# EARLY CRETACEOUS DEPOSITS OF THE CEAHLĂU NAPPE (ROMANIAN CARPATHIAN BEND REGION)

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**Abstract**. The investigations carried out in the bend area of the Romanian Carpathians (the Bucegi Mts.) indicate that a continuous sedimentation took place within the Early Cretaceous (interval covered by the NJK-NJK3 and NC4-NC8 Calcareous Nannoplankton Zones). The base of the Bucegi Conglomerates is placed within the earliest Albian (in the NC8 Calcareous Nannoplankton Zone). The detailed sedimentological studies focussed on the Bucegi Conglomerates indicate that the sediments are of orthoconglomerate type, containing mainly sub-rounded clasts, which prevailed over the matrix.

**Key words**: Early Cretaceous, litho-and biostratigraphy; sedimentology; Bucegi Conglomerates; Romanian Carpathian Bend area.

## INTRODUCTION

This study presents the lithological, sedimentological and biostratigraphical features of the Early Cretaceous sediments which belong to the Ceahlău Nappe from the bend area of the Romanian Carpathians. The Ceahlău nappe is the most spatial developed and the main tectonic unit of the Outer Dacid Nappe System (Murgeanu *et al*., 1963; Dumitrescu and Săndulescu, 1968; Săndulescu, 1984) (Fig. 1).

The Ceahlău nappe is composed, in the bend region of the Romanian Carpathians, of Late Jurassic radiolarites, with basic igneous rocks described as the Azuga Facies. Within the Tithonian-Neocomian interval, mostly shaly and calcareous turbidites occured - the Sinaia Beds (Murgeanu *et al*., 1963; Patrulius, 1969; Patrulius *et al*., 1976; Săndulescu *et al*., 1980), which are followed by Barremian to Aptian proximal turbidites (Comarnic Beds) - Jipa, 1961; 1965. The Aptian turbidites are overlying by Late Aptian to Albian massive sandstones and by a thick pile of conglomerates – the Bucegi Conglomerates (Patrulius, 1969; Ştefănescu, 1976, 1995) (Fig. 2). The oldest tectonic movement which folded the sediments of the Ceahlău Nappe is the Early Cretaceous orogeny ("Austrian" phase), which started in Late Barremian times (at around 130 Ma) and ended at around 100 Ma (Aptian to earliest Cenomanian post-tectonic cover), being followed by an extensional collapse (Săndulescu, 1988, 1994; Ştefănescu and Melinte, 1996; Cloetingh *et al*., 2006).

Herein we aim to point out some liho- and biostratigraphical aspects, as well as sedimentological features of Early Cretaceous deposits of the Ceahlau Nappe, which occur in the Romanian Carpathian bend area. A consistent part of our investigations was focused on the study of the Bucegi Conglomerates, cropping out in the Bucegi Mountains (Fig. 1). We also intend to bring new lights on the paleoenvironmental significance of the Bucegi Conglomerates, which were considered to be shallow water deposits (Patrulius, 1969) or, by contrary infranetic to abyssal sediments (Stanley and Hall, 1978).

## LITHOSTRATIGRAPHY

The Ceahlău Nappe has a complex structure, with several subunits (Dumitrescu and Săndulescu, 1968, Săndulescu, 1984). In the central and southern part of the Eastern Carpathians, several digitations such as Bratocea, Comarnic, Secăria, Ciuc and Bodoc were delimited (Ştefănescu, 1976).

We investigated the Early Cretaceous sediments of the Bratocea Digitation, which is the innermost (western) tectonic unit of the Ceahlău Nappe. The oldest sediments are the Sinaia Beds, composed of calcareous turbidites, divided into three subunits (Murgeanu *et al*., 1963; Patrulius, 1969; Patrulius *et al*., 1976; Jipa, 1980): (1) the Lower Sinaia Beds (Shaly subunit); (2) the Middle Sinaia Beds (Sandy-Calcareous

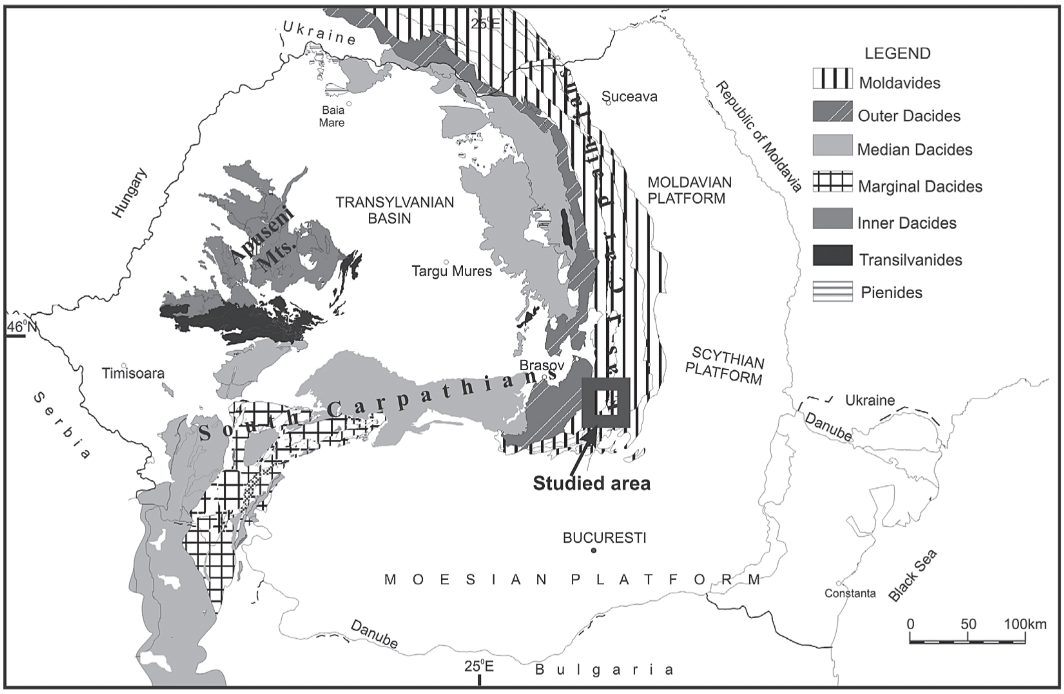



**Fig. 1** Location of the studied area (tectonic map of Romania simplified after Săndulescu, 1984)

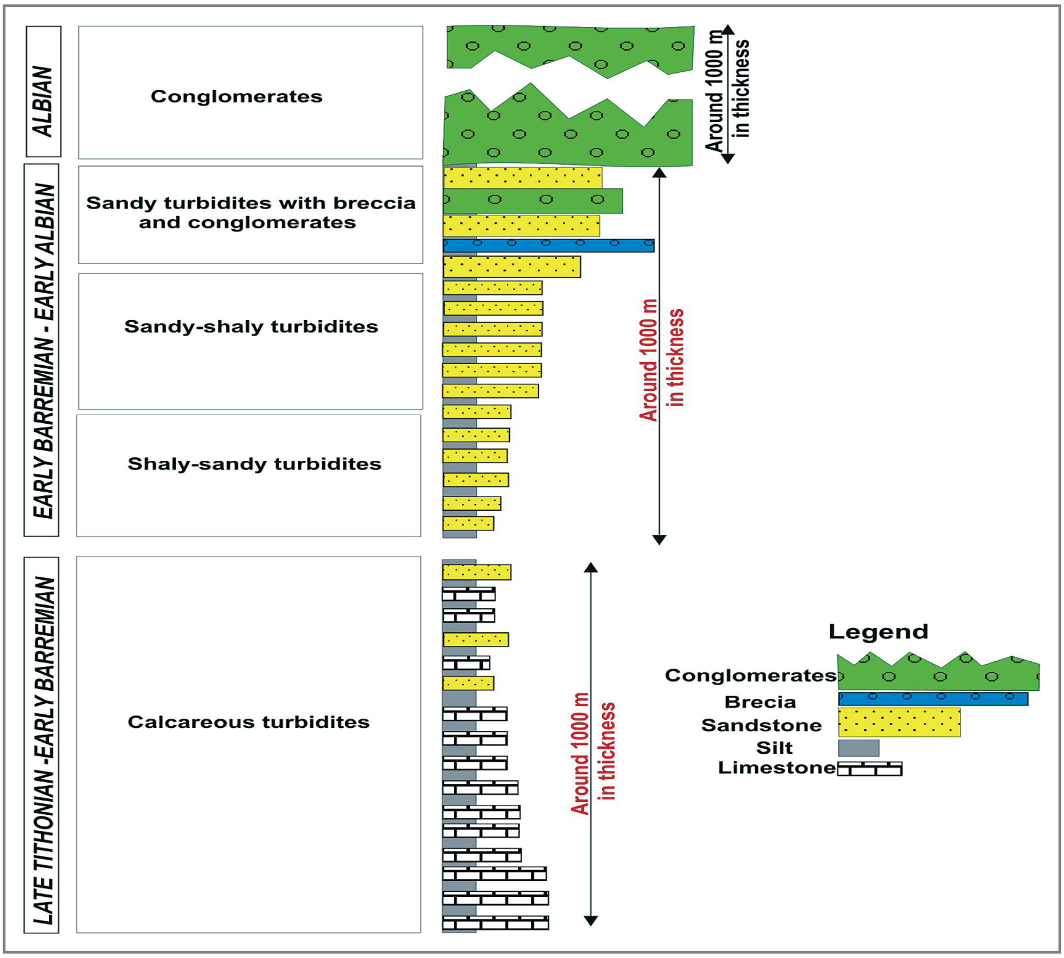



**Fig. 2** Late Jurassic-Early Cretaceous sediments of the Ceahlău Nappe in the Romanian Carpathian Bend region

subunit); (3) the Upper Sinaia Beds (with Lamellaptychus angulicostatus) (Fig. 3).

Towards the base of the Sinaia Beds, red and green phyllites occurred, usually with basic igneous rocks (*i.e.*, the Azuga Formation). The occurrences of concordant lava flows within the Azuga Beds, associated with basic tuffs and jaspers, is an evidence that volcanism was contemporaneous with the sedimentation of the Sinaia turbidites, within the Jurassic/Cretaceous boundary interval. The presence of the Azuga Beds is linked by the existence of an immature island arc in the Romanian Carpathian bend area, with an active volcanism, particularly during the end of the Jurassic, concomitantly with the flysch deposition (Săndulescu *et al*., 1980; Ştefănescu and Micu, 1987).

The Piscu cu Brazi unit follows the Sinaia Beds and occurred only in the inner part of the Bratocea Digitation. This unit is composed by sandstones, alternating with pelites. In the outer part of Bratocea Digitation, within the stratigraphic interval corresponding to the sedimentation of the Piscu cu Brazi unit, the facies changes such that three lithostratigraphic entities could be distinguished: the Comarnic Beds, the Vârful Rădăcinii Beds and the Sandy-Shaly Flysch (Murgeanu *et al*., 1963; Patrulius, 1969).

From the Albian, a thick pile, up to 2000 m, of conglomerates and sandstones, known as the Bucegi Conglomerates, was deposited. Previous works indicated a shallow marine and nearshore origin of the Bucegi conglomerates (Patrulius, 1969), described as a molasse (Panin *et al*., 1961) mainly due to its coarse nature, its stratigraphic position above turbidite formations, and presumably also to its,post-tectonic' position within the mobile belt. Some authors (Stanley and Hall, 1978) considered that the Bucegi Conglomerate accumulated in an infraneritic to deep marine environment and that it records progradation of coarse material directly onto the slope and base of slope of a turbidite basin.

In summary, the Aptian sequence from below the Bucegi Conglomerates in the Bucegi Mts. area include several sediments types, which are according to Patrulius (1969):

- Marly-shally turbidites with biocalcarenites (Barremian-Bedoulian in age) – the Comarnic Flysch;
- Marly –sandy rusty turbidites (Barremian-Apţian) – the Piscu cu Brazi Flysch;
- Sandy and sandy-conglomerate turbidites with thick sandstones "fluxoturbidite type" (Gargasian-Clansaysian);
- Lower Bucegi Conglomerates;
- Reef limestones and reefs (the Urgonian facies)

The Upper Aptian conglomerates are characterized by a large lithological-textural variety. Accordingly, Patrulius (1969) distinguished the following Aptian rudite types:

- The breccias and conglomerates Raciu type;
- The breccias-conglomerates Rotunda type;
- The polymictic conglomerate Peleş type;
- The breccias-conglomerates Velicanu Mic type;
- The tilloid conglomerates Gherţălău type;
- The massive sandy conglomerates Colţii Brăţii (Pietroşiţa) type.

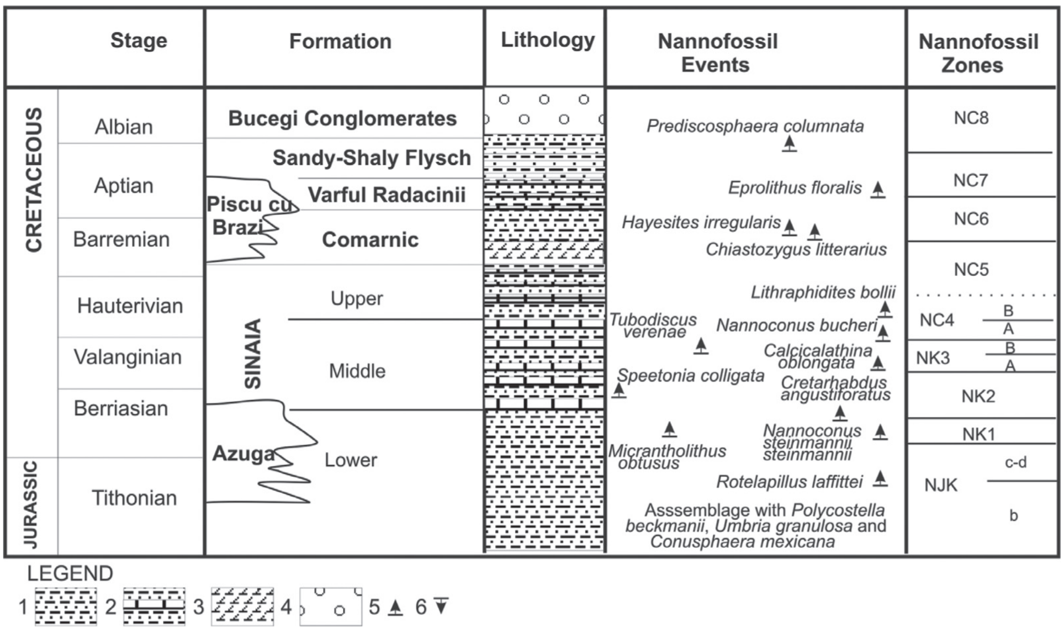



**Fig. 3** Early Cretaceous litho - and biostratigraphy of the Ceahlău Nappe from the Romanian Carpathian Bend area (after Melinte and Jipa, 2007). **1** turbidites; **2** limestones; **3** marlstones; **4** conglomerates; **5** first occurrence; **6** last occurrence. Nannofossil Zones NK after Bralower *et al.* (1989) and NC after Roth (1983)

## BIOSTRATIGRAPHY

The Early Cretaceous sediments of the Ceahlău Nappe from the bend area of the Romanian Carpathians were previously dated based on calipionellid, foraminiferal and macrofaunal assemblages (Patrulius, 1969; Patrulius *et al*., 1976; Pop, 1997). The calcareous nannoplankton investigations accurately dated the above-mentioned Early Cretaceous deposits (Melinte, 1996; Melinte and Mutterlose, 2001; Melinte and Jipa, 2007, and herein). The calcareous nannofloral biostratigraphy follows the Bralower *et al.*'s Zonation (1989) for the Tithonian-Valanginian interval and the Roth's Zonation (1983) for the Hauterivian-Albian interval. The calcareous nannofossil taxa referred herein are indexed in Perch-Nielsen (1985) and Bown *et al*. (1998).

The oldest investigated deposits (*i.e*., Lower Sinaia Beds) contain calcareous nannoplankton assemblages with common *Conusphaera mexicana*, *Polycostella beckmanii* and *Umbria granulosa*, taxa indicative of the NJK Biozone, Subzone b (Fig. 3), Late Tithonian in age. The first occurrence (FO) of the nannofossil *Rotelapillus laffittei* marks the base of the NJKc Subzone, which includes the Jurassic/Cretaceous (= Tithonian/Berriasian) boundary. Hence, the above-mentioned boundary falls towards the upper part of the Lower Sinaia Beds. These data are in agreement with the age identified based on calpionellid assemblages, which argue for the presence of the *Calpionella alpina* (Patrulius *et al*., 1976; Pop, 1997) within the upper part of the Lower Sinaia beds. The youngest Subzone (d) of the NJK nannofossil zone of Bralower *et al*. (1989) could not be identified, as the FO of *Nannoconus steinmannii minor* (its index species) was already recorded within the latest Tithonian in the investigated area.

The boundary between the NJK and NK1 calcareous nannofossil zones (which is placed around the Early/Middle Berriasian boundary, according to Handerbol *et al*., 1998), is marked by the FO of the nannofossil *Nannoconus steinmannii steinmannii*, and was recognized towards the top of the Lower Sinaia Beds. The NK2 calcareous nannofossil zone (which covers in the Romanian Carpathians the Late Berriasian- Early Valanginian interval, according to Melinte and Mutterlose, 2001) extends from the top of the Lower Sinaia Beds to the upper part of the Middle Sinaia Beds. Another nannofossil event of this biozone is the FO of *Speetonia colligata*, which approximated the Berriasian/Valanginian boundary in the Carpathian area (Melinte and Mutterlose, 2001).

The FO of the nannofossil *Calcicalathina oblongata*, which marks the base of the NK3 calcareous nannofossil zone, was observed bwithin the Middle Sinaia Beds.. The regional distribution of this biozone is restricted to the Late Valanginian interval, based on the calibration with ammonites and calpionellids in other Carpathian areas (Melinte and Mutterlose, 2001). Our investigations indicate that the NK3 Biozone covers the upper part of the Middle Sinaia Beds, and includes also the FO of the nannofossil *Tubodiscus verenae*.

The base of the NC4 Biozone, latest Valanginian-Early Hauterivian in age (Handerbol *et al*., 1998) was observed, towards the top of the Middle Sinaia Beds, based on the FO of *Nannoconus bucheri*. This event is followed by the FO of *Lithraphidites bollii*, which is placed towards the upper part of NC4, within the Early Hauterivian (Roth, 1983). The next biozone, NC5 (including all its subzones), which extends within the Late Hauterivian-Late Barremian interval, is originally defined based on successive LO of the nannofossils *Cruciellipsis cuvillieri*, *Speetonia colligata*, *Lithraphidites bollii*, and *Calcicalathina oblongata* (Roth, 1983; Bralower *et al*., 1995). Because the sediments investigated by us are turbidites, and consequently they often contain reworked nannofossils from older deposits, the base of the NC5 biozone could not be pointed out. The NC6, NC7 and NC8 zones, recognized based on the successive first occurrence of the nannofloral taxa *Chiastozygus litterarius*, *Hayesites irregularis*, *Eprolithus floralis*, and *Prediscosphaera columnata*, were observed within the Comarnic, Piscu cu Brazi and Shaly-Sandy Flysch lithological units.

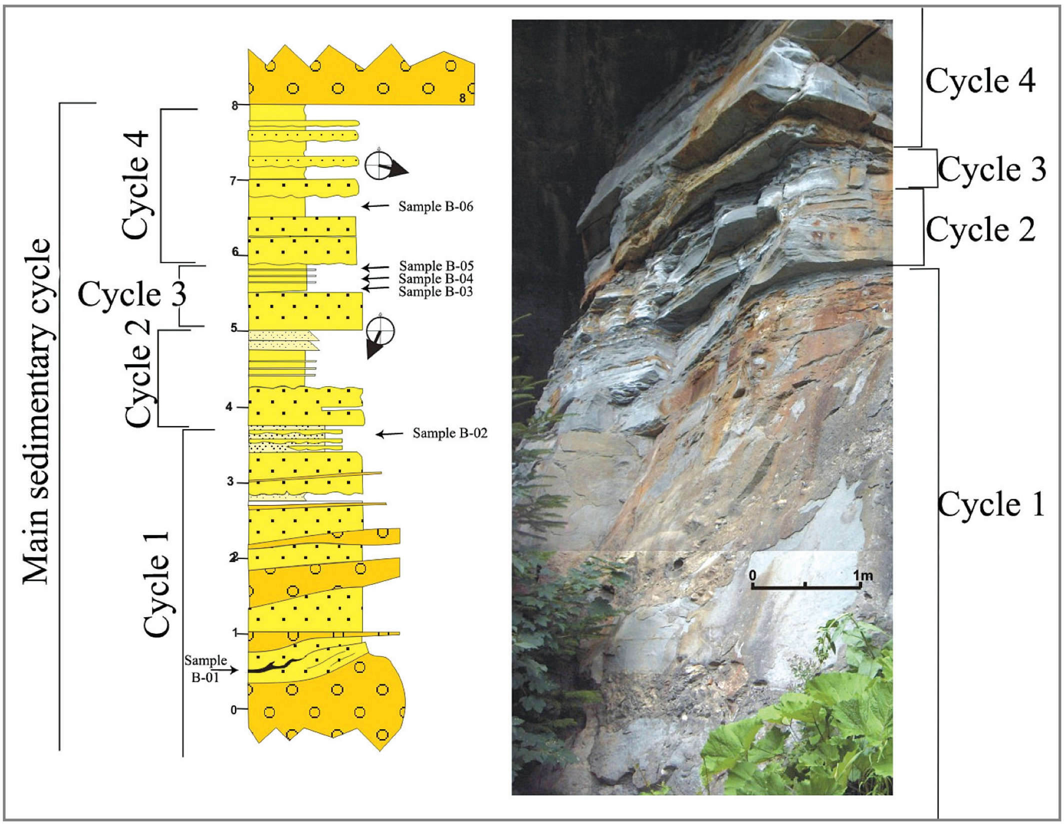
## SEDIMENTOLOGY

Our sedimentological investigations focussed on the Lower Cretaceous conglomerate sequences which crop out in the Bucegi Mts. Area. Three sections which display Early Cretaceous conglomerate outcrops, namely Valea Spumoasă, Valea Jepilor and Valea Mălăieşti, were analyzed sedimentological point of view. The investigated successions of the Bucegi Conglomerates display one major sedimentary cycle, which could be divided in 4 sedimentary cycles (Fig. 4). All the 4 cycles yielded a normal grainsize, and are characterized by an alternance of conglomerates, sandstones and silts.

Additionally, several types of sedimentary structures were encountered within the Upper sandy-conglomerate turbidites placed below the Bucegi Conglomerates in the Jepilor Valley (left slope). Ripple marks, parallel laminaţion, lamina intercalated as thin fine sandy beds in a silt-clayey matrix, as well as silt-clayey intercalations in a sandy matrix are the most frequent sedimentary structures observed. Within the Bucegi Conglomerates, we identified a succession of sequences, made by, towards the base of conglomerates, which are followed towards the top by sandstones. The conglomerate-sandstone sequences repeated (Fig. 5), the passing from the conglomerate to the sandstone is gradual, throughout by microconglomerates beds.

Detailed sedimentological analysis were achieved on photographs taken of several conglomerate sequences (Fig. 6). Hence, we have studied the matrix-element ratio (Fig. 7), the round degree of the clasts (Fig. 8), the number of clast contacts (Fig. 9), and also the type of contacts between the clasts (Fig. 10).

It may be observed that always the matrix is smaller than the clasts in several locations of the Bucegi Conglomerates of the Jepilor Valley. Most of the clasts are sub-rounded, except for the D location, where the sub-angular clasts prevailed. In




▲ **Fig. 4** Upper Aptian sequence at the base of the Bucegi Conglomerates in the left slope of the Jepilor Valley

◀ **Fig. 5** Conglomerate-sandstone sequence


**Fig. 6** The analyzed detailed photpgraphs of the Middle Bucegi Conglomerates in Jepilor Valley

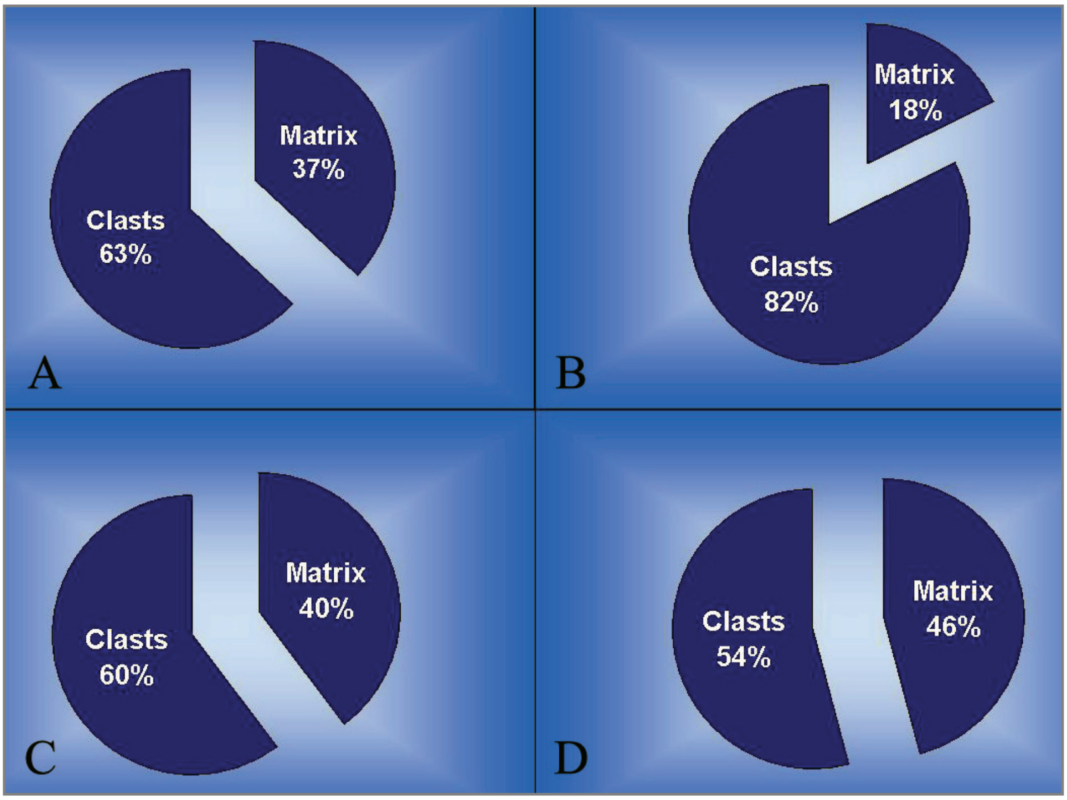



**Fig. 7** The matrix/clast ratio of the Middle Bucegi Conglomerate studied sequences in the Jepilor Valley

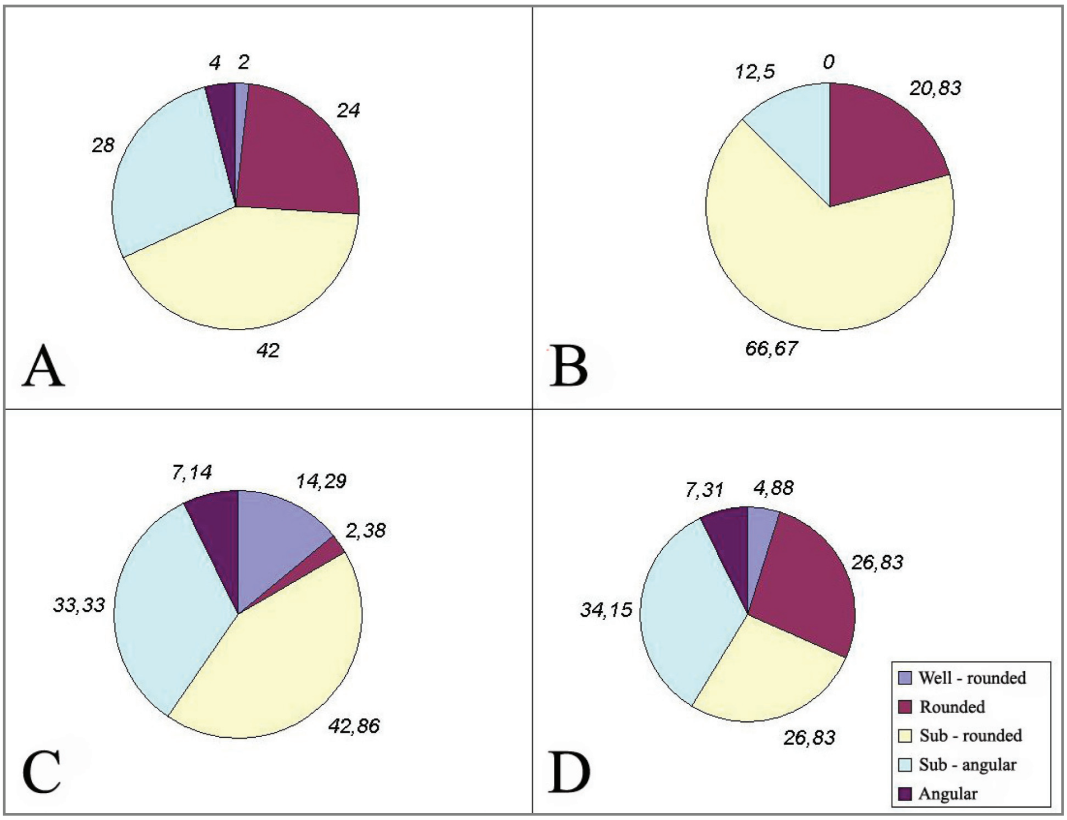



**Fig. 8** The round degree of the clasts of the Middle Bucegi Conglomerates in the Jepilor Valley

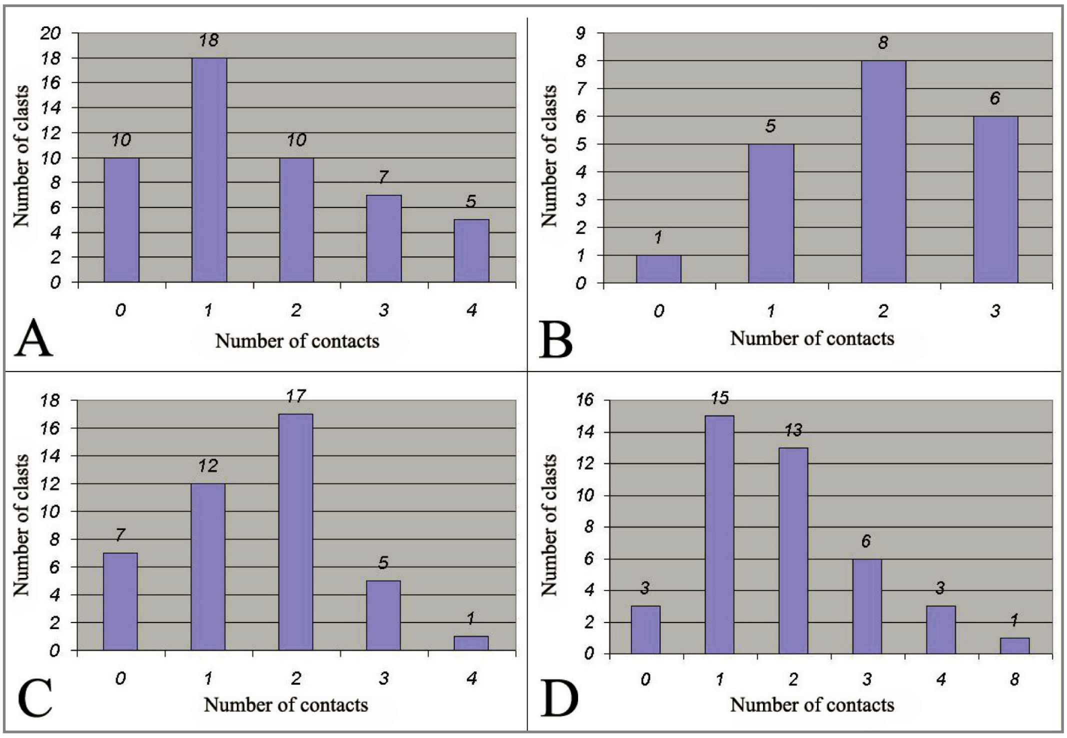



**Fig. 9** Number of clast contacts of the Middle Bucegi Conglomerates in the Jepilor Valley

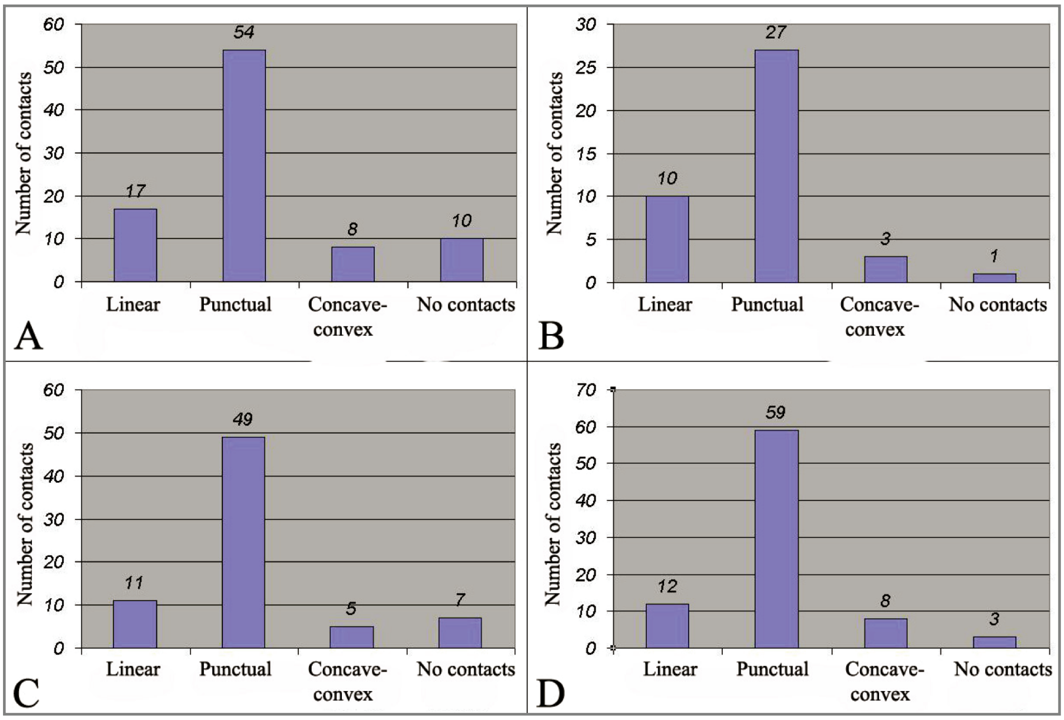



**Fig. 10** The type of clast contacts in the Middle Bucegi Conglomerates from the Jepilor Valley

the locations A and D, the clasts with a single contact are predominant, while in the location B and C the clasts with two contact are the main. The maximum contact number of a clast was recorded in the location D, being eight. In whole the studied locations, the punctual contact type is dominant, being followed by the linear one, and by the concave-convex contact, which is the rarest. A very few clasts show no contact.

## CONCLUSIONS

Our investigations indicated that a continuous sedimentation took place, in the Romanian Carpathian bend area (the Bucegi Mts. region) within the latest Tithonian-Albian interval. All the calcareous nannoplankton zones characterizing the above-mentioned interval were recognized by us.

During Early Cretaceous times, the sedimentation is mainly characterized by the presence of turbidites, which are followed by thick piles of conglomerates. Our detailed sedimentological investigations of the Bucegi Conglomerates revealed the presence of a major depositional cycle, which could be divided into 4 sedimentary cycles.

The investigated Bucegi Conglomerates are orthoconglomerate type. In all the studied sections, the clasts prevailed over the matrix, and the dominant type of clasts is sub-rounded.

We may assume that our future investigation on the topic presented herein will bring also answers concerning the depositional environment of the Bucegi Conglomerates.

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## REFERENCES

Bown, P.R., Rutledge, D.C., Crux, J.A., Gallagher, L.T., 1998. Lower Cretaceous. *In*: Bown, P.R. (Ed.), Calcareous nannofossils Biostratigraphy. *British Micropaleontological Society Publications Series* (Chapman & Hall Ltd/Kluwer Academic Press), 86-102.

Bralower, T.J., Monechi, S., Thierstein, H.R., 1989, Calcareous nannofossil zonation of the Jurassic-Cretaceous Boundary Interval and Correlation with the Geomagnetic Polarity Timescale. *Marine Micropaleontology*, **14**, 153-235.

Cloetingh, S., Bada, G., Maţenco, L., Lankreijer, A., Horváth F., Dinu, C. 2006, Modes of basin (de)formation, lithospheric strength and vertical motions in the Pannonian-Carpathian system: inferences from thermo-mechanical modelling. *In*: Gee, D.G. & Stephenson, R.A. (Eds.): *European Lithosphere Dynamics*. Geological Society London Memoirs, **32**, 207-221.

Dumitrescu I., Săndulescu M. 1968, Problèmes structuraux fondamentaux des Carpates roumaines et de leur avant-pays. *Annuaire du Comité Géologique*, **XXXVI**, 195-218.

Hardenbol J., Thierry, J., Farley, M.B., Jacquin, T., de Graciansky, P.-C., Vail, P.T., 1998, Chart 5: Cretaceous Biochronostratigraphy. In: De Graciansky, P.-C., Hardenbol J., Jacquin, T., Vail, P.T. (Eds.), *Mesozoic and Cenozoic sequence chronostratigraphic framework of the European basins. Society of Economic Paleontology and Mineralogy, Special Publications*, **60**, 3-15.

Jipa, D., 1961, Calcarenitele stratelor de Comarnic: curenţi, sedimentaţie, geneză. *Studii si cercetari geologice*, **VI/1**, 27-54.

Jipa, D., 1965, Asupra genezei şi nomenclaturii unor calcare eocretacice din flişul Carpaţilor Orientali. Studii si cercetari geologice, geofizice si geografice, Seria geologie, **9/2**, 525-532.

Jipa, D., 1980, Orogenesis and Flysch Sedimentation. Critical Remarks on the Alpine Model. *Sedimentary Geology*, **27/3**, 229-239.

Melinte M.C., 1996, Calcareous nannoplankton from the Sinaia Formation (Ceahlău Nappe, Eastern Carpathians). *Anuarul Institutului Geologic al României*, **69/1**, 144-150.

Melinte, M., Mutterlose, J., 2001, A Valanginian (Early Cretaceous) 'boreal nannoplankton excursion' in sections from Romania. Marine Micropaleontology, **43**, 1-25.

Melinte, M.C., Jipa, D., 2007. Stratigraphy of the Lower Cretaceous sediments from the Romanian Carpathian Bend area. *Acta Geologica Sinica, English Edition*, **81/6**, 949-956.

Murgeanu, G., Patrulius, D., Contescu, L., Jipa, D., Mihailescu, N., Panin, N., 1963, Stratigrafia şi sedimentogeneza terenurilor cretacice din partea internă a curburii Carpaţilor. *Geological Carpatho-Balkan Association, Congress V*, **III/2**, 31-58.

Panin, N., Mihăilescu, N., Jipa, D., Contescu, L., 1961, Asupra modului de formare al Conglomeratelor de Bucegi. *Geological Carpatho-Balkan Association, Congress V Bucarest,* **III/2**, 89-105.

Patrulius, D., 1969, Geologia Masivului Bucegi şi a Culoarului Dîmbovicioara. Editura Academiei R. S. R., 321 pp.

Patrulius, D., Neagu, Th., Avram, E., Pop, G., 1976, The Jurassic-Cretaceous boundary Beds in Romania. *Anuarul Institutului de Geologie şi Geofizică*, **50**, 71-125.

Perch-Nielsen, K., 1985. Mesozoic calcareous nannofossils. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy: Cambridge* (Cambridge Univ. Press), 329–426.

Pop, G., 1997, Tithonian to Hauterivian praecalpionellids and calpionellids: bioevents and biozones. Mineralia Slovaca, **29(4-5),** 304-305.

Roth, P.H., 1983, Jurassic and Lower Cretaceous calcareous nannoplankton in the western North Atlantic (Site534): biostratigraphy, preservation and some observations on biogeography and palaeoceanography. *Initial Reports of Deep Sea Drilling Projects*, **76**, 587-621.

Săndulescu, M., 1984, Geotectonica României. Editura Tehnică Bucureşti, 336 pp.

Săndulescu, M., 1988, Cenozoic tectonics history of the Carpathians In: Royden, L.H. and Horwath, F. (eds.), The Pannonian Basin: a study in basin evolution. *AAPG Memoir*, **45**, 17-26.

Săndulescu M., 1994, Overview on Romanian Geology. *Romanian Journal of Tectonics and Regional Geology*, **75**, 2, 3-15.

Săndulescu, M., Micu, M., Ştefănescu, M., Jipa, D., Mihăilescu, N., 1980, Cretaceous and Tertiary Molasses in the Eastern Carpathians and Getic Depressions. *Guidebook Series of the Geological Institute of Romania*, 3-72.

Stanley, D.J., Hall, B., 1978, The Bucegi Conglomerates: a Romanian Carpathian submarine slope deposit. *Nature*, **276**, 60-64.

Ştefănescu, M., 1976, O nouă imagine a structurii flişului intern din regiunea de curbură a Carpaţilor. *Dări de Seamă ale Institutului de Geologie şi Geofizică*, **LXII/5**, 257-279.

Ştefănescu, M., 1995, Stratigraphy and structure of Cretaceous and Paleogene flysch deposits between Prahova and Ialomiţa valleys. *Romanian Journal of Tectonics and Regional Geology*, **76**, 1, 4-49.

Ştefănescu, M., Micu M., 1987, Flysch deposits in the East Carpathians. *In*: Ştefănescu M. (*ed.*), *Flysch deposits from the Hartz, the Thuringian and Vogtlandian Slate Mountains, the Carpathians, the Balkans and the Caucasus*. Editura Academiei RSR, 65-99.

Ştefănescu, M., Melinte, M., 1996, Cretaceous-Early Miocene subsidence and the related source and reservoir rocks in the Moldavids. *In*: Wessley G. and Liebl W. (eds), *Oil and Gas in Alpidic Thrustbelts and Basins of Central and East Europe*, Vienna 1996. EAGE Special Publication, **5**, 197-200.