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Integrated biostratigraphy and palaeoenvironmental interpretation of the Upper Cretaceous to Paleocene succession in the northern Moldavidian Domain (Eastern Carpathians, Romania)

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ABSTRACT

This study of the upper Maastrichtian to Danian sedimentary succession from the northern part of the Romanian Eastern Carpathians (Varniţa section) aims to establish an integrated biostratigraphy based on calcareous nannofossils, organic-walled dinoflagellate cysts (dinocysts) and foraminiferal assemblages, and to reconstruct the depositional environments of the interval. The stratigraphic record across the studied section is incomplete, considering that an approximately 16 m thick strata interval from the top of the Maastrichtian to lowermost Danian cannot be analyzed due to a landslide covering the outcrop. The upper Maastrichtian is marked by a succession of biostratigraphic events, such as the First Appearance Datum (FAD) of the nannoplankton taxon *Nephrolithus frequens* and FAD of the dinocyst species *Deflandrea galeata* and *Disphaerogena carposphaeropsis*, and the Last Appearance Datum (LAD) of *Isabelidinium cooksoniae* in the lower part of the section. These bioevents are followed by the LAD of the *Dinogymnium* spp. and *Palynodinium grallator* dinocyst markers in the top of the Maastrichtian deposits analyzed. In terms of foraminiferal biostratigraphy, the upper Maastrichtian *Abathomphalus mayaroensis* Zone is documented in the lower part of the studied section. Some bioevents, such as the bloom of the calcareous dinoflagellate genus *Thoracosphaera* and the FAD of the organic-walled dinocysts *Damassadinium californicum*, *Senoniasphaera inornata*, *Xenicodinium lubricum* and *X. reticulatum* suggest an early Danian age for the middle part of the section. From the Danian deposits in the Varniţa section, we describe a new organic-walled dinocyst species, *Pentadinium darmirae* sp. nov., which is until now the only species of the *Pentadinium* genus discovered in the Paleocene. The occurrence of the global Danian dinocyst marker *Senoniasphaera inornata* in the top of the section, suggests an age not younger than middle Danian (62.6 Ma) for the analyzed deposits.

The palynofacies constituents, as well as the agglutinated foraminiferal morphogroups, used to reconstruct the depositional environments, show that the late Maastrichtian sediments were deposited in an outer shelf to distal (bathyal) environment, followed by a marine transgression during the Danian.

1. Introduction

Numerous paleontological studies have revealed a major mass extinction at the Cretaceous–Paleogene (K–Pg) boundary. This global extinction event of most of the marine and terrestrial biota at the end of the Cretaceous is supposed to be caused by an asteroid impact (Alvarez et al., 1980), intense volcanic activity from western India (Keller, 2008; Keller et al., 2009) or climatic changes (Courtillot et al., 1986; Courtillot, 1990).

Many groups of organisms such as dinosaurs and ammonites suffered a mass extinction at the K–Pg boundary. An important decline is also shown by the marine microfossils such as planktonic foraminifera and calcareous nannoplankton (Paul, 2005; Twitchett, 2006; Westerhold et al., 2008), while deep-water benthic foraminifers, radiolarians and organic-walled dinoflagellate cysts were less affected by the crisis (Hansen, 1977; Brinkhuis and Zachariasse,

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1988; Hollis, 1996; Coccioni and Marsili, 2007; Slimani et al., 2010; Machalski et al., 2016).

The Maastrichtian–early Paleocene foraminiferal assemblages from the central and northern parts of the Moldavidian Units, Eastern Carpathians, were studied by Ionesi and Tocorjescu (1968), Ionesi (1966, 1975), Ion et al. (1982) and Guerrera et al. (2012). The Maastrichtian assemblage is mainly composed of various taxa of calcareous foraminifera, such as *Abathomphalus mayaroensis* and *Globotruncana* spp., and agglutinated foraminifera, e.g. *Caudammina ovula*, *Rzehakina inclusa*, *Spiroplectammina spectabilis*. Among the Danian taxa, mainly agglutinated foraminifera were identified, an biostratigraphic marker being *Rzehakina fissistomata* according to the authors listed above.

From the same Moldavidian tectonic units, some palynological results at the K–Pg transition were presented by Olaru (1978). The author noted that in the Maastrichtian, the Normapolles group (primitive angiosperms) dominates the palynological assemblages (65–70%), spores and dinocysts being less abundant. The Paleocene microflora shows a decline of the Normapolles group, the prevalent taxa being the mono- and dicotyledonous angiosperms, as well as some pteridophytes and gymnosperms. As to the relative frequency of the dinoflagellate cysts, Olaru (1978) records a decrease in the Paleocene marine assemblages, compared to those identified in Maastrichtian deposits. In the Campanian–Paleocene stratigraphic interval of the Eastern Carpathians, Antonescu and Alexandrescu (1979) established four dinocyst zones, namely: the *Cerodinium diebelii – Palaeocystodinium golzowense* Zone (upper Campanian–lower Maastrichtian), *Deflandrea druggi* Zone (upper Maastrichtian), *Trithyrodinium evittii – Cerodinium striatum* Zone (Danian) and *Cerodinium speciosum – Deflandrea* cf. *oebisfeldensis* Zone (Thanetian). The first two zones were identified in the Hangu Formation, the third zone in the uppermost 10 m of the Hangu Formation, in the Runcu Formation and the lower part of the Izvor Formation, while the fourth zone was recorded in the Izvor Formation.

Other biostratigraphical studies of the K–Pg boundary are based on calcareous nannofossil assemblages from the south-western part of the Eastern Carpathians. In the Ialomiţa Valley section, Melinte and Jipa (2005), Bojar et al. (2009) and Bojar and Bojar (2013) identified an uppermost Maastrichtian mass extinction of the calcareous nannoplankton, followed by some earliest Danian bioevents represented by two extensive blooms, one a calcareous dinocyst genus *Thoracosphaera*, and one of the nannofloral species *Braarudosphaera bigelowii*. In the northern part of Eastern Carpathians, Ionesi (1997) recorded a Paleocene calcareous nannoplankton assemblage from the Runcu Formation, with *Ellipsolithus macellus* indicating the NP4 Zone (late Danian).

The aims of the present paper comprise: (1) the establishment of the stratigraphic distribution of dinocysts, calcareous nannoplankton and plaktonic and benthic foraminifera from the Varniţa section; (2) a detailed biostratigraphical interpretation of the upper Maastrichtian to Danian sedimentary succession, based on these micropaleontological assemblages, and (3) the evaluation of the palaeoenvironmental conditions based on palynofacies characteristics and the microfossil taxa.

2. Geological setting

The Eastern Carpathians represent a segment, over 600 km long, of the Carpathian tectonic chain, composed mainly of Jurassic to Miocene deposits. According to Săndulescu (1984), the Carpathian chain in Romania resulted from a collision between the African-Arabic and European plates, which led to the gradual closure of the Tethys Ocean during the Cretaceous and Miocene convergence events. The deformation in the Romanian Carpathians took place in two stages (Săndulescu, 1984): in the Cretaceous, when the Transylvanide and Dacide Units were build up; and during the Miocene, when the Moldavidian Unit in the Eastern Carpathians was formed. The Moldavidian Unit is divided, from west to east, into the Inner Moldavides (the Teleajen, Macla and Audia nappes), consisting mainly of Cretaceous deposits, and the Outer Moldavides (the Tarcău, Vrancea and the Pericarpathian nappes) comprising Cretaceous to early Miocene "flysch" deposits (Săndulescu, 1984; Grasu et al., 1988; Bădescu, 2005) (Fig. 1C).

The geological cross section analyzed in this paper is located in the eastern part of the Tarcău Nappe (Fig. 1A), more precisely on the Varniţa river, 2 km southwest of the Gura Humorului city. The Cretaceous–Paleocene sedimentary succession identified along the river was assigned to three geological formations, namely the Hangu, Runcu and Izvor formations (Ionesi and Tocorjescu, 1968; Ionesi, 1971; Ionesi, 1997).

The Hangu Formation (~800 m thick), of which we analyzed only the upper part (about 23 m in thickness; Fig. 2), is characterized by an alternation of marlstones with fucoids, claystones (30–70 cm thick), sandy limestones (40–60 cm thick) and calcarenites (up to 90 cm thick). The fucoids mostly belong to *Chondrites intricatus* (Bojar and Bojar, 2013), possibly indicating an anoxic environment (Uchman, 2004). The calcarenites sometimes show calcite diaclases. In the study section, these deposits lie in normal position with a southwest inclination of approximately 60° (Fig. 1A). The top of the Hangu Formation contains debris-flow deposits, some 1 m thick, consisting of black unstratified shales with marlstone lithoclasts derived from older Cretaceous deposits (Fig. 2C).

Upwards, the succession continues with the Runcu Formation (~15 m thick, according to Ionesi, 1997), which does not outcrop completely in the study area because of partial cover by a landslide. The formation is composed of debris-flow deposits (Ionesi, 1997) consisting mainly of black shales matrix mixed with greenish claystones without stratification (Fig. 2A). This matrix of pelitic rocks contains thin intercalations of quartzarenites, reddish fine sandstones, as well as some reworked lithoclasts of marlstones and sandstones derived from the Cretaceous (Audia and Hangu formations). The black shales encountered in the Runcu Formation also are reworked from the Audia Formation (Ionesi, 1997). Guerrera et al. (2012) interpreted the lithologic interval assigned to the Runcu Formation as a slumped body (olistostrome) deposited on the continental slope.

The Runcu Formation is followed by the Izvor Formation, consisting mainly of turbiditic deposits represented by laminated black shales (20–100 cm thick), greenish claystones and calcarenite interlayers (15–110 cm thick). In the studied section, only the lower part, some 35 m thick of the formation, was identified. According to our observations, these deposits show a reverse position, due to strong folding of the area.

3. Previous stratigraphic results

Research based on foraminiferal, dinocyst and nannofossil assemblages by various authors led to the attribution of some slightly different biostratigraphic dating of the sedimentary units across the Cretaceous–Paleogene succession in the study area.

The upper part of the Hangu Formation in the Varniţa section yielded a foraminiferal assemblage comprising *Abathomphalus mayaroensis*, *Eponides bolli*, *Globotruncana arca*, *G. contusa*, indicating a late Maastrichtian age (Ionesi and Tocorjescu, 1968; Ionesi, 1971). A different opinion concerning the age of this stratigraphic interval (the top of the Hangu Formation, the uppermost 10 m) in the same section was advanced by Antonescu and Alexandrescu (1979), who recorded a dinocyst assemblages with *Cerodinium*