IGCP 609: Climate-environmental deteriorations during greenhouse phases: Causes and consequences of short-term Cretaceous sea-level change

and

EARTHTIME-EU Sequence Stratigraphy: Eustasy and sequence stratigraphy in the Cretaceous Greenhouse

GUIDE OF FIELD TRIP 1, August 26 - 28

Cretaceous cyclic sedimentation in the Eastern Carpathians

FIELD TRIP GUIDE

Mihaela C. Melinte-Dobrinescu and Relu-Dumitru Roban

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EARTHTIME-EU SEQUENCE STRATIGRAPHY WORKSHOP
Eustasy and sequence stratigraphy in the Cretaceous Greenhouse

GUIDE OF THE FIELD TRIP 1
26th-28th August 2014
CRETACEOUS CYCLIC SEDIMENTATION
IN THE EASTERN CARPATHIANS

Mihaela C. Melinte-Dobrinescu and Relu-Dumitru Roban

Bucharest
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Mihaela C. MELINTE-DOBRINESCU and Relu-Dumitru ROBAN

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1. THE ROMANIAN CARPATHIANS

The Romanian Carpathians belong to the Carpathian mountain system, which extends over more than 1300 km from the Danube Valley in Austria to the Danube Valley in Southern Romania. To the north, the Romanian Carpathians are linked to the Western Carpathians, while to the south they grade into the Balkan chain.

The nappes of the Romanian Carpathians were grouped into several major units, based on the age of their deformation and mutual areal position (Sândulescu, 1984, 1994). Hence, the main tectonic units of the Romanian Carpathians are: (i) the Transylvanides and the Dacides (both nappe systems mainly deformed during Late Cretaceous times), (ii) the Moldavides (which were mainly folded during the Early Miocene), and (iii) the Pienides (which underwent the effects of two main tectonic phases, during Late Cretaceous and Early Miocene times) – Fig. 1.
2. THE EASTERN CARPATHIANS

The Eastern Carpathians are a segment (over 600 km long) of the Carpathian Orogen, which develops between the Tisa Spring (towards north) and the Dâmboviţa Valley (towards south-west). Inwards (westwards), the East Carpathians are bordered by the Transylvanian Basin and the easternmost part of the Pannonian Basin. Outwards (eastwards), the orogen massif is bordered by the Moldavian and Scythian Platforms and by the Moesian Platform (towards the south-east and the south) (Fig. 2).

The Eastern Carpathians consist of a nappe pile made up of basement nappes in the western part, and Early Cretaceous pelitic marine deposits, Late Cretaceous to Palaeogene flysch deposits, as well as Miocene to Quaternary molasse deposits, in the central and eastern parts. Imbrication and internal deformation of the nappes took place in several periods of deformation, from the Late Cretaceous to Quaternary times (Sândulescu, 1984, 1995; Csontos and Vörös, 2004; Bădescu, 2005).

![Geological map of the Eastern Carpathians](image)

The Moldavides - a nappe system located in the outermost part of the Eastern Carpathians - cover the main part of the Outer Flysch Zone. From inside (W) to outside (E), the Moldavides contain the following tectonical units (according to Sândulescu, 1984): the Teleajen, Macla and Audia nappes, which formed the Inner Moldavides, as well as the Târcău, Vrancea (= Marginal Folds) and Subcarpathian nappes, which composed the Outer Moldavides. All these units are sedimentary allochtonous bodies, overthrusted over the foreland. Their sedimentary and post-tectonic covers, showing different lithofacies, extend mainly within the Early
Cretaceous-Early Miocene interval (Sândulescu, 1975, 1984; Ştefănescu, 1995). The Lower Cretaceous black shales of the Eastern Carpathians occur only in the Moldavide nappes, being overlain, in most of these tectonical units (Melinte-Dobrinescu et al., 2009; Melinte-Dobrinescu & Roban, 2011), by the Cretaceous Oceanic Red Beds (CORB).

3. ITINERARY OF THE FIELD TRIP. FIRST DAY, 26th AUGUST

Bucharest – Urziceni – Buzău – Râmnicu-Sărat – Focşani – Tulnici – Lepşa (overnight in Lepşa)

From Bucharest, the route follows a NE direction (Fig. 3), by crossing the Moesian Platform (morphologically represented by the Romanian Plain). Afterwards, the route enters, N of the Râmnicu-Sărat town, the Subcarpathian Nappe, the outermost structure of the Eastern Carpathians. (Fig. 3).

Fig. 3 – Itinerary of the Field Trip 1.

From the Focşani town, the capital of the Vrancea County, we go westwards to enter the Carpathian structures, through the Putna Valley (Fig. 4).

The Putna Valley crosses the central part of the Eastern Carpathians from West to East and intersects the following Carpathian tectonic units (from E to W):

1) The Subcarpathian Nappe, composed of Palaeogene (mainly Oligocene) and Neogene sediments;
2) The Vrancea Nappe (= the Marginal Folds), which occurs in this area as the Vrancea Halfwindow, containing Lower Cretaceous-Neogene deposits;
3) The Tarcău Nappe, made by Cretaceous, Palaeogene and Neogene sediments, covering large areas of the whole Eastern Carpathian bend.
In the Putna Valley, complete Cretaceous, Palaeogene and Neogene deposits, belonging to the Vrancea Nappe, are exposed. In the first day of the field trip, we will examine Cretaceous deposits of the Vrancea Nappe that crop out in the Vrancea Halfwindow (Figs. 5 and 6).

<table>
<thead>
<tr>
<th>Age</th>
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<td>Lower Monilites Shales Fmn.</td>
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<td>Casin and Pietra Uscata Fmn.</td>
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<tr>
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<td>Lapa Fmn.</td>
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<td>Upper Mi.</td>
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<tr>
<td>Strei Fmn.</td>
<td>40</td>
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Fig. 4 – The geology and tectonics of the Eastern Carpathians (central and southern part), after the Geological Map of Romania, 1:1,000,000.

Fig. 5 – Lithostratigraphy of the Early Cretaceous-Palaeogene interval in Putna Valley Vrancea Nappe, Eastern Carpathians (redrawn after Vârban, 2003).
Stop 1 – Lower and Upper Cretaceous sedimentation in the Tişţa Natural Reserve; cyclic sediments of the mid- Cretaceous interval

Latitude: N 45°56′40″, Longitude: E 26°53′48″

A continuous Cretaceous deposition, starting probably in the Barremian and ending in the Maastrichtian, occurred in the Tişţa Natural Reserve, crossed by the Tişţa Creek, a tributary of the Putna River. The Cretaceous deposits crop out on the flanks of an anticline (Dumitrescu, 1952; Dumitrescu et al., 1968). In its axis, the oldest Cretaceous sediments (Barremian-Albian in age) of the Streiu Formation, occur. This unit is followed by the Tisaru Formation, Albian-Campanian in age, and Lepsa Formation, which extends in the Campanian-Early Palaeocene interval (Fig. 6).

Stop 1a – The Eocene Caşin Formation

The first unit cropping out at the entrance in the Tişţa Natural Reserve belongs to the Eocene Caşin Formation. This unit, 400 m in thickness, is composed of a rhythmically alternating sequence of calcareous clays, silts and sandstones. Deformational structures, i.e., slumps and debris flow, with clasts of green schists of Dobrudja type, i.e., metagraywacke, have been identified. These structures suggest a deposition in a deep marine environment. The green schists have an outer (eastern) source, located in the Moldavian Platform.
Stop 1b – The Palaeocene Piatra Strei Formation and the Campanian-Maastrichtian Lepşa Formation

The Piatra Strei Formation, 150-200 m in thickness, consists of ortho- and paraconglomerates with Dobrudja-type green clasts in a sandy matrix interbedded with sandy levels (Fig. 7). Fining upward sequences, 4-5 m in thickness, have been recognized; however, the general trend is a coarsening up. At the upper part of the Piatra Strei Formation, there are paraconglomerate and diamictite levels with an argillaceous matrix and green clasts and blocks from the underlaying Upper Cretaceous Lepşa Formation.

The Lepşa Formation is dominantly turbiditic, characterized by the occurrence of two terms: (i) a fine carbonate, and (ii) a sandy-microconglomeratic one, almost exclusively made by Dobrudja-type green schists (Figs. 7 and 8). From the base towards the upper part, a prograding tendency has been remarked, owing to the progressively coarsening character. Upwards 22 m from the base of the unit, there is a 4 m thick level of red marls and clays. The age identified above the red level (Fig. 8) is Late Campanian, based on nannofossil assemblages with *Uniplanarius trifidus*, whereas 145 m farther above, in the stratigraphic section, the Maastrichtian/Palaeocene boundary is marked by boundary between the foraminiferal zones *Abathomphalus mayaroensis* and *Parvularoglobigerina eugubina* (Ion and Szasz, 1994).

Fig. 7 – A: Lithostratigraphy and age of the Lepşa and Piatra Strei formations; B – Facies model of the Piatra Strei Formation (redrawn after Vârban, 2003).

Fig. 8 – Details in the Lepşa Formation. A: the carbonate laminated term alternating with sandstones and microconglomerates; B: the carbonate term alternating with red marlstones.
Stop 1c – Turonian-Campanian variegated sediments of the Tisaru Formation (Upper Member)

The Upper Member of the Tisaru Formation, around 90 m in thickness, is made by a rhythmic alternance of a dominantly white or greenish carbonate term and a clayey one, with parallel lamination and red colour through its oldest 15 m (Figs. 9 and 10). At the upper part, the unit becomes prevailingly clastic, with intercalations of conglomerates, more than 10 cm in thickness, almost exclusively consisting of green schist clasts.

The red colour appears in the finer lutitic-siltic granulometric fraction; the colour of some clay levels may be exclusively linked to recent oxidations. These appear as reddish diffuse zones along the same greenish lamina. The general coarsening up tendency suggests an increase in the rate of erosion and denudation in the source area, concomitantly with increased frequency of the resedimentation processes.

The age of the Upper Member of the Tisaru Formation has been assigned based on calcareous nannofossil assemblages. Towards the base, the presence of Quadrum gartneri, in assemblages with Eprolithus floralis and Helenea chiastia indicate the Early Turonian age. The unit extends to the Late Campanian, as indicated by the co-occurrence of Ceratolithoides aculeus and Uniplanarius sissinghi.
Stop 1d – Albian-Cenomanian Lower Member of the Tisaru Formation

The Lower Member of the Tisaru Formation, mainly composed of couplets of radiolarian cherts and grey to black shales, follows the grey and black shales of the Streiu Formation (Barremian-Albian in age). The former unit is overlain by couplets of red shales/wackestones and red shales/grey-greenish marlstones belonging to the Tisaru Formation Upper Member.

The Late Albian-Early Turonian age of the Lower Member of Tisaru Formation has been assigned based on the calcareous nannofossil biostratigraphy; the whole succession is comprised between the FO (first occurrence) of Eiffellithus turriseiffelii and the FO of Quadrum gartneri.

All the Late Albian-Early Turonian nannofossil assemblages yielded a poor diversity and abundance, but their continuous presence all over this unit indicates that the deposition has taken place above the CCD. The bioclasts and carbonate pellets found in the chert/shale couplets indicate a similar palaeoenvironment.

STOP 2 – Mid-Cretaceous sediments in the Putna Valley

Latitude: N 45°56'42”; Longitude: E 26°35'02”

On the cut-off of the route along the Putna Valley, the Lower Member of the Tisaru Formation is exposed (Fig. 11). The Late Albian-Early Turonian interval is mainly made by green radiolarian chert/grey to black siliceous shale couplets and clastic radiolarites. The base of the Tisaru Formation is latest Albian in age, being placed in the CC9 nannofossil zone; the boundary between the Lower Member and the Upper Member of this unit is Early Turonian, as indicated by the first occurrence of the nannofossil Quadrum gartneri that marks the base of the CC11 zone.

High TOC values, ranging between 1.2% and 3%, have been found in the black shales identified within the Albian/Cenomanian and Cenomanian/Turonian boundary intervals (Fig. 10). In the rest of the succession, in the grey shales and radiolarites, the TOC content is approximately 0.1%. Possibly, the deposition of the cm-thick black shales noticed in the above-mentioned intervals is linked to the generation of the mid-Cretaceous global oceanic anoxic events, OAE1d and OAE2. Yet, this assumption must be argued by isotope investigations. The compacted thickness of a radiolarite/shale couplet of the Tisaru Formation Lower Member averages 6 cm (Fig. 12), while the uncompacted thickness is assumed to be 20 cm (Vârban, 2003). For the decompacted model, a 2x factor has been used for shales and 5x for the radiolarites (Tada, 1991). Considering the global sedimentation rates of those times, i.e., 10-33 m/1 My for decompacted sediments (De Wever & Baudin, 1996), we may assume that the radiolarite/shale couplets correspond to the precessional Milankovitch cycles.
It is to suppose that the radiolarites accumulated during cooler episodes, characterized by an estuarine circulation and intensification of the upwelling nutrient-rich currents, while the clayey sedimentation prevailed in warmer intervals. As in the decompacted couplets the radiolarites dominated over the clays, we may assume that a high bioproductivity prevailed in the Eastern Carpathian outer part, during the latest Albian-Early Turonian interval. Probably, the cooler/warmer climatic modes alternated in short intervals, of 10,000-20,000 y. A change took place in the Early Turonian, when the red shales started to be accumulated, linked to a significant terrigenous influx. This probably corresponds to the event KTu2 of Haq (2014).
4. ITINERARY OF THE FIELD TRIP. SECOND DAY, 27th August

Lepşa – Târgu-Secuiesc – Cernatu – Teliu – Poiana Florilor – Braşov – Bran - Moeciu

Stop 3 – Lower Cretaceous black shales of the Streiu Formation in the Streiu Valley (Lepşa village)

Latitude: N 45°57'18.5"; Longitude: E 26°35’20.4”

The Streiu Formation, around 300 m thick, is exposed only in the axis of the Coza anticline of the Vrancea Halfwindow (Fig. 6). This unit (Fig. 13) shows similarities with the “Black Shale” units of the Eastern Carpathian inner structures, such as the Inner Moldavides (Roban & Melinte-Dobrinescu, 2012).

The Streiu Formation is mainly made by black and grey-green clays, alternating with cm thin sandstones and siderites. The sandstones show parallel and crossed lamination, and rarely convolute lamination, slump type, sedimentological features related to a deep marine environmental setting. Total Organic Carbon (TOC) values of the black clays fluctuate between 0.5 and 1.5 %, while the types II and III of the kerogen are indicative for a hydrocarbon mother rock (Fig. 13).

The Streiu Formation extends within the Barremian – Albian interval; the age is argued based on calcareous nanofossil assemblages that belong to the zones NC5 d-e, NC6, NC7, NC8 and NC9 of Roth (1978; 1983). In the Streiu Formation, nanofloraal successive FOs of *Hayesites irregularis*, *Epifolithus florialis*, *Prediscosphaera columnata*, *Tranolithus orionatus* and *Axopodorhabdus albianus* have been identified.
Fig. 13 – A: Litho- and biostratigraphy of the Streiu Formation; B: Fluctuation of the TOC (Total Organic Carbon); C: Outcrop of the Streiu Formation at its stratotype (picture by Adrian Popa); D: Pseudo-Van Krevelen Diagram showing the kerogen types; NC – calcareous nannofossil zones after Roth (1978).

From the Lepşa village, the route crosses the inner part of the Eastern Carpathians, reaching west, towards, the Transylvanian region. The first town encountered, Târgu-Secuiesc, is the capital town of the Covasna County. The settlement is one of the historical and traditional centres of the Székelys (Terra Siculorum), which established in the area in the 12th Century. Nowadays, the ethnic Hungarian population is present in a significant number in the region.

The next stop is in the westernmost part of the Eastern Carpathian structures, at the foot of the Bodoc Mountain, nearby the Cernatu village.

Stop 4 – Albian/Cenomanian boundary interval and the OAE1d in the Teleajen Nappe (Cernatu Valley)

Stop 4a – The Albian Teleajen Formation: High density turbidites

Latitude: N 45°58’55.56”; Longitude: E 25°35’59”

At this stop, we will examine the deposits of the Teleajen Nappe, the innermost (western) nappe belonging to the Inner Moldavide structures. The most developed lithological unit of the Teleajen Nappe is the Upper Aptian-Upper Albian Teleajen Formation (Ion, 1978; Melinte et al., 2009); towards the top of this unit, massive
sandstones accompanied by conglomerates commonly occurred. Previous studies (Ştefănescu & Melinte, 1996) assumed that towards the end of the Early Cretaceous, in the Late Albian, a significant influx of terrigenous material was delivered by inner (western) sources into the basin, where the deposits of the Teleajen Nappe were sedimented.

At Stop 4a, the following units are cropping out in an old quarry (Fig. 14):

- **The Middle Member of the Teleajen Formation** that is Middle-Late Albian *pro parte* in age. This unit is made of massive calcareous sandstones, with interbedded thin grey-green clays and marls. The agglutinated foraminiferal assemblages identified in the above-described formation commonly contain *Plectorecurvoides alternans*, *Thalmannammina neocomiensis*, *Glomospira irregularis*, *Gaudryna filiformis*, *Rhizammina spp.*, and *Saccammina spp.*, microfaunas that were assigned to the *Plectorecurvoides alternans - Haplophragmoides gigas minor - H. concavus* Interval Zone (Ion, 1975, 1978).

<table>
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<tr>
<th>Stage</th>
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![Fig. 14 – Litho- and biostratigraphy of the Teleajen and Cernatu units in the Cernatu Valley.](image_url)
- **The Upper Member of the Teleajen Formation**, which is Late Albian in age. This lithostratigraphic unit is composed by thin grey-green calcareous sandstones that are rhythmically alternating with grey and green pelites. At the top of the Teleajen Formation, the presence of siderites and limestones is to be noted. The lower and middle parts of this member contain similar agglutinated foraminiferal assemblages as described above, characteristic of the Plectorecurvoidea alternans - Haplophragmoidea gigas minor - H. concavus Interval Zone. Around the middle part of the Upper Member, the benthic foraminiferal species *Pleurostomella obtusa* occurred, bio-event which is followed by the first occurrence of the *Quadrimorphina allomorphophoides* (Ion, 1978). The FO of the planktonic foraminiferal taxon *Hedbergella infracretacea* has been identified towards the top of the Upper Member (Ion, 1975). Among macrofaunas, *Neohibolites minimus*, *Puzosia mayoriana*, *Stoliczkaia dispar* and *S. notha* could be listed.

**Stop 4b – The Albian/Cenomanian boundary interval in the Cernatu Formation**

Latitude: N 45°59′40″; Longitude: E 25°59′26″

The Cernatu Formation comprises grey and blackish shales at the base, followed by red shales interbedded with thin blackish, grey and green shales. The top of this formation is mainly made by red marlstones and shales (Fig. 15).

Several lithofacies were described (Melinte-Dobrinescu et al., submitted) in the Cernatu Formation:

(i) The shaly lithofacies, which prevailed in the studied section, contains grey-green, red and red-green couplets, with low CaCO$_3$ contents, up to 5%. Sedimentary structures observed are horizontal parallel lamination; (ii) The carbonate shaly lithofacies comprises fine-graded sediments, with the CaCO$_3$ contents between 20 and 25%; (iii) The marly lithofacies is present only at the base of the studied section. The grey marlstones, up to 20 cm in thickness, have a high CaCO$_3$ contents, of almost 50%; (iv) The sandstone lithofacies is present only in the lower part of the studied section as one bed up to 10 cm in thickness. The CaCO$_3$ contents is 26%; this quite high values are probably linked to carbonate cement and clasts (Fig. 15).

![Fig. 15 – The Cernatu Formation (Teleajen Nappe) exposed in the Cernatu Valley. A: the transition between grey and red shales (the stick in the picture is 110 cm). The younger deposits are located on the right side. B: the upper part of the shaly lithofacies of the Cernatu Formation: red shales with an intercalation of dark-grey shales](image-url)

The presence of the ammonite *Stoliczkaia notha* indicates a Late Albian age towards the lower part of the Cernatu. Concerning the calcareous nannofloras, the poorly preserved assemblages, containing among other taxa the nannofossil *Eiffelliithus turriseiffelii*, have been assigned to the NC10a subzone that extends in the latest Albian-earliest Cenomanian interval (Roth, 1978; Burnett, 1998).

In the oldest part of the section, the foraminiferal assemblages are dominated by deep water benthic agglutinated taxa. In the upper part of the section, some benthic calcareous foraminiferal species occur too, but no planktonic species have been noticed. The foraminiferal associations contain index species, such as *Plectorecurvoidea alternans*, *Haplophragmoidea falcatusuralis* and *Bulbobaculites problematicus* that are used in the zonation
of Geroch & Novak (1984), Neagu (1990) and Neagu et al. (1992) to characterize the Late Albian-Early Cenomanian interval of the Carpathian area. Most of the investigated samples commonly contain taxa of the *Pseudonodosinella* genus, i.e., *P. parvula* (Huss) that is considered by Geroch and Kaminski (1995) a deeper water equivalent of “Reophax” *minuta* Tappan as well as *P. troyeri* (Tappan). The former species are more common in the oldest part of the studied section. Other components of the agglutinated foraminiferal associations are *Gerochammina stanislawi* Neagu (both shorter and elongated morphotypes), having its first occurrence in the Early Albian and the acme and maximum size in the Cenomanian (Neagu, 1968; 1990), as well as *Trochammina umiatensis* Tappan, whose distribution covers the latest Albian-earliest Cenomanian interval (Neagu, 1972a). The *Recurvoides* genus is represented especially by *Recurvoides imperfectus* (Hanzilikova), more frequent in the upper part of the studied section and *Recurvoides ex. gr. walteri* (Grzybowski), especially encountered in the oldest investigated sediments. The calcareous foraminifers occur towards the top section (Fig. 16); the assemblages contain lagenids, such as *Nodosaria oligostegia*, *Lenticulina pachynota*, *Ramulina novaculeata*, as well as buliminids, such as *Pleurostomella obtusa* and *Nodosarella frequens*. Frequently, the species *Osangularia cretacea* also occurs. The benthic foraminifers suggest a deep-marine depositional setting, probably lower bathyal or even abyssal, at around 2,000-2,500 m depth.

The δ¹³C values vary throughout the section between -25.30 ‰ and -24.01 ‰. Within the Late Albian, a positive excursion of the isotope δ¹³C, which increases with 1.3‰, up to -24.01 ‰, has been recorded. This positive excursion has been interpreted as a regional expression of the OAE1d in the Moldavian Trough of the Eastern Carpathian basin. The interval of the positive excursion of the isotope δ¹³C contains very scarce and poorly preserved nannofloras, with *Watznaueria barnesiae* over 80 % of total assemblages. This taxon is regarded as an indicator of diagentic processes, nannofloras with >40 % *W. barnesiae* are regarded to be heavily altered (Roth & Krumbach, 1986).
Towards the top of the section, where mainly red shales have been deposited, calcareous foraminifers occur too, together with more consistent nannofossil assemblages. This biotical change possibly mirrored the alteration of the palaeoenvironment, which shifted from the anoxic/dysoxic setting towards an oxic one. This change is possibly linked to climatic fluctuation, i.e., instauration of a warm and humid climate mode. The intense tectonic activity that took place in the area of the Eastern Carpathians during mid-Cretaceous times could be also responsible for the environmental changes, by modifying the circulation pattern in the Moldavian trough, from a restricted circulation to a more open one.

Fig. 17 – Foraminiferal distribution in the Cernatu (after Melinte-Dobrinescu et al., submitted).

From the Cernatu village, we return to the European route E574 up to the Ozun locality; afterwards, we change direction towards S, up to Teliu.

**Stop 5 – Albian-Turonian hemipelagic deposits at Teliu-Poiana Florilor**

Around the Teliu locality, there are few outcrops of the Bobu Nappe (Fig. 18), a unit that belongs to the Outer Dacide Nappes system. The Outer Dacides comprise two nappes, Bobu and Ceahlău (Sândulescu, 1984), being formerly described as ‘the Inner Flysch Zone’ of the Eastern Carpathians. These nappes were involved only in Cretaceous tectonic phases, i.e., mid-Cretaceous (‘Austrian’) and Laramian.
The oldest deposits of the Bobu Nappe are Barremian-Albian turbidites, which are followed by the hemipelagic sediments of the Dumbrăvioara Formation (Neagu, 1970; Ştefănescu, 1995). The later unit comprises three members (oldest first): the **Lower Member**, mainly made by red variegated marls and clays; the **Middle Member**, composed of grey marls and clays, rarely interbedded with cm siderites and limestones, and the **Upper Member**, dominantly composed of red marlstones.

**Stop 5a - Albian-Lower Turonian Middle Member of the Dumbrăvioara Formation in Teliu**

Latitude: N 45° 40’56”; Longitude: E 25° 55’43”

At this stop, the Middle Member (Fig. 19) of the Dumbrăvioara Formation is exposed. This unit is composed of grey marls, interbedded with thin cm limestones.

These sediments contain macrofaunas, such as inoceramids (*Inoceramus labiatus*), and also, rarely, ammonites, i.e., *Euclaycoceras sp.* (Dumitrescu et al., 1968; Neagu, 1970). Based on the planktonic foraminiferal biostratigraphy, the Middle Member of the Dumbrăvioara Formation has been assigned to the Albian-Lower Turonian interval.

Towards the upper part of this unit, the boundary between the *Whiteinella archaeocretacea* and *Helvetoglobotruncana helvetica* foraminiferal zones are present (Neagu, 1970), indicating the Cenomanian/Turonian boundary.

Diversified and well preserved nannofloras have been encountered in the Lower Member. Towards the top of this unit, the Cenomanian assemblages containing, among other taxa, *Corollithion kennedyi*, *Lithraphidites acutus*, *Axopodorhabdus albianus*, *Eprolithus floralis* and *Helenea chiastia*, have been replaced by latest Cenomanian assemblages with *Quadrum intermedium* and *Eprolithus moratus* (Fig. 20); higher in the succession, *Quadrum gartneri* firstly occurs, indicating an Early Turonian age.

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![Fig. 18 – Geological map of the Poiana Florilor area (after Neagu, 1970).](image)

![Fig. 19 – Albian-Turonian hemipelagic deposits of the Dumbrăvioara Formation.](image)

A: The Middle Member; B: The Upper Member.
The Upper Member of the Dumbrăvioara Formation is mainly composed of red marls and clays. Its age was firstly assigned based on planktonic foraminiferal biostratigraphy (Neagu, 1970); the presence of the assemblages of *Helvetoglobotruncana helvetica*, *Marginotruncana sigali* and *Dicarinella concavata* indicates an Early-Turonian-Early Santonian age. The calcareous nannofossil identified in this unit indicates the same age, as the successive first occurrences of *Eiffellithus eximius*, *Micula decussata* and *Lucianorhabdus cayeuxii*. Besides, the LO (last occurrence) of *Lithastrinus septenarius* has been identified towards the top of the Upper Member; this nannofossil event is situated within the Early Santonian.

From the Teliu locality, we go eastwards, to reach again the European route E574; at Prejmer, we go southwards, to the Brașov town.

*Brașov* (=Kronstadt, in German) is the 7th largest city in Romania. The town, surrounded by the Carpathian Mountains, is located almost in the centre of Romania (176 km far from Bucharest). The city provides a mix of wonderful mountain scenery in the nearby Poiana Brașov (a well-known winter resort) and medieval history with German influences in the old town.

The *Brașov* town is located at the foot of the Postăvaru Mts., consisting of Triassic, Jurassic and Cretaceous rocks that belong to the Getic Nappe; partly, the above-mentioned succession occurs in the Tâmpa Hill (E of the Brașov downtown), which is built up of Upper Jurassic (Kimmeridgian-Tithonian) limestones. Outcrops of Urgonian rocks, as well as Lower Jurassic ones (the Gresten Facies) that lies on the Triassic (Ladinian) massif limestones, could be seen in the town. Most of the old monuments and houses, dating from the 16th-17th Century have been made by Cretaceous rocks, i.e. limestones and sandstones.

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*Fig. 20 – Calcareous nannofossils of the Middle Member, Dumbrăvioara Formation.*

*Stop 5b – Lower Turonian – Santonian red beds of the Upper Member of the Dumbrăvioara Formation in Poiana Florilor*

Latitude: N 45°40’39’’; Longitude: E 25°56’39’’

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*Fig. 21 – Downtown of Brașov (the old City Hall is in the middle of the Council Square).*
Leaving the Brașov town, the route passes through the SW part of the Țara Bârsei Depression, and then enters the Dâmbovicioara region (described in the Romanian geological and geographical literature as ‘the Dâmbovicioara Couloir’). From a geographical point of view, this area is the junction zone between the Eastern Carpathian and the Southern Carpathians. Before entering the Dâmbovicioara Couloir, towards W, it is a nice view of the Piatra Craiului Massif and the crests of the western part of the Bucegi Mountains, towards E.

The first term of the post-tectonic cover of the Median Dacides from the Dâmbovicioara area is the Brașov Formation (Upper Albian-Cenomanian in age), which is composed of conglomerates and sandstones and covers a morphological and structural palaeorelief with grabens and horsts. On the Bran-Mâgura Mică threshold, at the northern end of the Dâmbovicioara Couloir, the Brașov Formation occurs exclusively as a polymictic facies of megabreccias with limestone sedimentary klippen (Patrulius and Avram, 1976). The Bran Castle from the Bran locality is placed on an impressive Lower Cretaceous sedimentary klippe.

Around the Bran locality, there are several outcrops of Palaeogene successions. The Palaeogene sedimentation is represented by limestones with large foraminifera (nummulites) and by Oligocene bituminous rocks.

The Bran Castle is a national monument and a landmark in Romania. The fortress is situated on the border between Transylvania and Wallachia. It is known as “Dracula’s Castle” (although there are several locations linked to the legend of Dracula, including Poienari Castle and Hunyad Castle). In 1212, the Teutonic Knights built the wooden castle of Dietrichstein as a fortified position in the Burzenland at the entrance to a mountain valley through which traders travelled for more than a millennium; in 1242, Dietrichstein Castle was destroyed by the Mongols. The first documented testimony of Bran Castle is the act issued by Louis I of Hungary, on November 19, 1377, giving the Saxons of Kronstadt (Brașov) the privilege to build the stone citadel at their own expense and with their labour force; henceforth, the settlement of Bran began to develop nearby.

In 1378, the castle was firstly used in defence against the Ottoman Empire; later, it became a customs point for the mountain pass between Transylvania and Wallachia. The castle briefly belonged to Mircea the Old of Wallachia, and, later, to his nephew, Vlad Țepeș (Vlad the Impaler).

From 1920, the castle became a royal residence of the Kingdom of Romania. It was the main residence of Queen Marie, and it is decorated largely with artefacts of her time, including traditional furniture and tapestries that she collected to evidence the skills of Romanian craftsmanship. The castle was inherited by Princess Ileana, Queen Marie’s daughter. In 1948, the castle was seized by the communist regime, after the expulsion of the royal family.

In 2005, the Romanian government passed a special law allowing restitution claims on properties such as Bran (which was seized by the Communist government). In 2006, the Romanian government awarded ownership to Archduke Dominic of Austria, Prince of Tuscany, known as Dominic von Habsburg, an architect in New York State and the son and heir of Princess Ileana. Archduke Dominic decided not to sell the castle and he turned it into a museum.

Overnight in Moeciu, about 5 km away from the Bran Castle.
5. ITINERARY OF THE FIELD TRIP. THIRD DAY, 28th August

Moeciu – Podu Dâmbovitei – Cheile Dâmbovicioarei – Rucăr – Pucheni

Geographically, the Dâmbovicioara region (often described in Romanian papers as ‘the Dâmbovicioara Couloir’) is a passage between the Eastern Carpathian and the Southern Carpathians and, also, the connection between the two historical Romanian provinces, Wallachia and Transylvania.

Along the Dâmbovicioara region, the Piatra Craiului Massif (belonging to the Southern Carpathian structures) could be seen towards W, while, towards E, the crests of the western part of the Bucegi Mountains could be visible.

The highest peak (2244 m) of the Piatra Craiului Massif is La Om (also known as Piscul Baciului). The massif has several peaks over 2000 m altitude, such as Padina Popii (2025 m), Vârful Ascutii (2150 m), Ţimbălul Mare (2177 m), Vârful dintre Ţimbale (2170 m), Sbirii (2220 m) and Vârful Căldării Ocolite (2202 m). Due to its natural attractions, including caves, gorges and magnificent landscapes, as well as several protected faunas and floras, a natural park, namely, the “Piatra Craiului Reservation”, was established in 1938 in this area, on over 1200 hectares.

Geologically, the Dâmbovicioara area belongs to the Southern Carpathians. In the region, the Mesozoic rocks belonging to the Getic Nappe (its easternmost occurrence) are mainly Jurassic-Early Cretaceous in age (Fig. 23). The Middle and Upper Jurassic deposits (nodular limestones) exceed the spreading areal of the Lower Jurassic sediments (mainly microconglomerates and bedded sandstones); the Jurassic formations occur south of the Bran threshold (in the Dâmbovicioara area) and in the western part of the Bucegi Mts., where they directly covered the crystalline schists of the Leaota Series (Patrulius, 1969).

During Late Jurassic-Early Cretaceous times, the carbonate deposition took place within a large, but fragmented carbonate platform, which was formed during an extensional tectonical regime. Deposits of this carbonate platform are known to occur in the whole Southern Carpathian area. Patrulius et al. (1976) interpreted the overall Upper Jurassic to Lower Cretaceous carbonate rocks from the Southern Carpathians as formed within several carbonate platforms, grouped under the name of the Getic Carbonate Platform. Structural and sedimentological data (Patrulius & Avram, 1976; Avram & Melinte, 1998; Barbu & Melinte-Dobrinescu, 2008) indicate the drowning of the carbonate platform of the Southern Carpathians in the Early Aptian. This event was related to the extensional tectonic regime of the area.

Fig. 23 – Geological map of the central part of the Dâmbovicioara region (after Patrulius, 1969);
Legend: th-v: Tithonian -Valanginian; h: Hauterivian; br: Barremian; ap: Lower Aptian;
vr-cm: Vraconian (= uppermost Albian) - Cenomanian.
The Dâmbovicioara area contains one of the richest macrofaunas (especially ammonites) in the Romanian Carpathians. Palaeontological studies started in the 19th Century (Herbich, 1888; Popovici-Hatzeg, 1898), continued at the beginning of the 20th Century (Jekelius, 1938; Oncescu, 1943) and significantly advanced with the investigations of Patrulius (1969). Recent investigations on Early Cretaceous ammonite faunas from the region belong to Avram (1999) and Avram & Melinte (1998).

The Upper Jurassic (Kimmeridgian)-Lower Cretaceous (Lower Valanginian) deposits, described as the Cheile Dâmbovicioarei Formation, included in the Getic Carbonate Platform of Patrulius (1969), are made by thick white limestones, which in some areas (i.e., Piatra Craiului) lie directly on the crystalline basement. Rich ammonite assemblages, one of the most diversified in the Romanian Carpathians, of Kimmeridgian, Tithonian, Berriasian and Early Valanginian ages (Patrulius 1969; Patrulius & Avram, 1976), have been identified in these sediments. The calcareous algae formed typical associations for reef slopes and internal platforms. The latter can be subdivided into: (1) restricted environments (low-energy subtidal-intertidal) dominated by rivulariacean-type cyanobacteria, and (2) open-marine environments (moderate to high-energy subtidal), in which mainly Dasycladales algae occur (Bucur, 1999; Mircescu et al., 2014).

Overall, the Kimmeridgian-Lower Valanginian carbonate succession consists of deposits formed in various depositional palaeoenvironments, from platform margin to internal platform carbonate deposits. Jointly with the progradation of the carbonate platform, the water became shallower. The sea-level changes have directly influenced the flora and fauna development. In the restrictive environments, cyanobacteria flourished, while some dasycladalean algae such as Clypeina sulcata, Salpingoporella annulata and Clypeina parasolkani developed optimally in the lagoons (Bucur et al., 2009; Mircescu et al., 2014).

The Upper Valanginian-Lower Aptian succession, described as the Dâmbovicioara Formation (Patrulius & Avram, 1976), transgressively overlies the Upper Jurassic-Lower Valanginian sediments (Fig. 23). It consists of three members (Patrulius & Avram, 1976; Avram et al., 1996), as follows (older first):

(i) **The Cetatea Neamţului Member**, Late Valanginian *pro parte*, around 50 m thick, which starts with a condensed coquina bed containing ammonites, bivalves and brachiopods; locally, glauconite-rich levels are present; the unit is mainly made by limestones.

(ii) **The Dealul Sasului Member**, Late Valanginian - Late Hauterivian in age, consists of marls and fine-grained calcarenites with cherts, in places with centimetre-thick glauconite-rich levels. The rich ammonite assemblages, identified especially in the marly levels, range from the Trinodosum Zone up to Balearis Zone. A sea-level rise has been identified (Avram & Melinte, 1998; Barragán & Melinte, 2006) in the latest Barremian, based on mixed Tethyan and Boreal macrofaunas (ammonites) and nanannofloras. This event has been succeeded by the restoration of a shallow-marine environment in the earliest Aptian. Subsequently, a major change occurred during the early Aptian when reef limestones and calcarenites were completely replaced by marl-dominated sequences containing again mixed Tethyan, Boreal and cosmopolitan florals and faunas, probably as a consequence of the Early Aptian global sea-level rise.

The Dâmbovicioara Formation is followed by the **Gura Râului Formation** (Late Aptian-?Albian in age). This is mainly composed of conglomerates. It is exposed only in the northern part of the Dâmbovicioara region (i.e., between the Brusturet-Ciocanu and the Bran-Zărneşti alignments).

The first term of the post-tectonic cover of the Getic Nappe from the Dâmbovicioara region is the **Braşov Formation** (Upper Albian - Cenomanian), which is composed of conglomerates and sandstones and covers a morphological and structural palaeorelief with grabens and horsts (Patrulius and Avram, 1976). On the Bran-Măgura Mică threshold, at the northern extremity of the Dâmbovicioara region, the Braşov Formation occurs exclusively as a polymictic facies, including megabreccias with limestone klippen. The youngest marine sediments so far known in the region are the grey-whitish marls, Cenomanian in age, described as ‘Radiolarian Shales’ (Patrulius, 1969; Dumitrică, 1975).

Stop 6 – Cretaceous deposits of the Dâmbovicioara Passage in Dealul Sasului – a Panoramic view

Latitude: N 45°24′34.9″; Longitude: E 25°13′33.4″

This stop is in the southern slope of Sasului Hill, where the road is enlarged, above the ruins of a small fortress, known as ‘Cetatea Neamțului’ (the German Fortress) or ‘Cetatea Orații’. This small castle was built to defend the old commercial route between the Wallachia and Transylvania.
The stop offers a panoramic view of the Upper Jurassic-Lower Cretaceous successions, including their complicate tectonic features, characterized by several graben and horst structures (Figs. 22 and 24). The grabens and horsts formed during the Late Jurassic-Lower Cretaceous extensional regime (Patrulius, 1969). Within the Aptian-Albian interval, a reactivation of the graben and horst structures took place, due to the intense tectonic activity in the area during the Mesocretaceous tectonic phases. Hence, the horsts contain older deposits, i.e., Upper Jurassic-Lower Cretaceous sediments, while the grabens are filled with siliciclastic Upper Aptian-Cenomanian deposits.

Around Cetatea Neamțului ruins, a complete succession of Upper Jurassic - Hauterivian is exposed; the oldest deposits, Tithonian-Early Valanginian in age, are made by limestones, biocalcareites and biosparites, topped by a hard-ground, and followed by limestones.

Along the road, nearby the coach parking, the upper part of the Dealul Sasului Member, made of cherts and calcarenites, Late Valanginian - Late Hauterivian in age, is exposed. This unit underlies the Pseudothurmannia marls of the Valea Muierii Member and the Upper Albian conglomerates. The lower part of the Dealul Sasului Member crops out in the highway cutting, at around 250-300 m south of the parking, in both banks of a creek. Marls with Valanginian ammonites, i.e., Himantoceras trinodosum, Leopoldia leopoldina and Haploceras desmoceratoides crop out.

To reach the next stop, we leave DN73 National Route and take a county route northwards, to the Dâmbovicioara Gorge and Dâmbovicioara cave. The gorges, 2 km in length, are imposing, due to the vertical or bent over bed walls, with heights exceeding 200 m, in some places. On the walls, gray-white bedding Upper Jurassic limestone, polished, arranged in banks thick at the bottom, and white Lower Cretaceous limestones at the top could be seen (Fig. 26).

The road cuts in the Upper Jurassic-Lower Valanginian limestones of the Cheile Dâmbovicoarei Formation. Within the earliest Cretaceous (Berriasian-Valanginian) interval, mudstones to pelletal-intraclastic packstones, in places with porostomatic nodules (A. Baltreș, unpublished data) have been deposited.

The Berriasian/Valanginian boundary is marked by a minor erosional unconformity, mirrored in the deposition of a 10 cm-thick breccia, containing clasts of mudstones and weakstones with the foraminiferal species Pseudotextularia salevensis. The upper part of the succession exposes interbedded mudstones and packstones, with sparse porostomatic nodules, and, in places, crowded shells of gastropods, i.e., taxa of Nerinea (Fig. 27).
Fig. 26 – The Dâmbovicioara gorges, cutting the Tithonian – Valanginian limestones.

Fig. 27 – Berriasian-Valanginian succession in Cheile Dâmbovicioarei (redrawn after Avram et al., 1996).
Stop 7 - Lower Cretaceous hemipelagic sediments in the Dâmbovicioara Gorges

Latitude: N 45°25’48.5”; Longitude: E 25°13’15.7”

Upstream the Dâmbovicioara Valley, the marlstones of the Dealul Sasului Member (Late Valanginian-Late Hauterivian in age), as well as of the Valea Muierii Member (Late Hauterivian-Early Aptian in age) are exposed. The nannofloras of the outcrop (Fig. 28) contain, besides other taxa, *Lithraphidites bollii*. This nannofossil firstly appears within the Hauterivian, while its extinction is situated within the Hauterivian/Barremian boundary interval (Burnett, 1998). The unit contains also Early Cretaceous macrofaunas.

![Fig. 28 – Hauterivian calcareous nannofossil identified at Stop 7.](image)

Stop 8 – Cenomanian hemipelagic deposits at Rucăr

Latitude: N 45°24’21.4”; Longitude: E 25°11’25.5”

At this stop, the youngest marine sediments of the region, Cenomanian in age, could be examined. This unit, described as ‘The Radiolarian Shale’ (Patrulius, 1969; Dumitrică, 1975) occurs in few small outcrops around the Rucăr and Podu Dâmboviței localities. The grey-whitish marls and clays, exposed in a sequence of 50 m stratigraphic sequence, contain rich microfaunas, i.e., planktonic and benthonic foraminifers (Ion & Szasz, 1994), radiolarian and sponge spicules.

According to Dumitrică (1975), a characteristic of the radiolarian assemblages is the dominance of nasselarians (90-95 %). Two distinct radiolarian assemblages, *Holocryptocanium barbiu* - *H. tuberculatum* in the lower part of the unit and *Holocryptocanium nanum* – *Excentropyloma cenomana* in the upper part, have been identified. Both assemblages belong to the *Dictyomitra venata* radiolarian zone that extends within the Late Albian – Coniacian interval; additionally, the presence of Aleivium taxa indicates a Late Cenomanian-Early Turonian age (Dumitrică, 1975). This age is in agreement with the foraminiferal biostratigraphy; the assemblages assigned to the *Rotalipora cushmanii* planktonic foraminiferal zone (Ion & Szasz, 1994) argue for a Late Cenomanian age. The calcareous nannofloras contain rich and diversified assemblages, with *Quadrum intermedium*, *Eprolithus eptapetalus*, *Helenea chiastia* and *Gartnerago segmentatum*, indicative for the Late Cenomanian interval. Additionally, macrofossils, such as *Inoceramus crippsi*, *I. tenuis*, *I. pictus*, *Scaphites aequalis*, *S. obliquus* and *Schloembachia varians* (Muţiu, 1974) support a Cenomanian age. **From the Rucăr locality, we leave the Dâmbovicioara region and change direction towards SE, crossing the southernmost structures of the Eastern Carpathians.**

Stop 9 – Uppermost Cretaceous Maastrichtian variegated marlstones at Pucheni

Latitude: N 45°11’18.2”; Longitude: E 25°15’57.3”

In the bend area of the Romanian Carpathians, a marine red marly succession, namely, the *Gura Beliei* formation, was sedimented at the end of Cretaceous, i.e., in the *Campanian-Maastrichtian* interval; this unit also crosses the K/T Boundary. The age of the Gura Beliei Formation was assigned based on is based on planktonic foraminiferal (Neagu & Georgescu, 1991) and calcareous nannofossil assemblages (Melinte & Jipa, 2005).
The red marls of the Gura Beliei Formation belong to the post-tectonic cover of the Eastern Carpathians structures, i.e., Ceahlău and Bobu nappes of the Outer Dacides, as well as of the Teleajen and Macla nappes of the Inner Moldavides. This unit crops out in a limited area, on around 50 km², at the southern end of the Eastern Carpathians. The palaeo-depth of the Gura Beliei red beds was estimated at about 200 m (Ştefănescu, 1995). The basin where the red marls of the Gura Beliei Formation accumulated, as a whole area of the Romanian Carpathian bend region, has been characterized by a long subsidence period, which started during the Late Cretaceous interval.

The Gura Beliei Formation is mainly made of marls (60-70%), calcareous clays (30%) and limestones (10%), with abundant microfossils (foraminifera and coccoliths). Frequently, different levels of sedimentary pyrite occur, only in the whitish-grey marls. The pyrite is present as individual crystals, but also as concretions with irregular surfaces. Towards the upper part of the Gura Beliei Formation, cm-thick sandstones were sedimented (Melinte & Jipa, 2005).

The red marls of the Gura Beliei unit are followed by the Palaeocene-Eocene turbidite deposits of the Sotriile Formation. Trace fossils, such as Belorhaphe and Paleodictyon gomezi were described from this unit (Brustur, 1993).

At Stop 9, in the Gura Beliei Formations, several sequences could be distinguished (Fig. 29):

(i) A dominant marly succession, Late Campanian-Early Maastrichtian in age, between the FO (first occurrence) of the nannofossil Ceratolithoides aculeus and FO of the nannofossil Lithraphidites quadratus (Fig. 30).

(ii) A variegated marly sequence, made of red and white marls, Early Maastrichtian-Late Maastrichtian in age, between the FO of the nannofossil Lithraphidites quadratus and FO of the nannofossil Micula murus (Fig. 30).

(iii) A grey-green succession of marls and clays, interbedded with cm-thick sandstones and limestones, latest Maastrichtian in age; in this unit, the FO of the nannofossil Micula prinsii has been recorded (Fig. 30).

Fig. 29 – The Gura Beliei Formation at Puchenii. A: basal red marls; B: middle part of the unit with variegated marls; C: the topmost grey marls and clays, interbedded with cm-thick sandstones.
Fig. 30 – Calcareous nannofossil identified in the Gura Beliei Formation at Pucheni.

References


