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Late Oligocene calcareous nannofossils from Albanian-Thessalian intramontane basin (Bozdovec Section, Albania) - a quantitative approach

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Abstract. Quantitative and semi-quantitative analyses of calcareous nannofossils were performed on samples collected from Bozdovec Section (Albanian-Thessalian intramontane basin, Albania). The calcareous nannofossil assemblages are dominated by: small reticulofenestrids, *Cycligargolithus floridanus, Coccolithus pelagicus, Sphenolithus* spp., *Reticulofenestra scrippsae, Helicosphaera* spp., *Clausicoccus* spp., *Reticulofenestra bisecta, Cycligargolithus abisectus*. Biostratigraphically, the studied outcrop is assigned to the Late Oligocene NP25 - *Sphenolithus ciperoensis* Zone. In the Mediterranean area, this interval can be correlated with the MNP25a - *Sphenolithus ciperoensis* Zone, while according to the zonation for low to middle latitudes the investigated material would belong to the CNO5 - *Sphenolithus ciperoensis* TZ. High amounts of small reticulofenestrids and sphenoliths point to warm well stratified paleoenvironment.

Keywords: Late Oligocene, Mediterranean area, Albanian-Thessalian intramontane basin, biostratigraphy, calcareous nannofossils, statistics.

INTRODUCTION

The Albanian-Thessalian intramontane basin (Fig. 1) was formed after the main folding of the Krasta (= Pindos) Zone and represents a narrow and elongated marine basin, filled with molasse-type deposits, which extends from southeast (SE) to northwest (NW), from Thessaly in Greece up to Devolli, Korça, Gora and Mokra regions and further to the Librazhdi and Burrel basins in Albania. Its substratum is represented by the deposits of Mirdita and Korabi zones (Papa and Pashko, 1966; Pashko et al., 1973; Pashko, 1977; Meço and Aliaj, 2000).

Bourcart (1922) named this part of the basin referring to the Mesohellenic Basin (Brunn, 1956), and later Pashko et al. (1973) named it Korça Basin.

Pashko (1996) describes three distinct sedimentary sequences of molasse-type deposits, starting with the first cycle which was deposited during Middle Eocene, followed by the second one which comprises sequences from Middle Oligocene up to Lower Miocene, while the third cycle is Burdigalian to Langhian.

The second molasses cycle is the most important of the Albanian-Thessalian intramontane basin and it overlies transgressively Lutetian deposits and, in some regions, the ultramafic basement of Mirdita Zone, showing a distinct angular unconformity (Papa and Pashko, 1966; Pashko, 1977, 1981, 1996).

Data on the biostratigraphy of the molasse-type deposits of the Albanian-Thessalian intramontane basin were published on: mollusks and corals (Bourcart, 1922, 1925), mollusks and foraminifers (Pashko et al., 1973; Pashko, 1977, 1986, 1987), foraminifera, mollusks and corals (Petro and Dodona, 1976), foraminifera, mollusks, palynomorphs and nannoplankton (Kumati et al., 1997), mollusks (Philippson and Oppenheim, 1894; Marku, 2000), fossil plants (Kleinholter, 2004) etc.

The first studies in Albania based on calcareous nannofossils and their application in biostratigraphy, were done by Islami and Prençi (1983), Islami and Çobo (1985), Çobo (1986, 1992, 1996), Vathi and Budri (1986), Dalipi and Çobo (1989), Vathi (1985, 1987, 1989, 1998) etc.

The purpose of this study is to bring new information on the calcareous nannofossils biostratigraphy and paleoecology of Upper Oligocene molasse-type deposits in the region.

GEOLOGICAL SETTINGS

The stratigraphical sequence of Middle Oligocene - Lower Miocene molasse deposits in Morava Mountain (Fig. 2), on the eastern margin of Albanian-Thessalian Basin, includes following formations according to Pashko (1996): the basal conglomerates of the Mborja-Dishnica Formation, the coal bearing Drenova Formation, the Drenica Formation (=Koralori), marlstones of the Chama Formation, the Plasa Formation, the Bozdovec Formation and the Guri i Capit Formation.

The Late Oligocene in the Korça Basin is represented by typical marine and lagoonal deposits overlaying conformably the Middle Oligocene and starting at the base with marlstones of the

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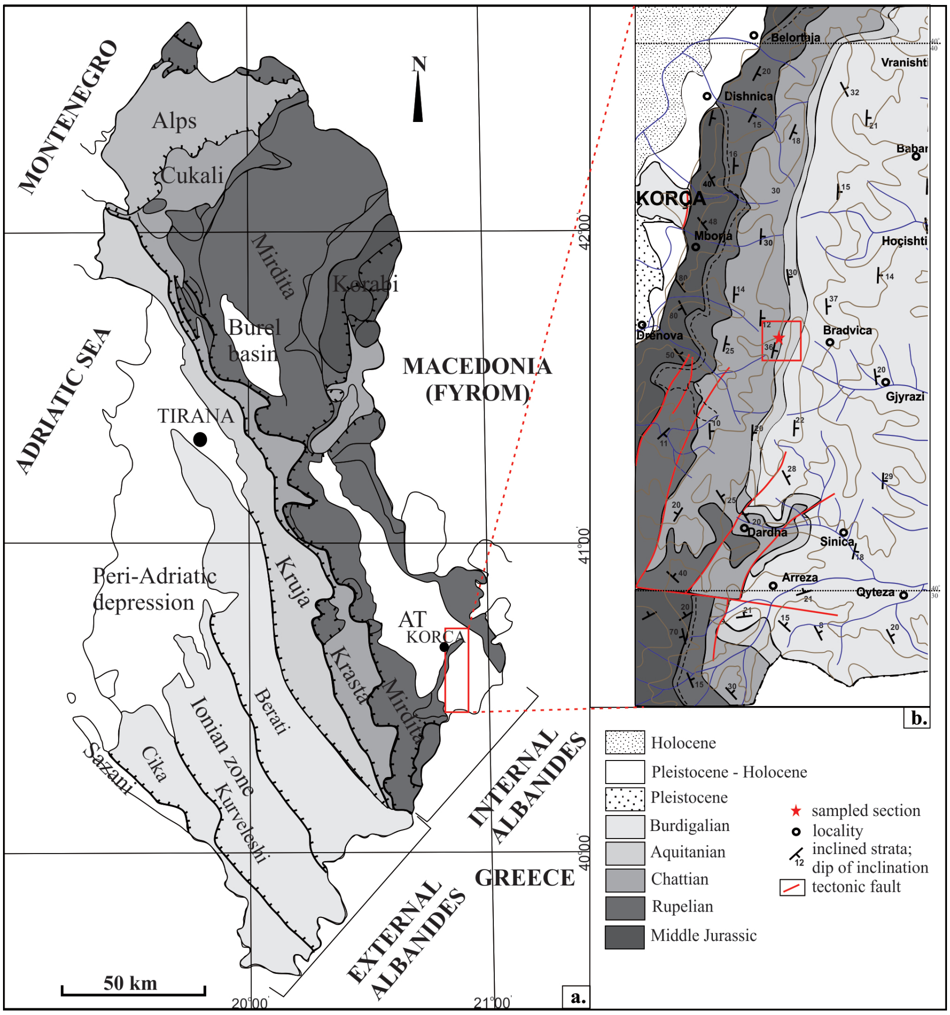

Fig. 1. *a) Tectonic map of Albanides; b) Geological map of the studied area 1:200000 (after Xhomo et al., 2002, modified).*

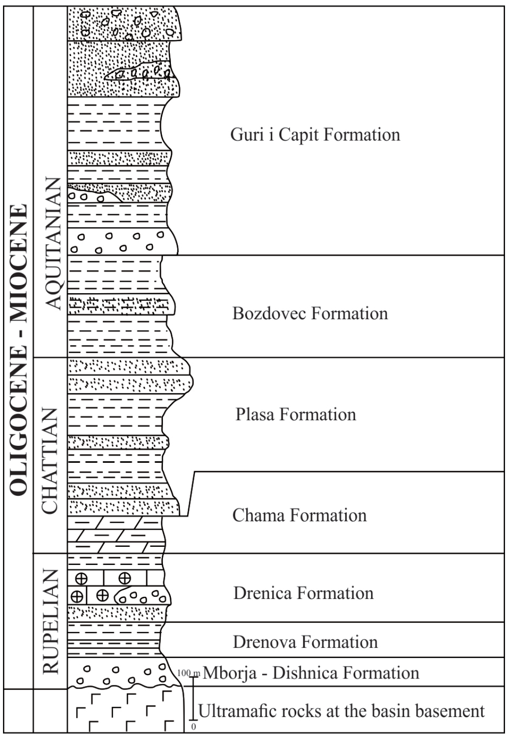

Fig. 2. *a) Stratigraphical section of the Middle Oligocene - Lower Miocene mollase in Morava Mountain, Albanian-Thessalian intramontane basin (after Pashko, 1996, modified).*

Chama Formation composed by carbonatic clays, marlstones and less siltstones with rich foraminifera and mollusks assemblages, followed by the Plasa Formation, represented by massive sandstones with plants, foraminifera and mollusks (Pashko, 1977; Kumati et al. 1997) etc. The Bozdovec Formation consists of marlstones, siltstones and sandstones strata alternations containing rich foraminifera and mollusks assemblages, and represents the base of the Aquitanian stage, which was constrained mainly using macrofauna content (Pashko, 1996).

MATERIAL AND METHODS

The studied outcrop is located in the eastern part of the Korça Basin (N40°34'48.374", E020°50'9.659") and lithologically comprises a continuous marly succession, alternating in the middle-upper part with marly siltstones and fine to medium grained sandstone layers.

A number of 103 samples were collected from marlstones and calcareous siltstones (Fig. 3), at a sampling distance of 0.50-1 m. For all samples, smear slides were prepared according to standard smear slide technique (Bown and Young, 1998). Quantitative analyses were performed on 73 samples, by counting at least 300 specimens per sample, and semi-quantitative analyses were performed on 29 samples, by counting at least 100 specimens per sample. On one sample only qualitative observations were possible due to low number of the encountered nannofossils.

The nannofossil abundance was assessed as follows: C - common (>10 specimens / FOV - field of view), F - few (1-10 specimens / FOV), R - rare (1-10 specimens /10 FOV); VR - very rare (when 1 specimen is present in more than 10 FOV). Additionally, 100 FOV were checked for rare taxa. The preservation was noted with: M - moderate and P - poor.

The software package PAST (PAleontological STatistics) was used for statistics interpretation (Hammer et al., 2001). Multivariate Cluster Analysis by Ward's method was used to group the samples into clusters, while the Principal Components Analysis (PCA) shows the grouping of samples into clusters according to environment variables and species environmental demands. The zonation scheme used in this study is that of Martini (1971), based on FO - First Occurrence and LO - Last Occurrence of index species.

Photographs were captured with a Canon Powershot A630 digital camera, under cross-polarized light (XPL) and parallel light (BF).

RESULTS

The examined material contains moderately to poorly preserved, diverse calcareous nannofossil assemblages, which are generally represented in order of abundance by: *Reticulofenestra minuta*, *Cyclicargolithus floridanus*, *Coccolithus pelagicus*, *Reticulofenestra* sp. (size 3-4.5 μm), *Sphenolithus moriformis*, *Reticulofenestra scrippsae*, *Sphenolithus ciperoensis*, *Cyclicargolithus abisectus*, *Reticulofenestra* cf. *minutula*, *Reticulofenestra bisecta*, *Sphenolithus conicus*, *Reticulofenestra dictyoda*, *Sphenolithus dissimilis, Helicosphaera euphratis, Discoaster deflandrei, Clausicoccus fenestratus*, *Zygrhablithus bijugatus, Clausicoccus subdistichus*, *Coccolithus miopelagicus*.

A total number of 127 calcareous nannofossil species was identified, from which 60 species are autochthonous, 44 are interpreted as reworked from lower stages of Paleogene – Early Oligocene and 23 species are reworked from Cretaceous deposits. The reworked taxa are diverse, but their abundance is very low. The total number of species and the number of counted specimens is given in Appendix 1.

The *Reticulofenestra* genus (Pl. I, Figs. 6, 13, 16-17, 19, 20-21, 26, 32a) is the most abundant in the investigated material. The most common species are: *Reticulofenestra minuta*, *Cycligargolithus floridanus*, *Reticulofenestra* sp. (small reticulofenestrids 3-4.5μm, with closed central area), *R. scrippsae*, *R.* cf. *minutula*, *R. bisecta*, *Cycligargolithus abisectus* (in sizes <10μm and >10μm), *R. dictyoda* etc.

From the Coccolithaceae family (Pl. I, Figs. 9-12, 18), the most abundant species is *Coccolithus pelagicus*, followed by *Clausicoccus* spp. (*Clausicoccus fenestratus* and *C. subdistichus*). Rare and irregularly distribution have *Coccolithus miopelagicus*, *C. eopelagicus* and *Hughesius tasmaniae*.

The *Sphenolithus* genus (Pl. I, Figs. 8a, 22, 23-24, 27-28, 33-34, 35-36) reach amounts up to 20% in some samples, being represented by species like: *Sphenolithus moriformis*, *S. ciperoensis*, *S. conicus*, *S. dissimilis*, *S.* cf. *delphix*, *S.* cf. *calyculus* and *Sphenolithus* sp. The marker species *S. ciperoensis* is well established and present through the entire profile.

The *Helicosphaera* genus (Pl. I, Figs. 1, 2, 3-4, 5, 32b) is rare, but continuous and the most common species are: *Helicosphaera euphratis*, *H. obliqua*, *H. recta*, *H. intermedia*, *H. perch-nielseniae*, *H. bramlettei*, *H.* cf. *carteri* etc.

Discoaster spp. (*Discoaster deflandrei* and *Discoaster* sp.) and the species *Zyghrablithus bijugatus* (subsp. *bijugatus*) have rare, but more or less continuous occurrence. The forms with tall spines (>12 μm) were assigned to *Z. bijugatus* subsp. *maximus*.

From the Pontosphaeraceae family, the most common species are: *Pontosphaera multipora*, *Pontosphaera* sp. and *Pontosphaera* cf. *enormis*, the last one appearing in 26 samples.

Very rare is *Triquetrorhabdulus carinatus* **(**Pl. I, Figs. 14-15), which appears in only 11 samples and *Thoracosphaera* spp. *Ilselithina fusa* is also very rare, but present in 11 samples.

The most common reworked species are: *Toweius rotundus*, *Toweius selandianus*, *Prinsius bisulcus*, *Prinsius dimorphosus*, *Prinsius martinii*, *Coccolithus bownii*, *Coccolithus foraminis*, *Chiasmolithus* spp., *Ericsonia* spp., *Watznaueria barnesiae*, *Micula staurophora*, *Microrhabdulus* sp., *Quadrum* sp. etc.

The abundance patterns of some mentioned species and taxonomical groups can be observed in figure 4.

Biostratigraphy

Biostratigraphically, the studied material ranges up to the late Chattian - *Sphenolithus ciperoensis* Zone (NP25) of Martini (1971). The attribution to NP25 is supported also by the absence of the marker species *Sphenolithus distentus* (with LO in top of NP24 *Sphenolithus distentus* Zone of Martini, 1971).

In terms of the Mediterranean Zonation, according to Fornaciari and Rio (1996), the studied interval would fall within MNP25a - *Sphenolithus ciperoensis* Zone, defined

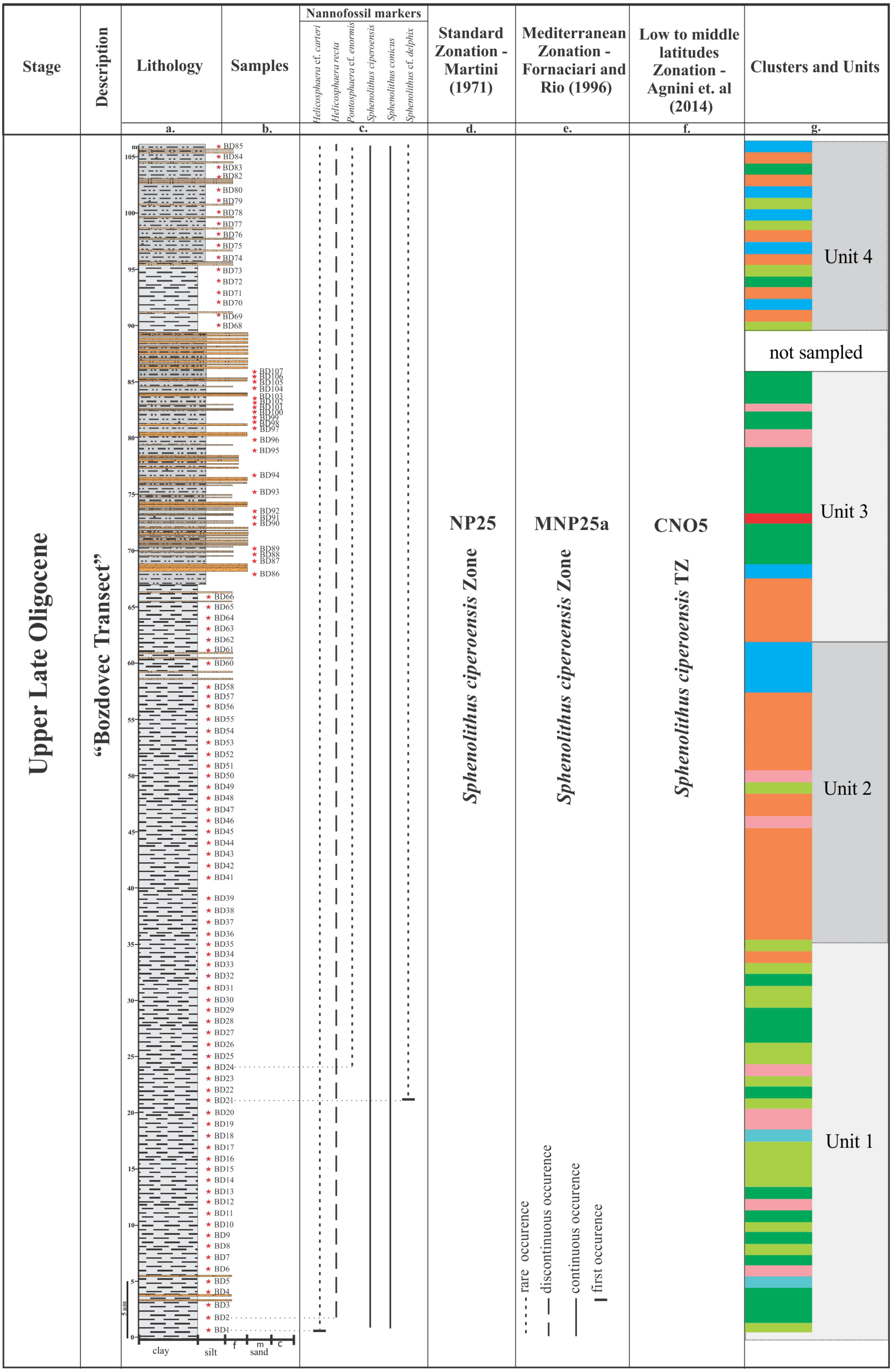

Fig. 3. *a - Lithology of the "Bozdovec Transect"; b) Samples position; c) Calcareous Nannofossil markers; d) Calcareous nannofossils standard zonation after Martini (1971); e) Mediteranean zonation after Fornaciari and Rio (1996); f) Low to middle latitude zonation after Agnini et al. (2014); g) Correlation of clusters and units separated based on nannofossils composition, plotted along the transect (in m).*

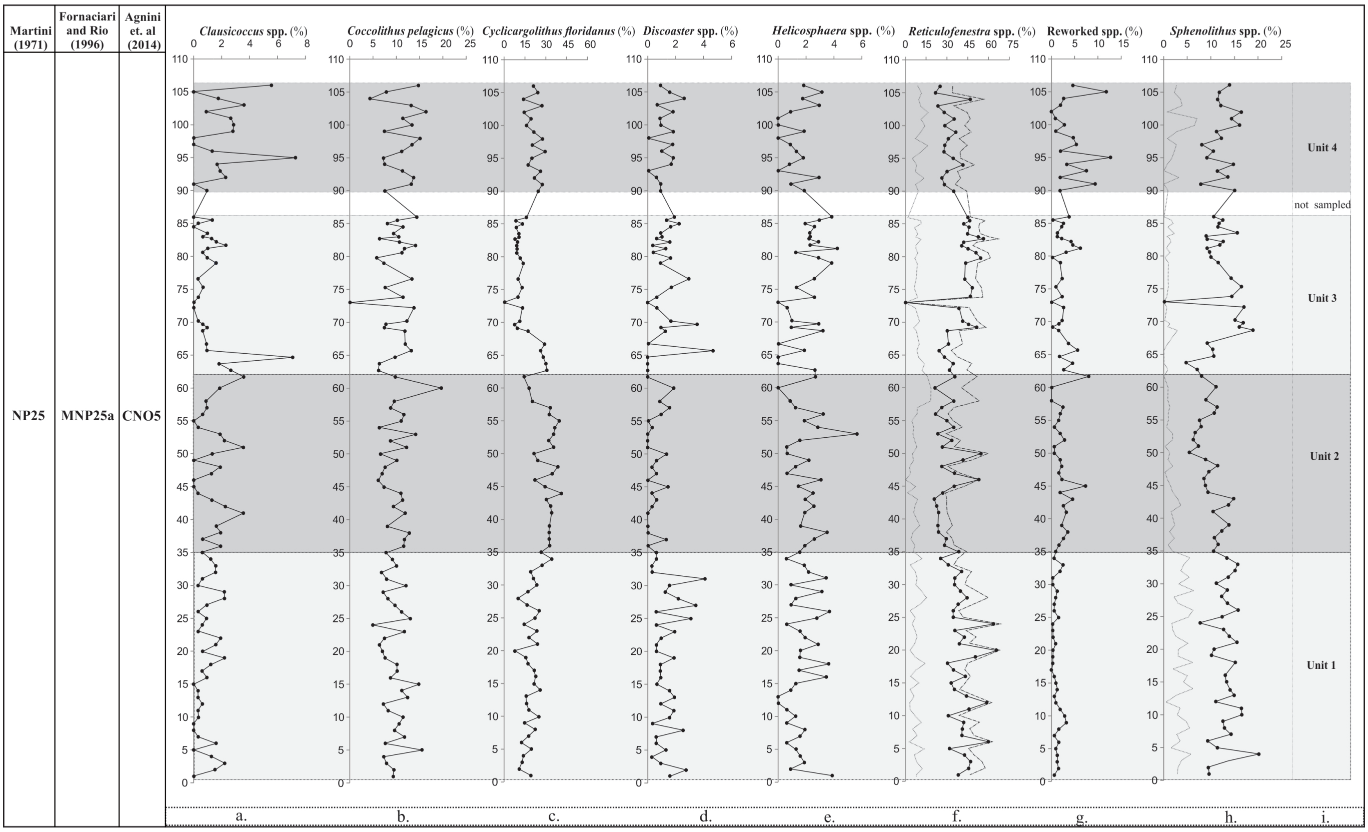

Fig. 4. *Abundance patterns (•–•) of the most important species and taxonomical groups plotted along the standard zonations of Martini (1971), Fornaciari and Rio (1996), Agnini et al. (2014) and along the sampling interval (in m): a.* Clausicoccus *spp.; b.* Coccolithus pelagicus*; c.* Cyclicargolithus floridanus*; d.* Discoaster *spp.; e.* Helicosphaera *spp.; f.* Reticulofenestra *spp. all (–•–) vs.* Reticulofenestra *small gr. and* Reticulofenestra *spp. (size >5) (·····); g. Reworked spp.; h.* Sphenolithus *spp. vs.* Sphenolithus ciperoensis *(·····); i. Units (see description in text).*

by the LO of *Sphenolithus distentus* at the base and LO of *Sphenolithus ciperoensis* at the top. The continuous presence of the marker species *Sphenolithus ciperoensis* in the transect, allowed correlation also with the CNO5 *Sphenolithus ciperoensis* TZ (Top Zone) of Agnini et al. (2014), defined by the Top of *Sphenolithus predistentus* at the base and Top of *Sphenolithus ciperoensis* at the top.

Paleoecology and Multivariate Statistics

The following species and taxonomical groups were considered for paleoecological interpretation and statistics: *Reticulofenestra* small group, *Cycligargolithus floridanus, Coccolithus pelagicus*, *Sphenolithus* spp., *Helicosphaera* spp. and *Reticulofenestra* spp. (> 5 µm).

Reticulofenestrids are the most abundant in the investigated material, reaching amounts up to 70 % in some samples. They were separated into two groups based on the coccolith size: the small reticulofenestrids group (size < 4.5 µm) and the *Reticulofenestra* spp. group (medium to very large sized specimens > 5 µm). The small reticulofenestrids group occurs continuously and in high amounts through the whole profile and includes *Reticulofenestra minuta*, *Reticulofenestra* sp. (small species 3-4.5 µm, with closed central area) and *Reticulofenestra* cf. *minutula*.

Cyclicargolithus floridanus is a major component of the assemblages, with an average participation of 21% from total (values in samples between 8% and 41%).

Coccolithus pelagicus appears continuously in the investigated material and represents about 10% of the total calcareous nannofossil assemblage (with values from 5% to 20%).

Sphenoliths are a major component of the assemblage (12% of the total), being continuously present through the whole section.

Helicoliths are species associated to surface waters and near-shore environments (Bukry et al., 1971; Krhovský et al., 1992) and, according to Perch-Nielsen (1985), are common in upwelling conditions. They are rare, but more or less continuously present and represent 2% of total nannofossil assemblage.

Pontosphaera genus is rare and has discontinuous appearance. In general, this genus is associated with shallow marine environments and decreased salinity (Krhovský et al., 1992; Nagymarosy and Voroniná, 1992).

Discoaster genus is very rare and reaches amounts up to 4%. It is confined to deep marine, oligotrophic environments, with warm waters and more stable conditions (Lohman and Carlson, 1981; Aubry, 1992; Young, 1998).

In summary, the nannofossil assemblages indicate predominantly shallow, nearshore marine environments, relatively stable, and minor eutrophic to oligotrophic changes.

Multivariate Hierarchical Clustering as shown in figure 5 and Principal Components Analysis (Fig. 6) grouped the samples according to their composition similarities. Five clusters were identified as follows:

- Cluster 1 - comprises 11 samples with highest content of *Reticulofenestra* small gr. (50 to 65%), followed by *Cyclicargolithus. floridanus* (7 to 22 %) and less *Coccolithus pelagicus* (up to 11%).

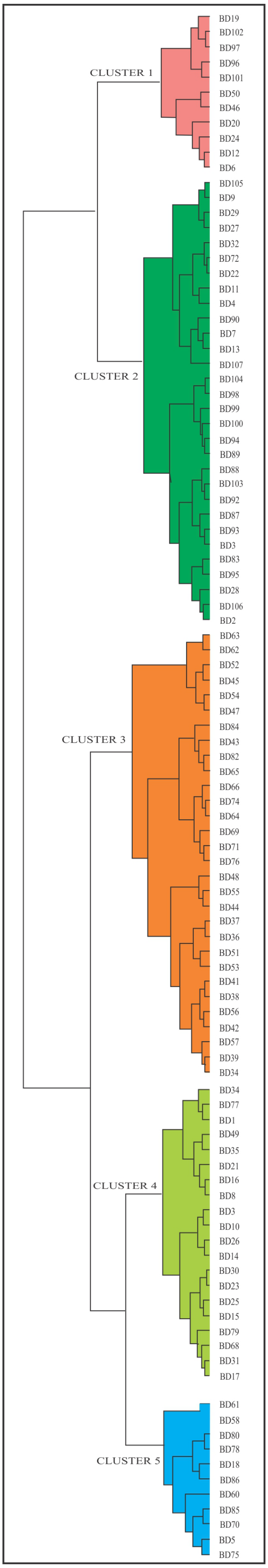

Fig. 5. *Multivariate Clustering by Ward's Method.*

• Cluster 2 - comprises 29 samples with high amount of *Reticulofenestra* small gr. (38 to 51%), followed by *Sphenolithus* spp. (9 to 20%), less *Cyclicargolithus floridanus* (8 to 19%) and *Coccolithus pelagicus* (4 to 14%).

• Cluster 3 - has 30 samples characterized by highest amount of *Cyclicargolithus floridanus* (30 to 41%), followed by *Reticulofenestra* small gr. (up to 35%), *Coccolithus pelagicus* (up to 14%), *Sphenolithus* spp. (up to 15%).

• Cluster 4 - has 21 samples with high amount of *Reticulofenestra* small gr. (31 to 43%), *Cy. floridanus* (19 to 27%), *Sphenolithus* spp. (9 to 17%), *C. pelagicus* (6 to 15%).

• Cluster 5 - has 11 samples with high amount of *Reticulofenestra* small gr. (up to 35%), *Cy. floridanus* (up to 22%), highest amount of *C. pelagicus* (10 to 19%) and *Reticulofenestra* spp. (>5µm) (8 to 19%), *Sphenolithus* spp. (8 to 19%).

DISCUSSIONS

Biostratigraphy

A special discussion will focus on the *Sphenolithus* genus, due to its biostratigraphical importance for the subdivision of the upper Early to Late Oligocene interval, based on presence/absence of *Sphenolithus predistentus*, *S. distentus* and *S. ciperoensis* lineage, according to the Martini (1971) zonation.

The *Sphenolithus ciperoensis* Zone of Martini (1971) was previously described from Upper Oligocene deposits from other sections in the Albanian-Thessalian intramontane basin (Kumati et. al., 1997), also in other areas in Albania (Vathi, 1998). The continuous presence of *S. ciperoensis* (Pl. I, Figs. 23-24), index species, and the presence of other sphenoliths like *Sphenolithus conicus*, *S. dissimilis*, *S. calyculus*, all with FO at the base of NP25, are supporting our attribution to this zone. The nannofossil zone NP24 was not found in this section.

In 19 samples the rare appearances of the important marker species *Sphenolithus* cf. *delphix* (Pl. I, Figs. 27-28, 33-34) is noticed, which raise a question mark regarding the presence of the *Sphenolithus delphix* Subzone MNN1b of Fornaciari and Rio (1996), described from the Mediterranean Zonation. First appearance of *Sphenolithus* cf. *delphix* is noticed at 21m, in sample BD21.

The synchronicity of the nannofossil events present below and above the Oligocene/Miocene boundary are formally described from Lemme-Carrosio Section in Northern Italy, were the FO of *Sphenolithus delphix* is placed within NP25 Zone, being continued upwards with FO and LO of *Sphenolithus capricornutus* and LO of *Sphenolithus delphix*. Correlation of these events was done with the ODP Site 522 from the South Atlantic Ocean (Raffi, 1999; Shackleton et al., 2000). *Sphenolithus delphix* and *S. capricornutus* are reported to be distributed from the Late Oligocene to the Early Miocene (Perch-Nielsen, 1985). The LO of *Sphenolithus delphix* is considered by Aubry and Villa (1996), as being the only event that marks the Oligocene/Miocene boundary. Despite the presence of *S.* cf. *delphix*, the boundary position in this outcrop cannot be assigned, due mainly to the absence of *Sphenolithus capricornutus*.

Sphenolithus conicus (Pl. I, Figs. 35-36) is present in the studied samples, from the first sample (BD1), and has a continuous distribution. Perch-Nielsen (1985) reports this

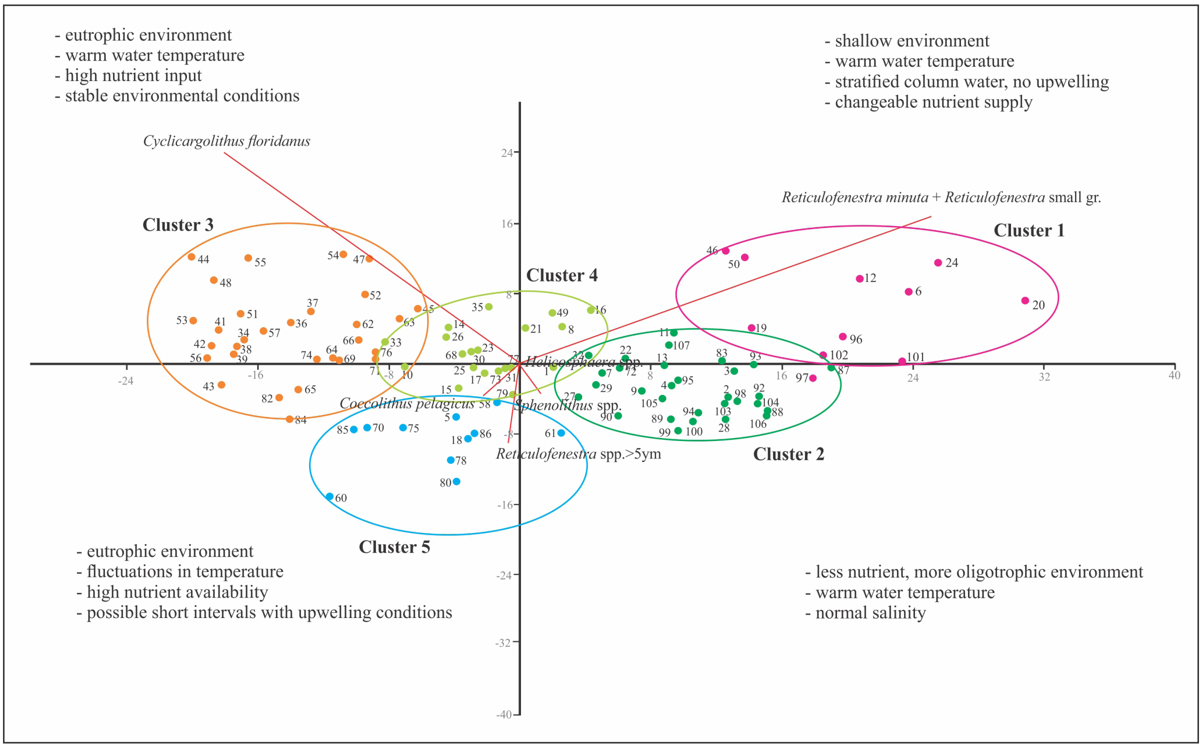

Fig. 6. *Principal Components Analysis showing the clusters distribution according to environmental variables (Davis, 1986; Harper, 1999).*

species from the Early Miocene NN1-NN3 Zones. In the Western Equatorial Indian Ocean, Fornaciari et al. (1990) recorded *S. conicus* from CN1-CN2 Zones of Okada and Bukry (1980).

During the past decades several nannofossil events (*e.g.* LO of *Sphenolithus ciperoensis*, LO of *Helicosphaera recta*, LO of *Zygrhablithus bijugatus*, LO of *Reticulofenestra bisectus*) were used by different authors (Martini, 1971; Martini and Müller, 1975; Müller, 1976; Okada and Bukry, 1980; Berggren et al., 1995; Fornaciari and Rio, 1996), to define the Oligocene/Miocene boundary, but not all proved to be reliable.

The LO of *Helicosphaera recta* (Pl. I, Figs. 3-4) proved not to be a reliable marker for the Oligocene/Miocene boundary, its range going up to base of NN2 - *Discoater drugii* Zone of Martini (1971) in some areas. Investigations from the Indian Ocean, by Bizon and Müller (1979), found the LO of *Clausicoccus fenestratus* (Pl. I, Fig. 10) to be together with the LO of *Sphenolithus ciperoensis*, *Dictyococcites bisectus* and *H. recta*, near the Oligocene/Miocene boundary.

Some authors (Martini and Müller, 1975; Müller, 1976) proposed the LO of *Zygrhablithus bijugatus* (Pl. I, Figs. 6, 8b) to approximate the top of NP25 and thus, the Oligocene/Miocene boundary in nearshore environments. This species is not common in deep-marine sediments and its abundance decreases with increasing of water depth.

Rare and discontinuous presence *of Helicosphaera* cf. *carteri* is recorded in only 9 samples. Vathi (1998) uses the presence of *H. carteri* to establish the Oligocene/Miocene boundary in other regions in Albania (Ionian Zone). His investigations mention this species as being present in the *Sphenolithus predistentus* and *S. distentus* zones of Martini (1971), missing in *S. ciperoensis* Zone and reappearing in the Early Miocene within his *Helicosphaera carteri* Zone.

Our data are in agreement with those of Holcová (2005), who report the FAD of *Helicosphaera carteri* within NP25 Zone, from material collected from several boreholes from the northern part of Buda Basin (South Slovak Depression, Central Paratethys). Other authors describe the presence of *H. carteri* from NN1-NN2 biozones (Perch-Nielsen, 1985; Mărunţeanu, 1992; Krhovský et al., 1995; Aubry and Villa, 1996).

Other important species is *Pontosphaera* cf. *enormis* (Pl. I, Fig. 25), which appears in 26 samples and which was used to define the base of NP25 in areas with poor sea way connection (Martini, 1981).

Paleoecology and Multivariate Statistics

Regarding the paleoecology, as a general trend, the presence in high amounts of *Reticulofenestra minuta,* a species usually abundant along continental margins (Haq, 1980), would suggest stable marine conditions, with warm, well stratified water column. Gartner et al. (1983) suggest that the changes in *R. minuta* abundance are connected with nutrient availability, while according to Kameo (2002) the *Reticulofenestra* spp. small are eutrophic species. According to Wade and Bown (2006), *R. minuta* can adapt to a wide range of salinities, from normal to hypersaline environments.

Holcová (2005), reports from the upper NP25 from the northern part of Buda Basin, an acme event of small reticulofenestrids, considered to be an ecostratigraphical event.

Abundant small reticulofenestrids (*R. minuta)* were documented from Lower - Middle Miocene of the Central Paratethys by Ćorić and Rögl (2004), Tomanová Petrová and Švábenická (2006), Ćorić and Hohennegger (2008) etc. Ćorić and Rögl (2004) suggest that they are abundant in warm waters without upwelling conditions.

Krhovský et al. (1992) suggest that *Cyclicargolithus floridanus* and *Cyclicargolithus abisectus*, are more frequent in near-shore environments. According to Shcherbinina (2010) *Cyclicargolithus floridanus* and *Reticulofenestra* are eurytopic genera, which adapt to a wide range of environmental conditions. *Cyclicargolithus floridanus* is considered a species which prefers eutrophic conditions (Aubry, 1992; Krhovský et al., 1992; Villa et al., 2008).

Coccolithus pelagicus is a cold water species, abundant between -1.5°C to +15°C (Okada and MacIntyre, 1979; Winter et al., 1994), and more common in eutrophic environments, surface waters with high nutrient input and upwelling areas (Rahman and Roth, 1990).

Regarding the paleoecology of *Sphenolithus* genus which is quite abundant in the investigated material, it is considered by Perch-Nielsen (1985) to be common in warm, shallow waters and oligotrophic environments.

Based on nannofossils quantitative analyses and the ecological preferences of the most abundant species, the palaeoenvironmental evolution of the investigated outcrop was distinguished. The five clusters identified by the means of statistical methods and their distribution along the transect, are given below. According to cluster analyses, four units divide the transect from base to the top as follows (Fig. 4):

Unit 1 - Comprises the interval from 0 to 35m, being occupied by samples belonging to Clusters 2 and 4. These clusters suggest relatively stable paleoenvironmental conditions, due to the presence of high amounts of small reticulofenestrids and *Cyclicargolithus floridanus*, with fluctuations in nutrient input as shown by Cluster 2 (with higher amounts of sphenoliths, meaning less nutrient input and less eutrophic environment) and Cluster 4 (high nutrient input and well established eutrophic conditions). Six samples of Cluster 1 show similar trends, except the two samples of Cluster 5, at 5m and 18 m, which suggest a slight deviation from these conditions, maybe some short temperature decrease.

Unit 2 - The interval from 35 to 62 m is dominated by Cluster 3, characterized by highest amount of *Cyclicargolithus floridanus* and high percentages of small reticulofenestrids. High percentages of *Cy. floridanus* point to the stable conditions without changes in the nutrient supply.

Unit 3 - The interval from 62 to 85 m, dominated by samples belonging to Cluster 2, is characterized by high percentages of small reticulofenestrids, sphenoliths and less *Cy. floridanus* and represents the transition interval from the stable conditions of Unit 2 to the unstable environment of Unit 4. Lower percentages of *Cy. floridanus* point to changes in the nutrient supply.

Unit 4 - The interval from 89 to 106 m is characterized by equal presence of all clusters, suggesting the most unstable environmental conditions. In this part a decrease in nannofloral abundance is noticed, but no sign of changed salinity. The diversity remains the same. This can be the result of changing of sedimentation conditions within the basin, due to upwelling regime, dynamics in nutrient supply. These changes are probably caused by regression events and reflect also changes in lithology.

Based on species abundance patterns, their palaeoecological demands, statistical distribution along the studied outcrop, the recorded shifts in species abundance between the clusters, the general conclusion is that during the deposition of these deposits, a warm stable marine environment was present, sometimes more eutrophic conditions, high nutrient availability (higher amounts of *Cyclicargolithus floridanus*), shallow, well stratified column water (small reticulofenestrids). Although, short periods of decreased temperature (highest % of *Coccolithus pelagicus*), fluctuations in nutrient availability and less eutrophic environment (higher content of *Sphenolithus* spp. which prefers more oligotrophic conditions) can be documented at some levels along the profile and more in last described unit.

CONCLUSIONS

First time, statistics based on calcareous nannofossils in this part of Albanian-Thessalian intramontane basin was applied.

Biostratigraphically, correlation of the investigated outcrop to the standard nannofossil Zone NP25, to the Mediterranean Zone MNP25a and to the new zonation for low to middle latitudes, was possible, and it is based on to the absence of species *Sphenolithus distentus* and continuous presence of index species *Sphenolithus ciperoensis*. The biostratigraphical events identified in NP25 - *Sphenolithus ciperoensis* Zone are: FO of *Sphenolithus* cf. *delphix* and FO of *Helicosphaera* cf. *carteri*.

Paleoenvironmental reconstruction of the "Bozdovec Transect" (Albanian-Thessalian intramontane basin) was done based on quantitative and semi-quantitative analyses of the selected nannofossils taxa and groups. High amounts of small reticulofenesdrids and of *Sphenolithus* genus were recorded, suggesting similar paleoconditions with other areas of the Central Paratethys domain.

No changes in calcareous nannofossils diversity were observed, only decrease in abundance in the upper part of the profile.

The calcareous nannofossils suggest warm, shallow and relatively stable marine conditions, going along with the general warm climate trend which dominated the upper part of the Late Oligocene - Early Miocene in Mediteranean and Central Paratethys domains.

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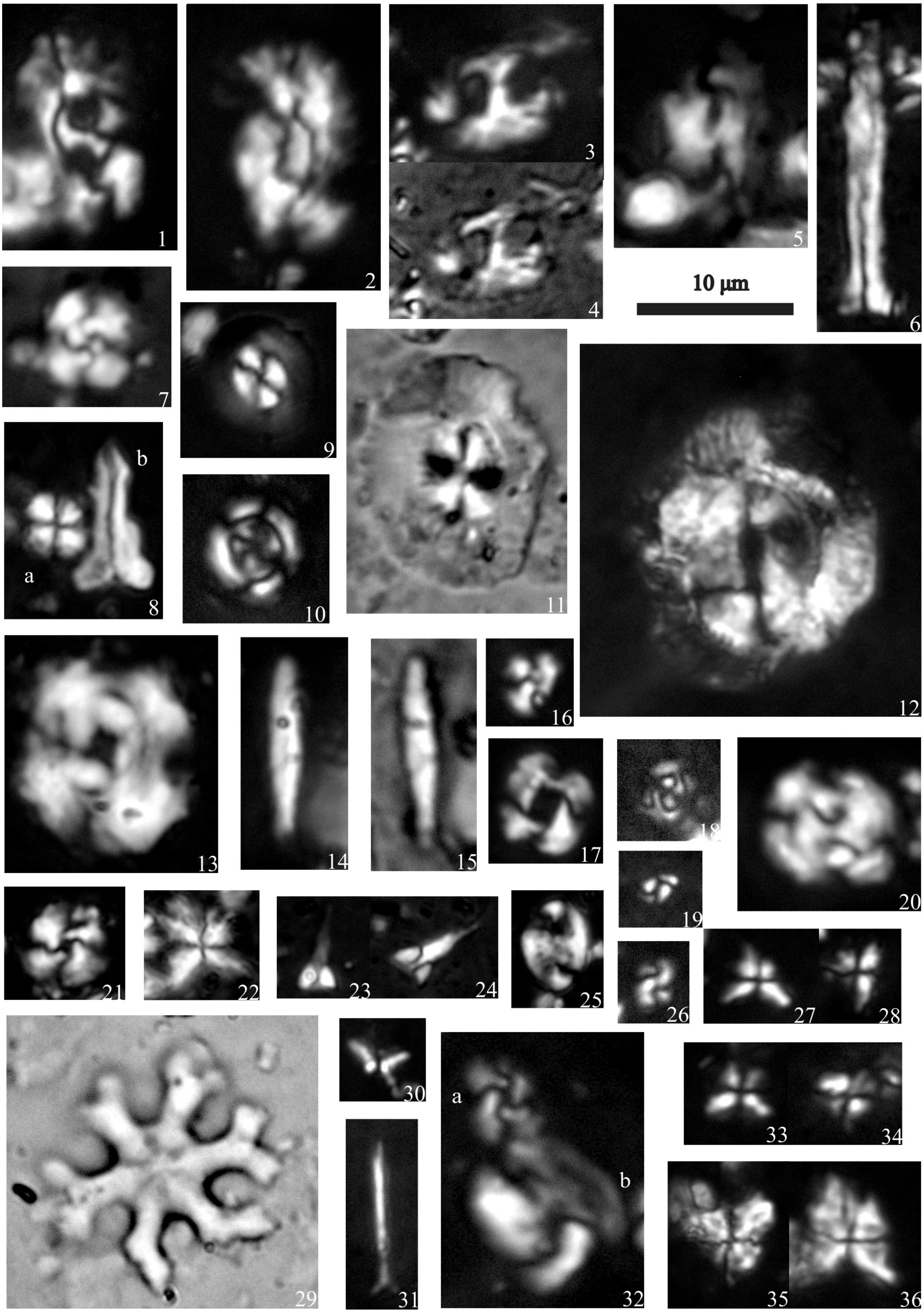
PLATE I. Calcareous nannofossils from “Bozdovec Transect” (Albania). Scale bar is 10µm. XPL - cross-polarized light, BF - bright field.

Fig. 1. - *Helicosphaera bramlettei* (Müller, 1970) Jafar and Martini, 1975 (Sample BD62, XPL);
Fig. 2. - *Helicosphaera intermedia* Martini, 1965 (Sample BD54, XPL);
Figs. 3-4. - *Helicosphaera recta* (Haq, 1966) Jafar and Martini, 1975 (Sample BD32, XPL and BF);
Fig. 5. - *Helicosphaera obliqua* Bramlette and Wilcoxon, 1967 (Sample BD105, XPL);
Fig. 6. - *Zygrhablithus bijugatus maximus* Bown, 2010 (Sample BD96, XPL);
Fig. 7. - *Reticulofenestra scrippsae* Bukry and Percival, 1971 (Sample BD86, XPL);
Fig. 8. - a) *Sphenolithus moriformis* (Bronnimann and Stradner, 1960) Bramlette and Wilcoxon, 1967; b) *Zygrhablithus bijugatus* (Deflandre *in* Deflandre and Fert, 1954) Deflandre, 1959 (Sample BD95, XPL);
Fig. 9. - *Coccolithus pelagicus* (Wallich 1877) Schiller, 1930 (Sample BD95, XPL);
Fig. 10. - *Clausicoccus fenestratus* (Deflandre and Fert, 1954) Prins, 1979 (Sample BD28, XPL);
Fig. 11. - *Coccolithus miopelagicus* Bukry, 1971 (Sample BD70, BF);
Fig. 12. - *Coccolithus eopelagicus* (Bramlette and Riedel, 1954) Bramlette and Sullivan, 1961 (Sample BD23, XPL);
Fig. 13. - *Cyclicargolithus abisectus* Muller, 1970 (Sample BD89, XPL);
Figs. 14-15. - *Triquetrorhabdulus carinatus* Martini, 1965 (Sample BD68, XPL and BF);
Fig. 16. - *Reticulofenestra* sp. small (Sample BD68, XPL);
Fig. 17. - *Reticulofenestra dictyoda* (Deflandre *in* Deflandre and Fert, 1954) Stradner *in* Stradner and Edwards, 1968 (Sample BD63, XPL);
Fig. 18. - *Hughesius tasmaniae* (Edwards and Perch-Nielsen, 1975) de Kaenel and Villa, 1996 (Sample BD44, XPL);
Fig. 19. - *Reticulofenestra minuta* Roth, 1970 (Sample BD52, XPL);
Fig. 20. - *Reticulofenestra bisecta* Hay, Mohler and Wade, 1966 (Sample BD23, XPL);
Fig. 21. - *Cyclicargolithus floridanus* Roth and Hay, *in* Hay et al., 1967 (Sample BD96, XPL);
Fig. 22. - *Sphenolithus moriformis* (Bronnimann and Stradner, 1960) Bramlette and Wilcoxon, 1967;
Figs. 23-24. - *Sphenolithus ciperoensis* Bramlette and Wilcoxon, 1967 (Sample BD9, 0˚- 45˚ XPL);
Fig. 25. - *Pontosphaera* cf. *enormis* (Locker, 1967) Perch-Nielsen, 1984 (Sample BD95, XPL);
Fig. 26. - *Reticulofenestra* sp. small (Sample BD61, XPL);
Figs. 27-28. - *Sphenolithus* cf. *delphix* Bukry 1973 (Sample BD64, 0˚- 45˚ XPL);
Fig. 29. - *Discoaster deflandrei* Bramlette and Riedel, 1954 (Sample BD86, BF);
Fig. 30. - *Ilselithina fusa* Roth, 1970 (Sample BD19, XPL);
Fig. 31. - *Rhabdosphaera* sp. (Sample BD65, XPL);
Fig. 32. - a) *Cyclicargolithus floridanus* Roth and Hay, *in* Hay et al., 1967; b) *Helicosphaera perch-nielseniae* (Haq, 1971) Jafar and Martini, 1975 (Sample BD26, XPL);
Figs. 33-34. - *Sphenolithus* cf. *delphix* Bukry 1973 (Sample BD32, 0˚ - 45˚XPL);
Figs. 35-36. - *Sphenolithus conicus* Bukry, 1971 (Sample BD48, 0˚- 45˚ XPL);

PLATE I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Appendix 1. *List of species present in "Bozdovec Transect" (Albanian-Thessalian intramontane basin) arranged in alphabetical order: a) autochthonous calcareous nannofossils; b) reworked calcareous nannofossils from Paleogene - Early Oligocene; c) reworked calcareous nannofossils from Cretaceous.*

	Number of specimens / specie
a. Autochtonous calcareous nannofossils	
Braarudosphaera bigelowii (Gran and Braarud, 1935) Deflandre, 1947	6
Calcidiscus sp. Kamptner, 1950	61
Clausicoccus fenestratus (Deflandre and Fert, 1954) Prins, 1979	183
Clausicoccus subdistichus (Roth and Hay *in* Hay et al., 1967) Prins, 1979	110
Clausicoccus sp. Prins, 1979	7
Coccolithus eopelagicus (Bramlette and Riedel, 1954) Bramlette and Sullivan, 1961	23
Coccolithus miopelagicus Bukry, 1971	83
Coccolithus pelagicus (Wallich 1877) Schiller, 1930	2606
Coronocyclus nitescens (Kamptner, 1963) Bramlette and Wilcoxon, 1967	15
Coronocyclus sp. Hay, Mohler and Wade, 1966	2
Coronosphaera sp. Gaarder *in* Gaarder & Heimdal, 1977	24
Cyclicargolithus abisectus (Muller, 1970) Wise, 1973	539
Cyclicargolithus floridanus (Roth and Hay, *in* Hay et al., 1967) Bukry, 1971	5481
Discoaster adamanteus Bramlette and Wilcoxon, 1967	11
Discoaster barbadiensis Tan, 1927	10
Discoaster deflandrei Bramlette and Riedel, 1954	187
Discoaster sp. Tan, 1927b	84
Helicosphaera carteri (Wallich 1877) Kamptner, 1954	12
Helicosphaera euphratis Haq, 1966	198
Helicosphaera intermedia Martini, 1965	88
Helicosphaera obliqua Bramlette and Wilcoxon, 1967	58
Helicosphaera perch-nielseniae (Haq, 1971) Jafar and Martini, 1975	53
Helicosphaera recta (Haq, 1966) Jafar and Martini, 1975	71
Helicosphaera sp. Kamptner, 1954	19
Hughesius tasmaniae (Edwards and Perch-Nielsen, 1975) de Kaenel and Villa, 1996	36
Ilselithina fusa Roth, 1970	15
Micrantholithus sp. Deflandre in Deflandre and Fert, 1954	1
Pontosphaera cf. *enormis* (Locker, 1967) Perch-Nielsen, 1984	31
Pontosphaera multipora (Kamptner, 1948 ex Deflandre *in* Deflandre and Fert, 1954) Roth, 1970	45
Pontosphaera sp. Lohmann, 1902	16
Pyrocyclus orangensis (Bukry, 1971) Backman, 1980	12
Rhabdosphaera sp. Haeckel, 1894	5
Reticulofenestra bisecta (Hay, Mohler and Wade, 1966) Roth, 1970	413
Reticulofenestra daviesii (Haq, 1968) Haq, 1971	31
Reticulofenestra dictyoda (Deflandre *in* Deflandre and Fert, 1954) Stradner *in* Stradner and Edwards, 1968	217
Reticulofenestra lockeri Müller, 1970	20
Reticulofenestra minuta Roth, 1970	7074
Reticulofenestra cf. *minutula* (Gartner, 1967) Haq and Berggren, 1978	438
Reticulofenestra scrippsae Bukry and Percival, 1971	1357
Reticulofenestra stavensis (Levin and Joerger, 1967) Varol, 1989	65
Reticulofenestra sp. 3-4.5 µm Hay, Mohler and Wade, 1966	2528
Scyphosphaera sp. Lohmann, 1902	1
Sphenolithus cf. *calyculus* Bukry, 1985	44
Sphenolithus ciperoensis Bramlette and Wilcoxon, 1967	639
Sphenolithus conicus Bukry, 1971	416
Sphenolithus cf. *delphix* Bukry 1973	19

Appendix 1 (continued)

Sphenolithus dissimilis Bukry and Percival, 1971	201
Sphenolithus moriformis (Bronnimann and Stradner, 1960) Bramlette and Wilcoxon, 1967	1722
Sphenolithus sp. Deflandre *in* Grassé, 1952	156
Syracosphaera sp. Lohmann, 1902	26
Thoracosphaera heimii (Lohmann 1920) Kamptner 1944	28
Thoracosphaera sp. Kamptner, 1927	10
Triquetrorhabdulus carinatus Martini, 1965	13
Triquetrorhabdulus sp. Martini, 1965	4
Umbilicosphaera detecta (de Kaenel and Villa, 1996) Young and Bown 2014	1
Umbilicosphaera edgariae (Bown and Dunkley Jones, 2012) Young and Bown 2014	2
Umbilicosphaera jordanii Bown, 2005	1
Umbilicosphaera sp. Lohmann, 1902	1
Zygrhablithus bijugatus (Deflandre in Deflandre and Fert, 1954) Deflandre, 1959	120
Zygrhablithus bijugatus maximus Bown, 2010	13
Total :	**25.652**
b. Reworked calcareous nannofossils from Paleogene – Early Oligocene	
Blackites sp. Hay and Towe, 1962	3
Campylosphaera eroskayi (Varol, 1989) Bown, 2005	2
Chiasmolithus bidens (Bramlette and Sullivan, 1961) Hay and Mohler, 1967	1
Chiasmolithus grandis (Bramlette and Riedel, 1954) Radomski, 1968	2
Chiasmolithus sp. Hay, Mohler and Wade, 1966	8
Chiastozigus sp. Gartner, 1968	2
Coccolithus bownii Jiang and Wise, 2007	24
Coccolithus crucis Bown, 2005	2
Coccolithus foraminis Bown, 2005	12
Coccolithus formosus (Kamptner, 1963) Wise, 1973	3
Coccolithus latus Bown, 2005	1
Coccolithus pauxillus Bown, 2010	7
Craticullithus? cassus (Bown, 2005) Bown, 2010	10
Cruciplacolithus cruciformis (Hay and Towe, 1962) Roth, 1970	2
Cruciplacolithus sp. Hay and Mohler *in* Hay et al., 1967	11
Discoaster lenticularis Bramlette and Sullivan, 1961	1
Discoaster mahmoudii Perch-Nielsen, 1981	1
Discoaster mediosus Bramlette and Sullivan, 1961	1
Discoaster multiradiatus Bramlette and Riedel, 1954	1
Ericsonia robusta (Bramlette and Sullivan, 1961) Edwards and Perch-Nielsen, 1975	5
Ericsonia sp. Black, 1964	16
Fasciculithus sp. Bramlette and Sullivan, 1961	3
Hornibrookina sp. Edwards, 1973	2
Isthmolithus recurvus Deflandre *in* Deflandre and Fert, 1954	1
Micrantholithus minimus Bown and Dunkley Jones, 2006	2
Neococcolithes dubius (Deflandre *in* Deflandre and Fert, 1954) Black, 1967	1
Pontosphaera rimosa (Bramlette and Sullivan, 1961) Roth and Thierstein, 1972	1
Prinsius dimorphosus (Perch-Nielsen, 1969) Perch-Nielsen, 1977	11
Prinsius martinii (Perch-Nielsen, 1969) Haq, 1971	3
Prinsius sp. Hay and Mohler, 1967	7
Pseudotriquetrorhabdulus inversus (Bukry and Bramlette, 1969) Wise and Constans, *in* Wise 1983	3
Reticulofenestra reticulata (Gartner and Smith, 1967) Roth and Thierstein, 1972	2
Reticulofenestra umbilicus (Levin, 1965) Martini and Ritzkowski, 1968	11
Reticulofenestra wadeae Bown, 2005	1
Rhabdosphaera gracilentus (Bown and Dunkley Jones, 2006) Dunkley Jones et al., 2009	3
Rhabdosphaera vitrea (Deflandre *in* Deflandre and Fert, 1954) Bramlette and Sullivan, 1961	1

Appendix 1 (continued)

Sphenolithus pseudoradians Bramlette and Wilcoxon, 1967	1
Sphenolithus radians Delfandre *in* Grassé, 1952	11
Syracosphaera tanzanensis Bown, 2005	1
Toweius callosus Perch-Nielsen, 1971	11
Toweius pertusus (Sullivan, 1965) Romein, 1979	6
Toweius rotundus Perch-Nielsen *in* Perch-Nielsen et al., 1978	34
Toweius selandianus Perch-Nielsen, 1979	14
Toweius sp. Hay and Mohler, 1967	3
Total :	**248**
c. Reworked calcareous nannofossils from Cretaceous	
Arkhangelskiella cymbiformis Vekshina, 1959	12
Calculites anfractus (Jakubowski, 1986) Varol and Jakubowski, 1989	5
Calculites obscurus (Deflandre, 1959) Prins and Sissingh *in* Sissingh, 1977	2
Calculites sp. Prins and Sissingh in Sissingh, 1977	8
Cretarhabdus sp. Bramlette and Martini, 1964	6
Cribrosphaerella ehrenbergii (Arkhangelsky, 1912) Deflandre *in* Piveteau, 1952	9
Eiffellithus gorkae Reinhardt, 1965	2
Eiffellithus sp. Reinhardt, 1965	5
Helicolithus compactus (Bukry, 1969) Varol and Girgis, 1994	2
Lithraphidites sp. Deflandre, 1963	1
Markalius inversus (Deflandre *in* Deflandre and Fert, 1954) Bramlette and Martini, 1964	4
Markalius sp. Bramlette and Martini, 1964	1
Microrhabdulus sp. Deflandre, 1959	4
Micula staurophora Gardet, 1955	11
Micula sp. Vekshina, 1959	9
Prediscosphaera sp. Vekshina, 1959	10
Retecapsa sp. Black, 1971a	3
Uniplanarius gothicus (Deflandre, 1959) Hattner and Wise, 1980	1
Uniplanarius sissinghii (Perch-Nielsen, 1986) Farhan, 1987	1
Quadrum gartneri Prins and Perch-Nielsen *in* Manivit et al., 1977	1
Quadrum sp. Prins and Perch-Nielsen *in* Manivit et al., 1977	4
Watznaueria barnesiae (Black *in* Black and Barnes, 1959) Perch-Nielsen, 1968	87
Watznaueria sp. Reinhardt, 1964	67
Total :	**255**
Total all species:	**26.155**