Oligocene hyaline larger foraminifera from Kelereşdere Section (Muş, Eastern Turkey)

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ABSTRACT: We present the most complete record of Rupelian to Chattian hyaline larger foraminifera in Mediterranean Tethys from Kelereşdere section (Muş region, eastern Anatolia) based on the biometric study of such stratigraphically important groups as *Miogypsina*, *Miogypsinoides*, *Nephrolepidina*, *Eulepidina*, *Nummulites*, *Cycloclypeus*, *Heterostegina*, *Operculina* and *Spiroclypeus*. The identified taxa, most of which are described for the first time in Turkey and represent the Shallow Benthic Zones 22A, 22B, 23, enable us to correlate them with comparatively well-known coeval taxa from other parts of the Tethys. Our data suggest that the populations of *Miogypsinoides*, *Eulepidina*, *Nephrolepidina* and *Cycloclypeus* are represented by more than one lineage for each of these groups during Oligocene. Some new taxa such as *Nephrolepidina musensis* n. sp., *Eulepidina anatolica* n. sp. and *Cycloclypeus pseudocarpenteri* n. sp. are introduced. The stratigraphic position of *Eulepidina elephantina*, highly disputed in previous works, was re-evaluated based on its occurrence in the late Chattian. We for the first time demonstrate the parallel evolution of *Miogypsina* and *Miogypsinoides* in the late Chattian of eastern Mediterranean region. *Miogypsinoides formosensis* is associated with *Miogypsina basraensis* at the lower part of upper Chattian and this association is accompanied by *Miogypsinoides sivasensis* at the uppermost part of the section. We compare our results with the available data from other parts of Tethys and remarks on Rupelian-Chattian boundary and the zonation of shallow-marine Oligocene of Mediterranean Tethys are made.

INTRODUCTION

Oligocene shallow-marine deposits of Tethys contain such diagnostic hyaline larger foraminifera as miogypsinids, lepidocyclinids and nummulitids that are used for biostratigraphic zonation and regional correlations (Drooger 1993; Drooger and Laagland 1986; Cahuzac and Poignant 1997). These groups include the genera *Cycloclypeus*, *Heterostegina*, *Operculina*, *Spiroclypeus*, *Eulepidina*, *Nephrolepidina*, *Miogypsina*, and *Miogypsinoides*, appearing progressively in the stratigraphic record following the extinction of many groups of nummulitids and all orthophragminid taxa at Eocene-Oligocene boundary.

Our state-of-art knowledge about the biometry, taxonomy and phylogenetic histories of many of the Western Tethyan Oligocene hyaline larger foraminifera is based on the data derived from separate localities in the circum-Mediterranean/European region and western India (see Drooger 1993 for a review). In this scheme, no contribution from Turkey has been made in the absence of data from this part of the Tethys. The Kelereşdere section, representing one of the most complete marine Oligocene successions in Turkey, contains larger foraminifera in numerous levels of a thick, mainly clastic/carbonate succession. This offers the opportunity to follow the evolution of many of the groups from Rupelian to the late Chattian. Our approach is based upon the biometric study of hyaline larger foraminiferal genera, the occurrence of which has been widely reported in the Oligocene deposits of Turkey.

Figured specimens prefixed by O/ are stored in the Özcan collection of Department of Geology, İstanbul Technical University while those marked by O. are in the Oligocene collection of the Geological Institute of Hungary (Budapest).

GEOLOGICAL SETTING AND DESCRIPTION OF KELEREŞDERE SECTION

Turkey is situated at the collisional boundary between Gondwana in the south and Laurasia in the north and its mountain ranges constitute the easternmost segment of the Mediterranean Alpine chain (e.g., Şengör and Yılmaz 1981; also see Şengör et al. 2008 for the tectonic map of eastern Turkey). A major part of Eastern Anatolia to the north of the Bitlis-Zagros suture is considered to be a part of one of the continental blocks located north of the Arabian plate (text fig. 1). The present tectonic framework is due to the elimination of Neo-Tethyan ocean floor as a result of collision between Arabia and Eurasia during the early Miocene time (Şengör and Yılmaz 1981; Şengör et al. 2008; Yılmaz 1993; Okay et al. 2010), although previously an Oligocene collision was also suggested (Allen and Armstrong 2008). The post-collisional period is characterized by the deposition of continental sediments and widespread volcanic activity. The eastern Anatolian high plateau, where the Muş Basin is located, is mostly underlain by an upper Cretaceous to Oligocene subduction-accretion complex (ophiolitic mélange and flysch units) mostly buried under Neogene-Quaternary volcanic cover.
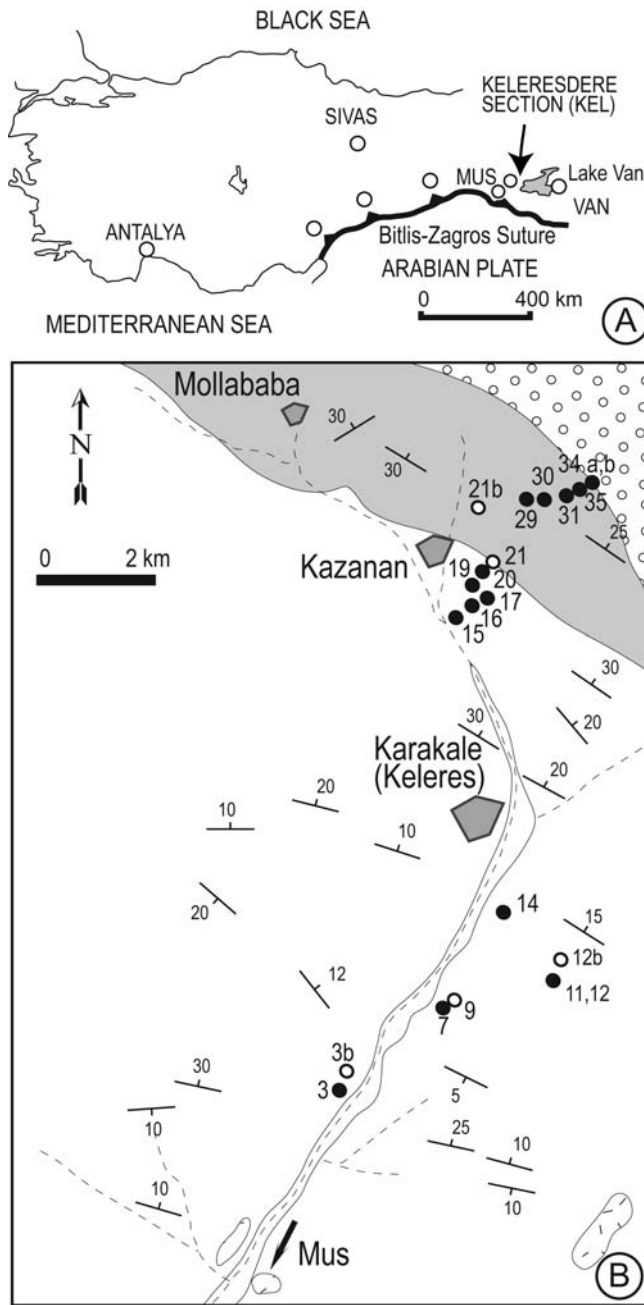
TEXT-FIGURE 1
Geological map of the Kazanan and Kelereş region to the north of Bitlis-Zagros suture zone (west of Lake Van) (A). The geologic map adopted from Akay et al. 1989. AT: Anatolide-Tauride Block, AP: Arabian Platform. Closed and open site markers refer to the levels studied for larger foraminifera and planktonic foraminifera/calcareous nannoplankton respectively. Outcrops with gray colour in the map (B) refer to the clastics and carbonates of undifferentiated Mollababa and Aktaş formations. The outcrops of Yazla Formation is shown by white colour. Circles in the map refer to the Miocene and younger clastic and volcanic rocks.

The Keleréşdere section, representing a succession of Oligocene deposits developed over this subduction-accretion complex to the west of Lake Van, includes marine units deposited in a variety of deep to shallow marine settings and yields successive benthic foraminiferal assemblages. In this respect, it is unique in eastern Mediterranean region in recording foraminiferal changes from the Rupelian to the end of Chattian.

The Oligocene development of the region can be briefly discussed using the sequence of the following units, mainly after Sakınç (1982) and Akay et al. (1989) (text-fig. 1). The overlying, poorly consolidated continental clastics, lacustrine units and volcanic rocks of middle (?)-late Miocene age will not be described. The lithostratigraphic names applied to these units by different authors are somewhat confusing mainly because of either the incorrect correlation of the units in the basinal scale or the absence of a detailed description of the lithostratigraphic units (Sakınç 1982; Akay et al. 1989; Sancay et al. 2006).

1. The Red continental clastics: The marine Oligocene sequence is underlain by an about 500-1250m-thick sequence of typically reddish- to brownish-colored continental conglomerates and sandstones with subordinate siltstones and mudstone, which are devoid of foraminifera. The age of the unit was considered to be either Eocene–early Miocene (?) based on its stratigraphic position below the lower Miocene units (Demirtaşlı and Pisoni 1965), or late Eocene (?) by correlating it with continental deposits in Muş region (Akay et al. 1989).

2. Yazla Formation: This is the most widespread unit cropping out in the region and is represented by a 2-3km-thick sequence of mainly turbiditic beds, redeposited biostromal and bioclastic calcarenites and coral rubble beds, which are common in its upper part. The unit was dated as Rupelian and Chattian by Sakınç (1982) based on benthic foraminifera, and by Sancay et al. (2006) based on calcareous nannoplankton and benthic foraminifera and as Middle to Late Oligocene by Akay et al. (1989) based on nannoplankton data.

3. Undifferentiated clastic and carbonate units (Mollababa and Aktaş formations): The upper, shallow-water unit conformably overlying the Yazla Formation is dominated by a succession of thick-bedded carbonaceous clastic units and coral and mollusc rubble beds and bioclastic calcarenites. This succession has been introduced under different lithostratigraphic names and in most cases it was incorrectly correlated with the Burdigalian coral-dominated Adilcevaz Formation widely outcropping north of Lake Van because of the assumed age equivalency of both units. The age of the units was vigorously debated in the previous studies. Sirel (2003) considered the age of this unit in the same locality as late Oligocene while Sancay et al. (2006) as Early Miocene. The currently adopted 'Aquitanian to Burdigalian' age for this clastic-carbonate unit relies on the misleading benthic foraminiferal assemblage documented by Sakınç (1982) which work later has been followed by subsequent publications dealing with the stratigraphy of the region (Akay et al. 1989; Sancay et al. 2006). We here do not adopt the widely used 'Adilcevaz Formation' for the shallow-marine sequence at the upper part of the studied section since it is originally used for coral and algae rich carbonate units of Burdigalian age in eastern Turkey (see Özcan and Less 2009 for the larger foraminiferal composition of the Adilcevaz Formation).
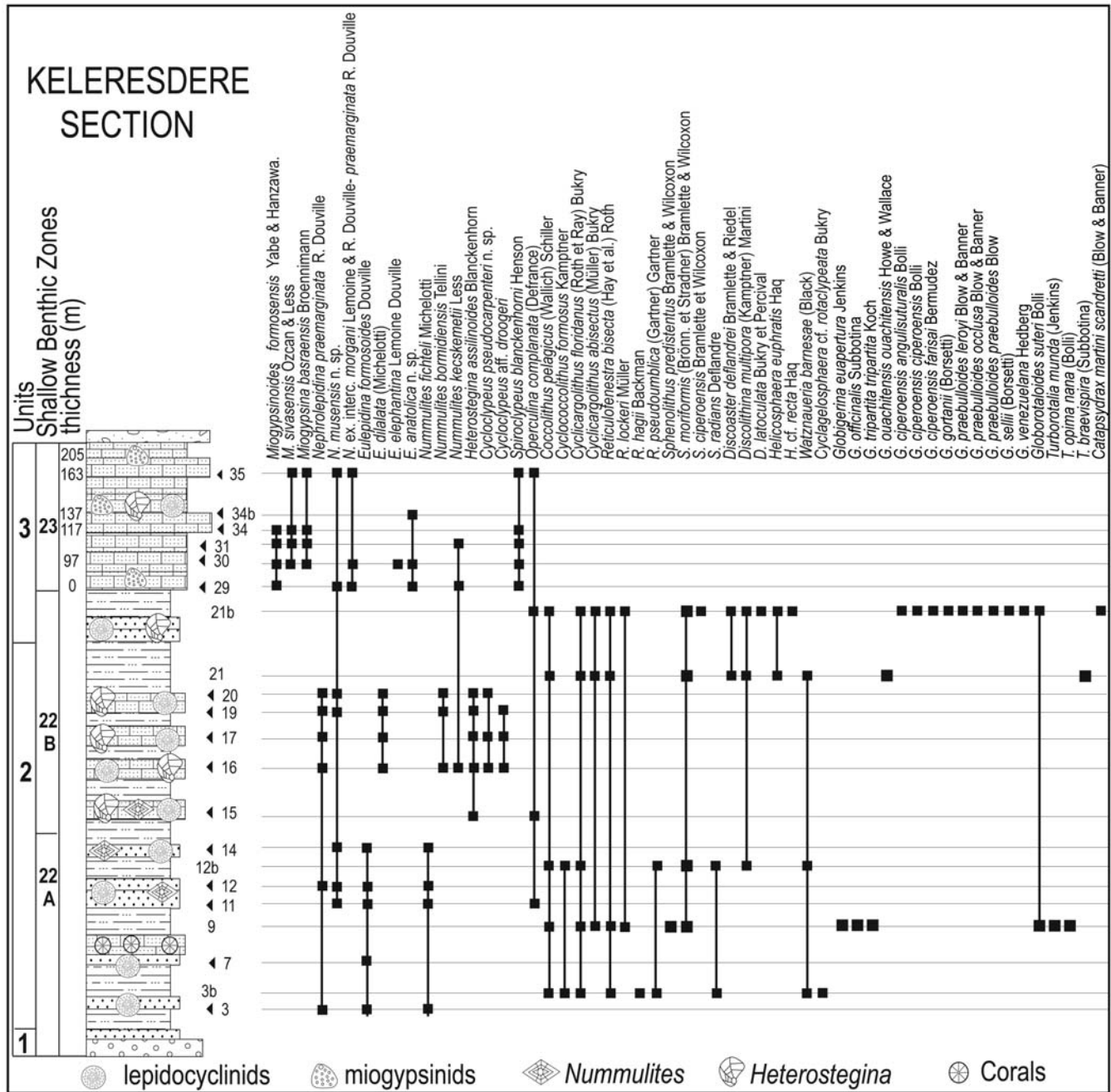
TEXT-FIGURE 2
Distribution of larger benthic foraminifera, calcareous nannoplankton and planktonic foraminifera in the Kelereşdere section. 1-Red continental clastics, 2-Yazla Formation, 3-Clastics and carbonates of undifferentiated Mollababa and Aktaş formations.

Recently Hüsing et al. (2009) elaborated a long section in the eastern part of the Muş Basin mainly for planktonic Foraminifera. Although they did not give either co-ordinates or other more detailed geographic datails, their section most likely corresponds to the Kelereşdere section discussed in this paper. Unfortunately, both their stratigraphic log (text-fig. 3) and description do not allow to link their results to ours in detail, however the stratigraphic range of the whole section given by them (the P 19 to 22 planktonic foraminiferal zones corresponding to the middle Rupelian to late Chattian interval) is

well in accord with our data (the SBZ 22A to 23 shallow benthic zones corresponding to the late Rupelian to late Chattian time-span).

The Kelereşdere Section

The section, in excess of several kilometers, is dominated by a predominantly shaly to-sandy turbiditic deep-marine succession (Yazla Formation), overlain by a clastic/carbonate unit depos-

TEXT-FIGURE 3
Overview of the resedimented bioherms in the shaly matrix at the lower part of Yazla Formation (sample KEL 7 is from the lower part of bioherm).

ited in a shelf-margin depositional setting (Mollababa and Aktaş formations) (text-fig. 2).

The lowermost, mainly shaly to silty turbiditic sequence of the Yazla Formation includes occasional biostromal and coral rubble beds that contain larger foraminifera abundantly (samples between KEL 3 and 14). The proximity to the reefs can be demonstrated by the presence of fragments of bioherms in the shaly matrix (text-fig. 3). Larger foraminifera in these re-deposited sediments mark the SBZ 22A Zone based on the assemblages of *Nephrolepidina praemarginata*, *Eulepidina formosoides*, *Nummulites fichteli* and *Operculina complanata* (text-fig. 2). *Nephrolepidina musensis* n. sp. occurs abundantly in sample KEL 12. The calcareous nannoplankton and planktonic foraminifera identified in pelagic marls (samples KEL 3B and 12B) include a mixture of reworked taxa and do not yield a precise age. However, the calcareous nannoplankton in sample KEL 9 (text-fig. 2) marks the NP24 Zone based on the co-occurrence of *Cyclicargolithus abisectus* and *Sphenolithus predistentus*. Based on the Hüsing et al. (2009) data the lowermost part of the Yazla Formation may correspond to the P 19-20 planktonic foraminiferal zones indicating a middle-late Rupelian age. This part of the section is overlain by a succession of turbiditic deep-marine sediments devoid of larger foraminifera and

passes upwards into the deposits belonging to the upper part of Yazla Formation.

The upper part of the Yazla Formation is represented mainly by deep-marine clastic units containing some few meters thick re-deposited biostromal and bioclastic calcarenites and coral rubble beds (KEL 15-17, 19-20). In these levels coral boulders up to several decimeters ten cm in size abundantly occur. Larger benthic foraminifera, more diverse and widespread compared to the underlying lower part of the section, include *Nephrolepidina praemarginata*, *N. musensis* n. sp., *Eulepidina dilatata*, *Nummulites bormidiensis*, *N. kecskemetii*, *Cycloclypeus pseudo-carpenteri* n. sp., *C.* aff. *droogeri*, *Hereostegina assilinoides*, *Operculina complanata* (text-fig.2). The joint occurrence of *E. dilatata*, *Heterostegina assilinoides* and *Cycloclypeus* suggests the SBZ 22B Zone for this part of the section. The calcareous nannoplankton and planktonic foraminifera determined in two levels (KEL 21, 21B) in the upper part of the section include a diverse association (text-fig. 2). The calcareous nannoplankton assemblage in sample KEL 21 suggests NP 24/25 based on *Sphenolithus ciperoensis*, *Cyclicargolithus abisectus* and *Helicosphaera* cf. *recta* (first appearing at the base of NP24 Zone), and *Reticulofenestra bisecta*, *Sphenolithus ciperoensis* and *Helicosphaera recta* (disappearing at the end of NP25

TEXT-FIGURE 4
Overview of the shallow-marine clastics and carbonates (of undifferentiated Mollababa and Aktaş formations) at the upper part of Kelereşdere section.

Zone). In terms of diverse planktonic foraminifera, this part of the section is referred to the *Globorotalia opima opima* (P21) Zone indicating a late Middle Oligocene age (Bolli and Saunders 1985). Our data fit well to those by Hüsing et al. (2009) according to whom the whole upper part of the Yazla Formation may roughly correspond to the P 21 to 22 planktonic foraminiferal zones indicating a latest Rupelian to late Chattian age.

The upper 200m thick regressive sequence (undifferentiated Mollababa and Aktaş formations (text-fig. 4) is, in general, dominated by a succession of thick-bedded carbonaceous siltstones/sandstones and coral and mollusc rubble beds and bioclastic calcarenites. It contains a wealth of fossils, of which larger foraminifera, corals and pectinids form a major constituent. The lowermost part of the sequence is represented by sandstones with minor shale intercalations usually devoid of larger foraminifera except for some calcareous beds almost entirely made up of test of *Operculina complanata* (sample KEL 21b). These are succeeded by partly calcareous sandstone and siltstones and coral rubble beds with larger foraminifera, corals, mollucs (mainly pectinids). In the upper part of the section, some conglomerates of about 1m thickness are also observed. Larger foraminifera suggest SBZ 23 based on the association of *Miogypsina basraensis*, *Miogypsinoides formosensis*, *M. sivasensis*, *Nephrolepidina* ex. interc. *morgani-praemarginata*, *Eulepidina elephantina*, *E. anatolica* n. sp., *Spiroclypeus blanckenhorni* and *Nummulites kecskemetii*. This implies a late Chattian age for the upper part of Kelereşdere section. In addition, the sporadic occurrence of *Planolinderina escornebovensis* in the upper part of this unit was recorded (Pl. 1, fig. 34). Based on the faunal association and facies characteristics, a shallow-marine outer shelf setting is proposed for the depositional environment of the unit.

DISCUSSION ON LARGER FORAMINIFERAL DISTRIBUTION IN KELEREŞDERE AND ITS IMPLICATION ON THE CURRENT ZONATION OF SHALLOW MARINE OLIGOCENE

The major foraminiferal groups, diagnostic for most of the Oligocene (late Rupelian to late Chattian) such as *Miogypsina*, *Miogypsinoides*, *Nephrolepidina*, *Eulepidina*, *Nummulites*, *Cycloclypeus*, *Heterostegina*, *Operculina* and *Spiroclypeus* are identified at successive levels of the Kelereşdere section. The spatial distribution of these groups and their associations in successive levels allows us to evaluate the biostratigraphic zonation of Oligocene shallow marine deposits in Turkey and also gives the opportunity to comment on the Oligocene benthic foraminifera zonation for Europe and the circum-Mediterranean region proposed by Cahuzac and Poignant (1997). A general synthesis is given below.

The lowest assemblage (samples KEL 3-9) in the lower part of Yazla Formation comprises *Eulepidina formosoides* and *Nephrolepidina praemarginata* accompanied by *Nummulites fichteli*. This assemblage is referred to ZBZ 22A Zone (upper Rupelian) considering the association of these taxa. The calcareous nannoplankton, identified at this part of the section, belong to NP 24 further supporting late Rupelian age assignment. In the overlying levels (samples KEL 11-14), although the composition of larger foraminifera in generic level stays almost the same (with the appearance of *Operculina complanata* at this part), two populations of *Nephrolepidina* having different C, A and n parameters are recorded. The *Nephrolepidina* specimens with higher number of adauxiliary chamberlets (parameter C) have
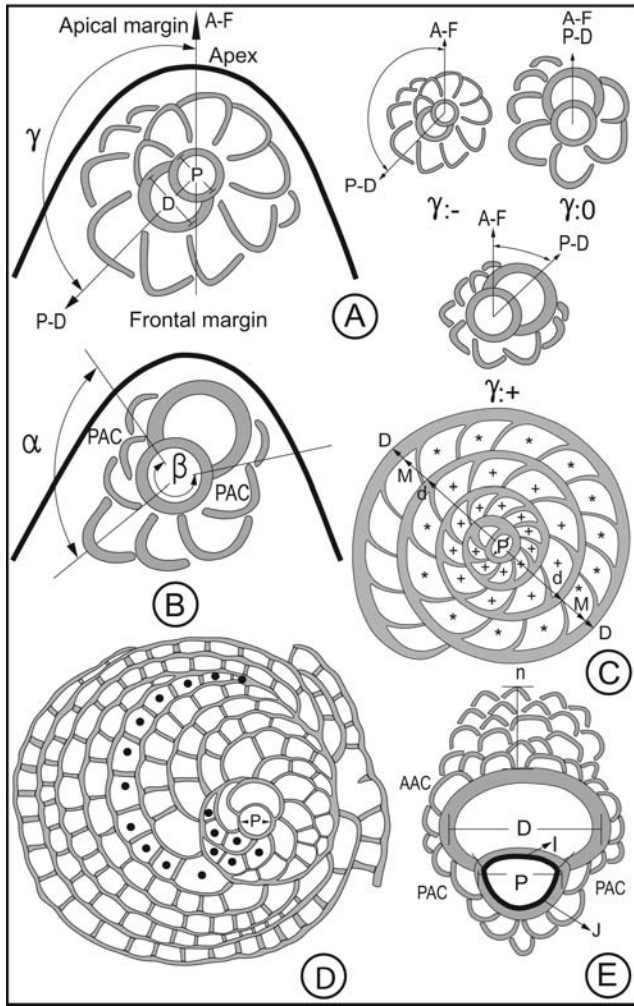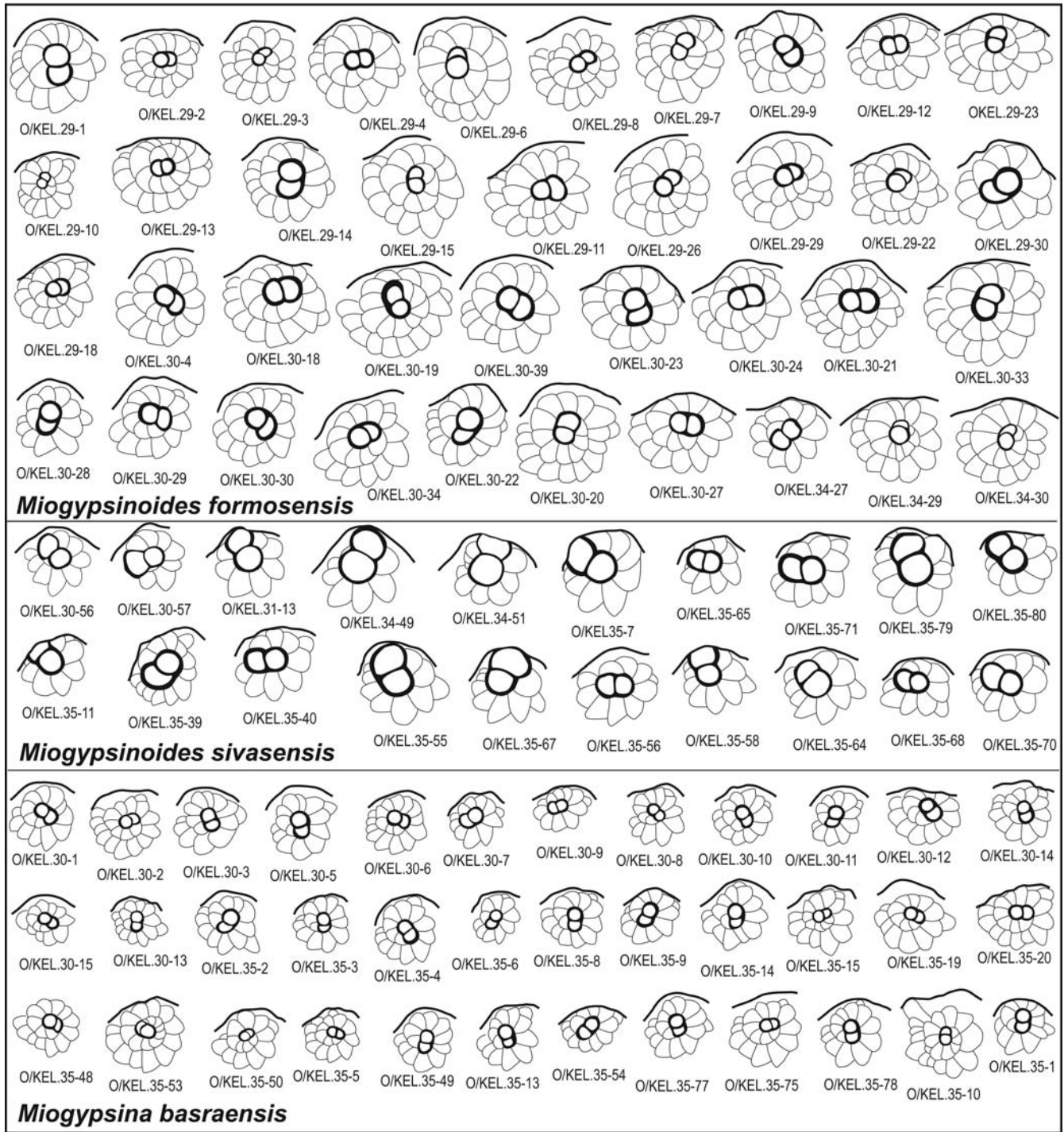
TEXT-FIGURE 5
Measurement system for megalospheric larger Foraminifera (most of the parameters are explained in the headers of Tables 1-5). A: single-spiralled miogypsinid (A-F: apical-frontal axis, P-D: embryonic axis; in this figure X=12, Y=5 and γ=negative). B: miogypsinid with two principal auxiliary chamberlets (PAC); in this figure γ=positive). C: *Nummulites* [D and M: outer and inner diameter of the third whorl; in this figure E=19, N (number of chambers in the third whorl) = 13]. D: *Cycloclypeus* (in this figure X=1, S_{4+5}=6, S_{14}=11, Y=18)]. E: *Nephrolepidina* [AAC: accessory auxiliary (adauxiliary) chamberlets with direct stolon connection with the deuteroconch (parameter C), I and J: circumference of the protoconch embraced (I) and not embraced (J) by the deuteroconch, n: number of annuli within 1 mm distance measured from the deuteroconch along the axis of the embryon].

also higher equatorial chamberlets and larger embryons than the *N. praemarginata* specimens occurring in the same level in late Rupelian (sample KEL 12) and lower Chattian (samples KEL 19, 20). These specimens, assigned to a new species, *N. musensis* sp., are also recorded in late Chattian part (sample KEL 35) of the section associating with *N. morgani*. Thus, the presence of two distinct *Nephrolepidina* groups during the late Rupelian and Chattian is proposed. Integrating our data from the interval of KEL 3-14, the SBZ 22A zone is characterized by the assemblage of *Eulepidina formosoides, Nephrolepidina praemarginata, N. musensis, Nummulites fichteli* and *Operculina complanata.*

A major faunal change and increase in the diversity of larger foraminifera are observed at the upper part of the Yazla Formation (samples KEL 15-21). This interval is characterized by the appearance of phylogenetically more advanced stages of *Eulepidina* (represented by *E. dilatata*), and reticulate *Nummulites* (represented by *N. bormidiensis*) and also by first appearance of such groups as *Heterostegina, Cycloclypeus* and *Nummulites kecskemetii. Nephrolepidina praemarginata*, *N. musensis* and *Operculina complanata* commonly occur as accompanying taxa. *Heterostegina* is represented by *H. assilinoides* and *Cycloclypeus* by two different taxa; *C.* aff. *droogeri* having as many as 25-35 pre-annular chambers and newly described forms having a larger embryon and a low number of pre-annular chambers ranging between 4 and 7. These specimens are thought to deserve a new taxonomic status, and were assigned to *C. pseudocarpenteri* based on the above mentioned internal features. Such forms are not known either in the Indo-Pacific (Tan 1932) or in the Mediterranean region (Laagland 1990; see also remarks in the systematic part). The assemblage of the above foraminifera is referred to SBZ 22B (lower Chattian) based on the very distinct foraminiferal turnover recognized by the appearance of *Cycloclypeus* accompanied by phylogenetically advanced members of reticulate *Nummulites* (*N. bormidiensis*) and *Eulepidina* (*E. dilatata*). Our data suggest that *E. dilatata* (with the newly assigned biometric parameters such as D_{mean}>1250μm and A_{mean}>83) disappeared before the Oligocene/Miocene boundary since in the upper part of the Keleresdere section (in SBZ 23), the *Eulepidina* populations cannot be compared to this species and suggest the occurrence of two distinct eulepinid groups (*E. elephantina* and *E. anatolica* n. sp.) with quite different internal features. Our data suggest that the first appearance of *Heterostegina* also corresponds to this zone and unlike what has been shown tentatively in Cahuzac and Poignant (1997), this taxon does not occur in the Rupelian. Thus, the appearance of *Cycloclypeus* together with *Heterostegina* can be adopted for the delimination of the SBZ 22A and 22B Zones. A rich assemblage of planktonic foraminifera and calcareous nannoplankton identified in the upper part of the package (sample KEL 21b) with the above diagnostic larger foraminifera suggest that these assemblages are referrable to P21 and NP24/25 corresponding to 'late middle Oligocene'. This independent age determination is also in accord with our proposal with benthic foraminifera.

Upsection, a major change in the foraminiferal composition is recorded by the first appearance of miogypsinid and spiroclypeid taxa accompanied by *Eulepidina* which is represented by two different varieties not documented in the previous studies in Turkey. These are accompanied by other groups such as *Nephrolepidina morgani*, *N. musensis*, *Nummulites kecskemetii* and *Operculina complanata. Heterostegina* is not recorded in these levels. In the lowermost part of the section, the miogypsinids are represented only by *Miogypsinoides formosensis* which is accompanied by *Miogypsina* in the most part of the section. This is the first record for the parallel evolution of *Miogypsinoides* and *Miogypsina* in the late Oligocene at the eastern Mediterranean region, which was previously presented only in few localities in Europe (Drooger 1993). Moreover, our data clearly show the presence of another *Miogypsinoides* taxon, *Miogypsinoides sivasensis*, co-occurring with *M. formosensis* and *Miogypsina basraensis*. This taxon (*M. sivasensis)* was originally described from the lowermost Aquitanian of central Turkey (Sivas Basin) in association with very primitive developmental stages of *M. gunteri* (Özcan et al.

TEXT-FIGURE 6
Embryonic-nepionic arrangement and variation in *Miogypsinoides formosensis*, *M. sivasensis* and *Miogypsina basraensis*. All ×20.

2009a). Thus, our integrated data suggest that the stratigraphic range of *M. sivasensis* extends from late Chattian to earliest Aquitanian. A major change in eulepidinid composition is also recorded in this part of the section since two groups of eulepinids are recognized as different from the stratigraphically lower *E. dilatata*. The first group of *Eulepidina* has relatively small embryo sizes (comparable with that of *Eulepidina formosoides* in late Rupelian). These specimens with strongly inflated test and presenting semi-globular embryon in vertical sections are assigned to a new species, *E. anatolica* occurring in levels clearly overlying the beds with *E. dilatata*. *E. anatolica* is accompanied by another eulepinid taxon, *E. elephantina* in one sample (sample KEL 30). This taxon has a larger embryon and higher equatorial chamberlets than any of the Oligocene
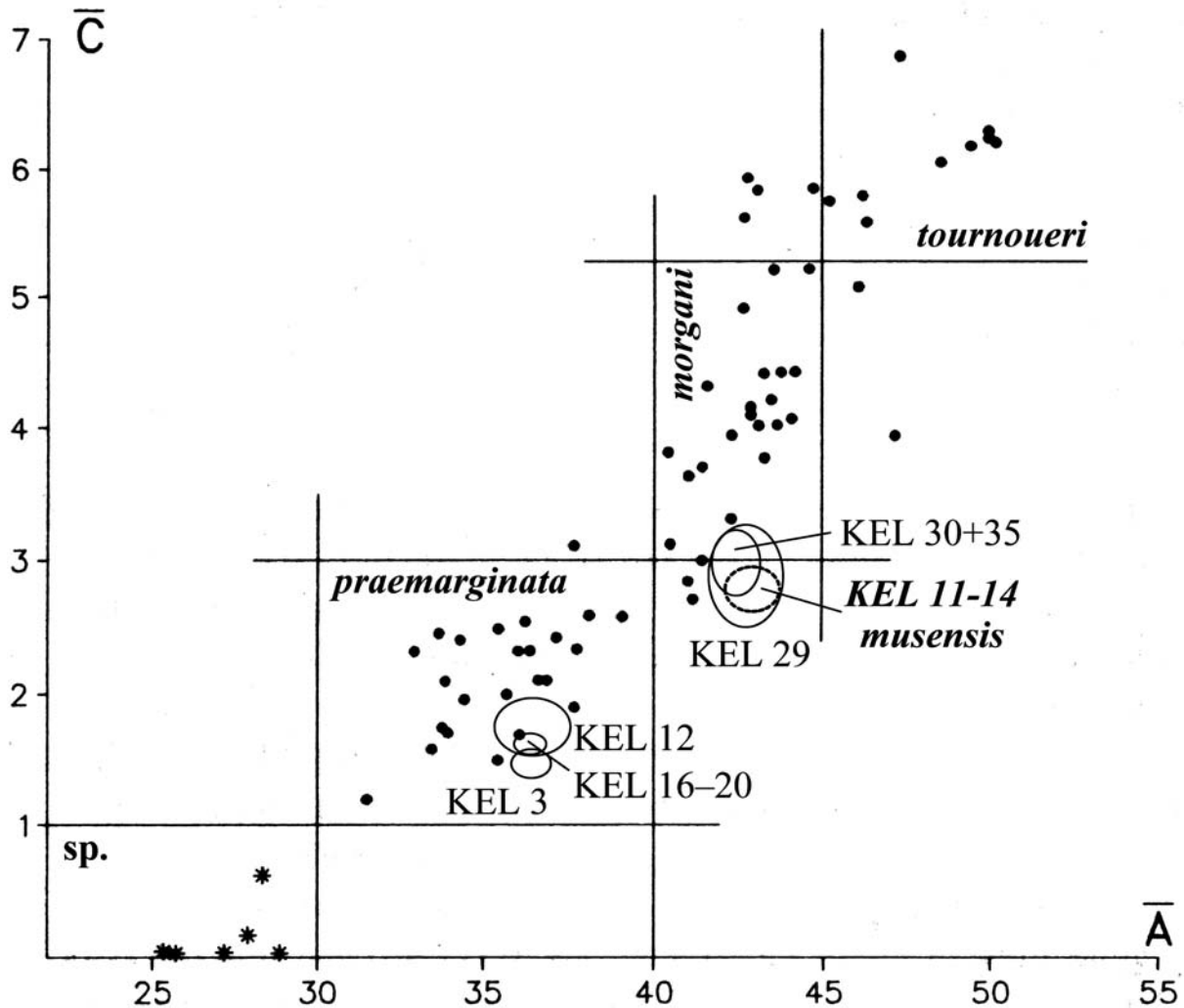
TEXT-FIGURE 7
Distribution of nephrolepinid populations from the Kelereşdere [marked by ellipses of the mean values at the 68% (1 s.e.) confidence level] in the Amean–Cmean bivariate plot for Western Tethyan nephrolepinid populations (their means are marked by dots, while the means of *Lepidocyclina* sp. of Freudenthal 1972 by asteriks) according to Drooger (1993).

Eulepidina and easily recognized in equatorial sections. Thus, our data suggest that stratigraphic range of *E. dilatata*, previously extended until the Chattian-Aquitanian boundary by Cahuzac and Poignant (1997), is to be revised as to confine it to SBZ 22B and to the lower part of SBZ 23. We assume no phylogenetic link between *E. dilatata* and these eulepinids in the latest Chattian.

Based on the above data, we suggest that the European larger foraminiferal zonation can also be applied and extended as far east as Eastern Turkey. There are, however, some differences as the specific composition of *Heterostegina* and *Cycloclypeus* are slightly different and *Nummulites vascus* do not occur in Keleresdere. Meantime, new taxa of both *Eulepidina* and *Nephrolepidina* have been identified in eastern Turkey.

PRINCIPLES OF SPECIES DETERMINATION

We follow the morphometric method described in detail by Drooger (1993), i.e. in each sample we group specimens into

populations, the members of which are clearly distinguishable from the specimens of the other populations of the same sample. Taxonomic determinations are based on these populations (as a whole) and not on their separate individuals. The principles of morphometric definition of miogypsinids, lepidocyclinids and nummulitids can be found in Özcan et al. (2009a, b).

SYSTEMATIC PALEONTOLOGY

Family MIOGYPSINIDAE Vaughan 1928

Most previous studies consider that in Western Tethys the Oligocene miogypsinids are represented by two genera, *Miogypsina* and *Miogypsinoides* (Drooger 1993) whilst in the Indo-Pacific only *Miogypsinoides* is recognized (Raju 1974; Adams 1984). The distinction between them mainly relies on the presence of lateral chamberlets in *Miogypsina* and thick, lamellar side walls and canal systems in *Miogypsinoides* (de Bock 1976; Drooger 1963, 1993).

Using the terminology proposed by Drooger (1952) and Amato and Drooger (1969), six parameters (explained in the header of Table 1 and using the measurements and counts, shown in text-fig 5) for 201 specimens are used to characterize the miogypsinid taxa. Statistical data are summarized in Table 1.

Genus *MIOGYPSINOIDES* Yabe and Hanzawa 1928

Drooger (1963, 1993) constructed a main *Miogypsinoides* lineage including a sequence of successive species, arranged in accordance with the general principle of nepionic acceleration, discussed in detail by Drooger (1993). In circum-Mediterranean region, the proposed succession of species and the numerical values of the biometric limits are: *Miogypsinoides butterlinus* (X_{mean}:> 23), *complanatus* (X_{mean}: 23-17)- *formosensis* (X_{mean}: 17-13)- *bantamensis* (X_{mean}:13-10). These taxa cover the stratigraphic interval from late Chattian to early Aquitanian. Although the occurrence of *Miogypsinoides* in upper Aquitanian and Burdigalian deposits was reported (de Bock 1976) no biometric data have been documented yet. According to Drooger (1993) *Miogypsinoides* did not evolve beyond the biometric level of *Miogypsinoides bantamensis* in the Western Tethys. The *Miogypsinoides/Miogypsina* transition was proposed to occur at different levels of the X scale, corresponding to the *formosensis* level (late Chattian) in Europe and to *bantamensis* (early Aquitanian) in India and in the Far East (Raju 1974; Adams 1984; Drooger 1993). Thus, it seems that the first appearance of *Miogypsina* is not coeval in the circum-Mediterranean region and in the Far East.

Miogypsinoides formosensis Yabe and Hanzawa 1928
Plate 1, figures 13–24; Text-figure 6

Miogypsina (*Miogypsinoides*) *dehaartii* van der Vlerk var. *formosensis* – YABE and HANZAWA 1928, p. 534, figs 1a-b.
Miogypsina (*Miogypsinoides*) *formosensis* Yabe and Hanzawa – DROOGER 1963, fig. 2. – FERRERO MORTARA 1987, p. 140-141, pl. 2, figs 1–8; pl. 3, figs 1–3; Text-figure 4c. – WILDENBORG 1991, p. 111, pl. 2, fig 10; pl. 3, fig. 13.

Remarks. This taxon represents the most primitive *Miogypsinoides*, described on the biometric grounds in Turkey. It co-occurs with *Miogypsina basraensis* and with *Miogypsinoides sivasensis* in upper part of its distribution in the Kelereşdere section. Apart from their differentiation based on the presence and absence of lateral chamberlets, *Miogypsina* and *Miogypsinoides* can also be differentiated on the biometric grounds, considering the embryon dimensions, which are much smaller in *Miogypsina* (*M. basraensis*) (see also other criteria for their distinction under *M. basraensis*). The distinction of the two taxa based only on the parameter X is not possible since the average number of the spiral chambers in each sample is very close to each other (Table 1). The biometric features of the *Miogypsinoides* species in sample KEL 29, which is about 97 m below sample KEL 30, fall very close to the biometric limit between *M. formosensis* and *M. complanatus*.

Miogypsinoides sivasensis Özcan and Less 2009
Plate 1, figures 25–33; Text-figure 6

Miogypsinoides sivasensis – ÖZCAN et al. 2009a, pp. 569–570, pl. 3, figs 7–19, 25; Text-figure 10. (with synonymy)

Remarks. The representatives of genus *Miogypsinoides* in samples KEL 31, 34 and 35 are separated biometrically into two distinct groups. Specimens with smaller embryon and with longer post- embryonic spiral are assigned to *M. formosensis* and those with shorter spiral and larger embryon to *M. sivasensis*. In
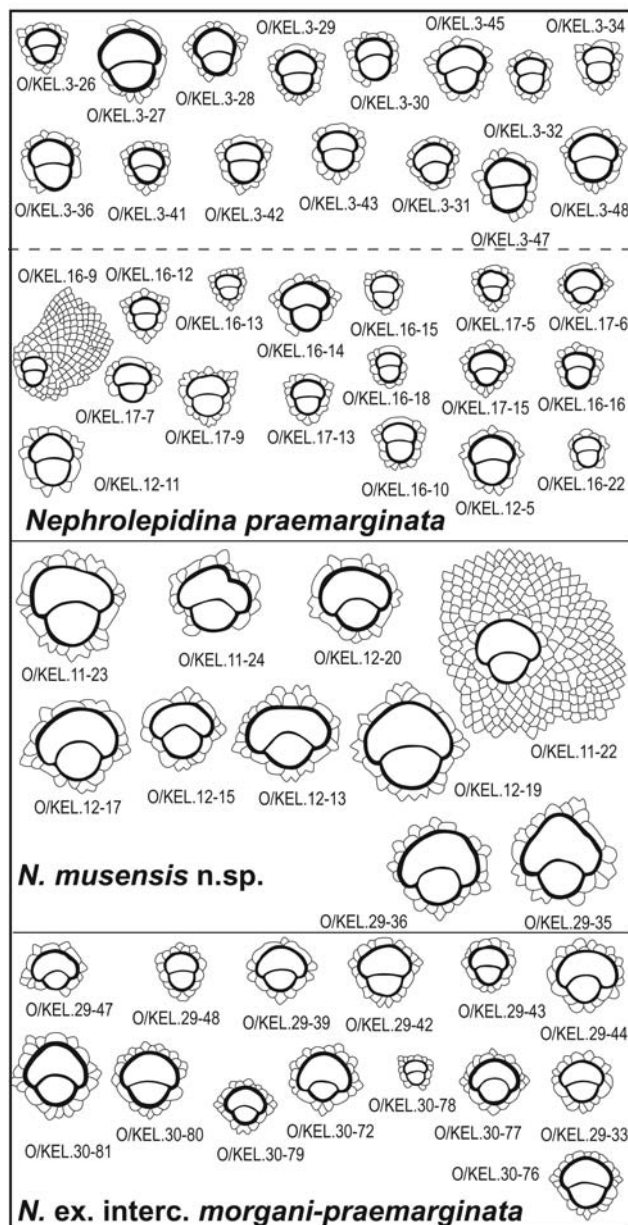
TEXT-FIGURE 8
Embryonic-nepionic arrangement and variation in *Nephrolepidina praemarginata*, *N. musensis* n. sp. and *N.* ex. interc. *morgani-praemarginata*. All ×20.

the Keleresdere section the latter predominates over the former in the upper part of the succession. *Miogypsinoides sivasensis* was originally introduced from the (early) Aquitanian deposits in central Turkey (Sivas Basin) where it co-occurs with *Miogypsinoides bantamensis* and with a primitive *Miogypsina gunteri,* a marker species for early Aquitanian in Tethys (Özcan et al. 2009a, see also for discussion). This species is diagnosed with very short spiral, low negative γ values (γ values tentatively between 0° and -90°) and relatively large embryon. Data from Kelereşdere permit us to consider this taxon to be a latest Chattian- earliest Aquitanian species.
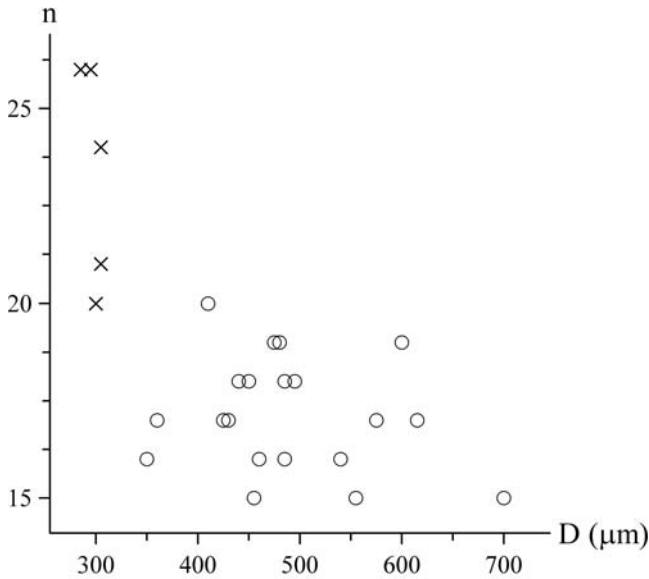
TEXT-FIGURE 9
Distribution of *Nephrolepidina* (*N. praemarginata*- crosses and *N. musensis* n. sp.- circles) specimens in sample KEL 12 in the D–n (the deuteroconch diameter vs. the number of annuli within 1 mm of the rim of the embryon) bivariate plot.

Genus *Miogypsina* Sacco 1893

According to Drooger (1993), two species of *Miogypsina*, *M. septentrionalis* (X_{mean}:>15) and *M. basraensis* (X_{mean}: between 12.5 and 15), occur in the late Chattian of circum-Mediterranean region.

Miogypsina basraensis Brönnimann 1940
Plate 1, figures 1–12; Text-figure 6

Miogypsina basraensis – BRÖNNIMANN 1940, pp. 86–88, pl. 6, figs 2, 4; pl. 8, figs 13–17.

Remarks. M. basraensis is recorded for the first time in Chattian of Turkey and its co-occurrence with *Miogypsinoides formosensis,* a widely reported late Chattian species, is demonstrated. This taxon is differentiated from the latter by having a more pustulose and smaller test, smaller embryonic chambers (both protoconch and deuteroconch) (Table 1), smaller spiral chambers (text-fig. 6) and by having rather poorly developed lateral chamberlets (Pl. 1, fig. 6). Our data show that the first appearance of Miogypsina lies below the Chattian-Aquitanian boundary as reported in several European localities (Drooger 1993; Ferrero Mortara 1987). The underlying beds below the first record of miogypsinids (sample KEL 29) are usually devoid of larger foraminifera precluding the possibility of finding more primitive stages of this species.

Family **LEPIDOCYCLINIDAE** Scheffen 1932

Using the terminology proposed by van der Vlerk (1959) and Drooger and Socin (1959), five parameters (explained in the header of Table 2 and using the measurements and counts shown in text-fig. 5) for 198 *Nephrolepidina* and 34 *Eulepidina* specimens are used to characterize the taxa (for statistical summary see Table 2).

Genus *Nephrolepidina* H. Douvillé 1911

A main Western Tethyan *Nephrolepidina* lineage based on the parameters A and C has been described by de Mulder (1975) which since then has been widely used in species designation. This includes the species succession as follows (parameters C and A are explained in the caption of Table 2):
N. praemarginata $1<C_{mean}<3$ $35<A_{mean}<40$
N. morgani $3<C_{mean}<5.25$ $40<A_{mean}<45$
N. tournoueri $C_{mean}>5.25$ $A_{mean}>45$)

N. praemarginata is characteristic for the late Rupelian to early Chattian SBZ 22 zone, the other two species partially overlap each other: *N. morgani* has a long stratigraphic range from the late Chattian to the early Burdigalian (SBZ 23 to the early part of SBZ 25) while *N. tournoueri* spans from the latest Aquitanian to the whole Burdigalian (late SBZ 24 and SBZ 25). The text-figure 7 shows the distribution of Western Tethyan nephrolepinid populations in A_{mean}–C_{mean} bivariate plot according to Drooger (1993) with adding our data from the Kelereşdere section.

Nephrolepidina praemarginata R. Douvillé 1908
Plate 2, figures 10–19; Text-figure 8

Lepidocyclina praemarginata – R. DOUVILLÉ 1908, p. 91, figs 1, 2, 4a.
Lepidocyclina (Nephrolepidina) praemarginata R. Douvillé – DE MULDER 1975, pp. 62–63, pl. 3, figs 6–8; pl. 4, figs 8–11.
Nephrolepidina praemarginata R. Douvillé – ÖZCAN et al. 2009b, p. 751, figs. 15.1-8, 15.10-12, 16.

Remarks. This is one of the most common taxa in the lower and middle part of the section and occurs both in upper Rupelian and lower Chattian beds. It is also reported from the lower Chattian of the western Taurides (Özcan et al. 2009b) where additional details can also be found.

Nephrolepidina ex. interc. morgani Lemoine and R. Douvillé 1904- **praemarginata** R. Douvillé 1908
Plate 2, figures 20–26; Text-figure 8

The *Nephrolepidina* in the upper part of studied section (samples KEL 29, 30 and 35) represents a primitive developmental stage of *N. morgani*.

Nephrolepidina musensis Özcan and Less **n. sp.**
Plate 2, figures 1–9; Text-figure 8

Etymology. From the city of Muş to the SW of Kelereşdere, the type-locality of the species

Holotype. Preparation KEL 12-20 (Pl. 2, fig. 4).

Paratypes. Specimens illustrated in Pl. 2, figs. 1-3, 5-9.

Type locality. Kelereşdere (eastern Turkey).

Type level. upper Rupelian.

Description:
External features: The test is slightly inflated, reaching as much as 3-4 mm in diameter with diameter/thickness ratios of around 2.0-3.0. The surface is covered by a network of lateral chamberlets that may reach a width of 200μm.

Internal features: The embryonic apparatus is nephrolepidine, with a semi-spherical protoconch some 265–340μm in average diameter joined to a deuteroconch, 400–558μm in average diameter. The parameter A is above 40 in average. The equatorial
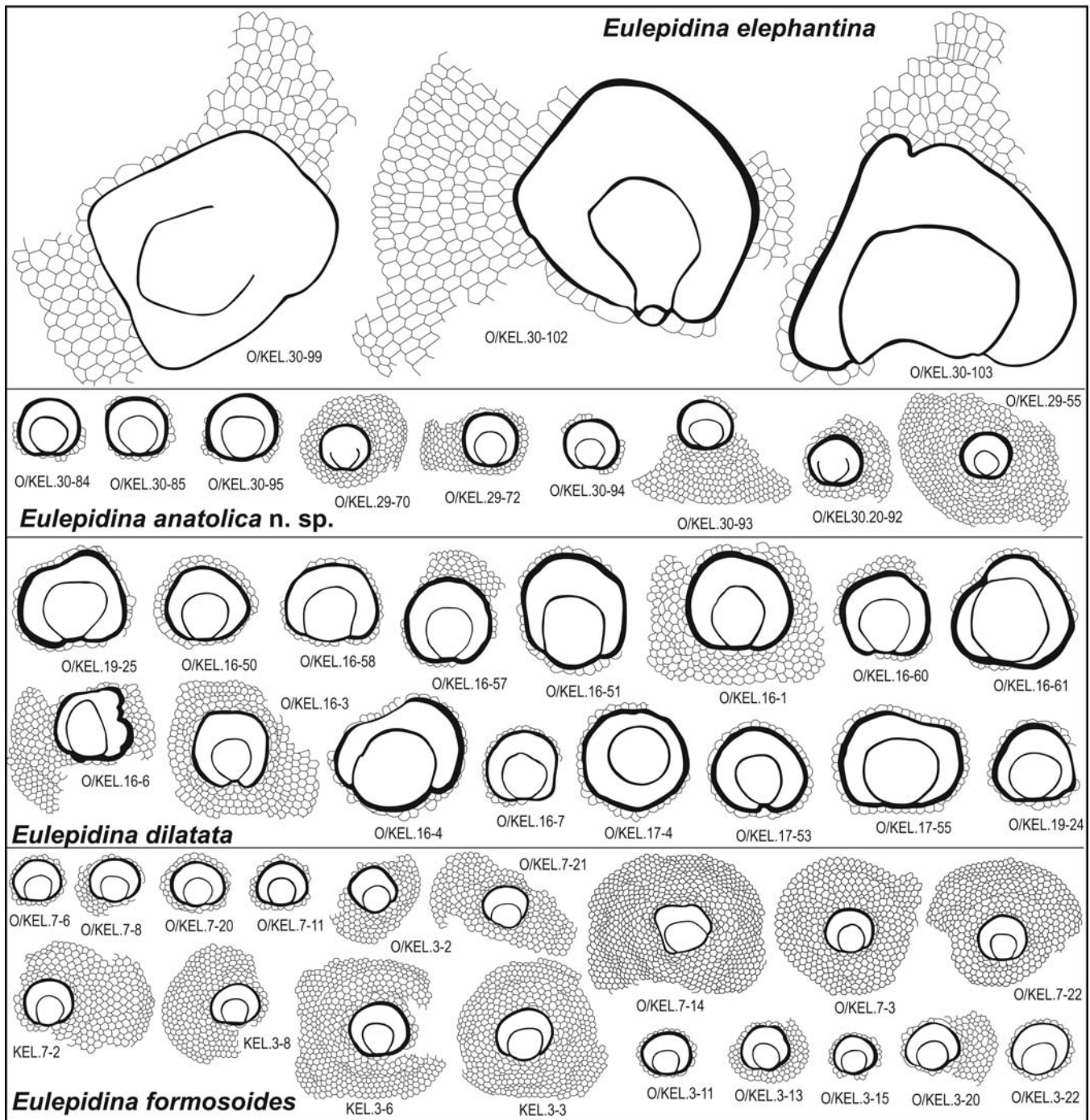
TEXT-FIGURE 10
Embryonic-nepionic arrangement and variation in *Eulepidina formosoides*, *E. dilatata*, *E. anatolica* n. sp. and *E. elephantina*. All ×10.

chamberlets are most commonly of arcuate to strongly spatulate shape.

In vertical sections the average thickness of the equatorial layer is 30-40μm in the early stage and 70-80μm at the peripheral part. The embryon is typically semi-globular, 250-300μm in height. In the central part of the test, generally more than 6 lateral layers. The lateral chamberlets, with a maximum thickness

of about 20 to 30μm are regularly arranged in tiers. The walls of lateral chamberlets are with an average thickness of 10-20μm.

Remarks. This species is very common in the upper Rupelian beds (sample KEL 12) in association with *N. praemarginata* and rather scarce in the Chattian in association with primitive developmental stage of *N. morgani* (samples KEL 29 and 35). Comparing *N. praemarginata* in the same level (sample KEL 12) at which they occur abundantly, the individuals of the new

Taxon	P_{mean} (µm)	Surface	Stage	SBZ zone
N. bullatus	65–100	granules, no reticulation	basal Bartonian	early SBZ 17
N. garganicus	100–140	heavy granules + reticulation	early Bartonian to middle late Bartonian	late SBZ 17 to SBZ 18B
N. hormoensis	140–200	heavy granules + umbo + reticulation	late Bartonian	SBZ 18
N. fabianii	200–300	heavy reticulation, weak granules + umbo	Priabonian to early Rupelian	SBZ 19–21
N. fichteli	200–300	weak reticulation to irregular mesh	late Priabonian to late Rupelian	SBZ 20–22A
N. bormidiensis	300–450	irregular mesh	early Chattian	SBZ 22B

TEXT-FIGURE 11
Subdivision of the *Nummulites fabianii*-lineage in the Bartonian to early Chattian time-span (Özcan et al. 2009b). SBZ 21–22B are in the sense of Cahuzac and Poignant (1997).

taxon have larger embryon dimension (parameter D) and rather high equatorial chamberlets (parameter n) (text-fig. 9). Meantime, they have more adauxiliary chamberlets (Table 2). In sample KEL 12, the number of adauxiliary chamberlets ranges between 2 to 4 and this is quite unusal for *Nephrolepidina* populations of late Rupelian age (also compare these parameters with that of *N. praemarginata* popolations from lower Chattian of Taurides in Özcan et al. 2009b). Moreover, the test of *N. praemarginata* is more inflated compared to *N. musensis*. Our data suggest that two parallel *Nephrolepidina* lineages occur during Oligocene.

Genus *Eulepidina* H. Douvillé 1911

There is little information about the biometry of Western Tethyan Eulepidina, the proven occurrence of which is known not only from late Rupelian and Chattian as it was previously thought (Cahuzac and Poignant 1997) but also from the Burdigalian of Turkey. (Özcan et al. 2009a, b; Özcan and Less 2009). Two successive and phylogenetically linked Oligocene taxa, E. formosoides reported from Rupelian and E. dilatata from Chattian deposits are widely cited although an overlap in their stratigraphic ranges was proposed by Cahuzac and Poignant (1997). Our present data from the Kelereşdere section permit us to differentiate these two taxa by the average size of the deuteroconch (D_{mean}=1250µm) and secondarily by the average degree of embracement of the protoconch by deuteroconch (A_{mean}=83). Meantime a new taxa, *E. anatolica,* is introduced from the upper Chattian of the Kelereşdere section and *E. elephantina,* a poorly known taxon was also found in the uppermost part of the section.

Eulepidina formosoides Douvillé 1925
Plate 3, figures 1–8; Text-figure 10

Lepidocyclina (Eulepidina) formosoides – Douvillé, 1925, p. 75, pl. 3, figs 2–4. – VAN HECK and DROOGER 1984, pl. 1, figs. 13–17; pl. 2 figs. 1–9; pl. 3, figs. 1–5.

Diagnosis. Populations of *Eulepidina* with D_{mean}<1250µm and A_{mean}<83

Remarks. This species is very common in the lower part of Yazla Formation and co-occurs with typical upper Rupelian assemblage. Our new data permit us to propose a biometric limit based on A and D to differentiate this taxon from its successor E. dilatata (see the remarks below).

Eulepidina dilatata (Michelotti 1861)
Plate 3, figures 9–12; Text-figure 10

Lepidocyclina (*Eulepidina*) *dilatata* – Michelotti 1861, pl. 1, figs. 1-2. – Less 1991, p. 443-445, pl. 5, figs. 3-6; pl. 6, figs. 1-6.
Eulepidina dilatata (Michelotti) – Özcan et al. 2009b, p. 752, figs. 15.19-20.

Diagnosis. Populations of *Eulepidina* with D_{mean}>1250µm and A_{mean}>83

Remarks. The *Eulepidina* specimens present a reasonable change in the embryon sizes from the lower to upper part of Yazla Formation. The *Eulepidina* associated with typical lower Chattian taxa (*Cycloclypeus, Heterostegina, N. bormidiensis*) have the embryon dimensions over 1400 microns. The specimens of this taxon in upper Rupelian sample KEL 14 (associating with *N. fichteli*) have an average deuteroconch size of 1229 microns and all the other Eulepidina assemblages in the upper Rupelian part of the section have lower values than this. In the same way, the *Eulepidina* in lower Chattian levels have higher A values (bigger than 83). Considering these data, a tentative biometric limit as as D_{mean}>1250µm and A_{mean}>83 is proposed to differentiate *E. dilatata* from *E. formosoides*. Our data suggest that *E. dilatata* (with the newly assigned biometric limits) is an early Chattian species since in the upper part of the Kelereşdere section (in SBZ 23), the *Eulepidina* populations cannot be compared to this species and suggest the occurrence of two distinct eulepinid groups (*E. elephantina* and *E. anatolica* n. sp.) with quite different internal features.

Eulepidina anatolica Özcan and Less **n. sp.**
Plate 3, figures 13–17; Text-figure 10

Etymology. From Greek Anatole, 'rising of the sun' or 'East'.

Holotype. Preparation KEL 29-55 (Pl. 3, fig. 13).

Paratypes. Specimens illustrated in Pl. 3, figs 14-17.

Depository. The Özcan Collection in the Geological Department of the İstanbul Technical University (Turkey)

Type locality. Muş (eastern Turkey).

Type level. upper Chattian.

Diagnosis. Test is large, inflated due to numerous lateral layers. Moderately large-sized eulepidine embryon (deuteroconch diameter is around 1000µm), semi-globular in vertical section. In the equatorial section, wide and low, spatulate to hexagonal equatorial chamberlets are arranged in regular annuli.
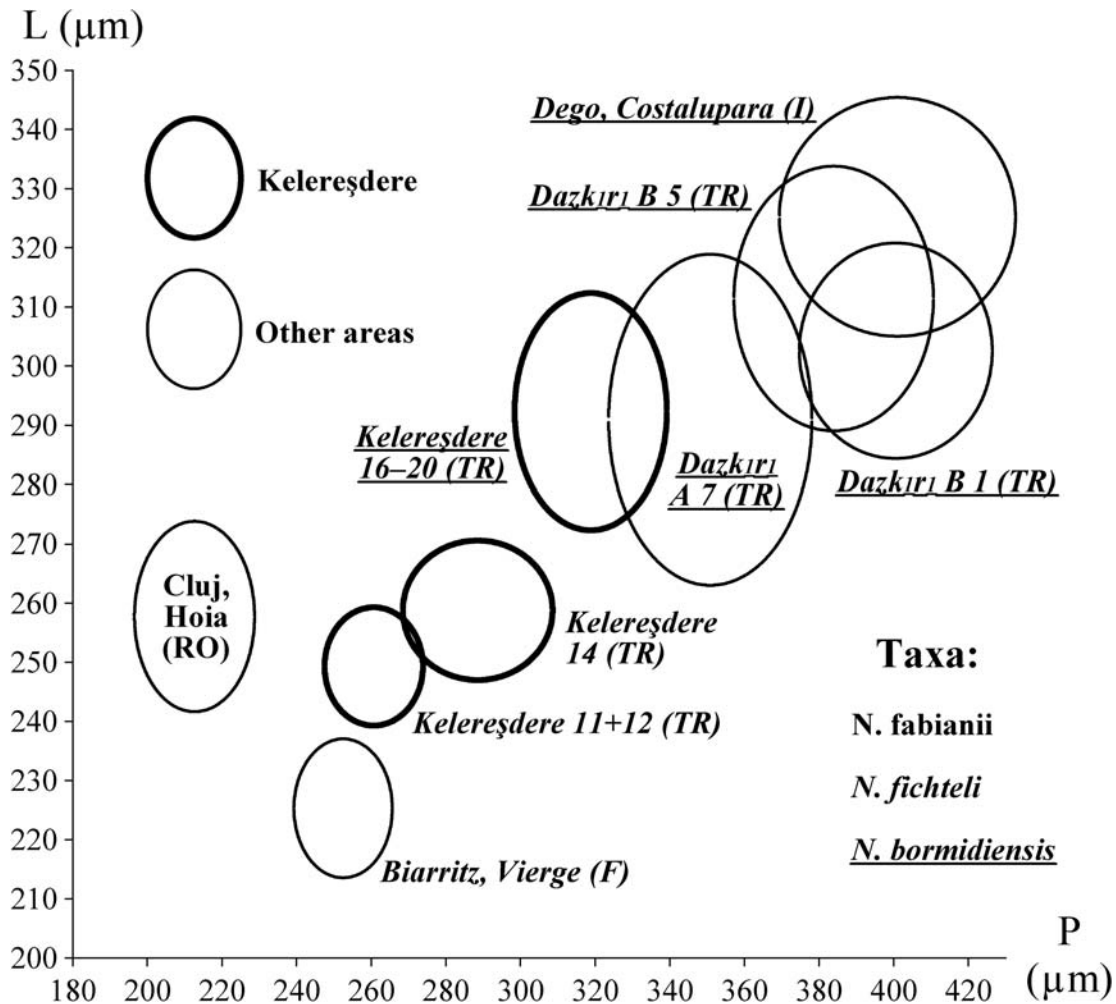
TEXT-FIGURE 12
Distribution of Oligocene reticulate *Nummulites* [mean values at the 95% (2 s.e.) confidence level] on the bivariate plot of P–L (proloculus diameter vs. chamber length in the third whorl) bivariate plot. For other areas unpublished data by Less are used.

Description (see Table 2, only megalospheric specimens were found):

External features: The test is inflated, reaching as much as 5 mm (the peripheral part is mostly broken and the test is not complete) in diameter with diameter/thickness ratios of around 1.5-2.5. The surface is covered by a network of lateral chamberlets that may reach a width of 250-300μm.

Internal features: The embryonic apparatus is bilocular, varying from nearly trybliolepidine to umbilicolepidine configuration with a semi-spherical protoconch some 540-560μm in average diameter joined to a deuteroconch, 910–950μm in average diameter. The parameter A is between 88 and 94 in average. The equatorial chamberlets are most commonly of spatulate shape.

In vertical sections the average thickness of the equatorial layer is 50-70μm in the early stage and 100-250μm at the peripheral part. The embryon is typically semi-globular, 650-700μm in height. In the central part of the test, generally more than 14 lateral layers, most probably each corresponding to subsequent

equatorial annuli, can be counted. The lateral chamberlets, with a maximum thickness of about 40 to 50μm are regularly arranged in tiers. The walls of lateral chamberlets, with an average thickness of 20-30μm become thicker around the triplets of adjacent two chamberlets.

Remarks. Eulepidina anatolica from late Chattian of Kelereş-dere have very similar biometric parameters in the equatorial section with those of *E. formosoides* from the late Rupelian. The main distinction lies on parameter A, which is comparatively high in the new taxon. They differ, however, not only in their stratigraphic position (reflected in the completely different accompanying fauna as well) but also in their exterior and vertical section: *E. anatolica* is strongly inflated, its embryon is semi-globular in the vertical section and covered by numerous lateral layers. Meanwhile *E. formosoides* (as well as *E. dilatata*, the phylogenetic offspring) is characteristically thin, with elongated embyon in the vertical section covered only by a few lateral layers (see Wieland-Schuster 2004, pl. 1, figs 3-4 for the vertical section of *E.* ex. gr. *dilatata* for comparison with Plate 3, fig. 17 illustrating *E. anatolica* in this paper). Therefore, we

TABLE 1

Statistical data for miogypsinid populations from the Kelereşdere section (see text for abbreviations of parameters). No.: number of specimens, s.e. - standard error.

Parameters		Medium cross-diameter of the embryonic chambers						Number of postembryonic spiral chambers						Orientation of the nepiont		
		protoconch			deuteroconch			total			with one opening			γ (°)		
		P (μm)			D (μm)			X			Y					
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Miogypsina basraensis	KEL 30-34	49	80 – 125	100.0 ± 1.2	47	80 – 130	101.4 ± 1.8	48	10 – 22	13.38 ± 0.35	43	3 – 15	5.95 ± 0.28	49	-454 – -118	-211.1 ± 8.0
	KEL 30	16	85 – 125	100.0 ± 2.5	14	80 – 120	102.1 ± 3.6	15	10 – 18	13.27 ± 0.57	13	4 – 8	5.69 ± 0.33	16	-290 – -118	-197.8 ± 10.7
	KEL 31	8	90 – 115	100.6 ± 3.0	8	80 – 130	101.3 ± 5.1	8	11 – 16	13.50 ± 0.53	7	5 – 7	5.43 ± 0.28	8	-266 – -180	-217.6 ± 11.5
	KEL 34	25	80 – 120	99.8 ± 1.6	25	80 – 120	101.0 ± 2.1	25	10 – 22	13.40 ± 0.55	23	3 – 15	6.26 ± 0.48	25	-454 – -120	-217.6 ± 13.4
	KEL 35	25	75 – 115	98.2 ± 2.4	24	65 – 125	98.1 ± 2.9	23	10 – 21	13.74 ± 0.49	21	3 – 8	5.67 ± 0.30	24	-360 – -140	-212.7 ± 11.1
Miogypsinoides formosensis	KEL 29	29	80 – 200	139.1 ± 5.0	25	75 – 200	145.0 ± 6.7	28	10 – 24	16.43 ± 0.54	26	4 – 10	7.12 ± 0.33	29	-470 – -112	-264.1 ± 14.6
	KEL 30-34	66	110 – 205	154.3 ± 2.6	61	105 – 230	159.8 ± 3.4	66	10 – 21	15.06 ± 0.36	61	4 – 14	7.30 ± 0.28	65	-415 – -90	-232.8 ± 9.4
	KEL 30	40	110 – 205	156.5 ± 3.0	37	110 – 230	159.7 ± 4.4	40	10 – 21	15.10 ± 0.48	36	4 – 14	7.39 ± 0.40	39	-415 – -90	-233.3 ± 12.5
	KEL 31	9	115 – 200	163.9 ± 9.1	9	105 – 220	165.6 ± 11.0	9	12 – 19	15.11 ± 0.82	8	4 – 11	7.88 ± 0.82	9	-320 – -112	-230.3 ± 25.3
	KEL 34	17	110 – 175	144.1 ± 4.2	15	105 – 200	156.7 ± 5.9	17	10 – 20	14.94 ± 0.70	17	4 – 10	6.82 ± 0.41	17	-387 – -112	-232.9 ± 17.2
Ms. sivasensis	KEL 30-34	11	160 – 310	217.7 ± 14.8	8	165 – 300	213.8 ± 18.0	11	6 – 11	8.00 ± 0.56	6	1 – 5	2.83 ± 0.68	11	-130 – 32	-31.8 ± 17.1
	KEL 30	3	160 – 210	180.0	3	165 – 180	173.3	3	8 – 11	10.00	2	2 – 5	3.50	3	-130 – -40	-91.7
	KEL 31	3	170 – 210	195.0	1		200.0	3	6 – 8	7.33	1		3.00	3	-85 – 12	-32.7
	KEL 34	5	175 – 310	254.0 ± 21.7	4	170 – 300	247.5 ± 26.1	5	6 – 10	7.20 ± 0.72	3	1 – 5	2.33	5	-80 – 32	4.6 ± 19.0
	KEL 35	21	140 – 255	193.3 ± 6.6	19	150 – 300	200.8 ± 8.9	20	7 – 12	8.80 ± 0.36	15	1 – 5	2.73 ± 0.29	17	-138 – 24	-57.6 ± 9.7

guess the ancestors of the new taxon outside the peri-Mediterranean region, maybe in the Indo-Pacific realm.

Eulepidina elephantina Lemoine and R. Douvillé 1904
Plate 3, figures 18–20; Text-figure 10

Lepidocyclina (Eulepidina) elephantina LEMOINE and DOUVILLÉ 1904, p. 13 pl. 2, fig. 13, 19.
Lepidocyclina (Eulepidina) dilatata (Michelotti) – RAHAGHI 1973, pp. 29–30, pl. 4, figs. 1–4.

Remarks. This taxon, originally described from supposedly 'Aquitanian' beds in Italy, has been reported in peri-Mediterranean or middle East region either from Chattian or early Miocene (David 1933 in Ellis and Messina 1965; *E.* cf. *elephantina* in Brönnimann 1940; and *E.* sp. aff. *elephantina* in Wielandt-Schuster 2004). However, none of these studies has provided a clear description of the taxon and internal test features are not known. In Kelereşdere, it is externally differentiated from the accompanying *E. anatolica* n. sp. by having a much larger test which is typically flat. In vertical sections, its embryon is not semi-globular but low and compressed (Pl. 3, Fig. 9). In equatorial sections two features are diagnostic; the embryon is much larger than any of *Eulepidina* species known in Oligo-Miocene as its dimensions vary between 2525 and 4225μm in sample KEL 30 and also the equatorial chamberlets are much higher (the parameter n varying between 4 and 5) than those of *E. formosoides* and *E. dilatata* (Table 2). The accompanying larger foraminifera suggest a Chattian age for this species and in the absence of *Eulepidina*-bearing material from Aquitanian in Turkey we can not discuss if its stratigraphic range straddles the Chattian-Aquitanian boundary or not. In the Qum formation of Central Iran Rahaghi (1973) illustrated similar forms associating with Spiroclypeus, however under the name of *Lepidocyclina (Eulepidina) dilatata.* He suggested Aquitanian age for this occurrence, although the accompanied miogypsinid is represented by *M. complanatus,* a late Chattian species.

Family NUMMULITIDAE De Blainville 1827

Genus ***Nummulites*** Lamarck 1801
Determination of *Nummulites* is based on both the surface characteristics and the features of the equatorial section. Since

B-forms are much less widespread we concentrate mostly on the megalospheric forms. Based on Drooger et al. (1971) Less (1999) introduced a measurement and parameter system to characterize the equatorial section of A-forms that is slightly modified here (text-fig. 5). Seven parameters (explained in the header of Table 3) are used to characterize the 108 megalospheric specimens of *Nummulites* whose statistical data are summarized in Table 3.

Most *Nummulites* (*N. fichteli* and *N. bormidiensis*) from the Kelereşdere section belong to the *N. fabianii* lineage with reticulate surface. Numerous populations of this lineage from the Western Tethys, spanning from the early Bartonian to the early Chattian, are elaborated and the lineage is revised according to the measurement and parameter system mentioned above. Based on our preliminary communication (Less et al. 2006) the lineage is subdivided into species by using the criteria shown in text-fig. 11. The *N. fabianii* lineage in sample KEL 3 is represented by one single specimen (Pl. 4, fig. 1), and, therefore cannot be determined more precisely than *N.* ex. gr. *fichteli-bormidiensis* (based on its biometric parameters, see Table 3, closest to these species).

Nummulites fichteli (Michelotti 1841)
Plate 4, figures 2–16.

Nummulites fichteli MICHELOTTI 1841, p. 44, pl. 3, fig. 7. – SCHAUB 1981, pp. 128–130, pl. 50, figs. 5–18. (with synonymy).

Material. Populations of A-forms from samples KEL 11, 12 and 14 (Table 3). A few microspheric specimens are also available from samples KEL 11 and 14. Their surface and the character of the spire (Pl. 4, figs. 4, 9, 10) correspond to those illustrated by Schaub (1981) for *Nummulites fichteli.*

Remarks. Biometric data (tabulated in Table 3) and the characteristic reticulate surface of megalospheric specimens from the samples listed above make their identification unambiguous according to text-fig. 11. From text-fig. 12 it is clear that populations KEL 11+12 and 14 are quite close to that from Biarritz, rocher de la Vierge (the type locality of *Nummulites intermedius*, the abandoned name for microspheric forms of *N. fichteli*), and at the same time are rather remote from the popu-

TABLE 2
Statistical data for lepidocyclinid populations from the Kelereşdere section (see text for abbreviations of parameters). No.: number of specimens, s.e.-standard error.

| Parameters | | Medium cross-diameter of the embryonic chambers | | | | | | Degree of embracement of the protoconch by the deuteroconch A=100×I/(I+J) | | | Number of adauxiliary chambers (AAC) C | | | Number of annuli in 1 mm from the embryon's rim n | | |
| | | protoconch P (µm) | | | deuteroconch D (µm) | | | | | | | | | | | |
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Nephrolepidina praemarginata	KEL 3	21	160 – 300	220.0 ± 7.8	24	210 – 395	284.4 ± 9.5	21	32.0 – 41.5	36.30 ± 0.59	19	1 – 2	1.47 ± 0.11	18	22 – 28	25.22 ± 0.45
	KEL 12	5	215 – 250	232.0 ± 5.4	5	285 – 305	298.0 ± 3.3	5	33.4 – 40.9	36.34 ± 1.13	4	1 – 2	1.75 ± 0.22	5	20 – 26	23.40 ± 1.12
	KEL 16-20	70	115 – 220	168.0 ± 2.8	71	140 – 320	224.0 ± 4.5	61	27.3 – 44.5	36.27 ± 0.48	63	1 – 3	1.62 ± 0.08	53	20 – 32	26.02 ± 0.37
	KEL 16	17	135 – 200	158.5 ± 5.0	18	155 – 320	208.3 ± 8.6	13	32.3 – 39.0	35.51 ± 0.62	14	1 – 3	1.64 ± 0.16	8	24 – 32	28.63 ± 0.95
	KEL 17	26	135 – 220	176.3 ± 4.6	26	185 – 320	238.1 ± 6.8	23	27.3 – 43.9	36.34 ± 0.81	24	1 – 3	1.71 ± 0.12	23	20 – 30	25.52 ± 0.49
	KEL 19	22	115 – 200	168.4 ± 4.9	22	140 – 295	225.2 ± 8.1	20	28.1 – 44.5	36.70 ± 0.99	20	1 – 3	1.55 ± 0.13	18	20 – 32	25.61 ± 0.61
	KEL 20	5	130 – 185	155.0 ± 8.4	5	165 – 230	202.0 ± 9.4	5	31.6 – 40.0	36.25 ± 1.24	5	1 – 2	1.40 ± 0.22	4	23 – 28	25.50 ± 1.03
N. ex. interc. morgani-praemarginata	KEL 29	13	170 – 250	212.7 ± 7.2	13	225 – 415	323.1 ± 15.8	11	35.8 – 48.2	42.69 ± 1.11	10	1 – 6	2.90 ± 0.39	12	20 – 30	22.67 ± 0.79
	KEL 30+35	33	125 – 310	212.6 ± 6.8	34	160 – 420	309.4 ± 10.1	30	35.1 – 51.1	42.40 ± 0.72	27	1 – 7	3.00 ± 0.25	23	18 – 30	22.13 ± 0.69
	KEL 30	18	125 – 310	224.4 ± 9.9	18	160 – 420	327.8 ± 14.4	18	36.8 – 51.1	42.85 ± 0.91	14	1 – 7	3.21 ± 0.37	13	20 – 30	23.85 ± 0.88
	KEL 35	15	160 – 260	198.3 ± 7.7	16	225 – 415	288.8 ± 12.2	12	35.1 – 48.0	41.72 ± 1.16	13	1 – 5	2.77 ± 0.31	10	18 – 24	19.90 ± 0.59
N. musensis	KEL 11-14	27	250 – 425	322.6 ± 9.1	27	350 – 700	489.1 ± 14.4	24	33.7 – 51.9	42.88 ± 0.81	20	2 – 4	2.80 ± 0.17	24	15 – 20	16.92 ± 0.31
	KEL 11	4	275 – 400	340.0 ± 24.9	4	445 – 560	497.5 ± 20.7	4	33.7 – 44.4	40.15 ± 2.04	4	2 – 3	2.50 ± 0.25	3	15 – 18	16.00
	KEL 12	22	250 – 425	318.6 ± 10.1	22	350 – 700	487.0 ± 17.3	19	36.1 – 51.9	43.56 ± 0.87	15	2 – 4	2.93 ± 0.20	20	15 – 20	17.15 ± 0.32
	KEL 14	1		340.0	1		500.0	1		40.97	1		2.00	1		15.00
	KEL 19-20	3	235 – 300	265.0	3	310 – 480	400.0	3	34.0 – 47.0	42.42	3	2 – 4	3.00	3	18 – 20	19.00
	KEL 19	1		300.0	1		480.0	1		46.96	1		4.00	1		18.00
	KEL 20	2	235 – 260	247.5	2	310 – 410	360.0	2	34.0 – 46.3	40.15	2	2 – 4	3.00	2	19 – 20	19.50
	KEL 29	3	310 – 490	371.7	3	545 – 575	558.3	3	40.1 – 50.0	44.56	2	4 – 7	5.50	3	14 – 16	14.67
	KEL 35	4	310 – 340	322.5 ± 6.5	4	460 – 525	502.5 ± 13.3	3	42.0 – 44.7	43.24	1		6.00	4	16 – 18	17.25 ± 0.41
Eulepidina formosoides	KEL 3	23	390 – 630	512.2 ± 14.7	24	630 – 1170	864.2 ± 24.9	20	59.7 – 92.5	73.94 ± 1.97				12	10 – 16	13.25 ± 0.49
	KEL 7	21	420 – 690	501.9 ± 15.9	22	640 – 1120	855.2 ± 26.6	18	51.6 – 84.2	70.52 ± 2.27				15	11 – 16	13.07 ± 0.41
	KEL 11-12	46	310 – 980	562.0 ± 21.3	49	505 – 1740	964.8 ± 34.5	44	60.4 – 92.9	77.87 ± 1.15				38	8 – 20	13.05 ± 0.37
E. formosoides-dilatata	*KEL 11*	19	405 – 870	578.4 ± 29.3	21	780 – 1445	1007.9 ± 44.4	19	65.1 – 92.9	79.05 ± 1.69				17	9 – 20	12.88 ± 0.57
	KEL 12	27	310 – 980	550.4 ± 29.6	28	505 – 1740	932.5 ± 49.6	25	60.4 – 92.4	76.97 ± 1.55				21	8 – 17	13.19 ± 0.47
	KEL 14	25	400 – 1120	738.2 ± 35.8	25	720 – 1760	1229.2 ± 48.6	22	62.4 – 100.0	80.46 ± 2.29				18	10 – 19	12.89 ± 0.51
E. dilatata	KEL 16-20	39	600 – 1430	895.3 ± 33.1	40	1060 – 2080	1477.6 ± 36.5	37	63.4 – 100.0	86.86 ± 1.46				35	8 – 12	9.97 ± 0.20
	KEL 16	20	600 – 1430	885.8 ± 52.0	20	1130 – 2025	1455.5 ± 52.3	20	63.4 – 100.0	84.27 ± 2.19				17	8 – 12	10.12 ± 0.31
	KEL 17	12	725 – 1220	899.2 ± 38.7	12	1335 – 1950	1529.2 ± 48.1	12	78.9 – 100.0	90.61 ± 1.84				12	8 – 11	9.50 ± 0.25
	KEL 19	6	615 – 1380	920.8 ± 100.2	7	1060 – 2080	1453.6 ± 116.2	4	83.4 – 98.1	90.27 ± 2.61				6	9 – 12	10.50 ± 0.39
	KEL 20	1		885.0	1		1470.0	1		79.95						
E. elephantina	KEL 30	4	1450 – 2625	1837.5 ± 230.6	6	2525 – 4225	3541.7 ± 244.8	4	84.7 – 100.0	93.57 ± 3.33				5	4 – 5	4.40 ± 0.22
E. anatolica	KEL 29	12	410 – 710	546.7 ± 26.2	21	640 – 1210	912.9 ± 32.9	12	84.9 – 94.1	88.39 ± 0.88				15	10 – 15	12.53 ± 0.38
	KEL 30+34b	34	400 – 700	545.1 ± 14.1	35	650 – 1200	946.6 ± 19.1	34	76.1 – 96.3	88.17 ± 0.84				29	9 – 15	11.48 ± 0.23
	KEL 30	16	400 – 700	555.6 ± 22.2	17	650 – 1150	938.8 ± 29.3	16	76.5 – 96.1	88.14 ± 1.23				15	10 – 15	11.80 ± 0.32
	KEL 34b	18	410 – 675	535.8 ± 17.4	18	800 – 1200	953.9 ± 24.7	18	76.1 – 96.3	88.20 ± 1.16				14	9 – 13	11.14 ± 0.30

lations of *N. bormidiensis*. The intermediate position of the population from sample KEL 14 between that from samples KEL 11+12 and 16–20, in accord with the stratigraphic position of the sample, can also be read from text-fig. 12. *Eulepidina* populations from the same samples follow each other in the same order (see Table 2).

Nummulites bormidiensis Tellini 1888
Plate 4, figures 17–22.

Nummulites intermedia var. *bormiensis* n. var. – Tellini 1888, pp. 219, pl. 8, figs. 14a, b, 15, 17.
Nummulites bormidiensis Tellini – Özcan et al. 2009b, 754–755, figs. 17.1–5. (with synonymy)

Material. Populations of A-forms from samples KEL 16, 19 and 20 (Table 3). Microspheric forms have not been found.

Remarks. The application of the name "*bormidiensis*" for lower Chattian reticulate *Nummulites* with mean proloculus diameter over 300µm (instead of "*sublaevigatus*" or "*fichteli*") is discussed in Özcan et al. (2009). Biometric data (tabulated in Table 3) and the characteristic surface of megalospheric specimens with irregular mesh from populations KEL 16 to 20 make their identification unambiguous according to text-fig.12. These data are clearly different from those of *Nummulites fichteli*.

Nummulites kecskemetii Less 1991
Plate 4, figures 23, 24

Nummulites kecskemetii n. sp. – LESS 1991, pp. 439–441, pl. 1, figs. 1–6, pl. 2, figs. 1–3. – ÖZCAN et al. 2009b, p. 755, figs. 17.6–10. (with synonymy)

Material. Populations of A-forms from samples KEL 16, 29, 30 and 31. B-forms have not been found.

Remarks. This small radiate form with diagnostically very small proloculus, rare and curved septa and open spire was only found occasionally in the Kelereşdere section (for biometric data see Table 3). Its distinction from the upper Priabonian *Nummulites budensis* and from the lower Rupelian *N. bouillei* (bearing similar features) is discussed in Less (1999) and Özcan et al. (2009). As in the Western Taurids (Özcan et al. 2009b), *N. keckemetii* co-occurs with *N. bormidiensis* (in sample KEL 16). On the other hand, as in Novaj (Hungary) and Escornebéou (France) (see deatails in Less 1991), it also co-occurs with miogypsinids (in samples KEL 29 to 31). Thus, the stratigraphic range of *N. kecskemetii* extends from the SBZ 22B to the SBZ 23 zone, i.e. to the whole duration of the Chattian.

Genus *Operculina* d'Orbigny 1826

Operculina complanata (Defrance 1822)
Plate 4, figures 25–31

TABLE 3

Statistical data for *Nummulites* populations from the Keleredere section (see text for abbreviations of parameters). No. : number of specimens, s.e. - standard error.

Parameters		Inner cross-diameter of the proloculus P (μm)			Outer diameter of the first two whorls d (μm)			Number of post-embryonic chambers in the first two whorls E			Index of spiral opening 3. whorl vs. first 3 whorls K=100×(D–d)/(D–P)		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
N. ex. gr. fichteli-bormidiensis	KEL 3	1		320.0	1		1395	1		14.00	1		34.25
	KEL 11-12	45	190 – 410	260.7 ± 6.6	45	920 – 1360	1183 ± 19	45	16 – 21	18.31 ± 0.19	45	24.7 – 40.6	33.17 ± 0.42
N. fichteli	KEL 11	37	190 – 410	260.4 ± 7.7	37	920 – 1360	1166 ± 21	37	16 – 21	18.41 ± 0.22	37	24.7 – 40.6	33.44 ± 0.48
	KEL 12	8	205 – 310	261.9 ± 11.0	8	1160 – 1360	1259 ± 26	8	17 – 19	17.88 ± 0.30	8	29.9 – 34.9	31.94 ± 0.64
	KEL 14	34	200 – 510	288.5 ± 10.0	34	1010 – 1450	1190 ± 21	34	15 – 21	17.29 ± 0.25	34	27.8 – 36.7	32.25 ± 0.40
N. bormidiensis	KEL 16-20	17	245 – 385	318.8 ± 10.2	16	1030 – 1470	1238 ± 25	16	14 – 20	17.75 ± 0.43	16	30.6 – 39.5	33.94 ± 0.60
	KEL 16	1		380.0	1		1390	1		14.00	1		33.55
	KEL 19	7	245 – 385	306.4 ± 17.3	6	1030 – 1470	1237 ± 54	6	16 – 20	18.33 ± 0.56	6	30.6 – 38.4	33.30 ± 1.09
	KEL 20	9	265 – 375	321.7 ± 11.4	9	1140 – 1350	1222 ± 19	9	16 – 20	17.78 ± 0.49	9	31.5 – 39.5	34.41 ± 0.75
N. kecskemetii	KEL 16	4	55 – 95	72.5 ± 8.9	4	800 – 1410	1208 ± 120	4	17 – 21	19.75 ± 0.82	1		59.62
	KEL 29	3	80 – 135	105.0	3	1080 – 1480	1287	3	20 – 22	21.33	2	56.9 – 62.8	59.85
	KEL 30+31	4	55 – 70	61.3 ± 2.7	4	750 – 1210	1038 ± 88	4	17 – 18	17.75 ± 0.22	2	48.7 – 60.2	54.42
	KEL 30	2	60 – 70	65.0	2	1140 – 1210	1175	2	17 – 18	17.50	1		48.66
	KEL 31	2	55 – 60	57.5	2	750 – 1050	900	2	18 – 18	18.00	1		60.17

Parameters		Third whorl								
		average length of chambers L=d×π/N (μm)			average shape of chambers F=100×(D–d)/(D–d+2d×π/N)			relative width of the spiral cord m=100×(D–M)/(D–d)		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
N. ex. gr. fichteli-bormidiensis	KEL 3	1		302.2	1		48.09	1		37.50
	KEL 11-12	45	192 – 329	249.3 ± 5.0	45	35.0 – 56.0	47.88 ± 0.54	45	15.1 – 46.7	23.53 ± 0.82
N. fichteli	KEL 11	37	192 – 329	247.6 ± 5.6	37	35.0 – 56.0	47.92 ± 0.61	37	15.1 – 46.7	23.21 ± 0.97
	KEL 12	8	230 – 324	257.2 ± 10.8	8	41.5 – 51.6	47.71 ± 1.20	8	20.6 – 29.2	25.00 ± 1.04
	KEL 14	34	207 – 337	258.8 ± 5.9	34	39.5 – 50.5	45.35 ± 0.47	34	11.4 – 27.1	20.84 ± 0.67
N. bormidiensis	KEL 16-20	16	226 – 369	292.3 ± 10.0	16	39.0 – 48.6	44.76 ± 0.65	16	12.2 – 36.2	21.17 ± 1.44
	KEL 16	1		335.9	1		43.15	1		19.61
	KEL 19	6	226 – 369	283.7 ± 18.2	6	39.9 – 48.6	45.14 ± 1.28	6	12.2 – 24.4	18.10 ± 1.72
	KEL 20	9	256 – 368	293.3 ± 11.8	9	39.0 – 47.9	44.68 ± 0.75	9	16.4 – 36.2	23.40 ± 1.99
N. kecskemetii	KEL 16	3	157 – 221	195.8	1		77.78	1		8.18
	KEL 29	2	170 – 211	190.5	2	81.2 – 83.3	82.22	2	6.6 – 7.1	6.85
	KEL 30+31	2	155 – 185	170.2	2	74.6 – 77.2	75.91	2	11.0 – 14.3	12.65
	KEL 30	1		185.4	1		74.61	1		11.01
	KEL 31	1		155.0	1		77.20	1		14.29

Lenticulites complanata n. sp. – DEFRANCE 1822. p. 453.
Planoperculina complanata (Defrance) – LESS 1991. p. 441–442, pl. 2, figs. 4–5; pl. 3, figs. 1–4. (with synonymy)
Operculina complanata (Defrance) – ÖZCAN et al. 2009b, p. 756, figs. 20.1, 2. – ÖZCAN and LESS 2009, p. 35, pl. 2, fig. 22. – ÖZCAN et al. 2009a, p. 577, pl. 3, fig. 31.

Remarks: This form occurs in almost all our samples starting from KEL 11 and upwards. According to Cahuzac and Poignant (1997) it ranges from the base of the Oligocene up to the Tortonian (SBZ 21–26) during which no detectable evolutionary change could be observed. It also shows a great range of intraspecific variability (Less 1991) and consequently we did not pay special attention to the detailed study of this taxon. We only measured the inner proloculus diameter (P) of the megalospheric specimens, which remarkably increases between samples KEL 15–19 ($P_{mean\pm s.e.}$=107.7±6.4μm based on 11 specimens) and KEL 29–43 ($P_{mean\pm s.e.}$=188.8±5.1μm based on 32 specimens). The first values correspond to those from sample Dazkırı (DAZ) A 7 from the western Taurids (Özcan et al. 2009b) with almost identical associated larger foraminifera, whilst the latter ones to those from Hungary (Less 1991) with larger foraminifera indicating the late Chattian SBZ 23 zone. In the meantime the proloculus size of *Operculina complanata* from the lower Burdigalian beds of Ahlat is once again around 110μm (Özcan and Less 2009). Anasteginid features (i.e. irregular, mostly incomplete secondary septa, see in detail in Hottinger 1977) occur rarely and only in samples KEL 15 to 19 (Pl. 4, fig. 26).

Genus **Heterostegina** d'Orbigny 1826

Since all *Heterostegina* in our material are involute (Pl. 5, fig. 7) and bear similar external characteristics, they are considered to belong to the same species (*H. assilinoides*). B-forms are very rare, therefore we concentrate mostly on the megalospheric forms. Based on the system introduced by Drooger and Roelofsen (1982), Less et al. (2008) introduced a measurement and parameter system to characterize the equatorial section of A-forms of the western Tethyan late Bartonian and Priabonian *Heterostegina* that we use here also for the Oligo-Miocene forms (text-fig. 5) by adding one more parameter (S_{4+5}). Six parameters (explained in the header of Table 4 and using the measurements and counts shown in text-fig. 5) for 27 heterosteginid (and also for 39 spiroclypeid and 9 primitive cycloclypeid) specimens are evaluated statistically by standard methods per populations. The results are summarized in Table 4.

Heterostegina assilinoides Blanckenhorn 1890, emend. Henson 1937
Plate 5, figures 1–4, 7

TABLE 4

Statistical data for *Heterostegina, Cycloclypeus* (*Cycloclypeus* aff. *droogeri*) and *Spiroclypeus* populations from the Kelereşdere section (see text for abbreviations of parameters). No.: number of specimens, s.e. - standard error.

Parameters			Inner cross-diameter of the proloculus P (μm)			Number of post-embryonic pre-heterosteginid chambers X			Total number of chamberlets in the fourth and fifth chambers S_{4+5}			Number of chamberlets in the fourteenth chamber S_{14}			Outer diameter of the first whorl d (μm)			Index of spiral opening $K = 100 \times (D-d)/(D-P)$		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Heterostegina assilinoides	KEL 15-20	27	140 – 350	214.3 ± 10.4	26	1 – 3	1.65 ± 0.15	25	2 – 8	4.16 ± 0.34	21	4 – 13	7.67 ± 0.55	26	690 – 2260	1186 ± 72	12	41.8 – 64.0	48.8 ± 1.7
	KEL 15	2	140 – 250	195.0	2	2 – 3	2.50	2	2 – 3	2.50	1		7.00	1		950	1		54.0
	KEL 16	10	145 – 350	228.0 ± 18.7	9	1 – 2	1.44 ± 0.17	9	3 – 8	5.11 ± 0.53	7	4 – 13	7.57 ± 1.05	10	690 – 2260	1286 ± 149	5	42.6 – 54.2	48.7 ± 1.9
	KEL 17	9	145 310	210.0 ± 18.1	9	1 – 3	2.00 ± 0.31	8	2 – 7	3.50 ± 0.66	9	5 – 13	7.44 ± 0.88	9	760 – 1775	1107 ± 94	4	41.8 – 64.0	49.3 ± 4.5
	KEL 19	3	180 – 275	220.0	3	1	1.00	3	3 – 5	4.00	3	6 – 11	8.33	3	1080 – 1445	1312	1		48.7
	KEL 20	3	165 – 210	188.3	3	1 – 2	1.33	3	3 – 5	4.33	1		9.00	3	740 – 1340	1047	1		46.8
Cycloclypeus aff. *droogeri*	KEL 16-19	9	65 – 125	97.8 ± 6.2	9	1 – 3	1.89 ± 0.25	9	2 – 8	4.22 ± 0.70	9	3 – 9	6.33 ± 0.57	9	480 – 1140	654 ± 64	8	34.6 – 53.9	45.4 ± 1.9
	KEL 16	4	65 – 105	88.8 ± 8.5	4	1 – 3	1.75 ± 0.41	4	2 – 7	4.50 ± 1.03	4	3 – 9	6.75 ± 1.14	4	495 – 1140	690 ± 131	3	43.4 – 53.9	47.3
	KEL 17	4	105 – 125	112.5 ± 3.8	4	1 – 3	2.00 ± 0.35	4	2 – 8	4.25 ± 1.14	4	5 – 7	6.25 ± 0.41	4	480 – 780	619 ± 53	4	34.6 – 48.3	42.9 ± 2.7
	KEL 19	1		75.0	1		2.00	1		3.00	1		5.00	1		655			
Spiroclypeus blanckenhorni	KEL 29	20	150 – 355	246.0 ± 12.7	20	1 – 2	1.05 ± 0.05	17	6 – 17	10.18 ± 0.77	14	8 – 31	18.00 ± 1.97	16	900 – 2200	1379 ± 85	6	34.6 – 48.3	42.4 ± 2.3
	KEL 30–35	19	140 – 410	246.1 ± 14.2	19	0 – 1	0.95 ± 0.05	15	5 – 14	8.20 ± 0.55	13	8 – 25	14.92 ± 1.35	17	900 – 2455	1491 ± 89	10	40.7 – 64.7	48.9 ± 2.2
	KEL 30	4	140 – 245	207.5 ± 20.5	4	1	1.00 ± 0.00	4	6 – 9	7.25 ± 0.65	4	9 – 14	12.00 ± 1.06	4	1100 – 1700	1388 ± 110	4	40.7 – 48.4	43.0 ± 1.6
	KEL 31	2	160 – 235	197.5	2	1	1.00	2	8 – 9	8.50	2	10 – 16	13.00	2	1110 – 1600	1355	1		52.3
	KEL 34	9	190 – 290	233.9 ± 11.5	9	1	1.00 ± 0.00	5	5 – 10	7.60 ± 0.73	3	8 – 18	14.00	7	900 – 1600	1304 ± 87	3	47.3 – 64.7	54.3
	KEL 35	4	295 – 410	336.3 ± 22.0	4	0 – 1	0.75 ± 0.22	4	6 – 14	9.75 ± 1.43	4	12 – 25	19.50 ± 2.36	4	1730 – 2455	1988 ± 141	2	46.8 – 55.1	51.0

TABLE 5

Statistical data for *Cycloclypeus* (*Cycloclypeus pseudocarpenteri* n. sp.) populations from the Kelereşdere section (see text for abbreviations of parameters). No. : number of specimens, s.e. - standard error.

Parameters			Inner cross-diameter of the proloculus P (μm)			Maximal inner diameter of the two-chambered embryon C_{12} (μm)			Number of post-embryonic pre-heterosteginid chambers X			Total number of chamberlets in the fourth and fifth chambers S_{4+5}			Number of pre-annular chambers (including the embryon) Y		
Taxon	Sample	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Cycloclypeus pseudocarpenteri	KEL 16-20	9	195 – 375	277.8 ± 18.9	9	305 – 575	412.2 ± 26.3	9	0 – 1	0.89 ± 0.10	9	7 – 31	20.11 ± 2.09	9	4 – 7	5.67 ± 0.31
	KEL 16	7	195 – 375	282.9 ± 22.9	7	305 – 575	423.6 ± 32.4	7	0 – 1	0.86 ± 0.13	7	7 – 31	19.43 ± 2.62	7	5 – 7	6.00 ± 0.29
	KEL 17	1		295.0	1		385.0	1		1.00	1		21.00	1		5.00
	KEL 20	1		225.0	1		360.0	1		1.00	1		24.00	1		4.00

Heterostegina assilinoides – BLANCKENHORN, p. 342, pl. 17, fig. 5 (non figs. 4, 6). – HENSON 1937, p. 48, pl. 4, figs. 1–5, pl. 6, fig. 2. – ÖZCAN et al. 2009b, pp. 756–757, figs. 20.5–9. (with synonymy)

Material. Populations of A-forms from samples KEL 15 to 17 and 19, 20, also united into a composite population (KEL 16–20). One microspheric specimen from sample KEL 16 is also observed.

Remarks. Biometric data (tabulated in Table 4) of our composite population are very similar to those from the Bey-Dağları composite population from the Western Taurids and to those from Ramleh (Israel) (for further discussion see Özcan et al. 2009b). Their associated fossils are also very similar and identify the early Chattian SBZ 22B zone. The representatives of *Heterostegina* from these three localities can morphologically be identified with *H. assilinoides*, the type locality of which is in Southern Turkey, close to the Syrian boundary. For comparison with European Chattian *Heterostegina* belonging to another species to be described yet see Özcan et al. (2009). As shown in Less et al. (2008), the Oligocene representatives of genus *Heterostegina* cannot be considered to have been derived from either *H. reticulata* or *H. gracilis*, known from the Eocene, although the number of operculinid chambers of the only microspheric specimen (parameter X in the same sense as used for the A-forms) of *H. assilinoides* (Pl. 5, fig. 4) is 12, which is much less than for the Eocene forms (compare with Table 4 in Less et al. 2008).

Genus *Spiroclypeus* H. Douvillé 1905

Spiroclypeus blanckenhorni Henson 1937
Plate 5, figures 11, 14, 15, 17, 18.

Spiroclypeus blanckenhorni – HENSON 1937. pp. 50-51, pl. 4, fig. 7, pl. 5, figs. 1-3. – ÖZCAN et al. 2009a, pp. 577–578, pl. 3, figs. 27, 29, 30, 32–34.

Material. Populations of A-forms from samples KEL 29 to 31 and 34, 35. Populations of samples 30 to 35, very close to each other, are united into a composite population (KEL 30–35). Microspheric specimens have not been observed.

Remarks. The same measurement and parameter system has been applied as for genus *Heterostegina*. The results are tabulated in Table 4. Based on them the representatives of genus *Spiroclypeus* from the top part of the Kelereşdere section can internally be considered very similar (although the proloculus size is slightly larger) to those from the basal layers of the Tuzlagözü section (sample TUZ 1) in the Sivas Basin (Central Anatolia) (Özcan et al. 2009a). Externally, of the two morphotypes found in Tuzlagözü, only the large flat forms could be observed in the Kelereşdere section. Associated larger foraminifera indicate a slightly younger (early Aquitanian) age (based on the presence of *Miogypsina gunteri*) for the Tuzlagözü sample than for the upper part of the Kelereşdere section (where *M. basraensis* sug-

gests still latest Chattian). The name "*blanckenhorni*" in both localities is given with some caution, since the Oligo-Miocene representatives of genus *Spiroclypeus* need a serious revision based on biometric data like in the case of the Priabonian forms (Less and Özcan 2008), from which they strongly differ in having a loose spiral as compared to the tight one of the Priabonian forms. Transitional forms are not known. Moreover, *Spiroclypeus* is completely unknown from Rupelian and lower Chattian deposits. Therefore, we think that the Priabonian and Oligo-Miocene forms are not directly connected with each other (Less and Özcan 2008). Rather, both they may have been originated from different *Heterostegina* once in the beginning of the Priabonian and then in the late Chattian. This latter connection (between *H. assilinoides* and *S. blanckenhorni*) is strongly supported by the data from the Kelereşdere section where the stratigraphic superposition of the two taxa can directly be observed. Moreover, in accord with the appearance of lateral chambers (Pl. 5, fig. 17), *S. blanckenhorni* also exhibits more advanced numerical evolutionary parameters than *H. assilinoides* (compare X, S_{4+5} and S_{14} in Table 4).

Genus *Cycloclypeus* Carpenter 1856

Although genus *Cycloclypeus* is rather rare in the Kelereşdere section, two different taxa can be distinguished, moreover in the same samples. For the forms called here *C.* aff. *droogeri* we apply the same measurement and parameter system as for *Heterostegina* and *Spiroclypeus*, since true cyclic chambers chambers cannot or can only be tentatively recognized in their case. Thus, their biometric data are tabulated in Table 4. At the same time cyclic chambers appear in a very early ontogenetic stage in the case of the other taxon, which is separated into *C. pseudocarpenteri* n. sp., itroduced below. Therefore, we apply for them a slightly different system, which includes five measurements. (explained in the header of Table 5, where also statistical data are summarized).

***Cycloclypeus* aff. *droogeri* Matteucci and Schiavinotto 1985**
Plate 5, figures 5, 6, 8.

Cycloclypeus droogeri – MATTEUCCI and SCHIAVINOTTO 1985, pp. 125-128, pl. 1, figs. 1, 3, 5.
Cycloclypeus (?) sp. – ÖZCAN et al. 2009b, p. 759, figs. 20.12, 13.

PLATE 1
All A-forms (×25) from Kelereşdere, upper Chattian

1-12 *Miogypsina basraensis* Brönnimann

1 O/KEL.30-10, equatorial section

2 O/KEL.30-3, equatorial section

3 O/KEL.30-11, equatorial section

4 O/KEL.31-10, equatorial section

5 O/KEL.31-5, equatorial section

6 O/KEL.34-53, vertical section

7 O/KEL.34-3, equatorial section

8 O/KEL.35-4, equatorial section

9 O/KEL.35-8, equatorial section

10 O/KEL.35-75, equatorial section

11 O/KEL.35-6, equatorial section

12 O/KEL.35-13, equatorial section

13-24 *Miogypsinoides formosensis* Yabe and Hanzawa

13 O/KEL.29-31, vertical section

14 O/KEL.29-8, equatorial section

15 O/KEL.29-21, equatorial section

16 O/KEL.29-19, equatorial section

17 O/KEL.29-30, equatorial section

18 O/KEL.30-62, equatorial section

19 O/KEL.31-19, equatorial section

20 O/KEL.30-21, equatorial section

21 O/KEL.30-30, equatorial section

22 O/KEL.30-49, equatorial section

23 O/KEL.34-41, equatorial section

24 O/KEL.34-31, equatorial section

25-33 *Miogypsinoides sivasensis* Özcan and Less

25 O/KEL.31-13, equatorial section

26 O/KEL.34-47, equatorial section

27 O/KEL.34-49, equatorial section

28 O/KEL.35-67, equatorial section

29 O/KEL.35-70, equatorial section

30 O/KEL.35-82, vertical section

31 O/KEL.35-79, equatorial section

32 O/KEL.35-7, equatorial section

33 O/KEL.35-64, equatorial section

34 *Planolinderina escornebovensis* Freudenthal, O/KEL.34-52, equatorial section.

All: 1 mm
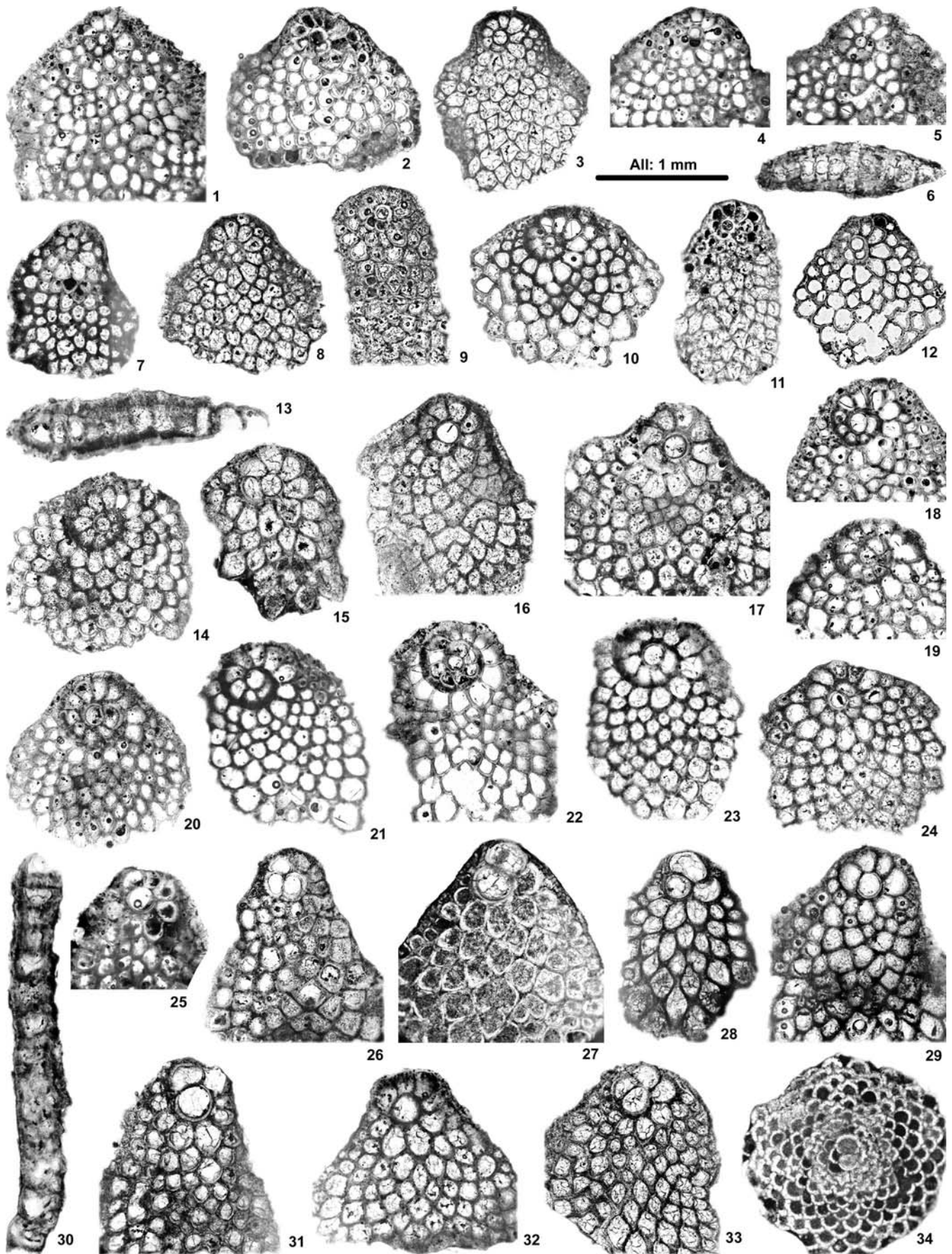
Material: Altogether nine megalospheric specimens in samples KEL 16, 17 and 19. In Table 4 they are also joined into the composite population KEL 16–19.

Remarks: These evolute forms, showing transitional character between *Heterostegina* and *Cycloclypeus*, co-occur with *Nephrolepidina praemarginata*, *Eulepidina dilatata*, *Nummulites bormidiensis*, *N. kecskemetii*, *Heterostegina assilinoides* and *Cycloclypeus pseudocarpenteri* n. sp. in the basal Chattian (SBZ 22A) beds of the Kelereşdere section. They exhibit a strong tendency to loose the operculinids spiral and to develope an annular chamber (Pl. 5, fig. 8). Therefore, the number of pre-annular chambers (including the embryon) can only be estimated as more than 25–35. Such values are known so far only for the most primitive *C. droogeri* (Laagland 1990) or *C. koolhoveni* from Indonesia (Tan 1932; Drooger 1993). This latter, however, have a considerably larger proloculus (around 150µm) and somewhat higher chamberlets than those of the Kelereşdere specimens (see Table 5).

Similar forms are described and illustrated only from the western Taurids by Özcan et al. (2009b). Based on their intermediate features between *Heterostegina* and *Cycloclypeus droogeri* (and also because of the insufficient material) we ascribe these forms to *C.* aff. *droogeri*. *Cycloclypeus droogeri* (with more than 23 pre-annular chambers in average, including the embryon) indicates the lower part of the SBZ 22B zone (Drooger and Laagland 1986; Cahuzac and Poignant 1997) and followed by *C. mediterraneus* (with below the above average value) in the upper part of the same zone. Taking also into consideration the associated larger foraminifera listed at the beginning of Remarks we think that *C.* aff. *droogeri* also determines the lower part of the SBZ 22B zone.

Cycloclypeus pseudocarpenteri Özcan and Less **n. sp.**
Plate 5, figures 10, 12, 13, 16.

Derivation of the name. Based on the similarity with the recent *Cycloclypeus carpenteri*.

Holotype. O/KEL.16-28 (Pl. 5, fig. 10), a megalospheric specimen split along the equatorial plane.

Depository. The Özcan Collection in the Geological Department of the İstanbul Technical University (Turkey).

Type locality. Kelereşdere (E Turkey), sample KEL 16.

Type level. Early Chattian, SBZ 22B zone.

Material. Altogether nine megalospheric specimens in samples KEL 16, 17 and 20. In Table 5 they are also joined into the composite population KEL 16–20.

Diagnosis: Medium-sized, flat, evolute forms with a distinct central knob and evenly distributed granules. In the equatorial section of the A-forms a relatively large embyon is followed by very few (2–5) pre-annular chambers, only the first of which is undivided. Annular chambers are subdivided into chamberlets that are rather low in the inner but higher in the outer annuli.

PLATE 2

All A-forms (7, 15, 16, 20: ×20; the others: ×40) except 24, B-form (×100). All from Kelereşdere

1-9 *Nephrolepidina musensis* n. sp. Özcan and Less
  1 O/KEL.11-22, equatorial section, upper Rupelian

  2 O/KEL.12-17, equatorial section, upper Rupelian

  3 O/KEL.12-13, equatorial section, upper Rupelian

  4 O/KEL.12-20, equatorial section, upper Rupelian

  5 O/KEL.12-53, equatorial section, upper Rupelian

  6 O/KEL.19-16, equatorial section, lower Chattian

  7 O/KEL.12-62, vertical section, upper Rupelian

  8 O/KEL.35-28, equatorial section, upper Chattian

  9 O/KEL.29-35, equatorial section, upper Chattian

10-19 *Nephrolepidina praemarginata* R. Douvillé 1908
  10 O/KEL.3-29, equatorial section, upper Rupelian

  11 O/KEL.3-42, equatorial section, upper Rupelian

  12 O/KEL.12-1, equatorial section, upper Rupelian

  13 O/KEL.16-12, equatorial section, lower Chattian

  14 O/KEL.17-19, equatorial section, lower Chattian

  15 O/KEL.3-60, vertical section, upper Rupelian

  16 O/KEL.16-37, vertical section, lower Chattian

  17 O/KEL.19-3, equatorial section, lower Chattian

  18 O/KEL.19-17, equatorial section, lower Chattian

  19 O/KEL.20-7, equatorial section, lower Chattian

20-26 *Nephrolepidina* ex. interc. *morgani* Lemoine and R. Douvillé- *praemarginata* R. Douvillé
  20 O/KEL.29-39, equatorial section, upper Chattian

  21 O/KEL.29-34, equatorial section, upper Chattian

  22 O/KEL.29-47, equatorial section, upper Chattian

  23 O/KEL.29-43, equatorial section, upper Chattian

  24 O/KEL.29-50, equatorial section, upper Chattian

  25 O/KEL.30-81, equatorial section, upper Chattian

  26 O/KEL.35-62, equatorial section, upper Chattian.

24: 200 µm
7, 15, 16, 20: 1 mm
rest: 500 µm
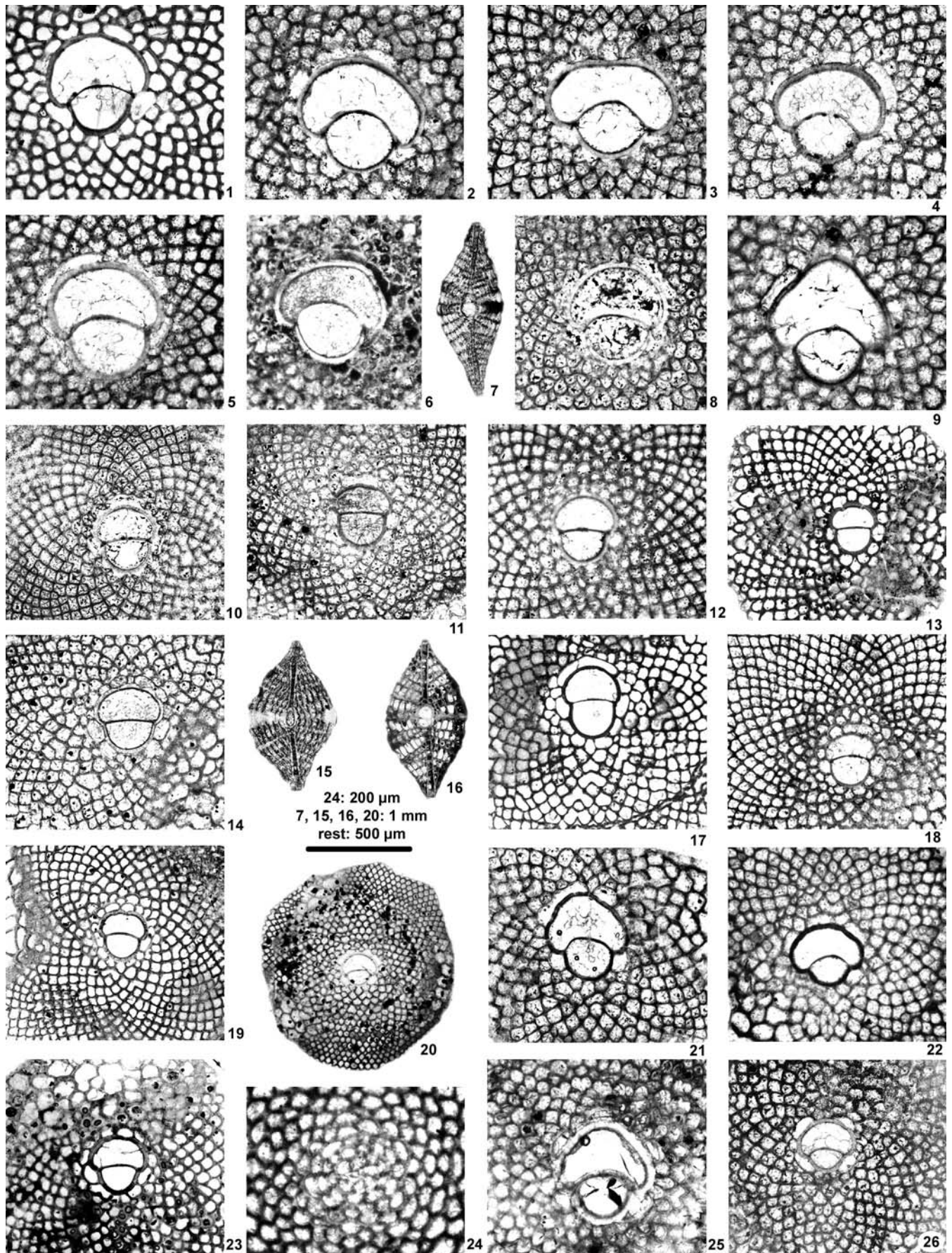
Description of the equatorial section of megalospheric (A) forms. (Pl. 5, figs. 10, 12, 13, 16, Table 5). The embryon is relatively large (P=195–375μm) and followed by very few (2–5) pre-annular chambers, only the first of which is undivided. Annular chambers are subdivided into (100μm wide in average) chamberlets that are rather low (60–80μm) in the inner but higher (120–150μm) in the outer annuli.

Remarks. These forms, co-occuring with *Cycloclypeus* aff. *droogeri* and associating with the same larger foraminifera (see there) are quite rare. Such forms from the Neogene (showing a gradual nepioic acceleration) are usually ranked with the recent *C. carpenteri*. The only similar record from the Oligocene is from sample SP 935 of Navazuelo (Granada, Spain, upper Chattian SBZ 23 zone) where, associating with *C. eidae*, three specimens are distinguished by Laagland (1990) as '*carpenteri*-types' based on their relatively large embryon (P=170–175μm) and low number of pre-annular chambers including the embryon (9–12). Our specimens from Kelereşdere, however, exhibit even more extreme values of these parameters (Table 6) from an even lower stratigraphic level (SBZ 22B). Therefore, we think that the Kelereşdere population is not linked phylogenetically with the recent *C. carpenteri* and a new name is erected for them. The closest taxon from stratigraphically lower horizons is *Heterostegina gracilis* known from the upper Priabonian (SBZ 20, Less et al. 2008) and can be imagined as a possible ancestor.

Range. Early Chattian, SBZ 22A zone.

CONCLUSIONS

The European Oligo-Miocene larger foraminiferal zonation is based on the correlation of different assemblages from isolated sites and on their relationship to other zonations. The direct su-

perposition of zones cannot be observed anywhere. We managed to prove the superposition of three Oligocene larger foraminiferal zones (SBZ 22A, 22B and 23) for the first time in the Kelereşdere section (E Turkey). We also obtained planktic foraminiferal and calcareous nannoplankton data from the quasi-autochtonous turbidites allowing us to correlate the larger foraminiferal subdivision with the planktic scheme.

The late Rupelian SBZ 22A Zone is characterized by the assemblage of *Nummulites fichteli*, *Operculina complanata*, *Eulepidina formosoides*, *Nephrolepidina praemarginata* and *N. musensis* n. sp. The latter, having surprisingly large embryon and equatorial chamberlets, cannot be placed into the *N. praemaginata–morgani–tournoueri* lineage having previously considered as the exclusive phylum of this genus in the Western Tethys. The calcareous nannoplankton indicate the NP 24 Zone.

In the early Chattian SBZ 22B Zone, *Nummulites fichteli* and *Eulepidina formosoides* are substituted by *N. bormidiensis* and *E. dilatata*, respectively, whereas the other three taxa listed in the SBZ 22 A Zone can be followed here as well. *Nummulites kecskemetii*, *Heterostegina assilinoides*, *Cycloclypeus* aff. *droogeri* (transitional between *Heterostegina* and *Cycloclypeus*) and *C. pseudocarpenteri* n. sp. are new elements in this zone. Calcareous nannoplankton characteristic of the NP 24–25 Zones and planktic foraminifera of the P 21 Zone have been determined from turbidites between the SBZ 22B and 23 Zones.

The late Chattian SBZ 23 Zone has been identified from the shallow-marine carbonate sequence composing the upper part of the section having formerly considered as Burdigalian. *Cyclocypeus* and *Heterostegina* disappear here, the latter is substituted by *Spiroclypeus blanckenhorni*. *Nummulites kecskemetii* remains the only representative of this genus. Meanwhile miogypsinids (represented by *Miogypsina basraensis*,

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PLATE 3
All A-forms ×15, except 2 (×5) from Kelereşdere

1-8 *Eulepidina formosoides* Douvillé 1925

    1 O/KEL.3-56, vertical section, upper Rupelian

    2 O/KEL.7-29, external view, upper Rupelian

    3 O/KEL.3-11, equatorial section, upper Rupelian

    4 O/KEL.7-14, equatorial section, upper Rupelian

    5 O/KEL.11-6, equatorial section, upper Rupelian

    6 O/KEL.12-35, equatorial section, upper Rupelian

    7 O/KEL.14-22, axial section, upper Rupelian

    8 O/KEL.14-9, equatorial section, upper Rupelian

9-12 *Eulepidina dilatata* (Michelotti 1861)

    9 O/KEL.16-64, vertical section, lower Chattian

    10 O/KEL.16-1, equatorial section, lower Chattian

    11 O/KEL.17-55, equatorial section, lower Chattian

    12 O/KEL.19-30, equatorial section, lower Chattian

13-17 *Eulepidina anatolica* n. sp. Özcan and Less

    13 O/KEL.29-55, equatorial section, upper Chattian

    14 O/KEL.30-84, equatorial section, upper Chattian

    15 O/KEL.34-13, equatorial section, upper Chattian

    16 O/KEL.34-3, equatorial section, upper Chattian

    17 O/KEL.29-77, vertical section, upper Chattian

18-20 *Eulepidina elephantina* Lemoine and R. Douvillé 1904

    18 O/KEL.30-105, vertical section, upper Chattian

    19 O/KEL.30-102, equatorial section, upper Chattian

    20 O/KEL.30-99, equatorial section, upper Chattian

2: 2 mm

Rest: 1 mm
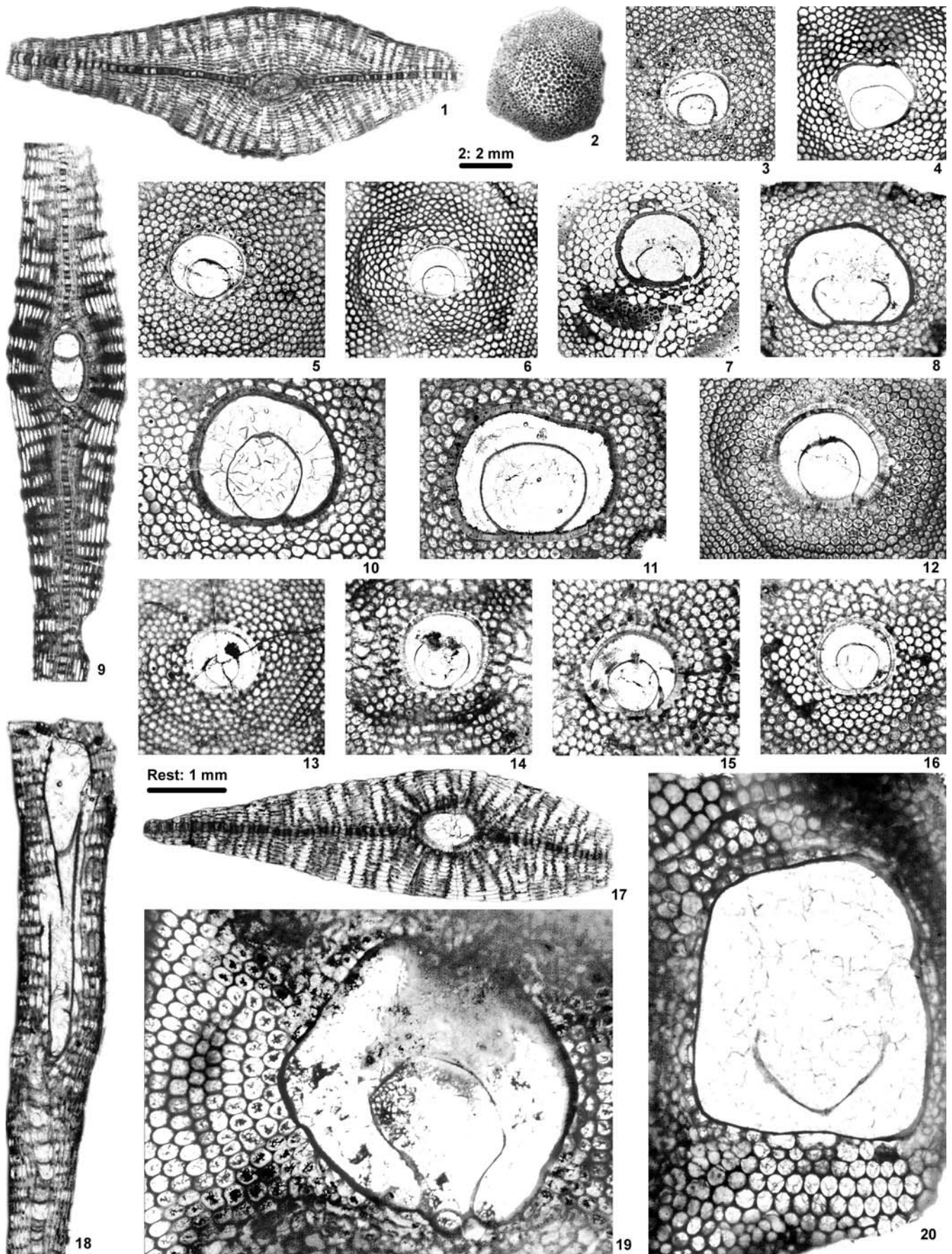
Miogypsinoides formosensis and *M. sivasensis*) first appear here. *Nephrolepidina praemarginata* is substituted by *N. morgani* whereas some specimens of *N. musensis* and *Operculina complanata* still occur here. *Eulepidina* are represented by *E. elephantina* (with giant embryon of 3–4 mm) and *E. anatoliensis* n. sp. (with relatively small embryon). None of them can be considered as having originated from *E. dilatata*.

Most of the larger foraminiferal taxa listed above correspond to those described from Europe. Therefore, the European larger foraminiferal zonation can also be extended to Eastern Turkey. There are differences as well, such as the specific composition of *Heterostegina* and *Cycloclypeus*, the lack of *Nummulites vascus*, and also the appearance of some new taxa of both *Eulepidina* and *Nephrolepidina*. The idea of one single Western Tethyan lineage for each of these latter two genera should be revised.

PLATE 4
All A-forms, except 4, 9-10, 21 B-forms. 3, 4, 7-10, 13-15, 18, 21: ×5, all the others: ×10. All from Kelereşdere

1 *N.* ex. gr. *fichteli* (Michelotti 1841)-*bormidiensis* Tellini 1888, O/KEL.3-37, equatorial section, upper Rupelian

2-16 *Nummulites fichteli* (Michelotti 1841)

   2 Sample KEL 11 (O.07.19), equatorial section, upper Rupelian

   3 Sample KEL 12 (O.07.16), external view, upper Rupelian

   4 Sample KEL 11 (O.07.18), external view, upper Rupelian

   5 Sample KEL 12 (O.07.17), equatorial section, upper Rupelian

   6 Sample KEL 11 (O.08.04), equatorial section, upper Rupelian

   7 Sample KEL 11 (O.08.04), external view, upper Rupelian

   8 Sample KEL 11 (O.08.05), external view, upper Rupelian

   9 Sample KEL 11 (O.08.06), equatorial section, upper Rupelian

   10 Sample KEL 14 (O.07.22), equatorial section, upper Rupelian

   11 Sample KEL 14 (O.07.21), equatorial section, upper Rupelian

   12 Sample KEL 14 (O.07.20), equatorial section, upper Rupelian

   13 Sample KEL 14 (O.07.20), external view, upper Rupelian

   14 Sample KEL 14 (O.07.23), external view, upper Rupelian

   15 Sample KEL 14 (O.08.07), external view, upper Rupelian

   16 Sample KEL 14 (O.08.08), equatorial section, upper Rupelian

17-22 *Nummulites bormidiensis* Tellini 1888

   17 Sample KEL 16 (O.08.09), equatorial section, lower Chattian

   18 Sample KEL 16 (O.08.09), external view, lower Chattian

   19 Sample O/KEL 20-1, equatorial section, lower Chattian

   20 Sample KEL 19 (O.08.10), equatorial section, lower Chattian

   21 Sample KEL 19 (O.08.11), equatorial section, lower Chattian

   22 Sample KEL 19 (O.08.12), equatorial section, lower Chattian

23-24 *Nummulites kecskemetii* Less 1991

   23 Sample KEL 31 (O.08.13), equatorial section, upper Chattian

   24 Sample KEL 29 (O.08.14), equatorial section, upper Chattian

25-31 *Operculina complanata* (Defrance 1822)

   25 Sample O/KEL 12-58, equatorial section, upper Rupelian

   26 Sample O/KEL 16-47, equatorial section, lower Chattian
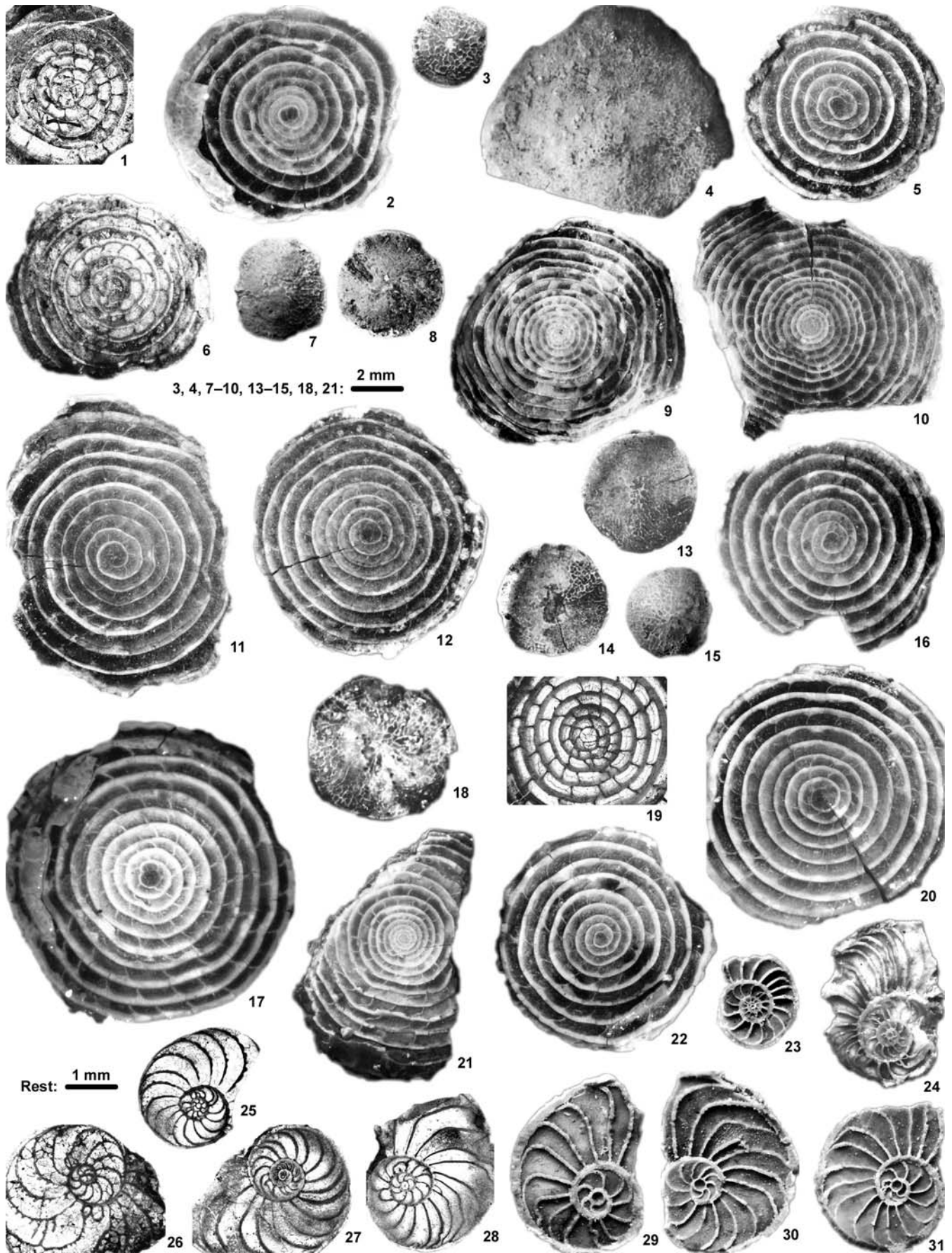
   27 Sample O/KEL 17-48, equatorial section, lower Chattian

   28 Sample O/KEL 19-35, equatorial section, lower Chattian

   29 Sample KEL 30 (O.08.15), equatorial section, upper Chattian

   30 Sample KEL 31 (O.08.16), equatorial section, upper Chattian

   31 Sample KEL 31 (O.08.17), equatorial section, upper Chattian.

3, 4, 7–10, 13–15, 18, 21: ▬ 2 mm

Rest: ▬ 1 mm

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PLATE 5
All A-forms (×20), except no. 4, B-form (×50). All from Kereleşdere

1-4,7 *Heterostegina assilinoides* Blanckenhorn, emend. Henson

    1 O/KEL.17-44, equatorial section, lower Chattian

    2 O/KEL.16-45, equatorial section, lower Chattian

    3 O/KEL.19-31, equatorial section, lower Chattian

    4 O/KEL.16-46, equatorial section, lower Chattian

    7 O/KEL.17-45, axial section, lower Chattian

5-6, 8-9 *Cycloclypeus* aff. *droogeri* Matteucci and Schiavinotto 1985

    5 O/KEL.16-27 equatorial section, lower Chattian

    6 O/KEL.17-47, equatorial section, lower Chattian

    8 O/KEL.17-46, equatorial section, lower Chattian

    9 O/KEL.16-49, equatorial section, lower Chattian

10, 12-13, 16 *Cycloclypeus pseudocarpenteri* n. sp. Özcan and Less

    l0 O/KEL.20-3, equatorial section, lower Chattian

    12 O/KEL.16-31, equatorial section, lower Chattian

    13 O/KEL.16-28, equatorial section, lower Chattian

    16 O/KEL.16-32, equatorial section, lower Chattian

11, 14-15, 17-18 *Spiroclypeus blanckenhorni* Henson 1937

    11 O/KEL.29-53, equatorial section, upper Chattian

    14 Sample KEL 29 (O.08.03), equatorial section, upper Chattian

    15 Sample KEL 29 (O.08.18), equatorial section, upper Chattian

    17 O/KEL.36-36, vertical section, upper Chattian

    18 O/KEL.36-32, equatorial section, upper Chattian

4: 500 µm

Rest: 1 mm
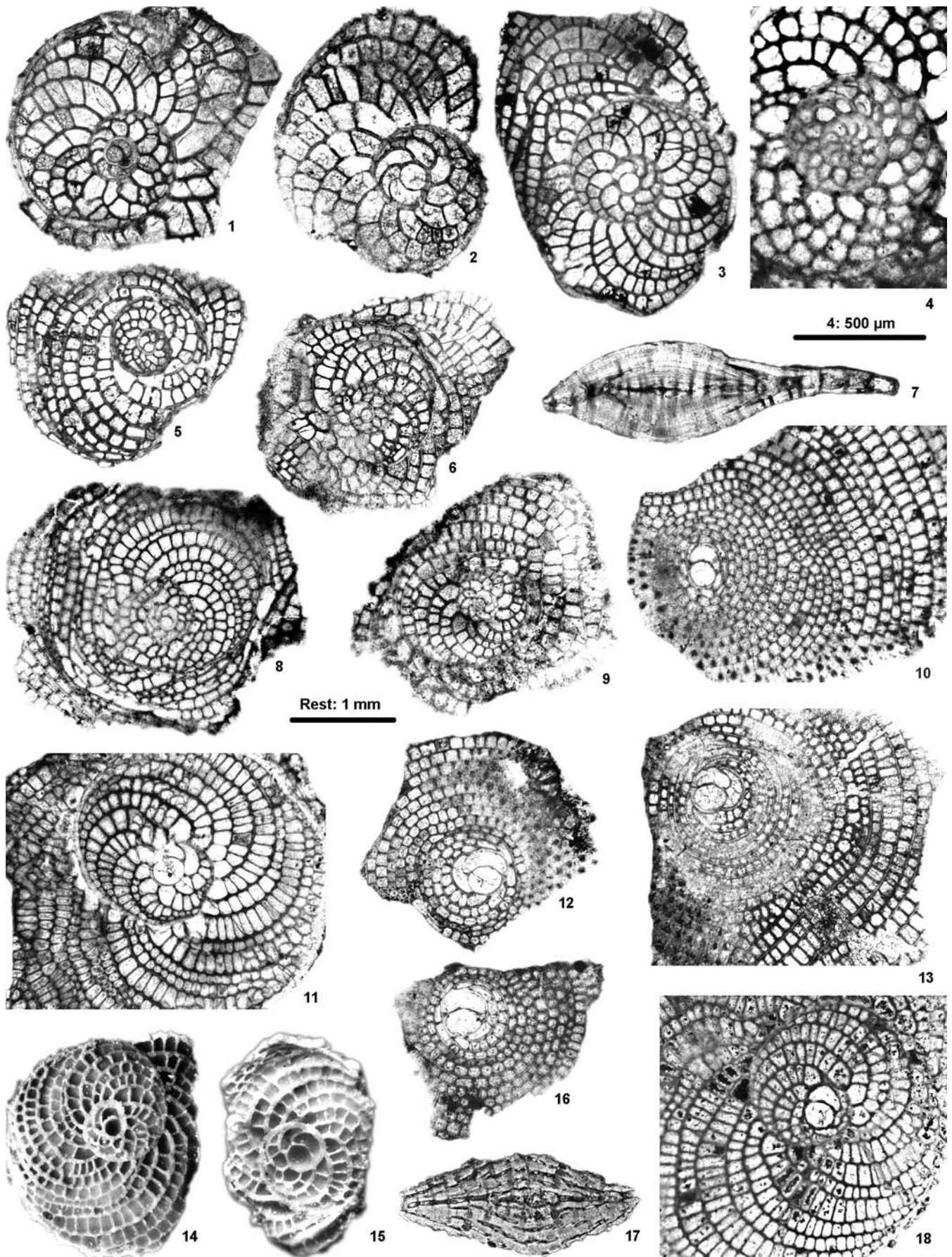
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