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Planktonic and benthic foraminiferal biostratigraphy of the Middle Eocene–Lower Miocene successions from the Sivas Basin (Central Anatolia, Turkey)

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Abstract: Planktonic and benthic foraminifera are described from the Middle Eocene-Lower Miocene successions in the Sivas Basin, Central Anatolia. An integrated foraminiferal zonation provides new age assignments in terms of a great number of taxa for the studied sections. Four biostratigraphical intervals are first recorded based on the concurrent ranges of sporadically occurring but well preserved planktonic foraminiferal assemblages. The first interval characterized by the co-occurrences of *Acarinina bullbrooki, Truncorotaloides topilensis* and *Turborotalia cerroazulensis* is referable to the E11 Zone of late Lutetian–early Bartonian. An assemblage yielding *Paragloborotalia opima* accompanied by *Globigerinella obesa* forms a basis for the late Chattian O5 Zone. The successive interval corresponds to the late Chattian O6 Zone indicated by the presence of *Globigerina ciperoensis* and *Globigerinoides primordius* along with the absence of *Paragloborotalia opima*. The early Aquitanian M1 Zone can be tentatively defined based mainly on the assemblage of *Globigerina, Globigerinella, Globoturborotalita* and *Tenuitella*. The biostratigraphical data obtained from the benthic foraminifera assign the studied sections to the SBZ 21–22, SBZ 23 and SBZ 24 ranging in age from Rupelian to Aquitanian. The SBZ 23 and 24 are well constrained biozones by the occurrences of *Miogypsinella complanata* and *Miogypsina gunteri*, respectively, whereas the SBZ 21–22 defined by nummulitids and lepidocylinids in the Tethyan Shallow Benthic Zonation is characterized dominantly by peneroplids, soritids and miliolids in the studied sections. Benthic foraminiferal assemblages suggest different paleoenvironments covering lagoon, algal reef and shallow open marine whereas planktonic foraminifera provides evidence for relatively deep marine settings on the basis of assemblages characterized by a mixture of small-sized simple and more complex morphogroups indicative for intermediate depths of the water column.

Key words: Biostratigraphy, planktonic foraminifera, benthic foraminifera, Oligocene-Early Miocene, Sivas Basin, Turkey.

Introduction

The Sivas Basin is one of the Central Anatolian basins and developed mainly after the closure of the northern branch of Neotethys (Poisson et al. 1996; Fig. 1). The Eocene–Miocene sedimentary sequences widely exposed in the basin are composed mainly of siliciclastics, pyroclastics, carbonates and evaporites which characterize a wide range of depositional environments from fluvial and lacustrine to coastal, shallow and deep marine. They have been the focus of numerous studies mainly on the stratigraphy, structural geology, sedimentology, evaporite geochemistry and petroleum potential of the basin (Blumental 1938; Yalçınlar 1955; Nebert 1956; Norman 1964; Pisoni 1965; Baykal & Erentöz 1966; Artan & Sestini 1971; Kurtman 1973; Gökçen 1981; İnan & İnan 1990; Aktimur et al. 1990; Cater et al. 1991; Poisson et al. 1992, 1996; Tekeli et al. 1992; Temiz 1994; Tekin 1995; Çubuk & İnan 1998; Dirik et al. 1999; Kangal & Varol 1999; Çiner et al. 2002; Gündoğan et al. 2005). Only minor emphasis has generally been placed on the paleontological investigations dealing with various fossil groups within the limited numbers of published papers (molluscs, corals and echinids by Stchepinsky 1939 and by Erünal-Erentöz 1956; benthic foraminifera by Dizer 1962; mammals by Sümengen et al. 1989 and by De Bruijn et al. 1992; palynomorphs by Akgün et al. 2000) and in unpublished reports (Aktimur et al. 1990; Kangal et al. 2005). More recently, Lower Miocene larger foraminifera were studied by Özcan et al. (2009), whereas Oligocene larger foraminifera including some new groups of taxa from four sections including two studied sections in the present study (Tuzlagözü and Eğribucak) were reported by Sirel et al. (2013).

Shallow water benthic foraminifera bearing limestones together with mudstones and siltstones have been variously reported by previous studies commonly as associated facies within the marine Oligocene–Lower Miocene sequences of the Sivas Basin (Kurtman 1973; Aktimur et al. 1990; Çubuk & İnan1998; Ocakoğlu 2001). However, planktonic foraminifera which form one of the most significant fossil groups for biostratigraphy and wide stratigraphic correlation has received very little attention so far or passed unobserved by the previous studies carried out in the basin. Poor data on the occurrence of planktonic foraminiferal taxa were reported in a few studies (Kurtman 1973; Gökçen 1981; Aktimur et al. 1990; Poisson et al. 1996; Kavak & inan 2001; Ocakoğlu

2001; Vrielynck et al. 2012), whereas biostratigraphic age determinations were provided only by Poisson et al. (1997). However, no detailed investigation on the planktonic foraminiferal assemblages and biozones has been carried out so far, although the marine Upper Oligocene sequences comprise several levels containing relatively abundant planktonic foraminifera. Therefore, one of the major problems encountered by the previous workers on the stratigraphic reconstruction in the basin was the poor age data especially on the Oligocene successions as a result of their poor fossil record.

In this paper we document for the first time occurrences of planktonic foraminiferal asssemblages by focusing mainly on four sections (İşhanı, Eğribucak, Tuzlagözü and Akçamescit) encompassing Middle Eocene–Lower Miocene lithostratigraphic units with special emphasis on the Oligocene–Lower Miocene interval measured from the central part of the Sivas basin (Fig. 2). A spot sample yielding rich planktonic foraminifera is also investigated to provide additional biostratigraphic information. We also document benthic foraminiferal assemblages from the same stratigraphical sections and thus, we aim to establish an integrated biostratigraphical zonation of planktonic and benthic foraminifera throughout the studied successions and to analyse paloenvironmental and paleoecologic conditions during the Oligocene–Early Miocene.

Geological setting and stratigraphy

The Sivas Basin is bounded by the Tauride belt along the southern margin and metamorphic rocks of the Kırşehir Massif and the allochthonous Neotethyan sequences along the western and northern margins (Poisson et al. 1996; Fig. 1). It is considered to be in peripheral foreland setting during the Late Paleocene–Middle Eocene, whereas it was a part of the large Central Anatolian molasse basins in the Oligo–Miocene time (Poisson et al. 1996). The Sivas Basin exposes a thick sedimentary sequence which is representative of a wide range of sedimentary environments from continental to deep marine (Fig. 2). The oldest sedimentary rocks, Tecer Formation, unconformably overlie ophiolitic units to the south and consist of Maastrichtian–Paleocene shallow water carbonates (İnan & İnan 1990). The genera lized stratigraphy of the Sivas Basin adopted in this study mainly follows Kurtman (1973) and Poisson et al. (1996) and is described as: At the base, the sequence is characterized by a Lower Eocene polygenic conglomerate (Bahçecik conglomerate) comprising clasts of ophiolite, marble, radiolarite, limestone and quartzite. The Bahçecik conglomerate is exposed along the northern and southern margins of the basin and unconformably overlies the ophiolitic basement. The Middle Eocene Bozbel formation conformably

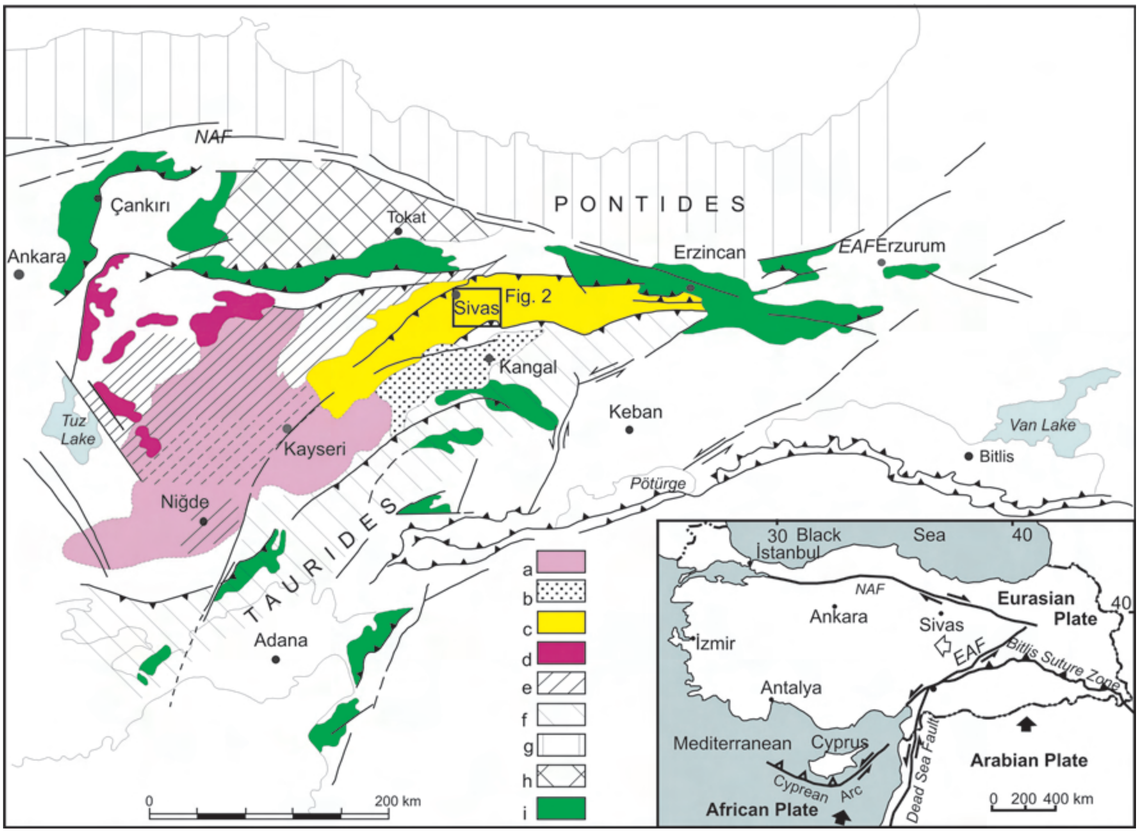


Fig. 1. Tectonic map showing major structural elements of Turkey and location of the Sivas Basin (from Poisson et al. 1996). **a** — Neogene-Quaternary volcanics; **b** — Kangal Basin; **c** — Sivas Basin; **d** — Late Cretaceous–Paleocene plutonic rocks; **e** — Kırşehir-Niğde massif; **f** — Tauride Belt; **g** — Pontide Belt; **h** — Tokat Massif; **i** — Ophiolites; ***NAF*** — North Anatolian Fault; ***EAF*** — East Anatolian Fault.

overlies the Bahçecik conglomerate and consists of flysch deposits with carbonate, volcanoclastic and olistrostrome intercalations. The Oligocene successions widely exposed in the basin represent various depositional environments from fluvial and lacustrine to marine. The Lower Oligocene Selimiye formation is a siltstone and sandstone dominated unit with subordinate gypsum levels in its lower part and overlies the Bozbel formation unconformably. It has been considered to be fluvial to lagoonal facies (Kurtman 1973; Özçelik 2000; Ocakoğlu 2001) or marine based on ostracod fauna (Gökçen 1981; Gökçen & Kelling 1985) and planktonic foraminifera (Poisson et al. 1996; Kavak & İnan 2001). The fluvial conglomerates, sandstones and mudstones which may be a lateral equivalent of the Selimiye formation, are referred to the Karayün formation (Poisson et al. 1996). The Late Oligocene charophytes characterizing lacustrine environments are determined by Vrielynck et al. (2012) in the Karayün formation. The Hafik formation consists of a massive gypsum sequence and is referred to the Oligocene age by means of its stratigraphic position. However, the lack of precise datings due to the poverty or absence of age diagnostic fossil groups as well as rapid lateral change of the lithofacies often make it difficult to assign the Oligocene deposits to the lithostratigraphic units. The Karacaören formation is composed mainly of limestone, sandy limestone in the lower part whereas marl, sandstone and shale alternation in the upper part. It was subdivided into three members by Poisson et al. (1996): lower detritics, limestones and upper detritics. The lower detritics are represented by marls near Sivas (Sivas marls) and overlie the evaporitic Hafik formation. These marls contain planktonic foraminifera of Middle–Late Oligocene and Early Miocene age (Poisson et al. 1996, 1997; Vrielynck et al. 2012). The limestone member is the best known and most widely exposed unit and was dated to the Early Miocene (Aquitanian–Burdigalian) by foraminifera (Dizer 1962; Kurtman 1973; Özcan et al. 2009). The Karacaören formation is overlain by the Benlikaya formation which consists of continental clastics (sandstone, conglomerate, silt and clay) with intercalated gypsum and lignite. It might be Middle Miocene in age based on its stratigraphic position. The poorly consolidated sands, conglomerates with marls and lacustrine limestones of Late Miocene–Pliocene age are assigned to the İncesu formation.

Material and method

Over 80 samples collected from four stratigraphic sections, İşhanı, Eğribucak, Tuzlagözü and Akçamescit, have been studied for foraminiferal biostratigraphic analysis. A spot sample rich in planktonic foraminifera from near Bakımlı was also investigated (Fig. 2). More than 40 samples were prepared for extraction of isolated planktonic foraminiferal specimens from the samples. Washed residues were obtained by disaggregating samples of mudstone with the standard washing technique of diluted hydrogen peroxide (%30). Planktonic foraminifera show mainly scattered occurrences with low to moderately abundant assemblages along the sections. Preservation varies from poor (recrystallized but clearly recognizable specimens) in the Middle Eocene to

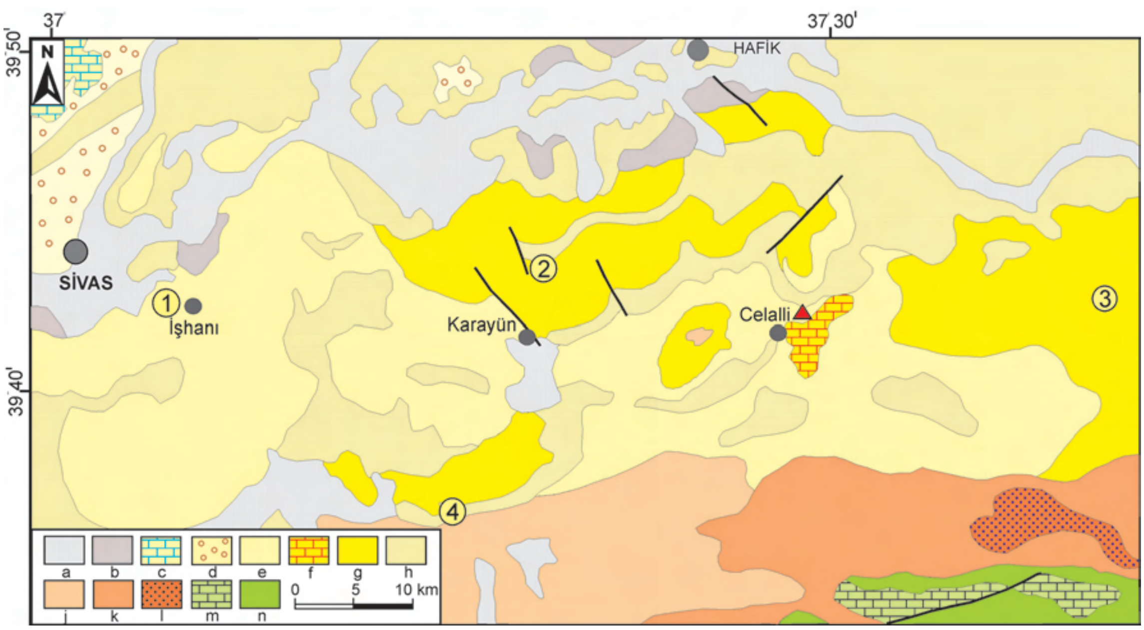


Fig. 2. Geological map of the Sivas region in the central part of the Sivas Basin and location of the studied sections (modified from Geological Map of Turkey (MTA, 2002). **1** — İşhanı section; **2** — Eğribucak section; **3** — Tuzlagözü section; **4** — Akçamescit section; **triangle** — Spot sample; **a** — Quaternary; **b** — Pleistocene (Continental clastics); **c** — Pliocene (Continental carbonates); **d** — Upper Miocene–Pliocene (Continental clastics); **e** — Lower–Middle Miocene (Continental clastics); **f** — Lower Miocene (Neritic limestone); **g** — Lower Miocene (Clastics and carbonates); **h** — Lower Miocene (Evaporitic sedimentary rocks); **j** — Oligocene (Continental clastics); **k** — Middle–Upper Eocene (Clastics and carbonates); **l** — Eocene (Volcanics); **m** — Upper Cretaceous–Paleocene (Neritic limestone); **n** — Ophiolites.

remarkably good in the Chattian and early Aquitanian. Benthic foraminifera have been analysed from 435 thin sections of 46 samples. Contrary to the planktonic foraminifera, benthic foraminifera are found in a great abundance in the samples. The taxonomic criteria adopted for planktonic foraminifera are taken from Bolli & Saunders (1985), Spezzaferri (1994) and Pearson et al. (2006a). The definition of planktonic foraminiferal biozones follows Berggren et al. (1995) and Berggren & Pearson (2005), whereas benthic foraminiferal biozones are largely based on the Shallow water Benthic Zonation (SBZ) by Cahuzac & Poignant (1997).

Studied sections

İşhanı section

The section was sampled to the E of İşhanı village which is located 5 km SE of Sivas (39°42'40.48"N; 37°04'17.64"E; Fig. 2). The whole succession exposed at the section measures more than 130 m. The İşhanı section begins with an alternation of grey-green mudstone with sandstone intercalations (30 m) belonging to the Bozbel formation and follows a 5 m thick gypsum interval. Above, the Karayün formation is characterized by thick (100 m) reddish fluvial conglomerates, sandstones and mudstones. The uppermost 15 m of the section consists of cream-white, fossiliferous limestones, clayey limestones and grey-green mudstones of the Karacaören formation (Fig. 3).

Eğribucak section

The Eğribucak section, 125 m thick, is located in the vicinity of Eğribucak village (39°43'48.08"N; 37°16'33.84"E), 30 km E of Sivas (Fig. 2). The section is characterized by highly variable and rapidly changing types of lithology. The lower 15 m of the section consists mainly of thin bedded siltstones and a few conglomerate intercalations. The major part of the section (~80 m) consists of mudstones intercalated with sandstone, clayey limestone, sandy limestone and gypsum layers which predominantly occur in the lower part. Planktonic foraminifera are absent or extremely poor and restricted to some layers in the middle part of this interval. Benthic foraminifera, however, are rich and characterized by a porcellaneous assemblage in the clayey limestones from the same interval (Fig. 4). Small benthic foraminifera (miliolid and peneroplid forms), echinid spines and ostracods are also present in some samples throughout the section. The upper 25 m part of the section consists of mudstones with limestone intercalations yielding abundant planktonic and benthic foraminifera and red algae (Fig. 4). The Eğribucak section is comparable to the Eğribucak formation which was introduced by Çiner & Koşun (1996). In the original description, the Eğribucak formation consists of fluvial sheet-sandstone and red mudstone (lower member), bedded to massive gypsum and red-green mudstone (middle member) and shallow-marine fossiliferous mudstone and sandy limestone (upper member). The Early-Middle Miocene age assigned to the formation (Çiner & Koşun 1996; Çiner et al. 2002) is revised to the Oligocene-Early Miocene by recent studies (Özgen-Erdem et al. 2013; Sirel et al. 2013; Kangal et al. 2014).

Tuzlagözü section

The Tuzlagözü section is exposed to the E of Tuzlagözü village (39°42'45"N; 37°40'41.23"E; Fig. 2). It is 150 m in thickness and comparable to the Karacaören formation. The section starts with a 10 m thick limestone-clayey limestone package. The lower 7 m of this interval is rich in porcellaneous benthic foraminifera and dasclad algae whereas the upper 3 m yields abundant hyaline miogypsinid foraminifera and coralline algae (Fig. 5). The upper interval from 10 m to the top of the section comprises a deep marine succession which consists of thick (140 m) green mudstones rich in planktonic foraminiferal assemblages and sandstone intercalations. The diversity of the assemblages is relatively high in the lower part, but lower in the upper part of this interval. Common pelecypod accumulations are also observed in the siltstone layers from the upper parts.

Akçamescit section

The 170 m thick section was sampled from the N of Akçamescit village (39°36'24.61"N; 37°14'59.95"E), 22 km SE of Sivas (Fig. 2). The section consists of a mudstone dominated unit with limestone intercalations overlying a gypsum level at the base and corresponds to the Karacaören formation. A sandstone level occurs in the lowest part of the section. The cream-white limestones are rich in benthic foraminiferal assemblages whereas planktonic foraminifera could be obtained from only two levels throughout the section (Fig. 6).

Foraminiferal biostratigraphy

Foraminiferal biozone schemes based on reliable age indicators provide a firm basis for worldwide and regional biostratigraphic correlations. On the basis of planktonic foraminiferal zonations, Oligocene–Lower Miocene biostratigraphy has been well documented from continuous sections in deep-sea sites (Miller et al. 1985; Spezzaferri & Premoli Silva 1991; Leckie et al. 1993; Spezzaferri 1994, 1995; Li et al. 2004, 2005; Wade et al. 2007). A majority of marker species, however, are sporadically present or missing in the areas of restricted marine setting due to their poor preservation. Likewise, the occurrences of larger foraminifera are often controlled by facies changes and therefore, this makes it difficult to apply the standard zonation (SBZ) to the successions of restricted marine setting.

The Oligo–Miocene time is marked by the restricted marine settings in Anatolia and adjacent regions resulting from the uplift of Alpine orogenic belt (Şengör & Yılmaz 1981). Besides, the Oligocene is a well known period characterized by large and abrupt climatic and paleoceanographic changes in the world oceans driven by changes in the continental- and polar-ice volume. These changes were reflected by the

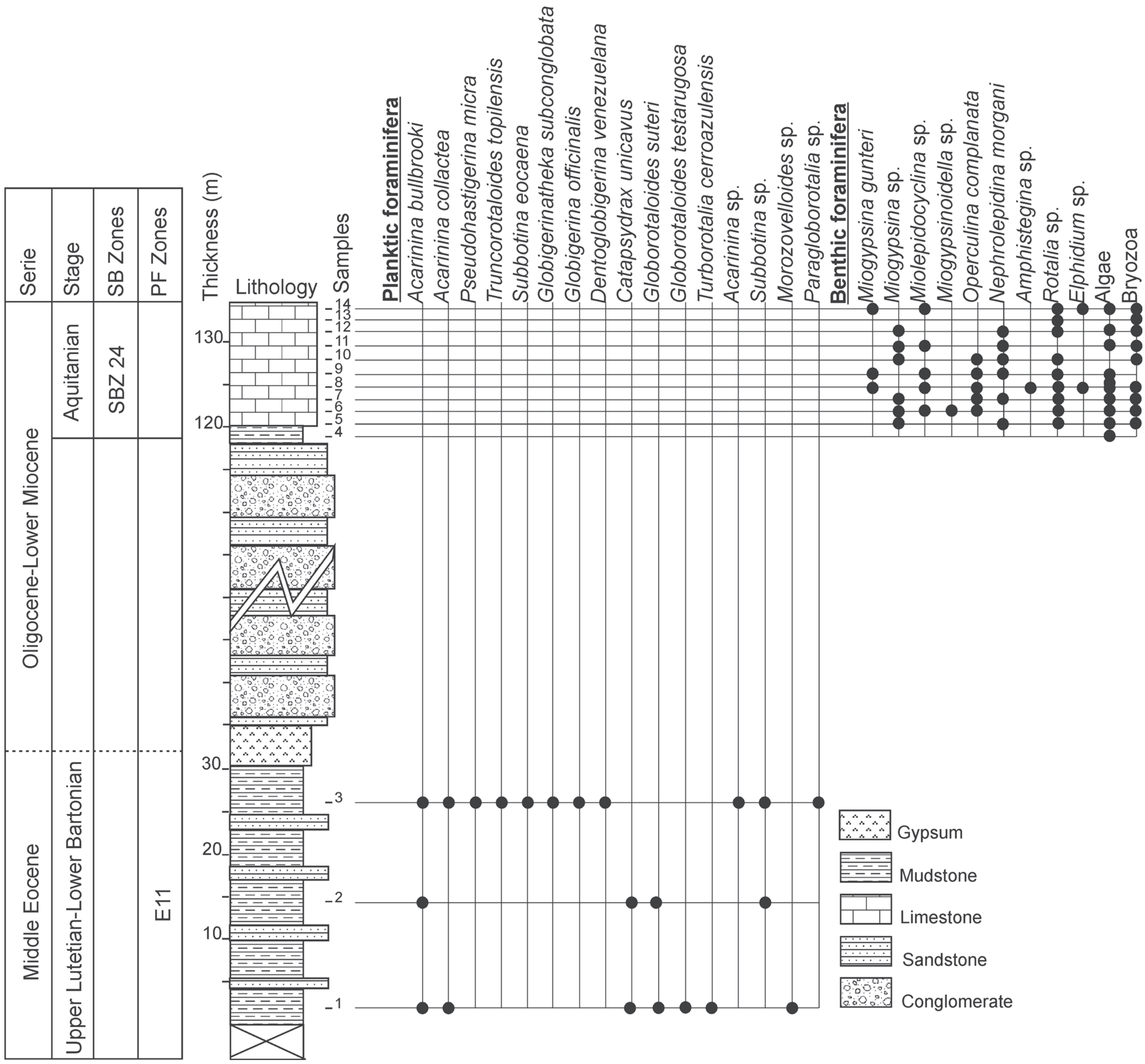


Fig. 3. Distribution of planktonic and benthic foraminiferal species with other fossil groups in the İşhanı section.

cool and warm periods accompanied by the sea level fluctuations as well as the global land-ocean reorganizations (Haq et al. 1988; Zachos 2001). After a major faunal turnover including the last occurrences of several planktonic foraminiferal groups (*Turborotalia, Hantkenina*, *Cribrohantkenina* and *Globigerinatheka*) at the Eocene–Oligocene boundary, the Oligocene interval is generally represented by long-ranged planktonic foraminiferal taxa (Coxall & Pearson 2006; Premoli Silva et al. 2006; Pearson et al. 2006b; Wade & Pearson 2008). For these reasons, a complete biostratigraphic sequence for the studied successions could be established by integrating benthic and planktonic foraminiferal zones with some modifications of standard zonations. In the present study, planktonic foraminiferal biozones are defined based mainly on the concurrent ranges of some age-diagnostic species due to the absence of biostratigraphic markers, whereas shallow benthic foraminiferal zones are well constrained by the occurrences of zonal species except for the Rupelian–lower Chattian interval (Fig. 7).

The lowermost mudstones from the İşhanı section are Middle Eocene in age based on an assemblage consisting predominantly of *Acarinina* associated with rare *Truncorotaloides* and *Morozovelloides* which last occurred in the latest Middle Eocene (Fig. 3). The concurrent ranges of *Acarinina bullbrooki, Truncorotaloides topilensis* and *Turborotalia cerroazulensis* confines this interval to within the E11 Zone which is defined by the partial range of the *Morozovelloides lehneri* between the LO of *Guembelitrioides nuttalli* and the FO of *Orbulinoides beckmanni* (Berggren & Pearson 2005; Wade et al. 2011). Although the zonal marker, *M. lehneri*, could not be recorded in the studied samples the combination of three diagnostic species (*A. bullbrooki, T. topilensis* and *T. cerroazulensis*) provides a worldwide correlation by their synchronous first and last occurrences (Berg-

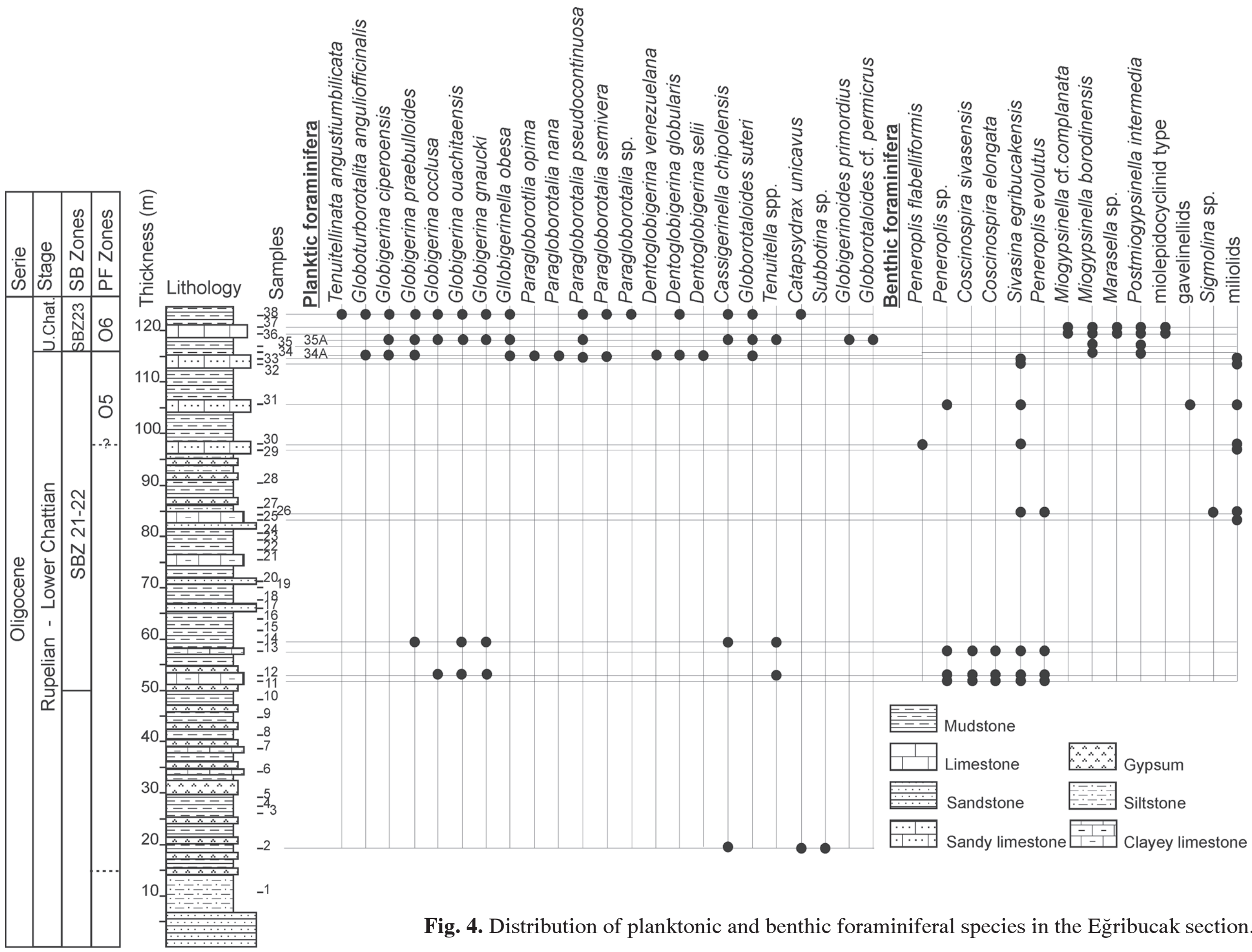


Fig. 4. Distribution of planktonic and benthic foraminiferal species in the Eğribucak section.

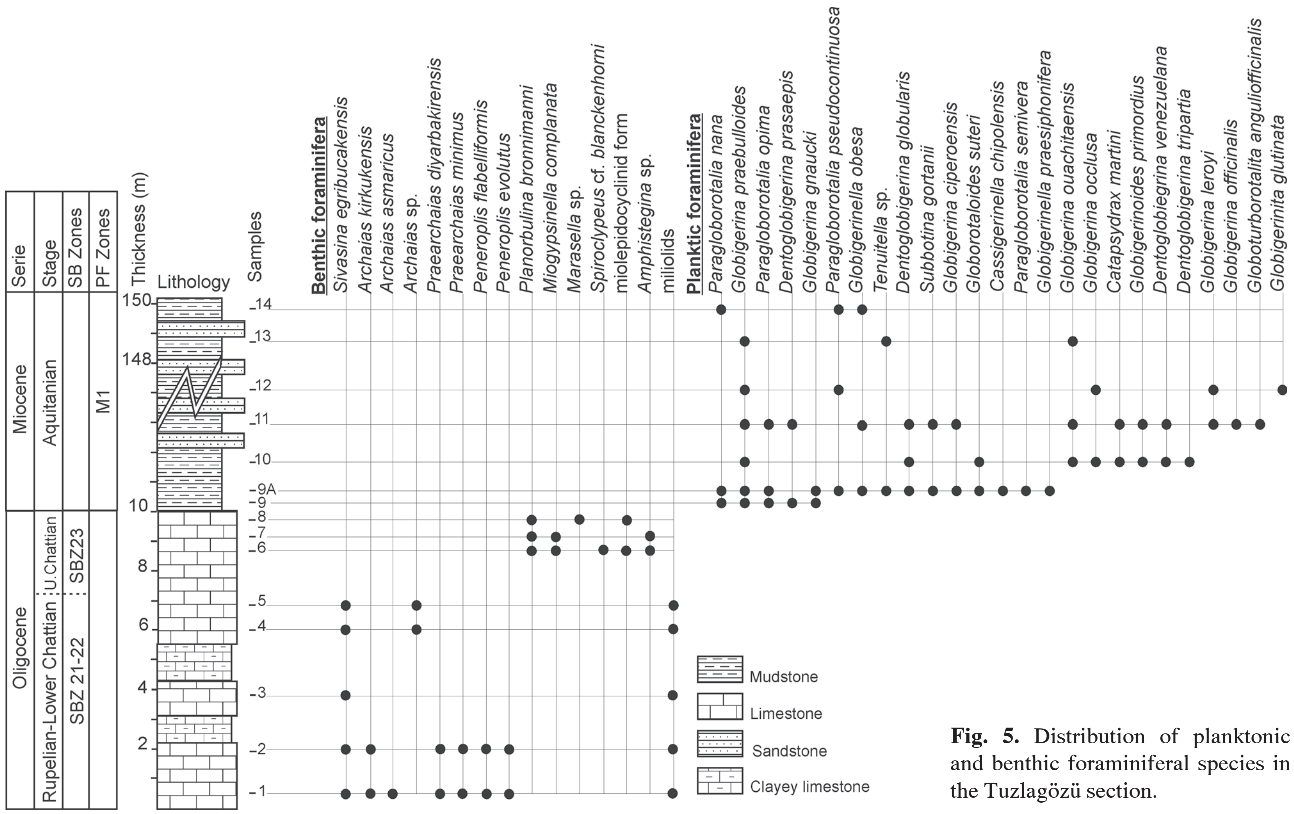


Fig. 5. Distribution of planktonic and benthic foraminiferal species in the Tuzlagözü section.

gren et al. 2006; Pearson et al. 2006b). No age data could be obtained from the overlying fluvial deposit of conglomerate, sandstone and mudstone completely devoid of fossil groups (Fig. 3).

The first biostratigraphic age from the Oligocene succession is documented by the benthic foraminifera in the Eğribucak and Tuzlagözü sections (Figs. 4, 5). The assemblages are rich in porcellaneous taxa including a remarkable group of new taxa which have recently been introduced and referred to the SBZ 21–22 (Rupelian–early Chattian) by Sirel et al. (2013). They are characterized by *Praearchaias diyarbakirensis*, *P. minimus, Archaias kirkukensis* and *A. asmaricus* associated with *Peneroplis evolutus, P. flabelliformis* and *Sivasina egribucakensis* in the Tuzlagözü section (Figs. 5, 9). On the other hand, the latter three species are accompanied by *Coscinospira sivasensis* and *C. elongata* with the exception of *P. diyarbakirensis*, *P. minimus, A. kirkukensis* and *A. asmaricus* in the Eğribucak section (Figs. 4, 9). It is known that a porcellaneous assemblage yielding specimens of *Praearchaias*, *Austrotrillina, Peneroplis* and *Archaias* which is not indicative for a precise zonation was referred to a combined SB 21–22 zonal interval from some SE Anatolian sections (Sirel 1996, 2003). Although *Nummulites vascus*, *N. fichteli* and lepidocyclinids, which characterize SBZ 21 and 22 (Cahuzac & Poignant 1997), were missing, a tentative SBZ 21–22 was established based on not only the overlying SBZ 23 (Sirel 2003; e.g. Malatya region, p. 277) but also a planktonic foraminiferal assemblage indicating the P21 Zone (revised O4 and O5 zones of Berggren & Pearson 2005) with the presence of *Paragloborotalia opima* (Sirel 2003; e.g. Muş region, p. 286). Following the zonal assignment of Sirel (1996, 2003) the rich porcellaneous assemblages from the Tuzlagözü and Eğribucak sections are referred to the SBZ 21–22 (Figs. 4, 5, 7). The planktonic foraminifera are extremely poor and restricted to some layers from this interval with *Globigerina praebulloides, G. occlusa, G. ouachitaensis, G. gnaucki, Cassigerinella chipolensis* and tenuitellids, which do not allow an assignment of biostrati-

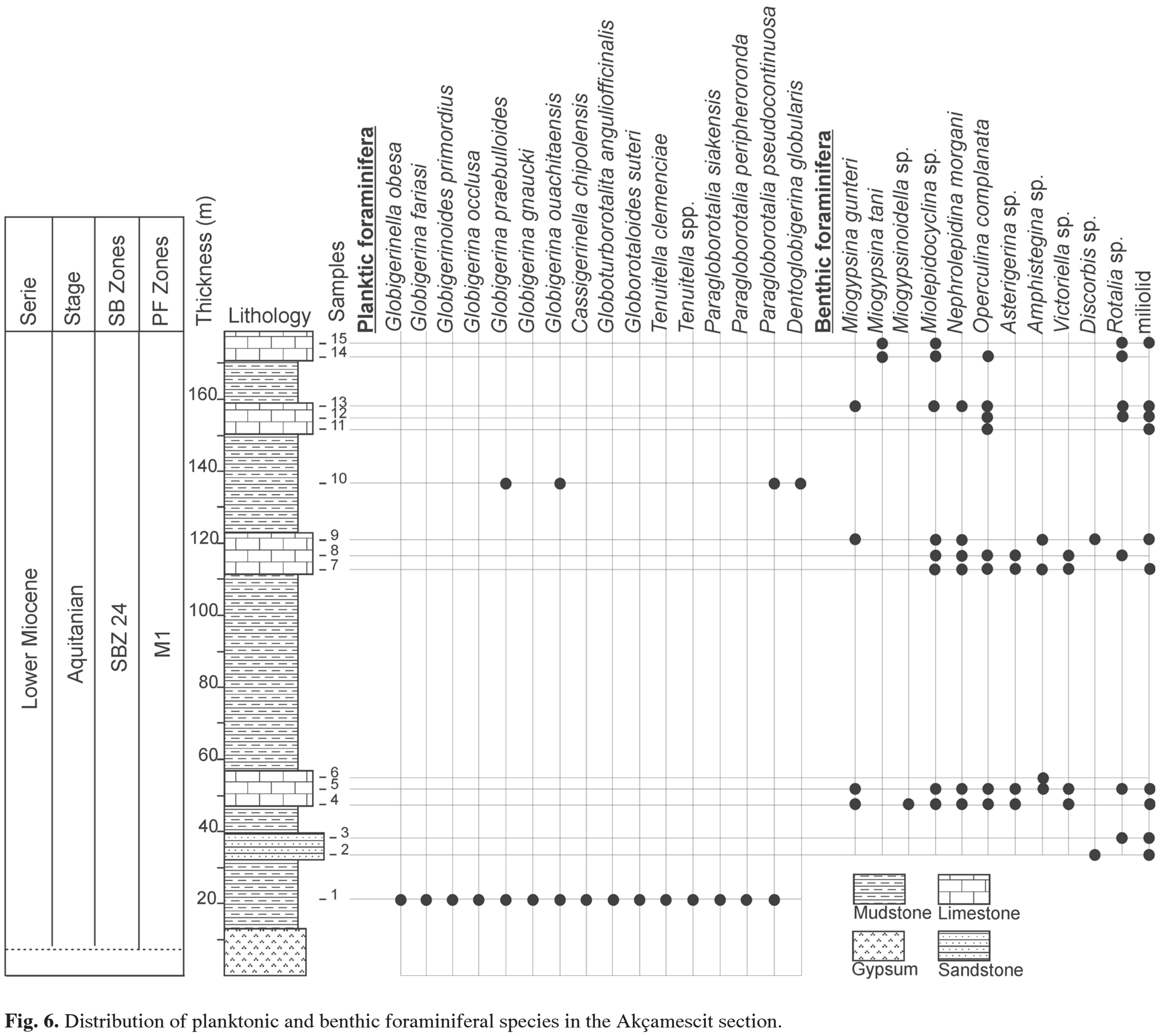


Fig. 6. Distribution of planktonic and benthic foraminiferal species in the Akçamescit section.

graphic age (Fig. 4), or are completely missing (Fig. 5). However, an abundant and diverse planktonic foraminiferal assemblage yielding *Paragloborotalia opima* and *Globigerinella obesa* in a single sample (34A) is referable to the late Chattian O5 Zone in the upper part of the Eğribucak section (Fig. 4). In addition, a spot sample (Bakımlı 22) from the mudstones, which are comparable to the upper parts of the Eğribucak section (1km NW of Bakımlı village; 39˚42'56.43"N; 37˚28'1.61"E; Fig. 2), yields abundant and well preserved planktonic foraminifera including *Paragloborotalia opima, Dentoglobigerina globularis, D. tripartita, D. venezuelana Globorotaloides permicrus, G. suteri, Globigerina occlusa, G. ciperoensis, G. ouachitaensis* and *Catapsydrax martini* (Figs. 8, 10). Although a precise biozone for single samples is difficult to establish, the co-occurrences of *Paragloborotalia opima* and *Globigerinella obesa* provides evidence for defining the O5 (*Paragloborotalia opima*) Zone since these species have overlapping ranges within this zone (Coccioni et al. 2008). This biostratigraphical data is in accordance with that of Poisson et al. (1997) who detected the P21 Zone (O4 and O5 zones of Berggren & Pearson 2005) based on the co-occurrences of *P. opima* and *Globoturborotalita angulisuturalis* from the Sivas marls in the close vicinity of Sivas. The O5 Zone is defined by the LOs of *Chiloguembelina cubensis* and *P. opima* and corresponds to the SBZ 22B (Berggren et al. 1995; Cahuzac & Poignant 1997). By considering this correlation between the O5 Zone and SBZ 22B (Fig. 7), the middle part of the Eğribucak section seems to be comparable to the SBZ 22 rather than a combined SBZ 21–22 suggested by Sirel et al. (2013). Moreover, this zonal assignment of SBZ 22 is supported by the SBZ 23, which is defined by the FO of *Miogypsinella complanata* in the overlying interval (Fig. 4).

The SBZ 23 is also recorded by the presence of *M. complanata* in the upper part of the basal limestone interval in the Tuzlagözü section (Fig. 5). *M. complanata* is the most common and indicative species for the SBZ 23 of Late Oligocene in the western Tethyan basins (Italy and Spain, Drooger 1954, 1956a, Wildenborg 1991; Aquitaine Basin, France, Drooger et al. 1955; Algeria, Drooger & Magné, 1959; as well as in Egypt (Ouda 1998, Boukhary et al. 2008) and in the Middle East (Sharland et al. 2004). This zone corresponds to the O6 (*Globigerina ciperoensis*) Zone which is defined by the partial range of *G. ciperoensis* between the FO of

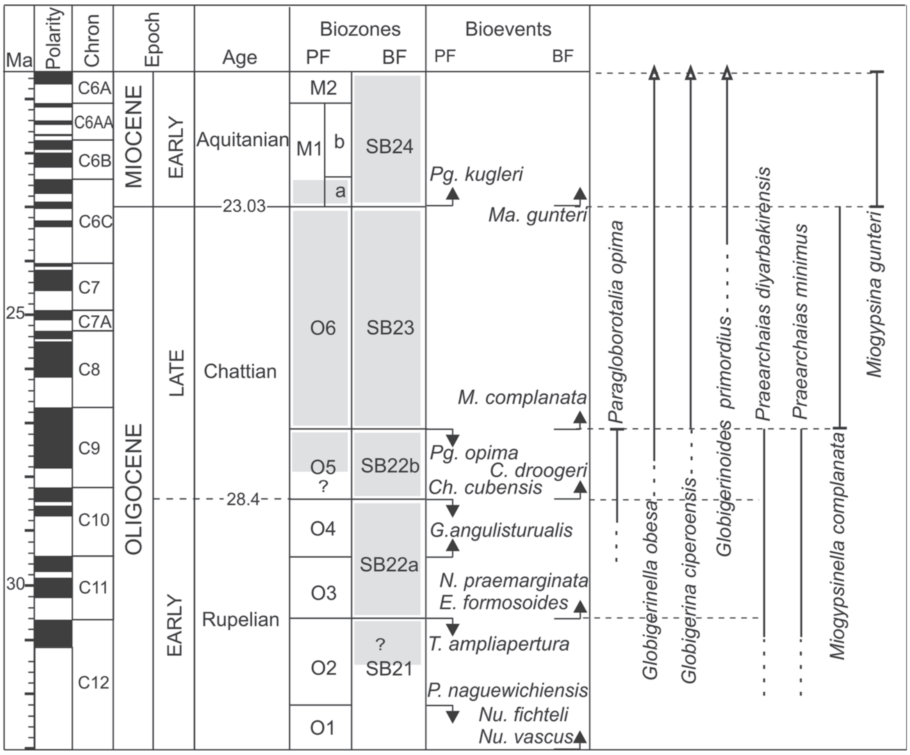
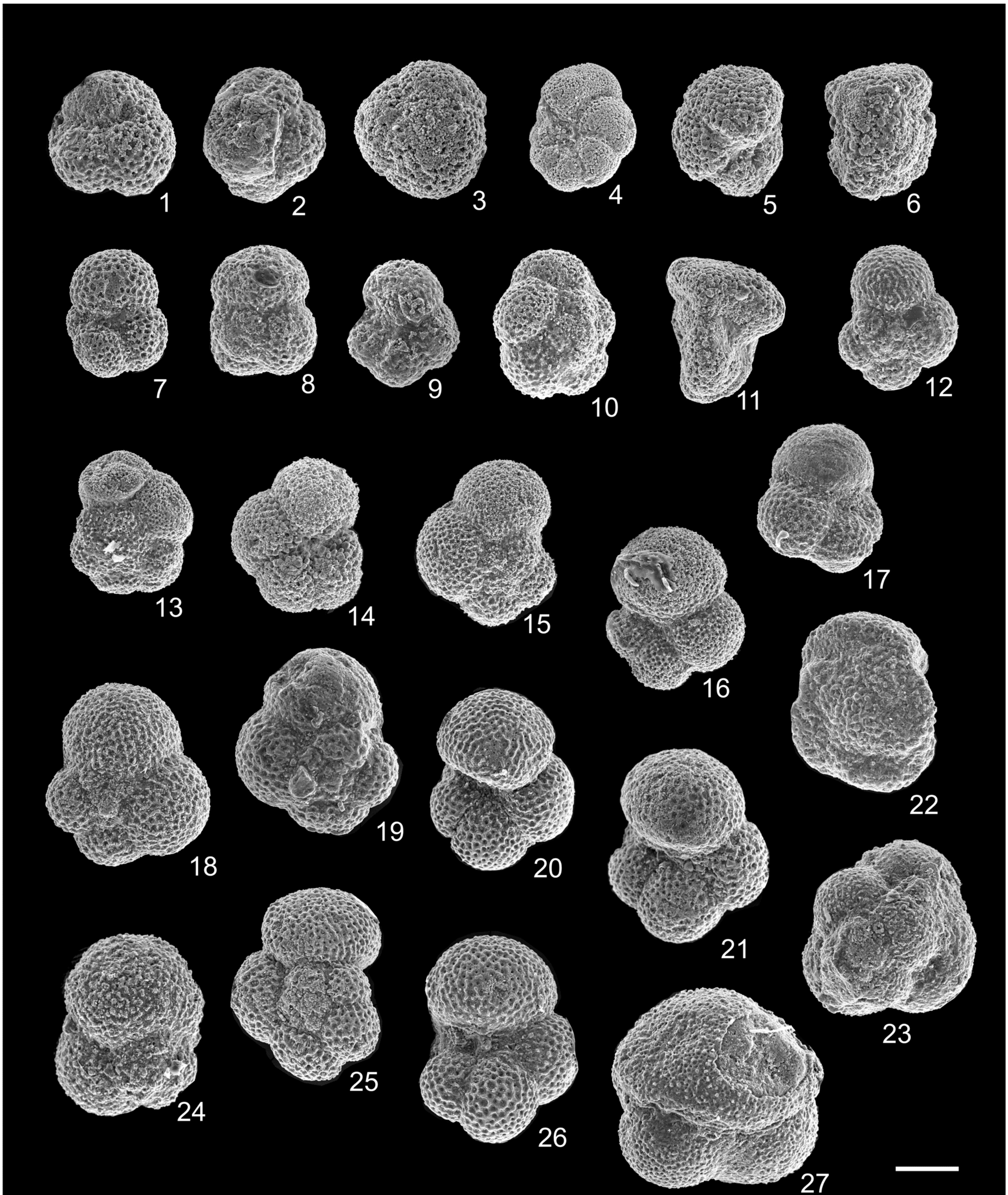


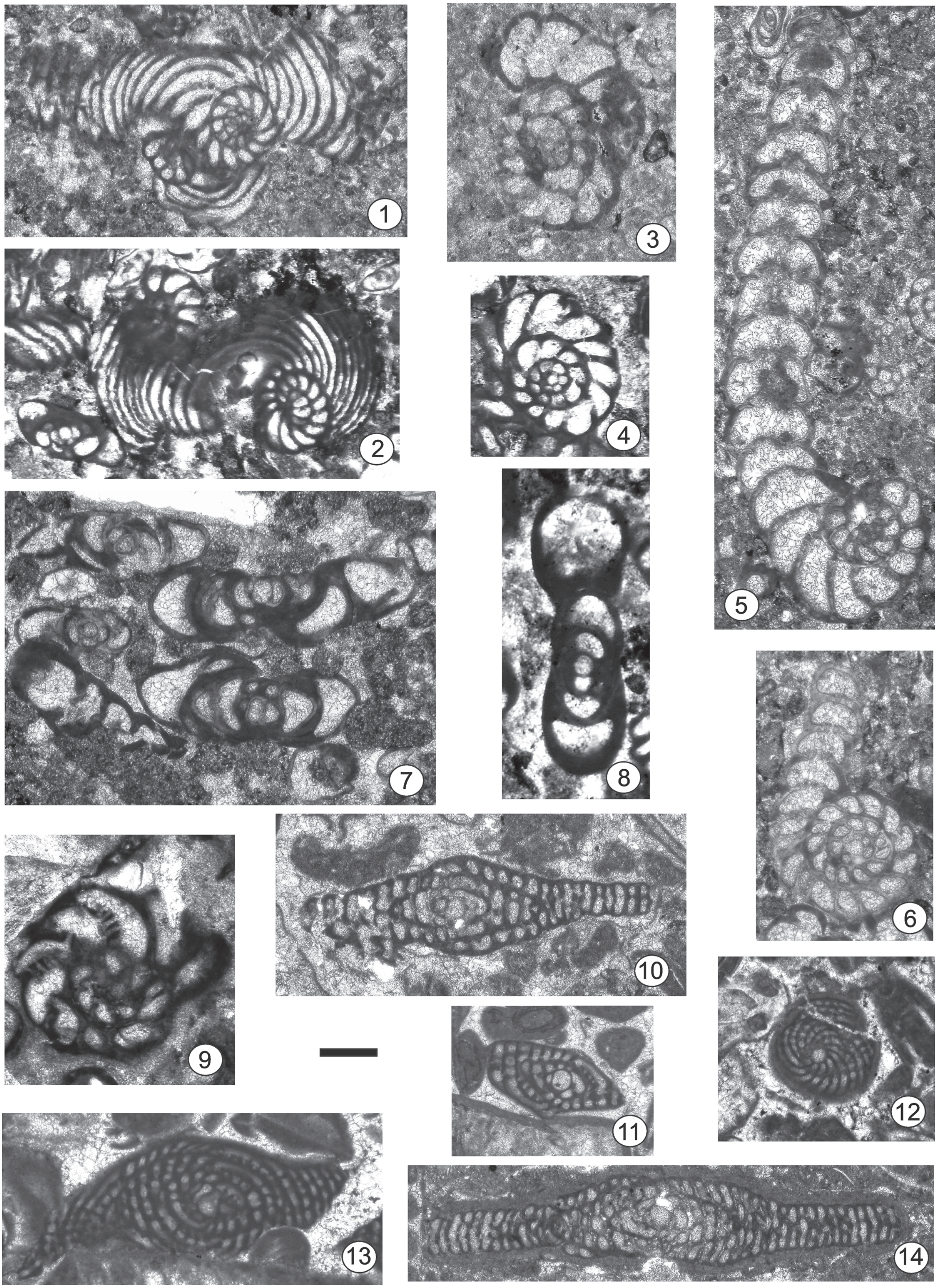
Fig. 7. Correlation chart of Oligocene–Lower Miocene planktonic and benthic foraminiferal biozones (Berggren et al. 1995; Cahuzac & Poignant 1997) and integrated biostratigraphic zonation established for the studied sections (in grey) with ranges of marker species (***P*** *— Pseudohastigerina,* ***T*** *— Turborotalia,* ***G*** *— Globoturborotalita,* ***Ch*** *— Chiloguembelina,* ***Pg*** *— Paragloborotalia,* ***Nu*** *— Nummulites,* ***E*** *— Eulepidina,* ***N*** *— Nephrolepidina,* ***C*** *— Cycloclypeus,* ***M*** *— Miogypsinella,* ***Ma*** *— Miogypsina*).

Fig. 8. SEM photograps of selected planktonic foraminiferal species from the studied sections. **1–3** — *Globigerinatheka subconglobata* (Shutskaya), İşhanı 3; **4** — *Pseudohastigerina micra* (Cole), İşhanı 3; **5** — *Acarinina bullbrooki* (Bolli), umbilical view, İşhanı 3; **6** — *Acarinina bullbrooki* (Bolli), side view, İşhanı 3; **7** — *Subbotina* sp., umbilical view, İşhanı 3; **8** — *Subbotina eocaena* (Guembel), spiral view, İşhanı 3; **9** — *Paragloborotalia* sp., umbilical view, İşhanı 3; **10** — *Acarinina collactea* (Finlay), spiral view, İşhanı; **11** — *Truncorotaloides topilensis* (Cushman), side view, İşhanı 3; **12** — *Globorotaloides suteri* Bolli, spiral view, Eğribucak 34A; **13** — *Paragloborotalia* sp., spiral view, Eğribucak 38; **14** — *Paragloborotalia semivera* (Hornibrook), umbilical view, Eğribucak 38; **15** — *Paragloborotalia pseudocontinuosa* (Jenkins), spiral view, Eğribucak 38; **16** — *Paragloborotalia pseudocontinuosa* (Jenkins), umbilical view, Eğribucak 38; **17** — *Globorotaloides suteri* Bolli, umbilical view, Eğribucak 34A; **18** — *Paragloborotalia opima* (Bolli), spiral view, Eğribucak 34A; **19** — *Paragloborotalia opima* (Bolli), spiral view, Tuzlagözü 9A; **20** — *Paragloborotalia opima* (Bolli), umbilical view, Bakımlı 22; **21** — *Paragloborotalia opima* (Bolli), umbilical view, Eğribucak 34A; **22** — *Turborotalia cerroazulensis* (Cole), spiral view, İşhanı 3; **23** — *Subbotina gortanii* (Borsetti), side view, Tuzlagözü 9A; **24** — *Dentoglobigerina sellii* (Borsetti), spiral view, Eğribucak 34A; **25** — *Dentoglobigerina globularis* (Bermudez), spiral view, Bakımlı 22; **26** — *Dentoglobigerina globularis* (Bermudez), umbilical view, Bakımlı 22; **27** — *Dentoglobigerina tripartita* (Koch), umbilical view, Tuzlagözü 10 (Scale bar: 100 µm).

Paragloborotalia opima and the FO of *Paragloborotalia kugleri* (Berggren et al. 1995; Cahuzac & Poignant 1997; Fig. 7). The O6 Zone is determined by the co-occurrences of *G. ciperoensis* and *Globigerinoides primordius* which first appears approximately at the same level as the LO of *P. opima* (Coccioni et al. 2008) in the uppermost part of the Eğribucak section (Figs. 4, 7).

The planktonic foraminiferal assemblages of O5 and O6 zones in the Eğribucak section are very similar to those of the Mediterranean and Iranian basins as well as those

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of some Anatolian basins. Corresponding assemblages were reported from Italy (Como Molasse, Rögl et al. 1975; March Basin, Menichini 1999; N Apennines, Mancin & Pirini 2001), from Egypt (Ouda 1998), from NW Greece (Wielandt-Schuster et al. 2004), central Iran (Qom Basin, Reuter et al. 2009), S Spain (Fenero et al. 2013), S Slovakian Basin (Ozdínova & Soták 2015), SE Anatolia (Muş and Elazığ basins, Hüsing et al. 2009), S Anatolia (Kahramanmaraş Basin, Işık & Hakyemez 2011).

The SBZ 24 of Aquitanian is recognized in the İşhanı and Akçamescit sections by the occurrence *of Miogypsina gunteri* (Figs. 3, 6, 11). This species is associated with *M. tani*, which is the second marker taxon of the SBZ 24 (Cahuzac & Poignant 1997) in the uppermost part of the Akçamescit section (Fig. 6). The SBZ 24 is an easily comparable biostratigraphic interval based on the common occurrence of the marker taxa, *M. gunteri,* throughout the Mediterranean and Indo-Pacific provinces (Drooger 1956b, 1963, Drooger et al. 1955; Drooger & Magné 1959; Raju 1974; de Mulder 1975; Ferrero Mortara 1987; Wildenborg 1991). This zone was previously documented based on *M. gunteri* in the Tuzlagözü and İşhanı sections from the Sivas Basin by Özcan et al. (2009). Our data is in accordance with that of Özcan et al. (2009) from the İşhanı section, whereas it differs from their data obtained from the lowermost limestones of the Tuzlagözü section where the lower part of SBZ 24 was recorded. The assemblage characterizing SBZ 23 Zone shows no evidence that the Tuzlagözü section presented here extends into the Aquitanian (Fig. 5).

In contrast to the larger foraminifera, the absence of *Paragloborotalia kugleri* and *Globoquadrina dehiscens*, marker species of the M1 (*Paragloborotalia kugleri*) Zone of lower Aquitanian, makes zonal assignment to this interval more difficult. The M1 Zone is defined by the total range of *Paragloborotalia kugleri* and is subdivided into two subzones by the FO of *Globoquadrina dehiscens* (Berggren et al. 1995; Wade et al. 2011). These two biostratigraphic markers are fairly common in the Aquitanian successions throughout the Mediterranean (Bizon et al. 1974; Krasheninnikov 1994; Iaccarino et al. 1996; Menichini 1999; Toufiq & Feinberg 2000; Mancin & Pirini 2001; Hakyemez & Toker 2010). Although the lack of *P. kugleri* and *G. dehiscens* prevents a precise biozonal attribution to the mudstones overlying the SBZ 23 in the Tuzlagözü section, this interval is referable to a tentative M1 Zone (Fig. 5). Single specimens of *Paragloborotalia opima* and *Subbotina gortanii* observed in the lower part might be considered to be evidence for reworking into the tentative M1 Zone (Fig. 8). A very similar assemblage in a sample (Sample 1) from the Akçamescit section seems to be comparable to the M1 Zone. Although this age assignment cannot be precisely defined due to the lack of biostratigraphical markers, it is confirmed not only by the absence of Oligocene species but also by the SBZ 24 determined in the overlying interval (Fig. 6).

Paleoenvironmental and paleoecologic interpretations

Planktonic and benthic foraminifera are one of the most important constituents of the marine sequences and commonly used in biostratigraphy. Their occurrences are strongly controlled by a complex interaction of physical and chemical environmental parameters, including bathymetry, water-energy, salinity, temperature, oxygenation, substrate condition, turbidity, nutrient concentration and hydrodynamics of the water mass. Since larger foraminifera occur most abundantly in shallow water carbonates their composition changing in different parts of carbonate platforms makes them valuable facies indicators in paleoenvironmental reconstructions. On the other hand, planktonic foraminifera are highly sensitive to oceanographic conditions and extensively utilized as proxies for climatic changes, such as warm and cool events, variations in temperature and mass stratification of water column in terms of quantitative analysis (relative abundances) of assemblages and oxygen isotope values from their tests. Their response to the increased environmental stress is indicated by decline in relative abundance of dominant species, sporadic richness of opportunistic species and abundance fluctuations in population of long-ranging species (Spezzaferri 1996; Spezzaferri & Spiegler 2005; Wade et al. 2007; Alegret et al.2008).

The studied successions represent different paleoenvironments changing from deep marine to lagoonal and protected very shallow marine during the Middle Eocene–Early Miocene time interval. The lowermost mudstones belonging to the E11 Zone in the İşhanı section (Fig. 3) clearly suggest a deep marine environment reflected by the presence of *Acarinina, Truncorotaloides* and *Morozovelloides* which are the prominent deep dwelling taxa within the tropical and subtropical oceanic sediments from the Late Paleocene to the

Fig. 9. Selected benthic foraminiferal species from the Eğribucak and Tuzlagözü sections. **1** — *Peneroplis flabelliformis* Sirel & Özgen-Erdem, incomplete equatorial view, Eğribucak 11/36 (Sirel et al., 2013, pl. I, fig. 1); **2** — *Peneroplis flabelliformis* Sirel & Özgen-Erdem, incomplete equatorial view, Eğribucak 11/37; **3** — *Coscinospira sivasensis* Sirel & Özgen-Erdem, slightly oblique view, Eğribucak 11/03 (Sirel et al., 2013, pl. II, fig. 12); **4** — *Coscinospira sivasensis* Sirel & Özgen-Erdem, equatorial view, Eğribucak 11/64; **5** — *Coscinospira elongata* Sirel & Özgen-Erdem, longitudinal view, Eğribucak 11/30. (Sirel et al., 2013, pl. III, fig. 13); **6** — *Coscinospira elongata* Sirel & Özgen-Erdem, longitudinal view, Eğribucak 11/31; **7** — *Sivasina egribucakensis* Sirel & Özgen-Erdem, axial views, Eğribucak 33/61; **8** — *Sivasina egribucakensis* Sirel & Özgen-Erdem, axial view, Eğribucak 11/34, (Sirel et al., 2013, pl. IV, fig. 7); **9** — *Sivasina egribucakensis* Sirel & Özgen-Erdem, equatorial view, Eğribucak 33/1e (Sirel et al., 2013, pl. V, fig. 2); **10** — *Praearchaias diyarbakirensis* Sirel, axial view, Tuzlagözü 2/2a; **11** — *Praearchaias minimus* Sirel, axial view, Tuzlagözü 1/6 (Sirel et al., 2013, pl. X, fig. 10); **12** — *Praearchaias minimus* Sirel, equatorial view, Tuzlagözü 1/7; **13** — *Archaias asmaricus* Smout & Eames, oblique equatorial view, Tuzlagözü 1/1b, (Sirel et al., 2013, pl. IX, fig. 14); **14** — *Archaias kirkukensis* Henson, axial view, Tuzlagözü 1/2 (Sirel et al., 2013, pl. IX, fig. 8) (Scale bar: 250 μm for 1–6, 166 μm for 7–9, 330 μm for 10–14).

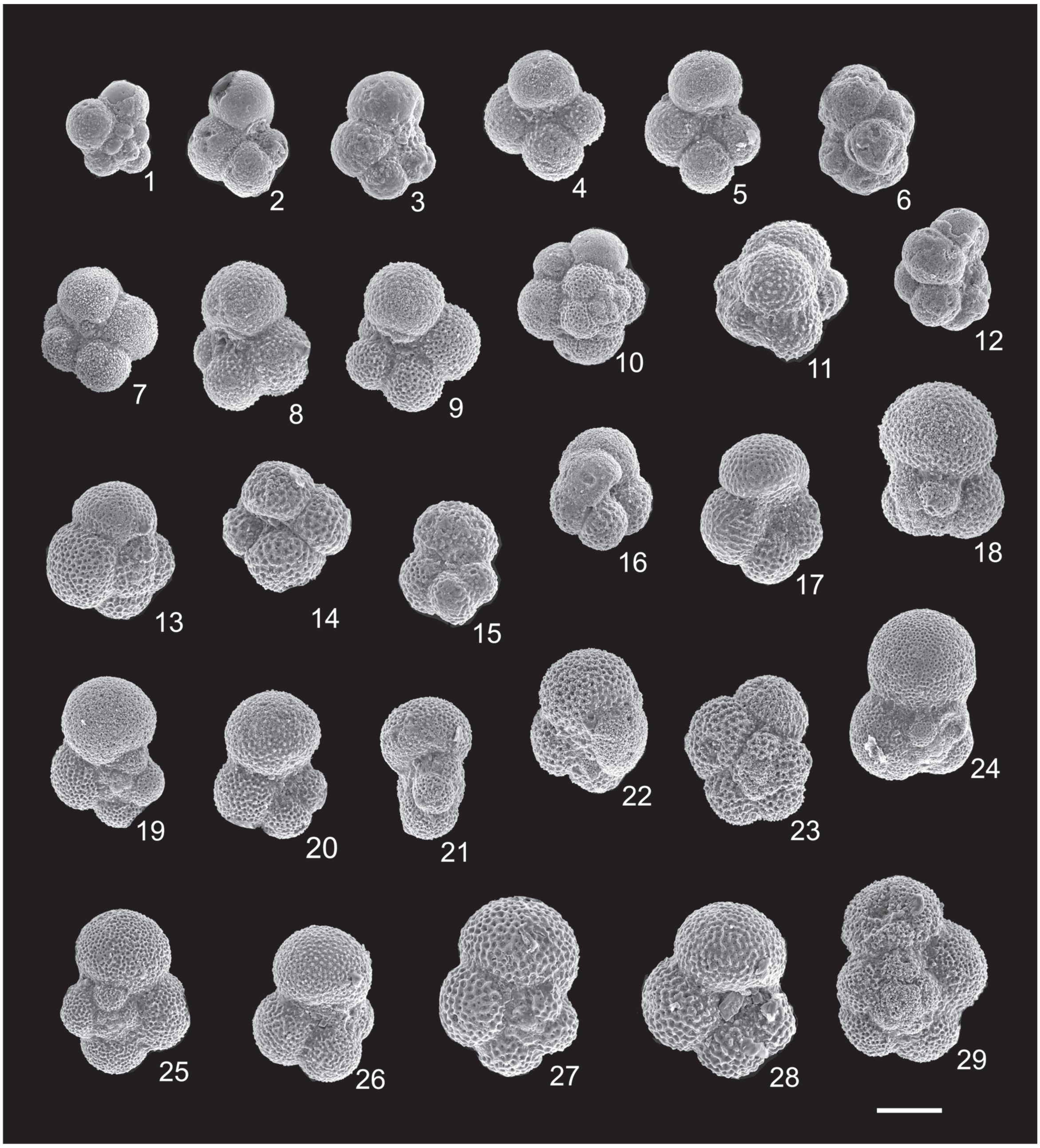


Fig. 10. SEM photograps of selected planktonic foraminiferal species from the studied sections in the Sivas Basin. **1** — *Tenuitella* sp., spiral view, Eğribucak 35A; **2** — *Tenuitella munda* (Jenkins), umbilical view, Eğribucak 35A; **3** — *Tenuitella* sp., umbilical view, Eğribucak 35A; **4** — *Globigerina ouachitaensis* Howe & Wallace, umbilical view, Akçamescit 1; **5** — *Globigerina gnaucki* Blow & Banner, umbilical view, Akçamescit 1; **6** — *Cassigerinella chipolensis* (Cushman & Ponton), Eğribucak 35A; **7** — *Tenuitellinata angustiumbilicata* (Bolli), umbilical view, Eğribucak 38; **8** — *Tenuitella clemenciae* (Bermudez), umbilical view, Akçamescit 1; **9** — *Tenuitella clemenciae* (Bermudez), umbilical view, Akçamescit 1; **10** — *Globigerina fariasi* Bermudez, spiral view, Akçamescit 1; **11** — *Globigerinita* sp., side view, Tuzlagözü 12; **12** — *Cassigerinella chipolensis* (Cushman & Ponton), Eğribucak 35A; **13** — *Dentoglobigerina venezuelana* (Hedberg), spiral view, Eğribucak 34A; **14** — *Dentoglobigerina venezuelana* (Hedberg), umbilical view, Bakımlı 22; **15** — *Globorotaloides* cf. *permicrus* (Blow & Banner), umbilical view, Eğribucak 35A; **16** — *Catapsydrax martini* (Blow & Banner), umbilical view, Bakımlı 22; **17** — *Paragloborotalia* sp., umbilical view, Eğribucak 38; **18** — *Globigerinoides primordius* Blow & Banner, spiral view, Akçamescit 1; **19** — *Globigerinella obesa* (Bolli), spiral view, Akçamescit 1; **20** — *Globigerinella obesa* (Bolli), umbilical view, Akçamescit 1; **21** — *Globigerinella obesa* (Bolli), side view, Akçamescit 1; **22** — *Catapsydrax unicavus* Bolli, Loeblich & Tappan, umbilical view, Eğribucak 38; **23** — *Globotuborotalita anguliofficinalis* (Blow), spiral view, Eğribucak 38; **24** — *Globigerina leroyi* Blow & Banner, spiral view, Tuzlagözü 11; **25** — *Globigerina occlusa* Blow & Banner, spiral view, Bakımlı 22; **26** — *Globigerina occlusa* Blow & Banner, umbilical view, Akçamescit 1; **27** — *Globorotaloides permicrus* (Blow & Banner), spiral view, Bakımlı 22; **28** — *Globorotaloides variabilis* Bolli, umbilical view, Bakımlı 22; **29** — *Globigerina ciperoensis* Bolli, spiral view, Eğribucak 38 (Scale bar: 75 µm for figures 1–9, 12, 18; 100 µm for others).

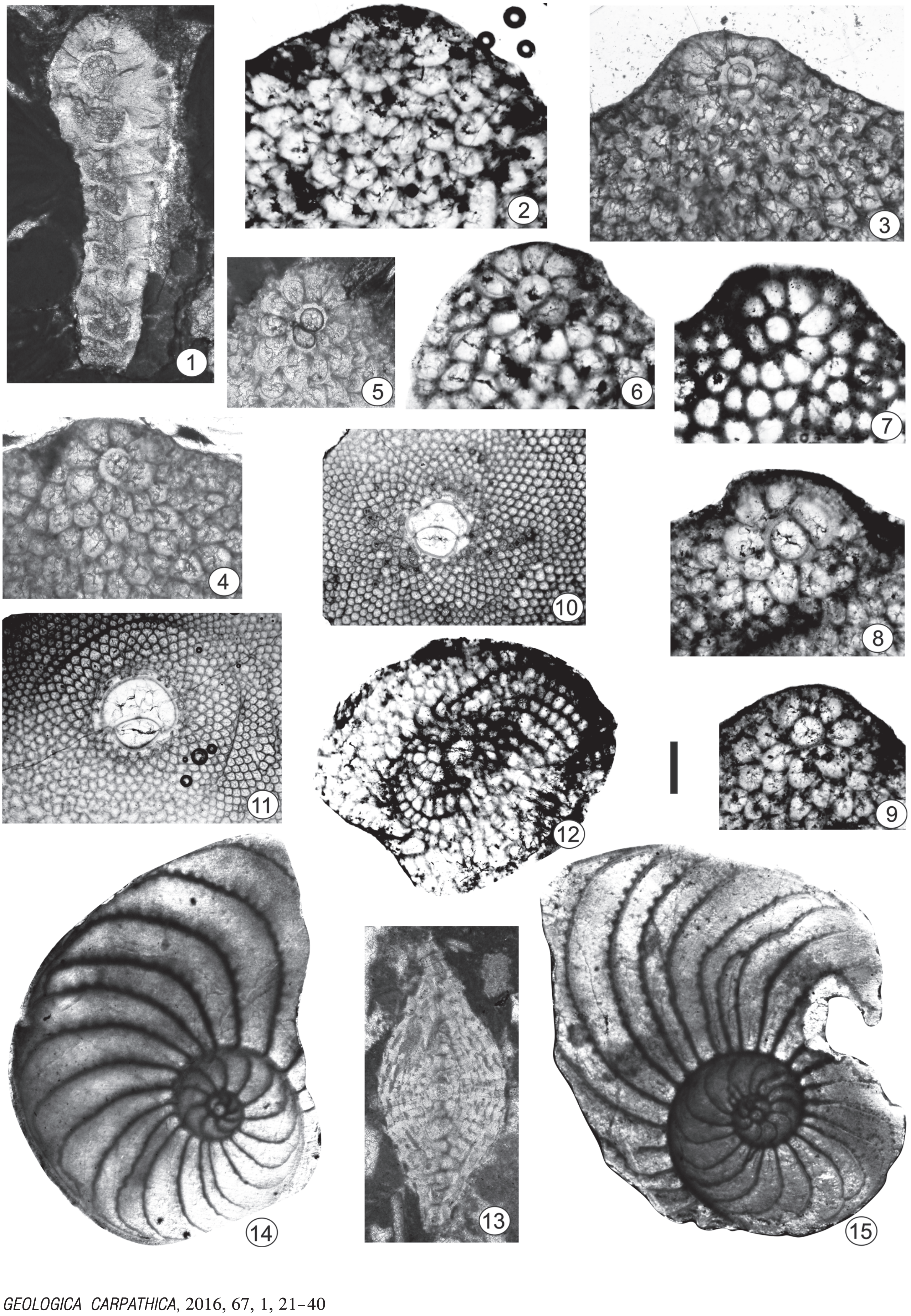
latest Middle Eocene. These deep marine sediments are comparable to a well documented Middle Eocene interval which characterizes widespread "flysch" deposition throughout Anatolia following the collision of the Anatolide-Torid platform with the Pontides during the Latest Paleocene–Early Eocene (Fig. 1; Şengör & Yılmaz, 1981; Poisson et al. 1996). A marked environmental change leading to the thick continental successions deposited during the Early–Middle Oligocene is reflected by the fluvial deposits unconformably overlying the Middle Eocene deep water mudstones in the İşhanı section (Fig. 3). Conversely, the marine Oligocene–Lower Miocene sections investigated provide evidence of different paleoenvironments covering lagoon, algal reef and shallow to deep marine settings based on the analysis of mainly benthic and planktonic foraminiferal abundance and distribution. Three larger benthic foraminifera-bearing biofacies are distinguished. The first biofacies characterizing the SB 21–22 zonal interval is dominated by the porcellaneous assemblages including species of *Peneroplis, Sivasina, Praearchaias, Archaias, Coscinospira, Austrotrillina* and miliolids in the lowermost part of the Tuzlagözü section (Figs. 5, 9). The limestones involving these assemblages consist of packstone-grainstone facies with frequent to abundant algae, byrozoa and bivalve fragments and is assignable to a shallow protected marine environment. It is known that abundant occurrence of porcellaneous benthic foraminifera (such as *Archaias*, *Peneroplis*, *Alveolina, Austrotrillina* and miliolids) characterizes protected areas under restricted marine conditions (e.g. shallow shelf lagoon; Wilson 1975; Epting 1980; Flügel 1982). Almost similar foraminiferal facies were reported from the shelf lagoon or inner ramp environments in Iran (Vaziri-Moghaddam et al. 2006; Amirshahkarami et al. 2007; Rahmani et al. 2009; Seyrafian et al. 2011 and Sajadi et al. 2014), from NE Italy (Bassi et al. 2007), from SE Turkey (Sirel 1996, 2003) and from back reef environments in Iraq (Edgell 1997; Al-Banna 2004).

In contrast to the Tuzlagözü section, the limestones enclosing the foraminiferal packstone-grainstone facies alternate with pelecypod bearing sandstone, fossiliferous (mainly ostracoda) siltstone with plant fragments, sandy conglomerate and evaporites and mudstones with planktonic foraminifera in the Eğribucak section (Fig. 4). The composition of larger foraminifera is similar to that of the Tuzlagözü section but less diverse (Figs. 4, 5). The planktonic foraminiferal assemblages from the same levels are dominated by the simple morphotypes with small-sized, spinose tests with thin walls and globular chambers, which are representatives of stressed environments such as *Globigerina praebulloides, G. occlusa, G. ouachitaensis, G. gnaucki, Cassigerinella chipolensis* and tenuitellids (Fig. 4). Such morphotypes are regarded as ecological opportunists (r-strategist), which are more resistant to the environmental perturbation than complex morphologies with compressed, keeled, non-spinose and thicker tests, which are not able to adapt to changing environmental conditions (K-strategist) (Spezzaferri & Spiegler 2005). The occurrences of a large variety of types of lithology may be considered to imply depositional processes under unstable conditions reflected by small scale relative sea-level fluctuations, possibly controlled by the regional tectonic activity during the Oligocene. Accordingly, it is concluded that the exclusion of *Nummulites vascus*, *N. fichteli* and lepidocylinids which characterize shallow water conditions of open marine settings appears to be controlled by protected shallow marine (Tuzlagözü) and lagoonal (Eğribucak) settings during the Rupelian–early Chattian interval. The overlying mudstone unit yields a highly diverse planktonic foraminiferal assemblage reflecting the rapid deepening of the environment in the uppermost part of the Eğribucak section. The larger foraminifera within the limestone intercalations might be redeposited from the reefal facies (Fig. 4).

The second foraminiferal facies documents an algal reef setting referable to the SBZ 23 of Chattian age in the Tuzlagözü section (Fig. 5). This biofacies is represented predominantly by red algae and consists of an algal boundstone. Red algae are accompanied by mainly *Miogypsinella complanata* and *M. borodinensis*, but some hyaline calcareous taxa such as *Amphistegina*, *Planorbulina* and *Spiroclypeus* occasionally occur (Fig. 11). The algal assemblage consists of coralline algae such as *Polystrata alba* (Pfender), *Sporolithon* sp., *Lithoporella* sp. and *Lithothamnion* sp. The overlying thick mudstone succession of Aquitanian age is rich in planktonic foraminifera but it lacks larger foraminifera and seems to indicate an environmental change towards deepening open marine in the Tuzlagözü section (Fig. 5).

The Aquitanian is well documented by the third benthic foraminiferal facies which is characterized by the presence of *Miogypsina, Nephrolepidina* and *Operculina* and clearly refers to the SBZ 24 in the İşhanı and Akçamescit sections (Figs. 3, 6). This larger foraminiferal assemblage accompanied by red algae suggests a shallow open marine environment in the İşhanı section (Fig. 3). On the other hand, the same larger foraminiferal taxa bearing limestones are intercalated with mudstones yielding planktonic foraminifera and are most likely transported from an adjacent shallow water environment into the deeper marine setting in the Akçamescit section (Fig. 6).

The planktonic foraminifera are mainly represented by abundant and medium to highly diversified assemblages from the upper Chattian (Eğribucak section; Fig. 3) and the lower Aquitanian intervals (Tuzlagözü and Akçamescit sections; Figs. 5, 6). Both the sporadic presence of planktonic foraminifera and the generally insufficient numbers of specimens preclude performing the paleoecological inferences based on the relative abundance of individual species by means of quantitative analysis. A tentative assessment, nevertheless, may be deduced from the comparable occurrences of ecologically sensitive species with those of numerous studies published recently. The assemblages yield a mixture of both surface/subsurface and intermediate dwelling morphogroups, among them *Globigerina ciperoensis, G. fariasi, Cassigerinella chipolensis* and *Globorturborotalita angulioffcinalis* lived in the warm surface water, whereas *Globigerina ouachitaensis, G. gnaucki, G. officinalis, G. praebulloides* are also surface dweller group but characterize somewhat cooler water conditions (Spezzaferri & Premoli Silva 1991; Li et al. 1992; Spezzaferri, 1994, 1995; Menichini 1999; Molina et al. 2006; Olsson et al. 2006; Wade et al.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2007). These two groups are recorded in similar abundances from the samples analysed. Other representatives of cool water are characterized by rare to common tenuitellids (*Tenuitella clemenciae, T. munda*), globorotaloidiids (*Globorotaloides suteri, G. variabilis*) and globigerinellids (*Globigerinella obesa, G. praesiphonifera*), which probably inhabited the subsurface of the mixed layer. An additional group of taxa are *Paragloborotalia* (*P. opima, P. nana, P. pseudocontinuosa, P. siakensis, P. semivera*) indicating intermediate depth of the water column observed in low numbers. However, exclusion of complex morphologies with large-sized and thick walled tests (such as *Catapsydrax dissimilis, C. unicavus, Globoquadrina dehiscens*) seems to imply that the water column is not sufficiently deep for this group of taxa which are characteristic of much greater water depths.

Discussion and conclusion

An integrated biostratigraphic investigation in terms of planktonic and benthic foraminifera from four sections provides new age data to contribute a well established stratigraphic framework and description of paleoenvironments for the Middle Eocene-Lower Miocene successions from the Sivas Basin. The Middle Eocene age is recorded in deep marine mudstones by diagnostic planktonic foraminiferal taxa such as *Acarinina*, *Morozovelloides* and *Truncorotaloides* which last occurred in the latest Middle Eocene. The co-occurrences of *Acarinina bullbrooki, Truncorotaloides topilensis* and *Turborotalia cerroazulensis* in the assemblage confine the biostratigraphic age to the E11 Zone of late Lutetian-early Bartonian. In contrast to the Middle Eocene interval, the lower parts of Oligocene sections investigated are characterized by the rich porcellaneous benthic foraminiferal assemblages dominated by soritids, peneroplids and miliolids. Although *Nummulites fichteli, N. vascus* and lepidocyclinids are missing, the assemblages yielding *Praearchaias diyarbakirensis*, *P. minimus, Archaias kirkukensis* and *A. asmaricus* together with a group of new taxa were referred to the SBZ 21–22 (Sirel et al. 2013) based on the correlation with those of some SE Anatolian sections (Sirel 2003). The exclusion of nummulitids and lepidocylinids which characterize shallow water conditions of open marine settings seems to be controlled by the protected shallow marine and lagoonal settings of the studied successions. A sporadic and poor occurrence of small simple planktonic foraminiferal morphotypes preventing an assignment of biostratigraphic age also reflects restricted marine conditions. Within the uppermost part of this interval, the O5 planktonic foraminiferal Zone of early Chattian which corresponds to the SBZ 22B (Berggren et al. 1995; Cahuzac & Poignant 1997) is recorded by the co-occurrences of *Paragloborotalia opima* and *Globigerinella obesa.* Considering this data, the combined SB 21–22 zonal interval seems to be referable to the SBZ 22 of late Rupelian–early Chattian age. This biostratigraphic age is in accordance with that of Poisson et al. (1997) who recorded P21 Zone of Mid-Oligocene (late Rupelian–early Chattian) in the Sivas marls. Moreover, the tentative SBZ 22 is also confirmed by the overlying SBZ 23 of late Chattian age.

The SBZ 23 is determined by the occurrence of *Miogypsinella complanata* accompanied by abundant algae which defines the second biofacies as an algal reef limestone. The O6 Zone of the upper Chattian, on the other hand, reflects a change towards a deepening open marine environment with a relatively high diversity of planktonic foraminifera. In this interval, benthic foraminifera possibly transported from the adjacent reef areas are enriched in the limestone interlayers and provide a clear correlation between the SBZ 23 and O6 Zone (Berggren et al. 1995; Cahuzac & Poignant 1997). Thus, the integrated foraminiferal data reveals that the lagoonal or protected shallow and the overlying deep marine intervals might be dated to the late Rupelian–Chattian age which is conformable with some previous studies (e.g. Lüttig & Steffens 1976; Gökçen 1981; Çubuk & İnan 1998; Poisson et al. 1997; Vrielynck et al. 2012).

The Lower Miocene sections indicate an environmental modification from protected shallow water and algal reef settings to either shallow open marine or deep marine environments. The SBZ 24 of the Aquitanian is well recorded by the presence of *Miogypsina gunteri* and documents the third foraminiferal biofacies of shallow marine, whereas the lack of biostratigraphic marker species of planktonic foraminifera makes it difficult to establish a precise biozonation for this time interval. Nevertheless, a moderately diversified assemblage points to a deep marine setting and is referable to a tentative M1 Zone of early Aquitanian based on the absence of both Oligocene taxa and *Globigerinoides* species such as *trilobus*, *sacculifer* and *quadrilobatus* which commonly occurred in the late Aquitanian.

The planktonic foraminifera are mainly characterized by the common to abundant occurrences of small simple morphotypes inhabiting in near surface water such as *Globigerina, Cassigerinella, Globoturborotalita* and *Dentoglobigerina* throughout the Chattian-Aquitanian interval. This group is

Fig. 11. Selected benthic foraminiferal species from the studied sections in the Sivas Basin. **1** — *Miogypsinella complanata* (Schlumberger), axial view, Eğribucak 36/1; **2** — *Miogypsinella complanata* (Schlumberger), equatorial view, Tuzlagözü 6/1; **3** — *Miogypsinella borodinensis* Hanzawa, equatorial view, Eğribucak 34/1c; **4** — *Postmiogypsinella intermedia* Sirel & Gedik, equatorial view, Eğribucak 34/1c; **5** — *Postmiogypsinella intermedia* Sirel & Gedik, equatorial view, Eğribucak 36/2; **6** — *Miogypsina gunteri* Cole, equatorial view, İşhanı 8/6; **7** — *Miogypsina gunteri* Cole, equatorial view, İşhanı 8/4; **8** — *Miogypsina tani* Drooger, equatorial view, Akçamescit 14/5–6; **9** — *Miogypsina tani* Drooger, equatorial view, Akçamescit 14/5–5; **10** — *Nephrolepidina morgani* Lemoine & Douville, equatorial view, İşhanı 7; **11** — *Nephrolepidina morgani* Lemoine & Douville, equatorial view, Akçamescit 9/5; **12** — *Spiroclypeus* cf. *blanckenhorni* Henson, equatorial view, Tuzlagözü 6/3; **13** — *Spiroclypeus* cf. *blanckenhorni* Henson, axial view, Tuzlagözü 6/4; **14** — *Operculina complanata* Defrance, equatorial view, İşhanı 6/1; **15** — *Operculina complanata* Defrance, equatorial view, İşhanı 6/3 (Scale bar: 250 µm for 1–9 and 500 µm for 10–15).

associated with *Tenuitella, Globorotaloides* and *Globigerinella* which are the representatives of subsurface habitats. A mixed occurrence of these two groups together with rare specimens of *Paragloborotalia* possibly provide evidence for warm to temperate conditions and intermediate depths of the water column.

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Taxonomic appendix for planktonic foraminifera

The appendix briefly describes 12 taxa and provides commentary regarding our taxonomic assignments.

Paragloborotalia sp.
(Fig. 8: 9)

The small and poorly preserved specimen is considered to belong to *Paragloborotalia* on the basis of position of the aperture and wall texture.

Dentoglobigerina globularis (Bermúdez)
(Fig. 8: 25, 26)

Globoquadrina globularis Bermúdez, 1961, p. 1311, pl. 13, figs. 4–6

The specimens assigned to this taxon have cancellate surface, rounded chambers and a weakly developed umbilical tooth.

Tenuitella munda (Jenkins)
(Fig. 10: 2)

Globorotalia munda Jenkins, 1966, p.1112, fig. 14

The smooth wall and the inflated chambers are the most typical features of this small species. It differs from *Tenuitella clemenciae* by its slightly smaller size and more inflated chambers.

Globigerina ouachitaensis Howe & Wallace
(Fig. 10: 4)

Globigerina ouachitaensis Howe & Wallace, 1932, p. 74, pl. 10, figs. 7a–c

This species is assigned to *Globoturborotalita* because of its well developed cancellate surface by Olsson et al. (2006). Because the specimens referable to *ouachitaensis* and *gnaucki* do not appear to have cancellate wall in our material we follow the concept of Spezzaferri (1994) for two species. *Globigerina ouachitaensis* is characterized by four globular chambers in the last whorl that increase slowly in size, and relatively wide umbilicus. It is distinguished from *Globigerina gnaucki* in having an umbilical aperture.

Globigerina gnaucki Blow & Banner
(Fig. 10: 5)

Globigerina ouchitaensis gnaucki Blow & Banner, 1962, p. 91, pl. 9, figs. L–N.

In contrast to *Globigerina ouachitaensis* this species has a distinctly umbilical-extraumbilical aperture. The distribution of *Globigerina gnaucki* is from the E11 Zone to the O2 Zone according to Olsson et al. (2006), but ranges up into the Miocene according to Spezzaferri (1994).

Tenuitella clemenciae (Bermúdez)
(Fig. 10: 8, 9)

Turborotalia clemenciae Bermúdez, 1961, p. 1321, pl. 17, figs. 10a, b

Specimens referable to this species have four chambers moderately increasing in size in the last whorl, weakly pustulose surface on the umblical side and low arched aperture with a bordered lip, triangular plate in shape. Kennett & Srinivasan (1983) report the FO of this species from the base of the N5 Zone, whereas it ranges down into the Lower Oligocene according to Blow (1969), Li (1987) and Spezzaferri (1994).

Globigerina fariasi Bermúdez
(Fig. 10: 10)

Globigerina fariasi Bermúdez, 1961, p. 1181, pl.3, figs. 5a–c.

A high trochospiral arrangement of the chambers is the specific feature that distinguishes *Globigerina fariasi* from *Globigerina ciperoensis*.

Globigerinita sp.
(Fig. 10: 11)

The specimen referred to this taxon appears to be a morphologically transitional form between *Globigerinita juvenilis* and G. *uvula.* It differs from *G. incrusta* and *G. glutinata* by its high-spired and non-bullate test.

Globorotaloides suteri Bolli
(Fig. 8: 12, 17)

Globorotaloides suteri Bolli, 1957, p. 117, pl. 27, figs. 13a–c.

This species has a considerable variation in the shape of the small and four- chambered test due to often having a bulla that is variable in size and shape

Catapsydrax martini (Blow & Banner)
(Fig. 10: 16)

Globigerinita martini martini Blow & Banner, 1962, p. 110, pl. 14, fig. O

It is characterized by a small test with four globular chambers rapidly increasing in size in the last whorl and a smaller bulla-like last chamber.

Globorotaloides permicrus (Blow & Banner)
(Fig. 10: 15, 27)

Globorotalia (*Turborotalia*) *permicra* Blow & Banner, 1962, p. 120, pl. 12, figs. N–P.

It is characterized by a strongly cancellate surface. It differs from *Globorotaloides variabilis* in having rapidly enlarging chambers in the last whorl and smaller umbilicus; differs from *Globorotaloides suteri* in lacking the bulla.

Globorotaloides variabilis Bolli
(Fig. 10: 28)

Globorotaloides variabilis Bolli, 1957, p. 117, pl. 27, figs. 15a–20c

It has a distinctly cancellate surface and flattened spiral side. We differentiate this species from *Globrotaloides suteri* and *Globrotaloides permicrus* by its less rapidly enlarging chambers and wide umbilicus.