OLIGOCENE - LOWER MIOCENE EVENTS IN ROMANIA

Mihaela MELINTE-DOBRIÑESCU1 & Titus BRUSTUR1

Abstract. This paper is focused on the biotical and lithological markers, which are present in the Eastern Carpathians and in NW Transylvania, and allows correlation of the Oligocene-Lower Miocece deposits of these two regions. In the both above-mentioned areas, the debut of the Oligocene is characterized by the instauration of an anoxic/hypoxic regime, related to the paleogeographic changes of those times (i.e., the first isolation of the Paratethys from Mediterranean). This event is marked by the appearance of endemic (Paratethyan) nannofloras in the Carpathian and Transylvanian areas, accompanied by endemic mollusc faunas, and slightly preceded by blooms of the low-salinity nannofossil Braarudosphaera bigelowii. Within the Early Oligocene interval, coccolithic laminitic limestones (Tylawa type) were accumulated within the NP23 Calcareous Nannofloral Zone. The Rupelian laminitic limestone brings bloom of endemic Paratethyan nannofossils. During the Late Oligocene interval, coccolithic laminitic limestones (Jaslo type) were identified both in the Eastern Carpathians and NW Transylvania, in the NP24 Calcareous Nannofossil Zone, and yielded blooms of cosmopolitan nannoflora taxa. The youngest level of coccolithic laminitic limestones (Zagórz type) was identified in uppermost Oligocene deposits of the Eastern Carpathians (within the NP25 Calcareous Nannofloral zone, Late Chattian in age), while in the Transylvanian area this marker was not found so far. The Oligocene/Miocene boundary (approximated by the first occurrence of the nannofossil Sphenolithus capricornutus) is pointed out both in the Eastern Carpathian and NW Transylvanian areas by a tuff level (placed within the NN1 Calcareous Nannofossil Zone). Around the Aquitanian/Burdigalian boundary (within the NN2 Calcareous Nannoplankton Zone), another tuff level was deposited in the southern and central regions of the Eastern Carpathians.

Key words. Oligocene-Lower Miocece; lithology; bio-events; Eastern Carpathians; NW Transylvania.

INTRODUCTION

The Oligocene is associated with a climatic deterioration (Aubry, 1992), expressed by an overall significant temperature decrease (Zachos et al., 2001), and by the instauration of ice caps in the Antarctic region. These changes are accompanied by a major sea-level fall, according to Haq et al., 1988 (Fig.1), concomitant with a global ocean-land reorganization (Scotese, 2002).

Additionally, the very active tectonic regime of the Oligocene interval led to important paleogeographic modifications: the Tethys Ocean was divided, in the European regions, in two main branches (i.e., the Mediterranean and the Paratethys - Báldi, 1980; Rusu, 1988; Sândulescu & Micu, 1989; Rögl, 1998).

Becoming isolated from the Mediterranean, the Paratethys domain displayed a distinct paleobiogeography, hydrological regime, and sedimentation dynamic. Therefore, the stratigraphers use regional stages for the two main Paratethys branches, including for the Central Paratethys (Cicha et al., 1998, Fig. 2) where the present Romanian territory was located (Mészáros, 1989; Rusu, 1989, Rögl, 1999, among many others).

Around the Eocene/Oligocene boundary interval, the termohaline water stratification and the primarily estuarine water circulation pattern, eventually resulting in recurrent episodes of stagnation, characterized the Paratethys domain, leading to the accumulation of hypoxic to anoxic sediments.

Fig. 1 Late Eocene-Early Miocece global climatic and sea-level fluctuations (climatic events and average global temperature after Zachos et al., 2001; sea-level after Haq et al., 1988).

1 National Institute of Marine Geology and Geo-ecology, Street Dimitrie Onciul, No. 23-25, RO-024053, Bucharest, Romania, e-mail: melinte@geoecomar.ro, tbrustur@geoecomar.ro
Fig. 2 Correlation of global stages with the central Paratethys stages, and with the foraminiferal and calcareous nannoplankton biozones (modified after Berggren et al., 1995 and Cicha et al., 1998). P-Paleogene Foraminiferal Zones; M-Miocene Foraminiferal Zones; NP-Paleogene Calcareous Nannoplankton Zones; NN-Neogene Calcareous Nannoplankton Zones.

Such type of deposition prevailed during the whole Oligocene and Lower Miocene times, and is referred as “the menilite and dysodile facies” in the Central Paratethys, including Romania (for a synthesis see Popescu et al., 1995 and Rusu et al., 1996). Intervals of high productivity water surface allow the accumulation of several levels of coccolithic laminitic limestones in the whole Central Paratethys (fide Uhlig, 1883; Nowak, 1965; Haczewski, 1981, 1989; Nagymarosy & Voronina, 1992; Krhovský et al., 1992; Švábenická et al., 2007), including Romania (Grasu et al., 1982; Alexandrescu & Brustur, 1985; Ionesi, 1986; Brustur & Alexandrescu, 1989; Štefánescu et al., 1989; Melinte, 2005).

The Oligocene coccolithic laminitic limestones represent excellent lithological markers, very useful for correlations in the whole Carpathian area. During the Oligocene - Lower Miocene, tuff levels are also known to occur in different areas from Romania; hence, they could be regarded as lithological markers, useful for regional correlations.

The aim of this paper is to reveal the lithological and paleobiological markers, which could be valuable for Oligocene-Lower Miocene stratigraphical correlation. Two Romanian regions were mainly investigated (i.e., the NW Transylvania, namely the Preluca sedimentation area, and the central-southern part of the Eastern Carpathians) (Fig. 3).

GEOLOGICAL SETTING

NW Transylvania

In the NW Transylvania, three distinct Paleogene sedimentation areas (Gilău, Meseș and Preluca) were distinguished (Rusu, 1970). In particular, the Preluca area displays a continuous marine sedimentation within the Oligocene-Early Miocene interval. Hence, the Early Oligocene is marked by the deposition of the Cuculiat Formation, mainly composed of grey and brown marlstones and claystones, followed by the bituminous marls of the Bizușa Formation and the bituminous shales of the Ileanda Formation (Fig. 4).

The Late Oligocene interval is characterized by the sedimentation of the Buzăș Formation, mainly made by an alternance of sandstones and marls, and by the younger lutite, hemipelagic Vima Formation. Towards NE, the Vima Formation progressively replaced the Buzăș Formation. The Oligocene/Miocene boundary (the boundary between the NP25/NN1 Calcareous Nannoplankton Zone of Martini, 1971) was previously identified, based on calcareous nannofossil assemblages, in the Vima formation (Mészáros et al., 1979; Mészáros & Ianoliu, 1989; Rusu et al., 1996).
Eastern Carpathians

The Oligocene-Lower Miocene sediments crop out on large areas in the Eastern Carpathians, belonging to (1) the sedimentary cover of the Moldavid Nappes (Outer Flysch Zone), (2) the post-tectonic cover of the Outer Dacid Nappes, and (3) the Pienid tectonic units (Săndulescu, 1984). Within the Moldavids, in the outer (eastern) part of the central and southern Eastern Carpathians, the Oligocene-Lower Miocene formations are involved in the Tarcău, Marginal Fold and Subcarpathian nappes, where they display two main lithofacies, namely the Bituminous Kliwa Facies in the external part and the Fusaru-Pucioasa Facies (similar to the Polish Carpathian Krosno facies), in the inner part - Săndulescu & Micu, 1989.

During the Paleogene, varying rates of subsidence were recorded in the Moldavids (Ştefănescu & Melinte, 1996). The subsidence was faster in the Eocene, Late Oligocene and Early Miocene, when mostly terrigenous rocks (flysch and molasses deposits) accumulated, and lower within the Late Eocene-Early Oligocene interval, when a pelagic sedimentation prevailed.

The Early Oligocene interval (= the Rupelian stage) is characterized in both lithofacies by the deposition of the Lower Dysodile Shale Formation, composed of bituminous shales with frequent sulphur and disarticulated fish remains (Fig. 5).

In the eastern (outermost) Kliwa Facies, the base of the Oligocene is characterized by the sedimentation of the Lower Menilite Formation, consisting of cherts and bituminous marls, followed by the Lower Dysodile Shale Formation, composed of bituminous shales. During Late Oligocene times (= the Chattian stage), in the inner Fusaru-Pucioasa lithofacies, turbiditic sequences made by calcareous sandstones interbedded with bituminous marls, as well as green and gray pelites, occur. Within the outer lithofacies, the same interval consists of the Kliwa Sandstone Formation, including white massive, orthoquartzitic sandstones interlayered with thin bituminous shales.

Around the Oligocene/Miocene boundary interval, shaly turbidites were deposited, namely the Vinetişu Formation in the inner facies, and the Podu Morii Formation in the outer facies (the later unit shows in addition prominent convolute sandstones). The Oligocene/Miocene boundary was identified, based on calcareous nanoplankton investigations, towards the base of the two above-mentioned units (Melinte, 1988; Ionesi & Mészáros, 1989; Micu et al., 1989; Ionesi et al., 1998; Mărunţeanu, 1999; Melinte et al., 1999; Melinte, 2005), within the NN1 Nannofossil Zone of Martini (1971) – Fig. 5.
Fig. 4 Lithology and main biotical events recorded in the Preluca area, NW Transylvania (modified after Rusu, Popescu & Melinte, 1996).
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LITHOLOGICAL AND BIOTICAL MARKERS

Early Oligocene

The restricted Early Oligocene circulation of the Paratethys realm, which led to the instauration of a hypoxic to anoxic regime, is mirrored in the sedimentation of both the NW Transylvania and Eastern Carpathian regions. There, the bituminous marls and shales of the Bizușa and Ileandă units (in NW Transylvania), as well as the bituminous cherts, marls and shales of the Menilite and Lower Dysodil Formation (in the Eastern Carpathians) were deposited within the Rupelian (=Early Kiscellian interval).

The initiation of the anoxic sedimentation is reflected in the calcareous nannoplankton fluctuation. The cosmopolitan Eocene nannofossils are sharply replaced by endemic taxa. The five Early Rupelian nannofossil extinctions of Discocoaster saipanensis Bramlette & Riedel, D. barbadiensis Tan, Clausiococcus subdistichus (Roth & Hay) Prins, Discocoaster tanii (Bramlette & Riedel) Bukry and Helicosphaera reticulata Bramlette & Wilcoxon are followed by another seven extinctions in the upper Rupelian (in NP23a Nannofossil Subzone of Melinte, 1995), the endemic nannofossils Reticulofenestra lockeri Müller, R. ornata Müller, Transversopontis fibula Gheța and T. latus Müller appeared (Pl. 1). The succession of these nannofloral events were recorded in all the sections investigated from the NW Transylvania, as well as from the central and southern part of the Eastern Carpathians. Moreover, these bioevents could be recognized everywhere in Romania (i.e., in the Getic Depression, according to Roban & Melinte, 2006), where continuous Early Oligocene rock-successions crop out.

In NW Transylvania, a distinct bio-horizon with the endemic Paratethyan macrofaunal taxa “Cardium lipoldi” and Janschinella garetzkii is present, towards the base of the Bizușa Formation (Rusu, 1988; Rusu et al., 1996), within the lower part of the NP23 Nannofossil Zone. Janschinella garetzkii bio-horizon is also present in the Eastern Carpathians, towards the base of the Lower Dysodile Formation, in the same stratigraphic position (i.e., Lower Rupelian), according to Rusu (1999). Remarkably, synchronously with the occurrence of the Janschinella garetzkii macrofaunal level, monospecific calcareous nannoplankton assemblages, with Braarudosphaera bigelowii (Gran & Braarud) Mohler & Wade and Transversopontis fibula Gheța disappeared (Figs. 4, 5). Between these two groups of extinctions, at the end of the early Rupelian (in NP23a Nannofossil Subzone of Melinte, 1995), the endemic nannofossils Reticulofenestra lockeri Müller, R. ornata Müller, Transversopontis fibula Gheța and T. latus Müller appeared (Pl. 1). The succession of these nannofloral events were recorded in all the sections investigated from the NW Transylvania, as well as from the central and southern part of the Eastern Carpathians. Moreover, these bioevents could be recognized everywhere in Romania (i.e., in the Getic Depression, according to Roban & Melinte, 2006), where continuous Early Oligocene rock-successions crop out.

Fig. 5 Lithology and main biotical events recorded in the central and southern part of the Eastern Carpathians (modified after Melinte, 2005).
Deflandre, was identified in the investigated NW Transylvanian region.

In several sections from the Preluca area of NW Transylvania (the better exposure being located in the Poieni Valley, the Făntânele Village – Fig. 4) several cm coccolithic laminitic limestones (Coccolithic limestone 1) occur, within the lower part of the bituminous shales of the Iileanda Formation (around the boundary of the NP23a/b Calcareous Nannofossil Subzones of Melinte, 1995). In the whole Eastern Carpathian bend, coccolithic laminitic limestones are present towards the base of the Lower Dysodile Formation, yielding also a Rupelian age (Fig. 5). Both in the NW Transylvania and in the Eastern Carpathians, the laminas of the Rupelian limestone are made by blooms of the endemic Paratethyan nannofossils, such as *Reticulofenestra ornata*, *R. lockeri* and *Transversopontis fibula* (Pl. 1).

Below the Early/Late Oligocene boundary (= the Rupelian/ Chattian boundary, placed in the NP24 Calcareous Nannofossil Zone - according to Berggren et al., 1995) the endemic Paratethyan nannofossils vanished, and new cosmopolitan taxa (Young, 1998), such as *Sphenolithus ciperoensis* Bramlette & Wilcoxon and *Chiasmolithus altus* Bukry and Percival, appeared (Figs. 4 and 5).

Synchronously, the pelitic anoxic sedimentation is replaced by sandy-shaly turbidites in the Eastern Carpathians (with more frequent bituminous rocks in the outer facies), and by sandstones and clays in the NW Transylvanian area.

**Late Oligocene**

The Late Oligocene (Chattian=Late Kiscellian and Early Egerian) is an interval characterized by cosmopolitan nannofloral assemblages in both the Preluca sedimentation area (NW Transylvania) and in the Eastern Carpathians. In fact, the nannoplankton zones of Martini (1971), completed with the Subzones of Melinte (1995) could be recognized in all the Upper Oligocene successions from Romania (Figs. 4 and 5).

In the both inner and outer Oligocene facies of the Eastern Carpathians, a coccolithic laminitic limestone (Coccolithic limestone 2) was deposited. Several cm to dm intercalations of this limestone could be observed from the northern part of the Eastern Carpathians until the bend area, in the Pucioasa-Fusaru Formation and in its outer equivalent, the Lower Kliwa Sandstone Formation (Fig. 5). The Lower Chattian laminitic limestone (placed in the NP24 Calcareous nannofossil Zone) contains, in its laminas, bloom of cosmopolitan nannoplankton species, such as *Dictyococcales bisectus* (Hay, Mohler & Wade) Bukry & Percival, *Zygbrhalithus bijugatus* (Deflandre) Deflandre, *Cyclargolithus floridanus* (Roth & Hay) Bukry and *Sphenolithus moriformis* (Brönning & Stradner) Bramlette & Wilcoxon (Pl.1).

The Lower Chattian laminitic limestone (Coccolithic limestone 2) is also present in the NW Transylvanian area (Rusu et al., 1996), placed in the Buzăş Formation (one of the best section where it is exposed is the Runcului Valley, Fig. 4). The nannofloral assemblages observed in the white laminae of this limestone are similar with those from the Eastern Carpathians and belong also to the NP 24 Calcareous Nannoplankton Zone.

Besides Lower Chattian coccolithic laminitic limestone identified in the both NW Transylvanian and in the Eastern Carpathian regions, another Chattian distinct level of coccolithic laminitic limestones (Coccolithic limestone 3) was observed only in the Eastern Carpathian bend. This is placed in the NP 25a Calcareous Nannoplankton Subzone, between the first occurrence of *Pontosphaera enormis* (Locker) Perch-Nielsen and the first occurrence of *Triquetorhabdulus carinatus* Martini, being Late Chattian in age (Fig. 5).

Below the Coccolithic limestone 3, towards the Oligocene top (in the latest Chattian) a high abundance of the calcarceous nannoplankton *Sphenolithus* and *Discoaster* genera was observed in the nannofloral assemblages. The two above-mentioned genera jointly amount to almost 50% of the total recorded nannofloras. This event was recognized only in the Eastern Carpathians, within the upper part of the Pucioasa-Fusaru, and respectively in the Lower Kliwa Sandstone formations.

**Early Miocene**

The Oligocene/Miocene boundary was recognized both in the NW Transylvania and Eastern Carpathians based on calcareous nannofossil assemblages. This boundary is placed within the NN1 Calcareous Nannofossil Zone (Berggren et al., 1995), and it is approximated by the first occurrence (FO) of *Sphenolithus capricornus* Bukry and Percival. Based on this bio-event we placed the Oligocene/Miocene boundary in the Eastern Carpathians towards the lower part of the Vinețișu Formation (in the inner facies), and within the lower part of the Podu Morii Formation (within the outer facies) (Fig. 5).

Just above the FO of *Sphenolithus capricornus*, a thin cm level of green tuff, described by Ștefănescu et al. (1989) as the Vinețișu Tuff, was observed in the both
Oligocene facies of the Eastern Carpathians. This tuff is synchronous with the tuff observed in the NW Transylvania, the Valea Coci Tuff, well preserved in the Cocii Valley (Măgocia Village). A younger tuff level (a 50 cm white tuff, described as the Miăcile Tuff by Ștefanescu et al., 1989, and as the Văleni de Munte Tuff by Alexandrescu et al., 1994) is present in the Eastern Carpathians (very well exposed in the southern part, between the Buzău and Teleajen valleys) and also in northern sectors (i.e., the Trotuș Valley at Târgu-Ocna, Alexandrescu & Brustur, 1996). This tuff is placed around the Aquitanian/Burdigalian boundary, shortly above the FO of Reticulofenestra pseudoumbilicularis Gartner (< than 7 µm), within the NN2 Calcareous Nannofossil Zone.

In the Trotuș Valley basin, tuff and bentonites were identified in the Upper Dysodile Formation of the Kliwa Sandstone Facies (Alexandrescu & Brustur, 1996). Several thin cm up to dm tuff levels were identified by the above-mentioned authors, who described them as the Livadea bentonites”. Notably, towards the top of the Upper Dysodile Formation, within the Early Burdigalian, a thicker tuff (3-4m) was observed, being described as “the Falcău Tuff” (Alexandrescu & Brustur, 1996).

DISCUSSION

Several levels of coccolithic laminitic limestones were identified in the NW Carpathians and Eastern Carpathian regions. We described herein these limestones as Coccolithic limestones, and they could be correlated (as age and lithology) with those described in other Carpathian areas (in particular in the Polish Carpathians – Haczewski, 1981; 1989) as follows: Coccolithic limestone 1 – the Tylawa Limestone (Rupelian in age), Coccolithic limestone 2 – the Jaslo Limestone (Early Chattian in age), and Coccolithic limestone 3 - the Zagăr Limestone (Late Chattian in age).

Even if these coccolithic limestones were sedimented during different paleogeographical settings, their deposition is probably due to similar paleoenvironmental conditions, related to a high nutrient input and absence of other planktonic competitors (i.e., foraminifers) than the calcareous nannoplankton. The Coccolithic limestone 1 (= the Tylawa limestone) was deposited during the first isolation of the Paratethys from the Mediterranean (the NP 23 Calcareous Nannoplankton Zone), fact argued by the presence of endemic nannofloras. Moreover, the occurrence of nannofloral monospecific assemblages with Braarudosphaera bigelowii (which blooms are related to low salinity surface waters – Lamolda et al., 2005 and cooler waters – Siesser et al., 1992) indicates an important shift of salinity, and probably a temperature decrease. Notably, Rupelian blooms of Braarudosphaera bigelowii were also recorded in other Carpathian areas (Krhovský et al., 1992; Nagymarosy & Voronina, 1992).

The occurrence of the Coccolithic limestone 2 (= the Jaslo Limestone) in the whole Paratethys area, including the present Romanian territory, is related to the restoration of the communication between the Paratethys and the Mediterranean, within Late Oligocene (= Chattian) times, in the NP24 Calcareous Nannoplankton Zone respectively. It is to assumed that similar paleogeographic conditions lasted in the upper part of the Chattian, when the youngest Oligocene laminitic limestone, Coccolithic limestone 3 (= the Zagăr Limestone), was sedimented, in the NP25 Calcareous Nannoplankton Zone.

Remarkably, both Chattian laminitic limestones (i.e., Jaslo and Zagăr) yielded blooms of cosmopolitan nannofossils. Such blooms, of Dictyococcolites bisectus, Zygryhablithus bijugatus, Cyclicargolithus floridanus and Sphenolithus moriformis were recorded in the whole Carpathian area in the above-mentioned nannoplankton zones, even in the absence of the laminitic limestones (Bubik, M., 1987; Švábenická et al., 2007). Consequently, the nannoplankton blooms are important Upper Oligocene biostratigraphical horizons, and could be used for Paratethys correlation.

Between the depositional intervals of the Coccolithic limestone 2 and 3 (Jaslo and Zagăr respectively), a bloom of the sphenoliths and diasteroids, nannofossils related to an open marine setting and warm surface temperature (Aubry, 1992; Fornaciari & Rio, 1996), was identified. This nannofloral event could regionally expressed the global Late Oligocene Warming Event (Zachos et al., 2001), synchronous with the sea-level rise (Fig. 6).

Taking into account the Oligocene nannofloral fluctuation pattern, we may assume that the Early Oligocene was characterized in the both studied Romanian areas by a significant cooling, followed by an increase of the temperature in Late Oligocene (Chattian) times. A similar paleoclimatic scenario was hypothesized, based on palynological evidence, by Olaru (1989). The above-mentioned author reported an important temperature shift at the base of the Oligocene, based on the presence of Arctic Tertiary
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Fig. 6 Main Oligocene-Lower Miocene lithological and biotical (calcuarceous nannofossil) markers of the NW Transylvanian and Eastern Carpathian regions.

Angiosperms, followed by a slight climatic warming in the depositional interval of the Fusaru, and respectively Kliwa Sandstone of the Eastern Carpathians.

Tuff and bentonites are well-known in the Oligocene-Lower Miocene sediments of the Eastern Carpathians, from the northern boundary of Romania up to Carpathian bend area (Mutihac & Ionesi, 1973; Catana et al., 1982; Màrza & Voiculescu, 1991). In particular, in the Moldavid tectonic units, thin cm tuff and bentonites occur in the Early Oligocene (Rupelian) Lower Menilite and Lower Dysodile formations, as well as in the Early Miocene (Burdigalian) Upper Menilite and Upper Dysodile lithological units (Alexandrescu et al., 1984, 1991; Ştefănescu et al., 1989), and may represent, regionally, useful lithological markers.

Another tuff level is the Vineţişu tuff, identified in the both Moldavid facies, Pucioasa-Fusaru and Lower Kliwa Sandstone (Ştefănescu et al., 1989). This green tuff, 25-30 cm in thickness, occurs slightly above the Oligocene/Miocene boundary (above the first occurrence of the nannofossil Sphenolithus capricornutus, according to Melinte, 1988, 2005), and it is synchronous with the Valea Coci tuff deposited in the NW Transylvania (Preluca sedimentation area). Another reliable event is the deposition of the 40-50 cm in thickness white Mîăcile Tuff, which could be a good marker to emphasize the Burdigalian base, at least in the southern and central parts of the Eastern Carpathians.

SUMMARY

The investigation of the Oligocene-Lower Miocene sediments of the NW Transylvania (Preluca sedimentation area) and of the Eastern Carpathians allows us to recognize
several events, which are, in the stratigraphical succession, the following (Fig. 6):
- The anoxic/hypoxic deposition, which marks the debut of the Oligocene;
- The presence of monospecific assemblages with *Braarudosphaera bigelowii*, within the Rupelian (Early Kiscellian), around the base of the NP23 Calcareous Nannoplankton Zone;
- The appearance of the endemic Paratethyan nannofloras, synchronously with the occurrence of the Paratethys macrofaunal biocluster with *Cardium* lipoldi and *Janschinella garetzkii*, also in the NP23 Calcareous Nannoplankton Zone;
- The deposition, in the Late Rupelian (Early Kiscellian), of the Coccolithic limestone 1 (the Tylawa Limestone), which contains blooms of endemic nannofossils, within the upper part of NP23 Calcareous Nannoplankton Zone;
- The extinction of the endemic Paratethys nannofloras around the top of the NP 23 Calcareous Nannoplankton Zone;
- The deposition, in the Early Chattian (Late Kiscellian), of the Coccolithic limestone 2 (the Jaslo Limestone), which contains blooms of cosmopolitan nannofossils, within the NP24 Calcareous Nannoplankton Zone;
- The occurrence of the *Sphenolithus* spp. and *Discoaster* spp. nannofossil blooms;
- The deposition, in the Late Chattian (the top of the Kiscellian), of the Coccolithic limestone 3 (the Zag/orz Limestone), which contains blooms of cosmopolitan nannofossils, within NP25 Calcareous Nannoplankton Zone;
- The FO of the nannofossil *Sphenolithus capricornutus*, which approximates the Oligocene/Miocene boundary (Early Egerian);
- The deposition of a tuff (referred as the Viteşcu Tuff in the Eastern Carpathians and the Valea Cocii Tuff in the NW Transylvania), slightly above the Oligocene/Miocene boundary, in the NN1 Calcareous Nannoplankton Zone;
- The deposition of the Măcile Tuff in the Eastern Carpathians, around the base of the Burdigalian (in the Eggenburgian), within the NN2 Calcareous Nannoplankton Zone.

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PLATE 1

LM, All the microphotographs are N+, except Figs. 12 and 20 which are in NII

Fig. 1. *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre, Poienii Valley (Fântânele Village), Bizușa Formation, NP22 Biozone.

Fig. 2. *Reticulofenestra pseudoumbilicus* (Gartner) Poienii Valley (Pântânele Village), Buzău Valley, Podu Morii Formation, NN2 Biozone.

Fig. 3. *Helicosphaera carteri* (Walln) Kampn, Buzău Valley, Podu Morii Formation, NN2 Biozone.

Fig. 4. *Sphenolithus moriformis* (Bröniman & Stradner) Bramlette & Wilcoxon, Vinețișu section, Pucioasa Formation, NP 24 Biozone.

Fig. 5. Bloom of *Reticulofenestra ornata* Müller, Băsca Rozilei (Nehoișu), Tylawa Coccolithic Limestone, NP 23 Biozone.

Fig. 6. Bloom of *Dictyococxites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Zygrhablithus bijugatus* (Deflandre) Deflandre, Târgu Ocna Section, Lower Menilite Formation, NP 24 Biozone.

Fig. 7. *Transversopontis fibula* Gheta, Târgu-Ocna Section, Lower Dysodilic Formation, NP23 Biozone.

Fig. 8. *Pontosphaera multipora* (Kamptner) Roth and *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre, Târgu-Ocna Section, Lower Menilite Formation, NP22 Biozone.

Fig. 9. *Reticulofenestra ornament* Müller, Târgu-Ocna Section, Lower Dysodilic Formation, NP23 Biozone.

Fig. 10. *Dictyococxites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Zygrhablithus bijugatus* (Deflandre) Deflandre, Târgu-Ocna Section, Lower Menilite Formation, NP 24 Biozone.

Fig. 11. *Reticulofenestra umbilica* (Levin) Martin & Ritzkowsk, Poienii Valley (Fântânele Village), Bizușa Formation, NP23 Biozone, N II

Fig. 12. *Reticulofenestra umbilica* (Levin) Martin & Ritzkowsk, Poienii Valley (Fântânele Village), Bizușa Formation, NP23 Biozone, N +.