in Berggren & Pearson (2005). In addition, this biozone is stratigraphically comparable with the upper part of the P17 biozone in Berggren *et al.* (1995). Thickness of this zone is about 42 meters. Common planktic foraminifers of this biozone consist of *Subbotina corpulenta*, *Catapsydrax unicavus, Subbotina jacksonensis, Globoturborotalita martini, Subbotina angiporoides, Catapsydrax* sp. 1*, Hantkenina compressa, Subbotina* sp. 3., *Turborotalia* sp.*, Hantkenina alabamensis, Subbotina* sp. 4*, Turborotalia increbescens, Globigerina* sp. 1*, Subbotina* sp. 1, *Subbotina* sp. 2, *Turborotalia ampliapertura, Chiloguembelina* sp*.*

**Biozone 5:** The Qom Formation visible in the Sabzevaran section contains various *Nummulites*, including *Nummulites fichteli* and *Nummulites intermedius* in the

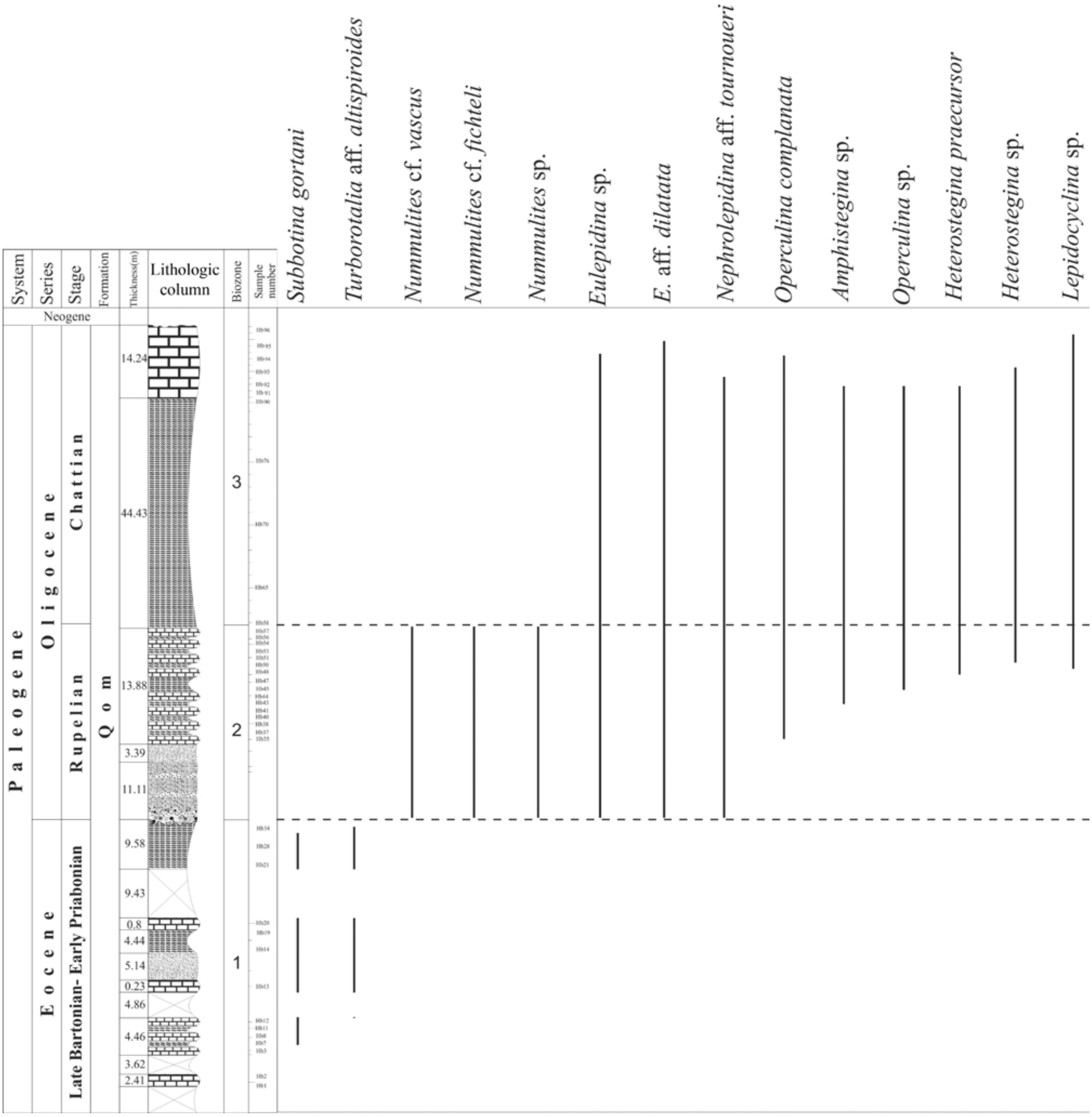


Fig. 5: Range chart of planktonic and large benthic foraminifers in the Sad section.

conglomerate layers which have not been studied in detail yet. Towards the top of the section, Lepidocyclinids are abundant. As we know Mohammadi *et al*. (2013), the first appearance of *Lepidocyclina* spp. occurs in the Rupelian, i.e. before the last occurrence of *Nummulites* spp. It should be noted that, the co-occurrence of *Nummulites* spp. and of *Lepidocyclina* spp. is observed in the first 60 meters of the Qom Formation, but *Nummulites* spp. disappears in the rest of the section. Therefore, a Rupelian-Chatian age can be proposed for the deposits of the Qom Formation in the Sabzevaran section.

### 3.4. The Eocene-Oligocene Boundary

Massive changes in climatic conditions have been recognized at the Eocene-Oligocene boundary, with a transition from a Eocene warm climate to an Oligocene cold climate including glacial conditions (e.g. Bohaty *et al.*, 2009), marked by gradual reduction of biodiversity (Retallack *et al.*, 2004). The Early Oligocene cooling (Bohaty & Zachos, 2003; Bohaty *et al.*, 2009; Edgar *et al.*, 2010) triggered a slow transition in planktonic foraminiferal faunas, with a shift from the Morozovellids

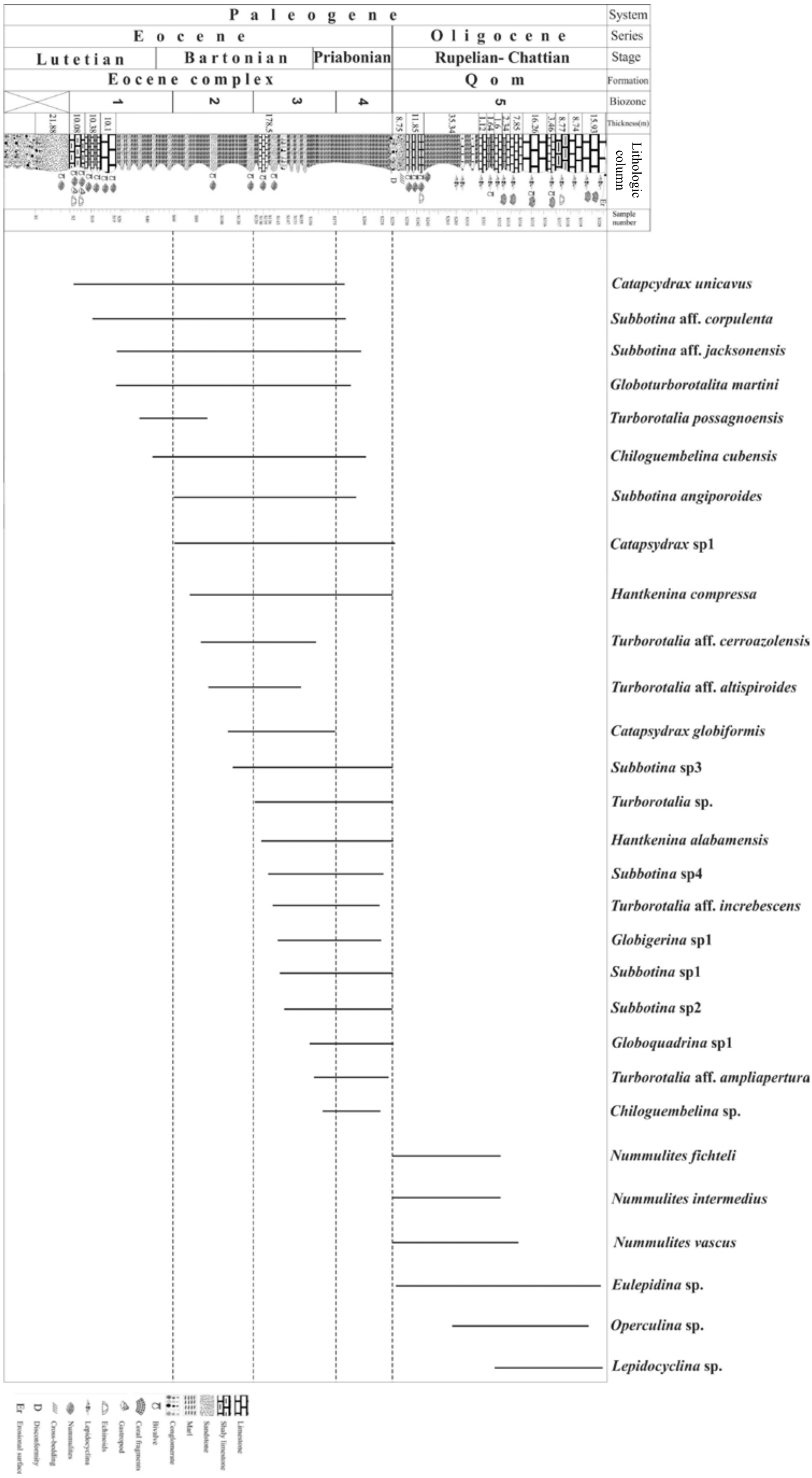


Fig. 6: Range chart of planktonic and large benthic foraminifers in the Sabzevaran section.

to the Subbotinids (Premoli Silva & Boersma, 1988). Subbotinid assemblages are dominant in the Sabzevaran and Sad stratigraphic sections. Disappearance of Hantkeninidae and reduction of *Turborotalia cerro-azulensis* has occurred during this time interval (Berggren & Pearson, 2005; Molina *et al.*, 2006; Wade & Pearson, 2008). Disappearance of Hantkeninids was used in this study for the determination of Eocene-Oligocene boundary and is coincident with the $E_{16}$-$O_1$ biozones (Berggren & Pearson, 2005; Bolli, 1957; Gonzalvo & Molina, 1998).

## 4. CONCLUSION

Vertical distribution of the Eocene planktic foraminifera identified in this study corresponds to other previous works (e.g., Berggren & Pearson, 2005). Planktonic foraminiferal biozones of both sections correspond to the Middle-Late Eocene biozonation, and large benthic foraminiferal biozones allow proposing Rupelian and Chattian ages. Moreover, collection of Eocene biostratigraphic data from the Sabzevaran and Sad stratigraphic sections allows recognizing similarities with the Asmari Formations in the Zagros area. Biozonation of both studied sections of Sad and Sabzevaran can be used as a biostratigraphic framework for other Eocene-Oligocene studies in Central Iran, although tectonic effect have affected this zone.

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Plate I

Foraminifera from the Sabzevaran field section. Samples are located in Fig. 3.

Fig. 1: *Catapsydrax* sp. sample #S120, Bartonian, Sabzevaran section.
Fig. 2: *Catapsydrax globiformis*, #S151, Bartonian, Sabzevaran section.
Fig. 3: *Catapsydrax unicavus* #S20, Lutetian, Sabzevaran section.
Figs 4, 5: *Catapsydrax* sp., #S86, Bartonian, Sabzevaran section.
Figs. 6, 7: *Subbotina* sp. #S220, Priabonian, Sabzevaran section.
Fig. 8: *Turborotalia* aff. *possagnoensis* #S102, Bartonian, Sabzevaran section.
Fig. 9: *Hantkenina alabamensis* #S162, Bartonian, Sabzevaran section.

**Plate I**

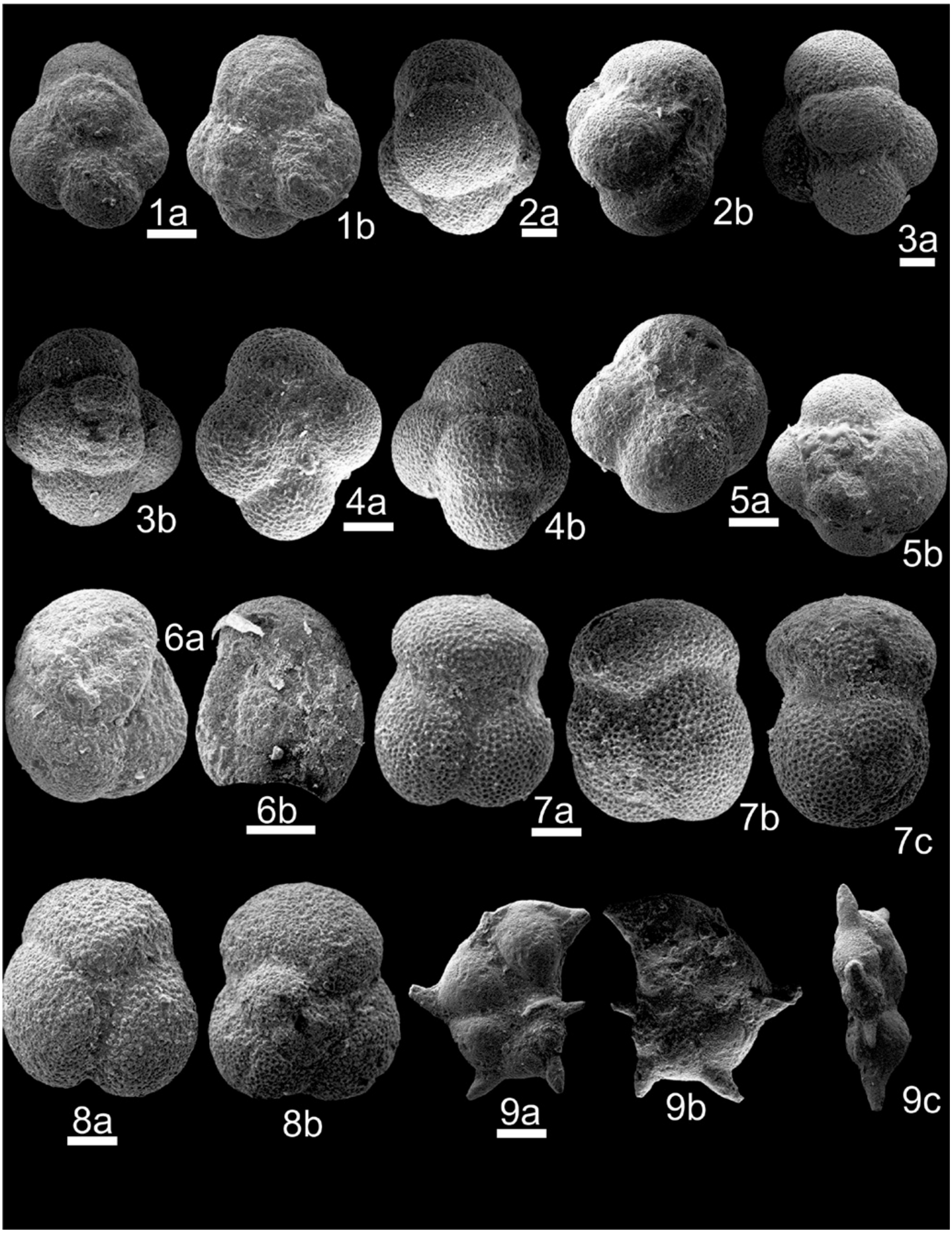
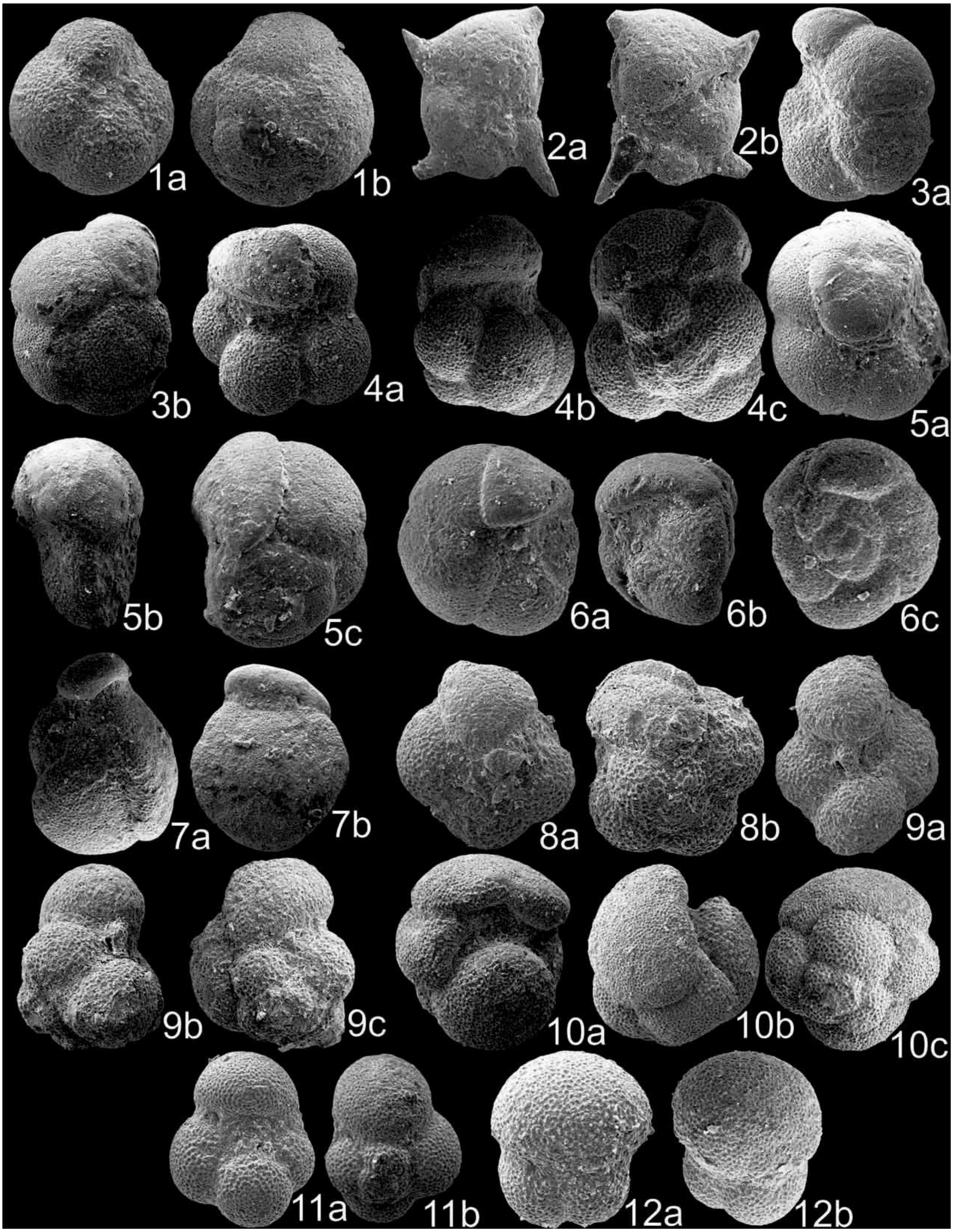


Plate II

Foraminifera from the Sabzevaran field section. Samples are located in Fig. 3.
Fig. 1: *Turborotalia* sp., sample #S171, Priabonian, Sabzevaran section.
Fig. 2: *Hantkenina compressa*, #S202, Priabonian, Sabzevaran section.
Fig. 3: *Subbotina* aff. *jacksonensis*, #S72, Bartonian, Sabzevaran section.
Fig. 4: *Globoturborotalita martini*, #S154, Bartonian, Sabzevaran section.
Fig. 5: *Turborotalia* aff. *increbescens,* #S177, Priabonian, Sabzevaran section.
Fig. 6: *Turborotalia* aff. *cerroazulensis,* #S147, Bartonian, Sabzevaran section.
Fig. 7: *Turborotalia* aff. *ampliapertura.,* #S208, Priabonian, Sabzevaran section.
Fig. 8: *Subbotina* sp1., #S144, Bartonian, Sabzevaran section.
Fig. 9: *Subbotina* sp2*,* #S177, Priabonian, Sabzevaran section.
Fig. 10: *Turborotalia* aff. *altispiroides*, #S112, Bartonian, Sabzevaran section.
Fig. 11: *Subbotina* cf. *corpulenta.,* #S37, Lutetian, Sabzevaran section.
Fig. 12: *Subbotina* sp.4 #S151, Bartonian, Sabzevaran section.

Plate II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11a
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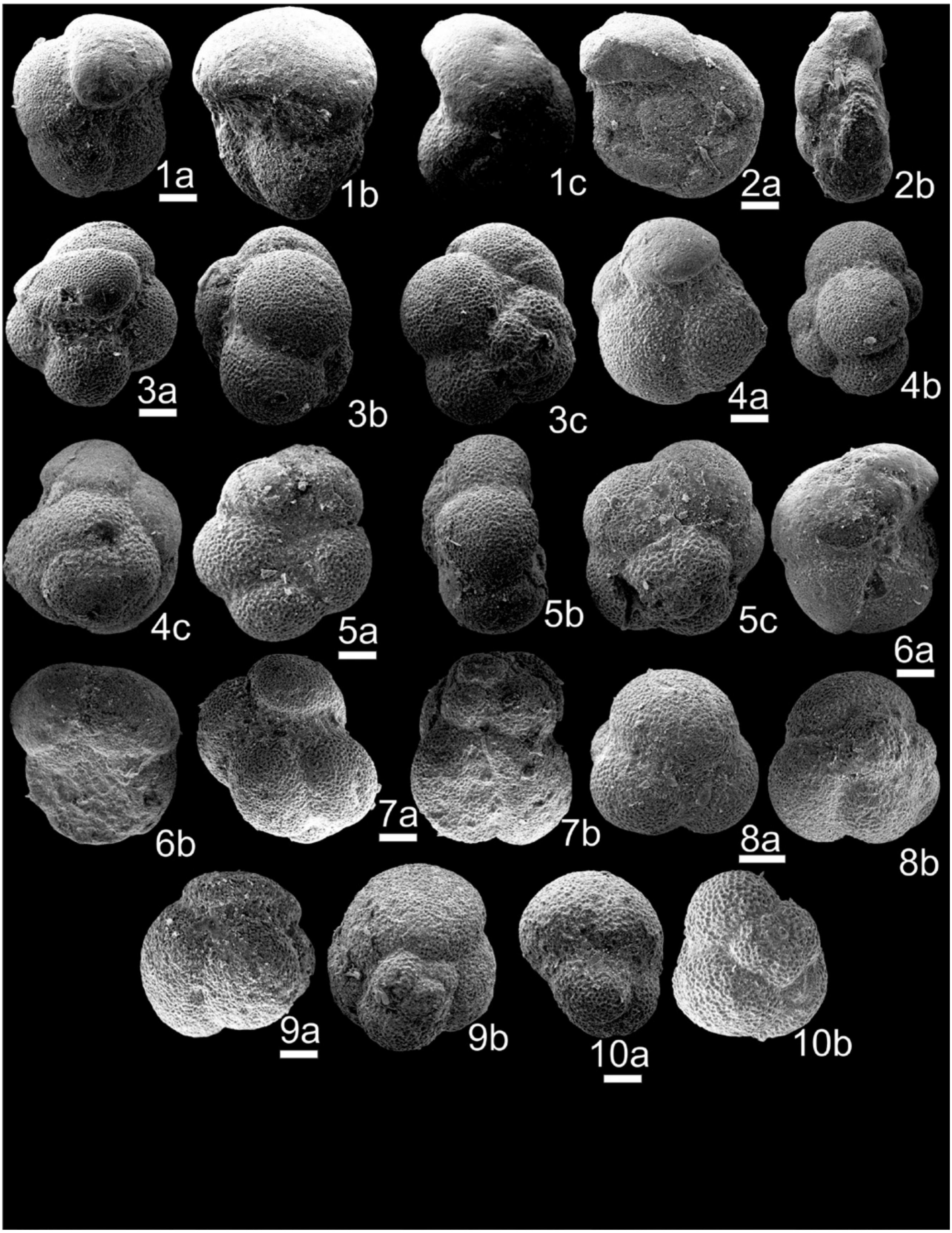
12a
12b

Plate III

Foraminifera from the Sabzevaran field section. Samples are located in Fig. 3.
Fig. 1: *Turborotalia* aff. *cerroazulensis,* sample #S121, Bartonian, Sabzevaran section.
Fig. 2: *Turborotalia* sp., #S202, Priabonian, Sabzevaran section.
Fig. 3: *Subbotina* aff. *corpulenta,* #S22, Lutetian, Sabzevaran section.
Fig. 4: *Subbotina* aff. *jacksonensis,* #S102, Bartonian, Sabzevaran section.
Fig. 5: *Subbotina* sp3*,* #S120, Bartonian, Sabzevaran section.
Fig. 6: *Turborotalia* aff. *cerroazulensis*.*,* #S104, Bartonian, Sabzevaran section.
Fig. 7: *Subbotina* sp.*,* #S120, Bartonian, Sabzevaran section.
Figs 8, 9: *Subbotina angiporoides,* #S102, Bartonian, Sabzevaran section.
Fig. 10: *Subbotina* sp. #S120, Bartonian, Sabzevaran section.

**Plate III**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10b