



Palaeoenvironmental changes across the Albian-Cenomanian boundary interval of the Eastern Carpathians



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ARTICLE INFO

Article history:

Received 9 May 2013

Accepted in revised form 24 October 2014

Available online 2 January 2015

Keywords:

Oceanic Anoxic Event 1d

Grey and black shales

Red marine beds

Biostratigraphy

Geochemistry

Romania

ABSTRACT

The studied Cernatu Valley section is situated in the central part of the Eastern Carpathians (Romania) and spans the interval covered *pro parte* by the NC10a (=CC9b) calcareous nannofossil Subzone, as well as the *Plectrocurvoides alternans* and *Haplophragmoides falcatusuturalis* agglutinated foraminiferal zones. The presence, within the lower part of the section, of the ammonite *Stoliczkaia notha* indicates a late Albian age, but the section possibly extends to within the Albian-Cenomanian boundary interval, based on the agglutinated foraminiferal assemblages. The deposits are grey to blackish and green shales that are followed by red shales interbedded with couplets of grey to blackish and green shales. The benthic foraminifers suggest a deep-marine depositional setting, probably lower bathyal or even abyssal, at around 2500 m depth. The deposition was probably near but above the Calcium Compensation Depth (CCD), as very scarce nannofloras and macrofaunas are present. The $\delta^{13}\text{C}_{\text{org}}$ values vary throughout the section between -25.30‰ and -24.01‰ . Within the upper Albian, a positive organic $\delta^{13}\text{C}_{\text{org}}$ excursion with increases of 1.3‰ , up to -24.01‰ , is recorded. This positive excursion has been tentatively interpreted as a regional expression of the Oceanic Anoxic Event OAE1d in the Moldavian Trough of the Eastern Carpathian basin. The upper part of the section, belonging to the *Haplophragmoides falcatusuturalis* agglutinated foraminiferal Zone, contains a weak positive $\delta^{13}\text{C}_{\text{org}}$ excursion marked by an increase in values of about 0.5‰ , which is assumed to represent late phases of the Albian-Cenomanian boundary Event. Towards the top of the section, consisting mainly of red shales, calcareous foraminifera also occur, together with more consistent nannofossil assemblages. This biotic change possibly mirrored an alteration of the palaeoenvironment, which shifted from an anoxic/dysoxic setting towards an oxic one. This change is possibly linked to climatic fluctuation, i.e., the onset of a warm and humid climate mode. The intense tectonic activity that took place within the Eastern Carpathians during mid-Cretaceous times could also have been responsible for the environmental changes by modifying the circulation pattern in the Moldavian trough from a restricted circulation to a more open one.

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1. Introduction

The mid-Cretaceous (i.e., the Barremian–Turonian interval, ca. 124–80 Ma) was an interval of significant changes in the Earth History. For this period, a global sea-level highstand, linked to a massive pulse of oceanic crustal production in the Cretaceous Normal Superchron, was assumed (Arthur et al., 1985; Larson,

1991). Most of the known Oceanic Anoxic Events (OAEs) took place during mid-Cretaceous times, being linked to pronounced changes in the Earth system, such as oceanic and atmospheric circulation patterns, modification in carbon, phosphorus and oxygen biogeochemical cycles, as well as fluctuations in marine biotas (Jenkyns, 1980; Erbacher et al., 1996; Larson and Erba, 1999; Hay, 2008). Isotopic investigations of Cretaceous oceanic anoxic events indicate important shifts in the global carbon cycle, most pronounced during the Early Aptian OAE 1a and the Cenomanian–Turonian boundary interval, during OAE2 (Schlanger and Jenkyns, 1976; Arthur et al., 1988), but between the above-mentioned oceanic anoxic events there are several less pronounced OAEs (sub-OAEs), such as OAE1b to OAE1d that extend from the Aptian up to the Albian–Cenomanian boundary interval.

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One of the sub-OAEs is OAE1d (Erbacher et al., 1996), described as the Albian–Cenomanian Boundary Event (Jarvis et al., 2006), which correlates with the Niveau Breistroffer of the Vocontian Basin in south-east France (Bréhéret, 1988) and the Piali Level of the Umbria–Marche Basin in Italy (Coccioni et al., 1987; Coccioni, 2001). The OAE1d has so far been identified in the Western Tethys, North Atlantic and Pacific regions. Therefore a global intensification of thermohaline stratification, playing an important role in preservation of organic carbon at the sea floor in these semirestricted basins, was assumed (Erbacher et al., 2001; Wilson and Norris, 2001; Coccioni et al., 2001; Bornemann et al., 2005; Robinson et al., 2008; Ben Fadhel et al., 2011; Scott et al., 2013).

Few OAEs have so far been identified in the Romanian Carpathians. OAE2 was described in the Southern Carpathians (Melinte-Dobrinescu and Bojar, 2008) and the southern part of the Eastern Carpathians (Cetean et al., 2008). The Valanginian Weissert Event was observed in the Carpathian bend area, as the regional late Valanginian Nutrifaction Event (Barbu and Melinte-Dobrinescu, 2008), while several OAEs (i.e., OAE1a, OAE1b and possibly OAE1c and OAE1d) were recognized in the Apuseni Mountains (Papp et al., 2013).

The aim of this paper is to present new lithological/sedimentological, micropalaeontological and geochemical data on the sediments deposited within the Albian–Cenomanian boundary interval in the central part of the Eastern Carpathians. The palaeoenvironmental setting is reconstructed, and possible links to the global oceanic anoxic events of the Albian–Cenomanian boundary interval are discussed.

2. Geological setting

The Eastern Carpathians consist of the western thick- and the eastern thin-skinned tectonic nappes. According to Săndulescu (1975, 1980) and Săndulescu et al. (1981), the following units were recognized (Săndulescu, 1975, 1980; Săndulescu et al., 1981): the Pienides, the Transylvanian Nappes, the Median Dacides (Central East Carpathians Nappes), the Outer Dacides, the Inner Moldavides and the Outer Moldavides, (Fig. 1). Shortening and thrusting of the Eastern Carpathian nappes, as for the Southern Carpathian ones, took place in several periods of deformation from the Late Cretaceous to Quaternary times (Săndulescu et al., 1981; Maţenco and Bertotti, 2000; Răbagia et al., 2011).

The Inner and Outer Moldavides belonging to the Moldavid Nappe System developed only in the Eastern Carpathians, in the outer (eastern) part of the Flysch Zone (Săndulescu, 1984; Ştefănescu, 1995). Although some effects of the Laramian movements deformed the inner units of these nappes (the inner units), the main movements, Miocene in age, structured the Moldavid nappe pile and thrust it eastwards over the East European Platform (Săndulescu, 1984, 1995; Ştefănescu and Polonic, 1988; Maţenco and Bertotti, 2000). The oldest deposits of the Moldavides are Early Cretaceous in age, developed in hemipelagic and turbidites facies, followed by Upper Cretaceous and Paleogene turbidites and hemipelagic sequences (Săndulescu et al., 1981; Melinte-Dobrinescu and Jipa, 2008; Melinte-Dobrinescu and Roban, 2011), and by huge piles of Neogene shallow marine and continental facies.

One of the major tectonic units of the Moldavides is the Teleajen Nappe, where the section herein presented is situated (Fig. 1). The Teleajen Nappe belongs to the western (innermost) structures of the Inner Moldavides (Dumitrescu et al., 1970). Taking into account its position, in the neighbourhood of the Outer Dacides, two deformation processes were assumed for this nappe, i.e., a first phase with predominant folding and a second phase mainly consisting of overthrusting (Săndulescu et al., 1981). This nappe shows

remarkable lithofacial diversity, both along strike (N–S) and transverse to the strike (W–E). The oldest deposits, Valanginian–Barremian in age, are represented by black and grey shales (Băncilă, 1958; Dumitrescu et al., 1970; Grigorescu, 1971; Grigorescu and Anastasiu, 1976; Antonescu et al., 1978), similar to those recorded in the outer nappes of the Eastern Carpathians (Roban and Melinte-Dobrinescu, 2012). The late Hauterivian–late Aptian interval is characterized by the deposition of shaly-sandy turbidites, consisting of grey shales and marlstones, as well as grey-greenish sandstones (Săndulescu, 1975; Ion, 1975). The Lower Cretaceous sedimentary rocks of the Teleajen Nappe accumulated at a very low rate, in a deep marine environment. Similar depositional conditions lasted until the latest Albian, when, as a result of the mid-Cretaceous deformations, the accumulation rate increased (Ştefănescu and Melinte, 1996).

The most developed lithological unit of the Teleajen Nappe is the upper Aptian–upper Albian Teleajen Formation (Ion, 1978; Melinte-Dobrinescu et al., 2009), composed of massive sandstones accompanied by conglomerates, occurring in several intervals. Towards the end of the Early Cretaceous (i.e., in the latest Albian), an important influx of terrigenous material was delivered by inner (western) sources into the basin where the deposits of the Teleajen Nappe were sedimented (Ştefănescu and Melinte, 1996). In the latest Albian–Coniacian interval, during which the Cernatu Formation was deposited, varying rates of subsidence, combined with a reduced supply of terrigenous material, conditioned the accumulation of condensed hemipelagic deposits (mostly variegated red, grey and green shales), interbedded with grey and black shales (Fig. 2). The red shales are similar to the Cretaceous Oceanic Red Beds (CORBs), described from many Tethyan areas, starting from the lower part of the Upper Cretaceous (Hu et al., 2005a; 2012; Wagreich and Krenmayr, 2005; Bâk, 2007; Yilmaz, 2008; Melinte-Dobrinescu et al., 2009). In general, this type of sedimentation lasted, in the Teleajen Nappe, up to the Coniacian. The post-tectonic cover of the nappe consists of Campanian–Maastrichtian red marlstones, followed by Paleogene flysch and Miocene molasse deposits.

3. Material and methods

The studied section is situated on the right bank of the Cernatu Valley (N 45°59'39.35"N, E 25°59'30.72") – (Fig. 1). In total, 14 m of rocks were sampled.

Calcareous nannofossils were analysed using simple smear slides and light microscope techniques (Bown and Young, 1998). In all, 19 samples have been studied. The preservation state was recorded as follows: M – moderate (around 50% of the specimens could be easily identified, while the remaining nannofossils show overgrowth and/or dissolution but the taxonomic identification is not hindered); P – poor (more than 75% of the specimens show dissolution and/or overgrowth and specific identification is often difficult).

The diversity (species richness) was estimated as the number of the total taxa in each sample. The absolute abundance is considered as the average nannofossil number in one field of view, as follows: A – abundant: >1 specimen/field of view (FOV); C – common: 1specimen/2–10 FOVs; F – few: 1specimen/11–20 FOVs; R – rare: 1/> 50 FOVs.

The samples used for calcareous nannofossil investigations were also used for foraminiferal analysis. The samples (about 0.75 kg each) were first completely dried, for eliminating the interstitial water, then boiled in 'Glauber's salt' (Na₂SO₄), and exposed to several freeze/thaw cycles. Finally, the samples were washed by using a battery of sieves (63–100–2000 µm). In each sample, the whole washed material resulting from the 750 g of the primary

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