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BIOSTRATIGRAPHY AND ZONATION OF THE LOWER CRETACEOUS CARBONATE SUCCESSION FROM CERNAVODĂ-LOCK SECTION, SOUTH DOBROGEA, EASTERN PART OF THE MOESIAN PLATFORM (ROMANIA)

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Abstract: A newly proposed biostratigraphic zonation of Early Cretaceous microfossils (mainly foraminifera) improved the resolution for dating the shelf carbonate platform deposits from Cernavodă-lock section, South Dobrogea, eastern part of the Moesian Platform. The zonation comprises 12 zones (biozones) for the Upper Berriasian-Valanginian-Lower Hauterivian. Benthic foraminifers marker are represented by *Protopeneroplis ultragranulata*, *Andersenolina elongata*, *Dobrogelina anastasiui* (Upper Berriasian), *Haplophragmoides joukowski*, *Montsalevia salevensis*, *Carasuella cylindrica* (Lower Valanginian), *Danubiella gracilima*, *Rumanoloculina robusta*, *Meandrospira favrei* (Upper Valanginian), respectively *Protopeneroplis banatica*, *Vercorsella tenuis*, *Moesiloculina danubiana* (Lower Hauterivian). The new biozonation scheme has allowed correlation of the studied succession with other major paleogeographic realms on the Romanian territory, in the eastern part of the Moesian Platform including South Dobrogea, in the Eastern Carpathians (Hăghimaş Mts., Transylvanian Carbonate Platform), the South Carpathians (Getic Carbonate Platform), the Apuseni Mts., as well as with Tethyan shelf basins of the European margin (France, Jura, Mont Saléve, Sardinia, Abruzzi Mts., Dinarides, Northern Calcareous Alps, West Carpathians, Stramberk Limestones) and the Western Pontides, Anatolia (Turkey).

Keywords: Biostratigraphy, Biozones, Foraminifers, Lower Cretaceous, Cernavodă, South Dobrogea. Moesian Platform.

1. INTRODUCTION

The Moesian Carbonate Platform is a major tectonic unit of the Romanian territory, confined to the north by the Carpathian Foredeep and to the south by the Balkan Orogene (Săndulescu 1984). The Moesian unit in the Romanian sector, or the Wallachian Platform, includes Jurassic and Lower Cretaceous deposits cropping out in its eastern part, in Central and South Dobrogea, and representing a wide range of depositional settings, from continental deposits to inner and middle shelf shallow marine carbonates, interlayered with Purbeckian evaporites (Dragastan 2001, Stoica 1997, 2007).

The investigated section is situated on the right bank on the Danube – Black Sea Channel near the Cernavoda lock, (Fig. 1). This new outcrop represent a west to east tending extension of the classical north-south oriented Cernavodă section, on the right bank of the Danube, described previously by Anastasiu (1896, 1898), Simionescu (1906, 1913), Macovei (1911), and Macovei & Atanasiu (1934).

A large amount of chronostratigraphic data concerning the local Lower Cretaceous were obtained by different biostratigraphical methods, using palaeontology, micropalaeontology (foraminifers and ostracods), palaeo-algology (calcareous algae), as well as microfacies and palaeoenvironmental reconstruction of the carbonate shelf.

The most important monographic review was the synthesis of Macovei & Atanasiu (1934) regarding the Cretaceous deposits of the Romanian Carpathians and Vorland, which also includes a synthesis and a drawing of the classical Cernavodă profile. The authors distinguished the followings lithological units:

- basal nodular limestones with *Diceras* sp., *Heterodiceras* sp., *Valletia tombecki* and *Monopleura valanginiensis*, intercalated with unfossiliferous marly-limestones, considered Valanginian in age;

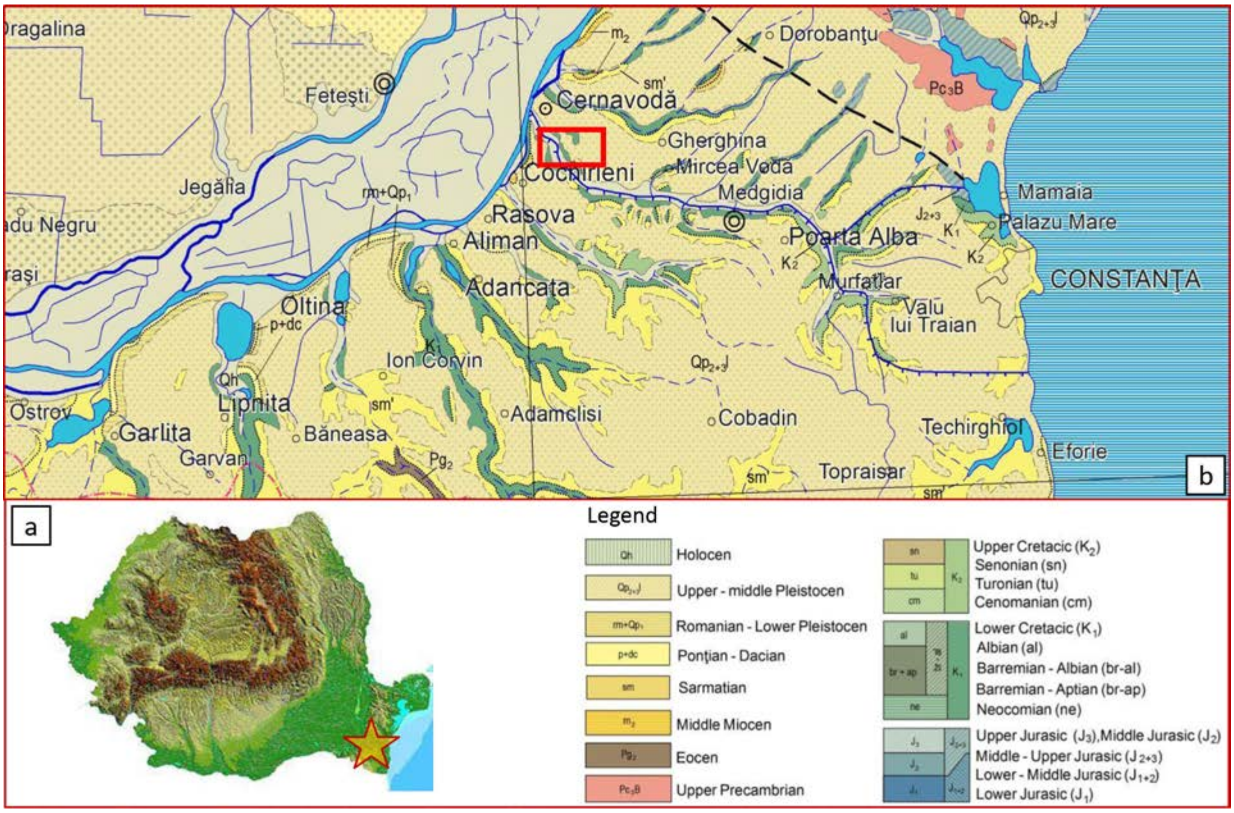

Figure 1. a) The location of the study area, South Dobrogea, Romania. b) Geological map of the South Dobrogea, with the location of Cernavoda lock section-red rectangle (from Geological Map of Romania, scale 1:1 000 000, with the approval No. 101/22.01.2014 of the Geological Institute of Romania)

- a non-fossiliferous sequence of marls and clays, limestones and siliceous nodules assigned to the Hauterivian;
- zoogenous limestones with brachiopods (*Terebratula dutempleana*), bivalves (*Exogyra couloni*, *Ostrea* sp., *Requienia ammonia*, *Toucasia carinata*), gastropods (*Harpagodes pelagi*), nautiloids (*Nautilus neocomiensis*), fishes (*Coelodus* sp.) and dinosaurs (*Megalosaurus* cf. *superbus* found at Cochirleni locality, 9 km south of Cernavodă). Based on these data, the succession was assigned to the Valanginian-Barremian age (Simionescu 1913), in spite of the presence of a mixture of Valanginian, Barremian or even Aptian-Lower Albian taxa. In fact, most of the reported taxa indicate a Valanginian age.
- Aptian limestones yielding terebratulids, bivalves, gastropods, ammonites, with intercalations of fluviatile sands and pebbles, as well as marly limestones with *Orbitolina lenticularis*.

The monographic paper of Dragastan et al., (1998) showed that the Hauterivian and Barremian deposits are absent from the classical profile of the Cernavodă, this interval corresponding to a hiatus in sedimentation.

The rich Early Cretaceous fauna, microfauna and microflora from the Cernavodă area became a well-known assemblage, representing different shelf and tidal flat to continental facies and communities. The area represents today a protected area, as a national paleontological and geological natural reserve.

2. SAMPLE LOCATIONS AND MATERIALS

The micropaleontological content (foraminifers, ostracods and microflora) reported herein originates from the Lower Cretaceous sedimentary successions cropping out on the right bank of the Danube-Black Sea channel at Cernavodă-lock, South Dobrogea (Fig. 1 and Fig. 7). These calcareous-marly and clayey deposits belong to the Cernavodă Formation (Upper Berriasian-Valanginian-Lower Hauterivian in age).

The studied material comprises 45 samples and 65 thin sections, sampled from the new outcrop of Cernavodă-lock situated in the vicinity of Cernavodă town. The samples and thin sections are deposited in L.P.B. Collection V-MMPP (Microfacies, Micropalaeobotany, Palaeobotany and Palynology), under the numbers 1215-1280, Laboratory of Palaeontology, Department of Geology, University of Bucharest.

3. LITHOSTRATIGRAPHIC UNITS

The lithostratigraphic zonation of the Jurassic-Cretaceous boundary and Lower Cretaceous deposits from South Dobrogea, in the eastern part of the Moesian Platform, is based on the descriptive paleontological and lithological classifications of different authors (Simionescu, 1906, 1913, 1926, 1927, Neagu et al., 1977; Dragastan, 1978; Neagu & Dragastan, 1984; Dragastan, 1985a,b; Avram et al., 1988, 1995-1996, Neagu et. al., 1997, Dragastan et al., 1998).

The Lower Cretaceous formations are represented by calcareous and detrital deposits interlayered with Purbeckian evaporite and fresh-brackish water deposits close to the boundary with the Jurassic. According to the present study of the new section, a hiatus which covers the Upper Hauterivian-Barremian stratigraphic interval is present in the Cernavodă area. These deposits are widely developed in South Dobrogea, being crossed by several boreholes and having very instructive, spectacular outcrops, such as the classical, historical outcrops from Cernavodă Bridge and Hinog Hills (south of Cernavoda), on the right bank of the Danube (Fig. 1). They are underlain by Upper Jurassic deposits, with two different facies: a calcareous, dolomitic facies, and an evaporitic tidalitic-lagoonal, more or less detrital one, the deposition both of these being influenced by the North Dobrogean emergent land that bordered Moesian Dobrogea along the Capidava-Ovidiu fault. These evaporitic-detrital deposits correspond to the Purbeckian facies occurring at the Jurassic-Cretaceous boundary (Băncilă, 1973; Stoica, 1997, 2007).

The Upper Jurassic - Lowermost Cretaceous deposits of South Dobrogea are divided into the following lithostratigraphic units:

1. The **Rasova Formation** Dragastan 1985a (Oxfordian–Tithonian), and

2. The **Amara Formation** Dragastan 1985a (Upper Kimmeridgian–Tithonian–Berriasian), subdivided into four members:

2.1. **Dunărea Member** Avram et al. 1995-1996 (Kimmeridgian / Upper Kimmeridgian);

2.2. **Cireșu Member** Avram et al. 1995-1996 (with *Clypeina jurassica*, Tithonian but not basal),

2.3. **Zăvoaia Member** in Avram et al. 1995-1996 (Lower Berriasian) and

2.4. **Medgidia Member** Avram et al. 1988 (Berriasian).

The Zăvoaia Member, following conformably on top of the Cireşu Member, is represented by polychrome clays, dolomites, red-greenish marls, and oncosparitic limestones with some marine dasyclad episodes yielding *Zergabriella praturloni* and *Z. embergeri*, both lower Berriasian in age. It grades towards the east, transitionally, into the *Medgidia Member*, a subunit defined in outcrops from the concrete factory and the harbour of Medgidia locality. It is a polygenic subunit, which contains dolomites with stromatolites, pelsparitic limestones with marls, and caolinitic clays with gypsum crystals (Figs. 2, 3).

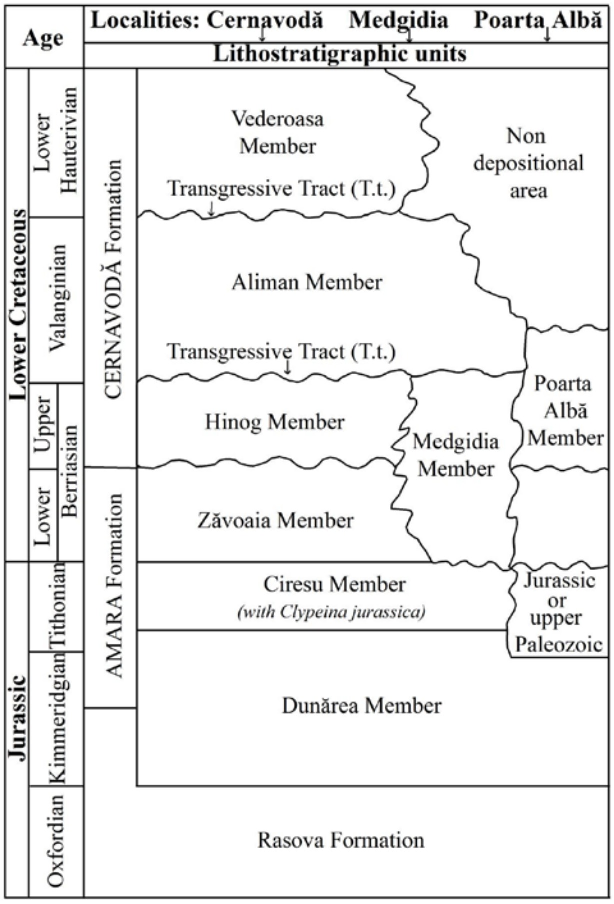

Figure 2. Upper Jurassic–Lower Cretaceous lithostratigraphic units from Cernavodă-Medgidia- Poarta Albă area, South Dobrogea, Romania (after Avram et al., 1995-1996, and Dragastan et al., 1998, modified).

The ostracods, charophytes and coprolites association recorded from this subunit indicates a Lower to Middle and possible upper Berriasian age developed in Purbeckian facies (Stoica, 1997, 2007).

Besides the already described *Amara Formation*, the Lower Cretaceous deposits are represented by:

3. The **Cernavodă Formation** Neagu and Dragastan1984 subdivided into four subunits:

3.1. **Hinog Member,** Dragastan in Avram et al. 1995-1996 Upper Berriasian);

3.2. **Poarta Albă Member**, Ghenea et al., 1984a, 1984b (Upper Berriasian–Lowermost Valanginian);

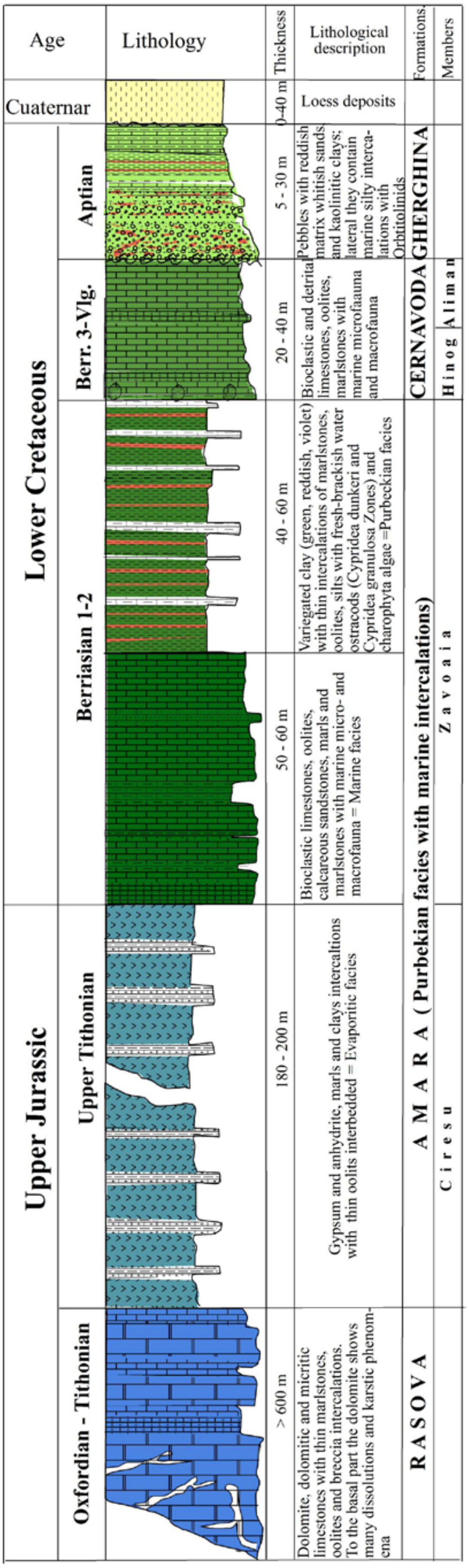

Figure 3. Synthetic column of the U. Jurasic-L. Cretaceous deposits in the Cernavodă area, South Dobrogea, Romania (after Stoica, 2007).

3.3. **Aliman Member**, Ghenea et al., 1984a, 1984b (Valanginian); and

3.4. **Vederoasa Member**, Avram et al., 1995-1996 (lower Hauterivian), (Fig. 2).

The **Cernavodă Formation** is a dominantly calcareous unit largely developed in South Dobrogea as well in eastern part of Moesian platform westward of the Danube. The lower boundary of the formation transgressively covers the *Zăvoaia* and *Medigidia Members* of the *Amara Formation*. Its upper boundary corresponds, in the Dunărea-Saligny-Rasova-Poarta Albă area, to a stratigraphic hiatus, encompassing the Hauterivian (pro parte, in the Cernavoda-lock profile) to Barremian interval. Towards the south from the Cernavodă-lock section, and along the Danube-Black Sea Channel, the Cernavodă Formation is unconformable covered by Aptian-Albian continental-lacustrine, brackish and marine deposits.

The **Hinog Member** (**Upper Berriasian**), identified in the drill cores at Hinog, but also in the Cernavodă-lock outcrop (samples 1, 1a, 1b, see Fig. 7), rests transgressively on the *Zăvoaia Member*, and consists of microconglomerates, grey marly limestones, oosparites, sandy clays, and biostromites limestone with *Harpagodes (Desorites) pelagi* at the top of the succession. In the *Hinog Member* deposits, *H. (Desorites) desori* is associated with the gastropod *Saulea neocomiensis* Pană (in Dragastan et al., 1998) and the fish *Lepidotus* sp. (Fam. Lepidotidae), (Fig. 4). *Lepidotus* is considered a durophagous taxon, feeding on thick-shelled bottom-dwelling invertebrates in shallow marine areas, especially around demospongiid reefs from the inner shelf and lagoons.

The **Poarta Albă Member**, a subunit with a transitional character grading from the Medgidia Member, occurs in the north - eastern part of South Dobrogea. It is dominantly dolomitic, with interlayered marls and clays. Its age was first established as late Berriasian based on its stratigraphic superposition. The sparse presence of the foraminifer *Andersenolina elongata* and of the calcareous algae *Clypeina* sp. and *Rajkaella* sp. (represented mostly by verticil debris), suggests a late Berriasian to earliest Valanginian age. This member is supposed to stay directly on Jurassic deposits or even on the Upper Paleozoic sediments (for the moment there are no drillings data available).

The **Aliman Member** is recorded from drillings, but also from outcrops near Aliman locality, south from the classical profile at Cernavodă, along the Danube River. This subunit covers unconformably and transgressively underlying units such as the Hinog Member, the Zăvoaia Member (pro parte) and the Medgidia Member (Fig. 2).

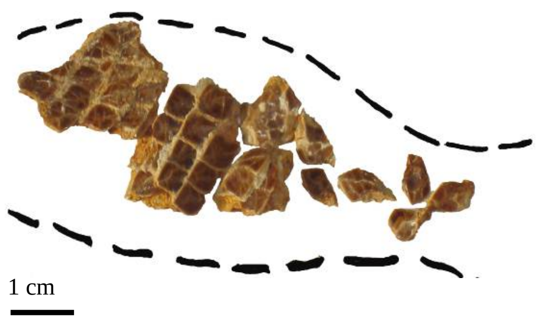

Figure 4. *Lepidotus* sp., a small part of the body covered by typical rhomboidal scales, Upper Berriasian, Hinog Member, Cernavodă Formation, Cernavodă-lock section. **Dragastan Collection**, Laboratory of Paleontology, Department of Geology, University of Bucharest.

The Lower Valanginian (samples 2a-20b) is dominated by limestones (Fig. 7). It begins with breccia containing marly limestones, grey micritic limestones, white-yellowish oolitic limestones, biostromites with *Nerinea* sp., marly clays, bedded lenses with pachyodonts (*Matheronia baksanensis, M. valanginiensis* identified by J. P. Masse – pers comm.) and *Demospongia* patch-reefs (P-R 1, sample 4a, 4b, 4 and P-R 2, sample 12, 12b).

The patch-reef P-R 1 is built of different taxa, mainly *Disparistromaria tenuissima* (Actinostromariidae) and *Granatiparietes simionescuii* Dragastan et al., 1998 (Varioparietiidae). Occasional branching colonies of *Steinerella gigantea* and *S. loxola* (Milloporidiidae) also occur. The reef is cemented by various bio-and lithoclasts, and its top is covered by an algal crust consortium of *Lithocodium* and *Bacinella*.

The patch-reef P-R 2 is built in a great proportion by *Steinerella neagui* (Dragastan et al. 1998), a large branching colony, together with the pharetonid *Barroissia anastomosans*. From between the reefs, remains of the pyconodont fish *Gyrodus* sp. (formerly described under the name *Coelodus* sp. by Simionescu, 1906) were reported from the Valanginian deposits of Cochirleni locality. This taxon fed on thick-shelled, shallow marine bottom-dwelling invertebrates, mostly pachyodonts and gastropods, populating the lagoons of the inner shelf.

The Lower Cretaceous succession continues with micritic-pelmicritic limestones interbedded with oolitic bar deposits, clays and marly limestone nodules, crossed by bioturbations resulting from infaunal activity. The base of this succession (sample 16a) presents ferruginous crusts and vertical flask-shaped borings. These borings resemble, by their shape and structure, the ones produced by the recent bivalve *Gastrochaena ovata*, and therefore identified as *Gastrochaenolites* sp. by Dragastan et al., (1998). The direct action of these burrowing bivalves combined chemical dissolution of the substrate with cementing the walls of the boring with calcium carbonate. The *Gastrochaenolites*-bearing bed is slightly tilted, as a bio-karstic surface of concordant nature, and can be used as a local marker level; it indicates distal lower intertidal and proximal subtidal depositional environments (Stearley, 1987).

A third patch reef with Demospongia (P-R 3i or lower) appears in the upper part of the profile (samples 17, 17a, 17b, Fig. 7). This *patch-reef* is a large table-reef, 10-15 m in length and 2.0 up to 3.0 m in thickness, built by different species of the genera *Actinostromaria, Steinerella, Steineria, Axiparietes*, with rare scleractinian corals. The main builder organisms forming the core of the reef are surrounded by pachyodonts (*Monopleura valanginiensis, Matheronia baksanensis*), the slopes of the reef are occupied by gastropods (*Ampullina, Nerinea)*, and the reef is covered by *Lithocodium-Bacinella* algal crusts (Dragastan et al., 1998, to see the reconstruction of the patch-reef).

The described succession of calcareous deposits cropping out along the Cernavodă-lock section (represented by samples 2a up to 20, 20a, 20b), including the different Demospongia patch-reefs (P-R 1, P-R 2, P-R 3i or lower) and the Gastrochaenolites-bearing surface is referred to the Lower Valanginian.

The **Upper Valanginian deposits** (samples 21a-26) begin with a detrital breccia including angular calcareous litho-and bioclasts, followed by cross-bedded coarse sands and oolitic sands, corresponding to an erosional channel. The unconformable, erosional nature of this basal succession attests the beginning of a short transgressive episode, concomitantly with a gradual deepening of the basin (Dragastan et al., 1998).

The succession continues with pelsparitic limestones interlayered with clays that are overlain by a massive patch-reef limestone (P-R 3 s or upper; samples 22-23, Fig. 7), with a thickness varying from 6.0 m up to 10 m. The patch-reef P-R 3 s (or upper) occurs as a massive limestone with a vertical growth, as expressed by successive accumulation of shells from various groups of organisms. The reef core is made up of lamellar crusts or dome-like colonies of Demospongia - *Chaetetides,* spongiostromiids, actinostromariids, parastromatoporiids (*Steinerella*), milleporidiids, and varioparietiids (*Granatiparietes* and *Varioparietes*). The core of the reef was covered successively by large pachyodont bivalve shells (*Matheronia baksanensis*) forming more or less tabular beds, passing laterally to gastropod-rich coquina limestones with *Nerinea, Purpuroidea, Leviathania, Harpagodes* and *Ampullina*. The uppermost part of this succession is represented by bedded limestones containing different types of ostreids, mostly shells of *Ostrea germiani* (samples 25a, 25b and 26), which build an oyster-reef bank with variable thickness, ranging between 10 cm and 20 cm.

The Valanginian deposits from the Cernavodă and Hinog areas have also yielded several nekto-benthonic species of Nautiloidea, like *Cymatoceras neocomiensis* and *C. pseudoelegans*, reported by Simionescu (1906) and restudied subsequently by Andrăşanu (1993).

The Valanginian fossil assemblage is both rich in individuals and taxonomically diverse, with about 175 lower-level taxa recognized up to now. The macrofauna is the most diverse, accounting for approx. 58% of the recorded diversity, while the microfauna, represented mainly by forams, and the microflora (cyanophycean, rhodophycean and chlorophycean algae)-(Neagu et al., 1997).

Within the microfauna, a diverse association of foraminifera recorded from the Cernavodă outcrops and drillings, shows the dominance of the involutinides (more than 40%) (represented by andersenolinids, trocholinids, and neotrocholinids), followed by textulariids and miliolides with variable rate ranging from 22 up to 40 % each of these two groups.

The macrofauna, comprising over 100 lower-level taxa, is dominated by invertebrates. The remains of vertebrates, represented by pycnodont fishes like *Gyrodus* sp. (= *Coelodus* sp., **Simionescu Collection**), are very rare.

An overview of the trophic and habitual composition of the fossil assemblage reveals several noteworthy features:

- *filter-feeding* organisms represent the most diverse trophic group; plant feeders (microphages and/or herbivores) and predators are also well represented, while *deposit-feeders* are less diverse;
- epifaunal organisms account for 83% of the taxic diversity. The sessile epifauna is less diverse than the vagile one. Semi-infaunal taxa are less diversified (represented mostly by bivalves and carnivorous gastropods), while both the nektonic or nekto-benthonic organisms and the deep infauna show an extremely low diversity.

The depositional setting of the Valanginian sediments was represented by shallow-water, inter-tidal to subtidal environments, as supported by the presence of typical intertidal (patellids, neritids) or subtidal (pachyodonts, ostreids, pleurotomariids, some brachiopods) organisms.

The widespread of the calcareous algae (chrolophyceans, pseudoudoteaceans), as well as the abundance of herbivorous organisms, point to the presence of an extensive vegetal cover, thus that of a low-bathymetry photic zone from the inner shelf depositional system. This is also supported by the sedimentary structures identified in the Valanginian deposits, such as the low-angle, large-scale tabular cross-stratification, crossed by the *Thalassinoides - Gastrochaenolites - Arenicolites* ichnofacies. The local association evolved under normal marine to slightly brackish conditions, as shown by the dominance of organisms typical for open marine reef environments (naticids, monopleurids, harpagodids, demospongids, chaetetids, and rare scleractinian corals). On the other hand, rich and taxonomically diverse assemblages usually mark normal marine environments (Boucot 1981). The distributional pattern of the Valanginian macro-microfauna and microflora from the Cernavodă area suggests a cyclic evolution for the local palaeocommunities, represented by the recurrence of *polytaxic communities*, succeeded by *oligotaxic communities*, and then by barren beds. Such an evolution was presumably controlled by cyclic, small-scale shifts (either basinward or landward) of the sedimentary environments within the intertidal to subtidal zones.
The Lower Hauterivian corresponds to the **Vederoasa Member** transgressively overlays the Aliman Member, and was for the first time identified at the Cernavodă-lock profile (samples 27a to 42). The type section of this subunit is separated in outcrops spanning both sides of the Vederoasa Lake (southeast of Aliman locality, to the south of Cernavodă). In the Cernavodă-lock section his subunit begins with sandy oolitic and oolitic limestones with different sized ostreid shells, followed by yellowish-white pelsparitic limestones and grey-white, rarely reddish, micritic limestones, in turn overlain by the patch-reef P-R 4 (corresponding to the levels with samples 28a, 28b).

The body of *patch-reef P-R 4* has a thickness of up to 2.0 m. The reef installed on top of a coquina bed with pachyodonts (*Matheronia* sp.) and its core was built by *Granatiparietes simionescui* (Dragastan et al., 1998), a strong fan-shaped colony, and subsequently by *G. rumanus* (Dragastan et al., 1998) and *Axiparietes tremulus* (Varioparietidae).

Actinostromariids (*Actinostromaria coacta*) and parastromatoporiids (*Steinerella neagui* Dragastan et al., 1998) also contributed to the growth of the up to 2 m thick reef. The slopes of the patch-reef are covered by algal crusts of the *Lithocodium-Bacinella* group and by rare scleractinian corals (Stylinidae), as well as by bioclastic breccia debris of sponges, algae and foraminifers. The presence of the *Lithocodium-*

Bacinella algae consortium is important due to its role in cementing the frame of the patch-reef.

The genus *Lithocodium* is a heterotrichale calcareous alga (Schlagintweit, 2010) abundant in the Lower Cretaceous of the Romanian Carpathians (Dragastan 1975, 2010) and in the Moesian Platform, including South Dobrogea. Meanwhile, the genus *Bacinella* was an organism that excavated branching galleries into biogenic hard substrates, such as *Lithocodium aggregatum* crusts; its morphology and boring activities are comparable to the recent filamentous-septatae euendolithic green algae of the Class Ulvophyceae (Schlagintweit & Bover-Arnal, 2012). The reef shows two growth trends, a first one with a vertical accretion tendency induced by the different *Steinerella* species, and a second, lateral one developing on the slopes of the reef, represented by bioclast breccias cemented by the *Lithocodium-Bacinella* consortium and by *Axiparietes*, a chaetetid builder. The top of the reef is covered by a platty bed cemented by the pachyodont *Monopleura* sp. Following on top of the patch-reef P-R 4, the succession continues with a cross-bedded oolitic level, corresponding to a channel fill (samples 32a, 32b, 33), as well as with variegated clay interbeds (samples 34a–36) and a bioclastic oolitic bar (samples 37a–38a).

The succeeding, uppermost part of the Vederoasa Member is represented by interbedded yellowish clays and bioclastic oolitic sands (samples 39–41a, b) with large *Ostrea* shells. The succession of the subunit is concluded by a mixture of sandy clays and platty yellow-red, fine calcarenites with a small *Actinostromaria coacta* patch-reef (P-R 5, sample 42, Fig. 7). After a stratigraphic hiatus corresponding to the Upper Hauterivian–Barremian, the Lower Hauterivian Vederoasa Member of the Cernavodă Formation is covered in the Cernavodă area and in the Cernavodă-lock profile by a transgressive tract advancing from the south; these overlying marine calcareous deposits correspond to the Ostrov Formation (Dragastan, 1985a). This lithostratigraphic unit, initially named the Ostrov-Gârliţa Formation after a small locality near Bugeac Lake, was revised recently by Dragastan et al. 1998. It is predominantly carbonatic, transgressively overlaying the various members of the Cernavodă Formation and consists of accumulations of pachyodont coquina with sponges, scleractinian corals, and intercalated levels with orbitolinids.

The **Ostrov Formation** Dragastan 1985a *was redefined and revised (Dragastan et al., 1998) to include the following subunits:*

4.1. The **Adâncata Member** Dragastan et al. 1998 (Lower Barremian)*;*

4.2. The **Gârliţa Member** Dragastan et al. 1998 (Upper Barremian);

4.3. The **Lipniţa Member** Dragastan et al. 1998 (Lower Aptian) and

4.4.The **Şipote Member** Dragastan 1985a (uppermost Barremian- Lower Aptian).

4.3. The **Lipniţa Member, Ostrov Formation**.

In the Cernavodă-lock profile, the succession of the Ostrov Formation starts with the Lipniţa Member, a Lower Aptian subunit covering transgressively and unconformably the lower Hauterivian Vederoasa Member of the Cernavodă Formation.

It is also possible, that a part of the Lower Aptian deposits belongs to the **Ramadan Formation** (Ghenea et al., 1984a). This unit represented by gravels, microconglomerates and sandstones more or less with glauconit, parallel as stratifications or with cross beddings, which contains gastropods and ostreids (see the geological map, Sheets 181 a, Peştera).

We consider that in the area of Cernavoda-Chochirleni, during the Lower Aptian the coast line between marine and littoral- continental lacustrine and fluviatile facies presented promontories with different shapes and lithologies being a laterally passing from N to S, between *Ramadan Formation* and *marine Lipniţa Member*, *Ostrov Formation with Palorbitolina lenticularis*. The presence of lumachelic calcarenites, calcirudites with pachyodonts, foraminiferal calcarenites and quartzose-orbitolinids, sands or sandstones, microconglomerates with gastropods and ostreids sensu Avram et al., (1995-1996) description (representing the Ramadan Formation), shows a mixture of fossils, lithologies and facies from littoral continental, fluviatile up to subtidal, marine inner shelf facies, the last one corresponding to the Lipniţa Member of Ostrov Formation, (Fig. 5).

The species *P. lenticularis* is considered a **Taxon-range Zone** in **the Lower Aptian** (Husinec et al., 2000). In the Cernavodă-Hinog area, on the right bank of Danube river, and also at Cernavodă-Bridge and Cernavodă-lock, the lower Aptian (Bedoulian, pro parte) is represented by a marine facies with *P. lenticularis* which passes laterally into Ramadan Formation, and is overlain by, the Gherghina Formation (Lower Aptian, pro parte, and Middle Aptian).

5. The **Gherghina Formation,** Avram et al., 1988 covers a restricted area in the southern part of Central Dobrogea and in the northern part of South Dobrogea. The type section of this unit is defined on the left bank of Ţibrinu Valley up to Gherghina village (Fig. 1), with a succession of about 60 m (Avram et al. 1995-1996). Covering unconformably the *Palorbitolina lenticularis* limestones of the Lipniţa Member of Ostrov Formation and the Ramadan

Formation, the Gherghina Formation contains an alternation of pebbles, conglomerates (Fig.5), followed by sandy, multicolored kaolinite clays and cross-bedded sands containing fragments of silicified wood (a large specimen, measuring 6.0 m in length and up 1.0 m in diameter, was discovered at Hinog by Neagu and Dragastan during fieldwork between 1974–1986). The study of these woods fragments from the sandy and multicolored kaolinite clays allowed Iamandei & Iamandei (2005) to describe a new species of protopinaceous conifer as *Protocupressinoxylon dragastanii*. A fragment of this conifer trunk was exposed at the Cernavodă city hall. It is not excluded that this level (Fig. 5) would yield vertebrate remains after systematic excavations in the near future.

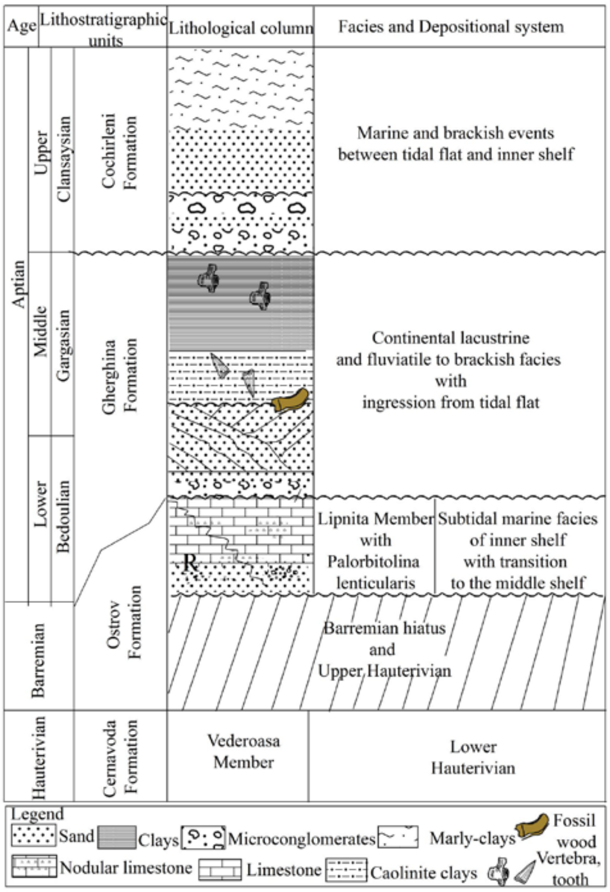

Figure 5. The lithological column of Aptian-lower Albian deposits from the Cernavodă area (South Dobrogea), including the Ostrov Formation (Lipniţa Member; Lower Bedoulian); Ramadan Formation(Lower Aptian); Gherghina Formation (upper Bedoulian–Gargasian) and Cochirleni Formation (Clansaysian–Lower Albian). Not to scale.

6. The **Cochirleni Formation** Avram et al., 1988, crops out on the right bank of the Danube, between Hinog and Cochirleni localities, overlying transgressively the Neocomian or the lower and middle Aptian deposits. The basal part of this unit is represented by pebbles and conglomerates with shelly debris, followed by argillaceous glauconitic sands and phosphate nodules, as well as marly clays with phosphatized shells of ammonites, gastropods and bivalves (Fig. 5). The ammonite assemblage described by Chiriac (1981, 1988) from this condensed phosphatic facies suggests the presence of the upper Aptian (Clansaysian) to lower Albian. These marly clays with phosphatic levels also have potential of yielding vertebrates, including dinosaurs or other reptiles.

4. THE PROBLEM AND THE AGE OF DINOSAURIA TOOTH DESCRIBED FROM COCHIRLENI BY SIMIONESCU (1913)

Up to now, only two dinosaurian fragments were found and described from this area, a vertebra, currently exposed in the Simionescu Collection from National Museum of Geology in Bucharest, under Nr. 11890, Barremian?, found at Cochirleni locality, and a tooth of *Megalosaurus* cf. *superbus* Sauvage, from the Valanginian–Barremian, fide Simionescu (1913), also from Cochirleni, exposed in the Simionescu Collection of the Department of Geology, “Al. I. Cuza” University from Iaşi (Fig. 6). The paper of Simionescu was published in 1913 with a description of *Megalosaurus* tooth at pages 686-687 and with figure 1 at page 687. The author compared the Cochirleni tooth with the species *M. bucklandi* Huxley and Owen, which had a large tooth of 68 cm in length, as well as with *M. superbus* Sauvage, that shows a similar shape, but different length and fine denticles continuing up to the neck region. Based on his comparisons, Simionescu considered the Cochirleni tooth as being comparable, but not identical, to the tooth from the Albian marine facies of Louppy-le Chateau, the type locality of Sauvage’s species.

According to Simionescu, the main differences from Sauvage’s species consist in the tooth shape, being conic-elongate, pointed to the distal part, compressed laterally and with small denticulites hull on the median opposite side, although both specimens have more similar sizes. According to new paleontological data, the correct name for this *Megalosaurus* species is *Erectopus superbus* (Sauvage 1882) Huene 1921 with alternative combinations as *Dryptosaurus superbus* and *Megalosaurus superbus*, an allosaurid theropod dinosaur (Carrano et al., 2012). The tooth was preserved in a grey-whitish, hard limestone whose age was disputed until now. By the courtesy of the colleagues from the Department of Geology, “Al. I. Cuza” University of Iaşi (Turculeț & Branzilă 2012), we have received two small samples from the original limestone preserving the *Megalosaurus* cf. *superbus* tooth from the Simionescu Collection.

The two sections from the original *Megalosaurus*-bearing limestone contains a rich and diversified association of foraminifers, ostracods and microproblematicae, including *Nautiloculina cretacea, Neotrocholina valdensis, Istriloculina emiliae, Scythiolina camposaurii, Kaminskia acuta, K. exigua, Earlandia conradi-brevis,* and frequent specimens of *Meandrospira favrei*. These are associated with rare and small algal nodules of *Tubiphytes morronensis*. Taking into account our recently established stratigraphic scale of the Aliman Member, Cernavodă Formation, at the Cernavodă-lock section, the foraminifer association from the original limestone corresponds to Biozone IX with *Meandrospira favrei*, a zone belonging to the uppermost Valanginian (Fig. 7). The stratigraphic range of *Meandrospira favrei* is uppermost Valanginian–lower Hauterivian, or Hauterivian (Charollais et al., 1966, Bucur 1988, 1997, Altiner 1991, Dragastan 2010, 2011).

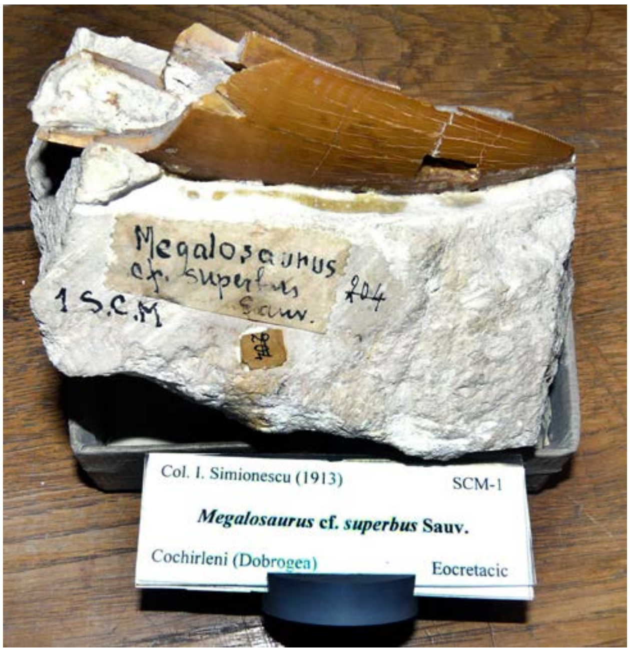

Figure 6. *Megalosaurus* cf. *superbus* (Sauvage 1882) tooth, described by Simionescu (1913) and found in the upper Valanginian (age based on new age determinations in two thin sections from the original limestone sample holding the tooth, from Cochirleni, South Dobrogea, Romania, currently in the **Simionescu Collection**, Department of Geology, "Al. I. Cuza" University of Iaşi).

To rediscover the original sites yielding the *Megalosaurus* vertebrae and teeth and other vertebrate remains (mainly fish fragments and tooth), a systematic prospecting of the Valanginian deposits of the Aliman Member (Cernavodă Formation) is necessary, along a profile from Hinog up to surroundings of Cochirleni, situated approximately 9 km south from Cernavodă. The Barremian deposits (Macovei 1913) and (Macovei & Atanasiu 1934) should not represent the focus of these investigations, since these deposits are missing in the Cernavodă-Hinog area. The Barremian transgression and its deposits are restricted to the south of Aliman locality, crossing the boundary with Bulgaria. Similarly, the possibility of extending such investigations into the area of Simionescu's discoveries, as well as into the outcropping areas of the middle Aptian–early Albian Gherghina and Cochirleni Formations (Chiriac 1981, 1988) must be considered. Only in this area and in the above-listed deposits will be possible to find vertebrate remains, including and dinosaurs.

Up to now, in Romania the presence of this group of dinosaurs was mentioned only based on isolated teeth. Nopcsa (1902) described *Megalosaurus hungaricus* from the Senonian deposits of Borod Basin, Transylvania, while Simionescu (1913) reported *Megalosaurus* cf. *superbus* (Sauvage 1882) from Cochirleni locality, South Dobrogea, now documented to come from the Uppermost Valanginian - Biozone with *Meandrospira favrei* of the Aliman Member, Cernavodă Formation.

5. BIOSTRATIGRAPHY AND ZONATION OF THE LOWER CRETACEOUS DEPOSITS FROM THE CERNAVODĂ-LOCK SECTION

A new biostratigraphic scheme consisting of 12 biozones (=Assemblage Zones), based only on benthic foraminifers (Fig. 7), is proposed for the two paleoenvironmental domains (tidal flat-inner shelf, respectively middle shelf) recognized in the Cernavodă area, South Dobrogea, as a part of the Moesian carbonate platform unit. This new scheme for the Berriasian (upper Berriasian)–Valanginian and lower Hauterivian deposits was preceded by a series of foraminifera Assemblage Zones established for the Lower Cretaceous from South Dobrogea by Dragastan (1978, 1980) and Dragastan et al., (1998), as follows:

- an assemblage dominated by *Andersenolina elongata, A. delphinensis, A. cherchiae,* with satellite species, such as *Anchispirocyclina maynci-neumanne, Dobrogelina ovidii, D. anastasiui* and the miliolids *Decussoloculina mirceai, D. barbui, D. granumlentis, Axiopolina granumfestucae,* upper Berriasian–lower Valanginian in age, an assemblage recorded within the Hinog and Aliman members of the Cernavodă Formation;
- an assemblage containing *Vercorsella camposaurii, Meandrospira favrei, Nautiloculina cretacea - broenimmani, Haplophragmoides joukowski* and *Bancilina rumana,* upper Valanginian in age,

recorded within the Aliman Member of the Cernavodă Formation;

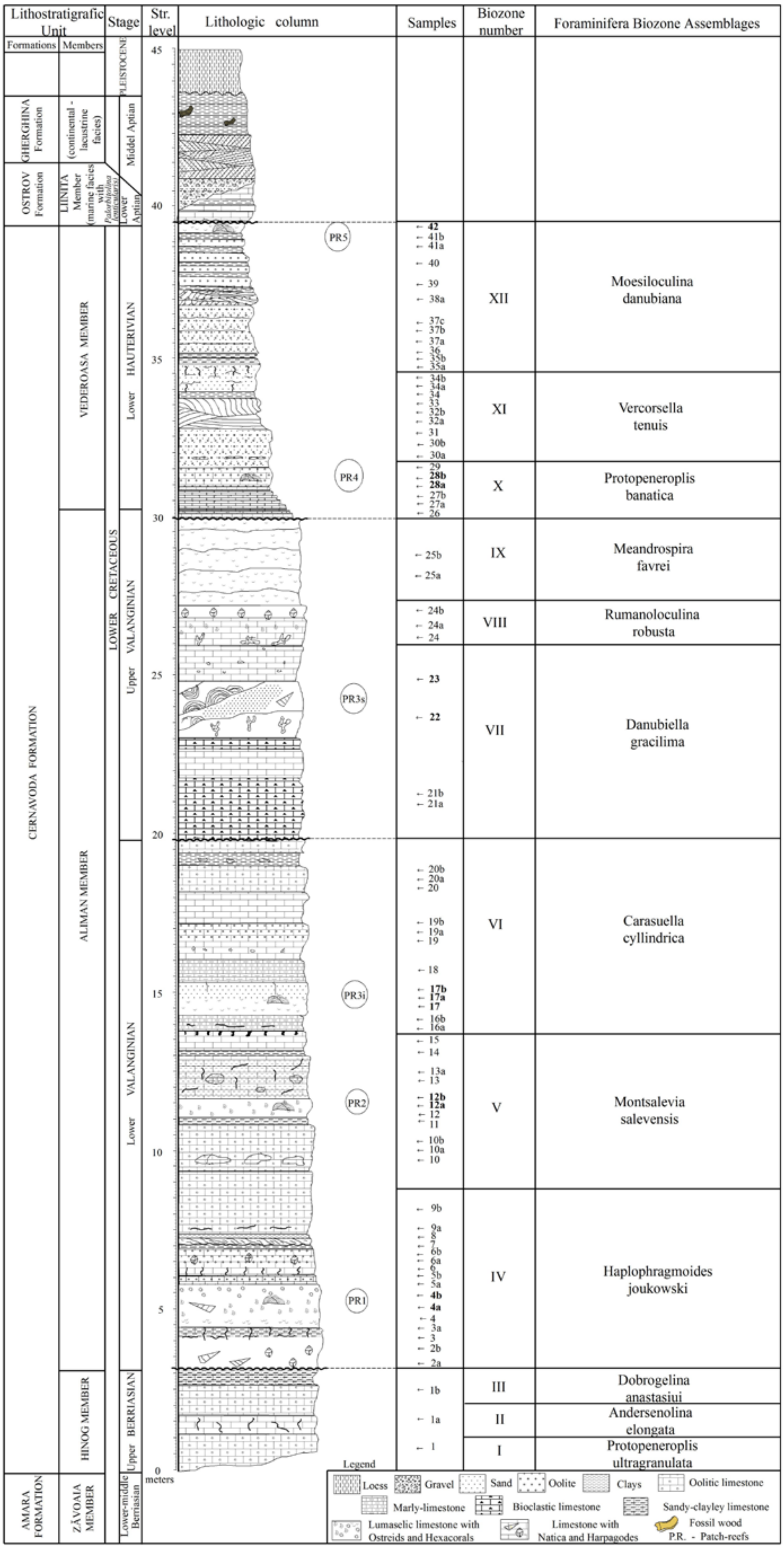

Figure 7. Biostratigraphic zonation, with the proposed benthic foraminifers zones (= Assemblage Zones) for the Cernavodă Formation (upper Berriasian-Valanginian-lower Hauterivian) from the Cernavodă-lock section, South Dobrogea, Romania.

- an assemblage with *Meyendorffina jourdanensis, Valdanchella miliani, Patellovalvulina patruliusi, Istriloculina alimanensis, Moesiloculina dobrogiaca, Scytholoculina confusa, Rumanoloculina massei, Dobrogellina discorbiformis* and *Pfenderina ammonoidea*, lower Hauterivian or Hauterivian in age, within the Vederoasa Member of the Cernavoda Formation.

Beside this benthic foraminifer zonation scheme, the same contributions also proposed the following Assemblage Zones based on calcareous algae for the Berriasian–Valanginian–Hauterivian deposits:

- an assemblage with *Rajkaella subtilis, R. bartheli, Salpingoporella steinhauseri* and *Zergabriella embergeri*. The assemblage also includes *Salpingoporella katzeri*, an alga with a small thallus, *S. annulata* with a robust thallus, recorded in the upper part of Hinog Member, upper Berriasian and in the lower part of Aliman Member, lowermost Valanginian, *Falsolikanella campanensis* (frequently found as non-articulated verticils), *Zergabriella praturloni* and *Clypeina marteli*. Episodic records of *Rivularia piae, R. theodori* (Cyanophyceans) and rare bryopsidaleans, species of *Garwoodia* and *Pseudoudotea* sp., were also noted. Only rare specimens of *Salpingoporella annulata, Likanella insignis* and *Teutloporella filiformis* are present in the upper Valanginian deposits of Aliman Member; and

- an assemblage with *Suppiluliumaella alimani, Megaporella fluegeli* and *Bancilaporella filipescui*, characteristic for the Hauterivian deposits of Vederoasa Member, Cernavodă Formation. This assemblage contains diversified algae with well-calcified thallic, an assemblage corresponding to the "refreshing" phase during the Hauterivian transgression (*for more information, see the English abstract, pp. 223–249, in Dragastan et al., 1998, Jurassic and Cretaceous deposits from Central and South Dobrogea: Paleontology and Stratigraphy, Supergraph publishing House, Cluj-Napoca*).

6. DESCRIPTION OF THE PROPOSED FORAMINIFER BIOZONES

Biozone I with Protopeneroplis ultragranulata, lower part of upper Berriasian, Hinog Member, Cernavodă Formation.

The zone was defined as the interval between the first occurrence of *Protopeneroplis ultragranulata* (Pl. 1, Fig. 1) and the first occurrence of *Andersenolina elongata* (Pl. 1, Fig. 2), a marker species for the upper boundary of this biozone. The lower boundary index species was firstly described and illustrated as *Hoeglundia* (?) *ultragranulata* by Gorbatschik (1971), but was extensively cited and used as *Protopeneroplis trochangulata* Septfontaine 1974. The synonymy of the two species was established first by Septfontaine et al., (1991) and by Bucur (1993, 1997).

The zone contains diversified microfauna including different species of foraminifera such as: *Mohlerina basiliensis, Andersenolina alpina, A. campanella, Pseudocyclammina lituus, Nautiloculina cretacea* (Pl. 1, Fig. 4), *Nautiloculina broennimanni, Danubiella cernavodensis, Mesendothyra dobrogiaca, Earlandia conradi* and *Patellina* sp.

The dasycladaleans are represented by dismembered verticils of *Rajkaella subtilis* and *R. bartheli*, taxa that occur at the Jurassic-Cretaceous boundary and then frequently in the Berriasian; at Cernavodă-lock, they appear in the upper Berriasian (Dragastan & Bucur 1993).

The stratigraphic value of this biozone, calibrated by calpionellids, is Berriasian in age (Altiner 1991). In addition, Septfontaine (1974) considered this species as a marker for the Berriasian, mentioned from the Jura Mts. at Monts Saléve (France), although Chiocchini & Mancinelli (1979, 1988) referred this zone to the Berriasian–basal Valanginian in the limestones of Sardinia and Abruzzi Mts.

Sotak (1987), considered that this taxon is an index species for the Berriasian, being found in the *Calpionella alpina* biozone in the West Carpathians, and having a regional paleogeographic distribution (Fig. 3, p. 658) across the northern part of the Tethyan carbonate shelf as well as on the carbonate shelves of the African continent including Apulia, the Dinarides-Hellenides and the Taurides (Fig. 8).

In the Outer Dinarides, the Lower Cretaceous deposits are represented exclusively by carbonate shelf sediments, where a biozone with *Protopeneroplis ultragranulata* was assigned by Velič (1988) to the Berriasian.

Similarly, Altiner (1991) in the North-Western Anatolia (Turkey) defined *Zone III (Protopeneroplis ultragranulata*, formerly described as *P. trochangulata*) in the North-Western Anatolia (Turkey), as the interval from the first occurrence of *P. ultragranulata* up to the first occurrence of *Montsalevia salevensis* having a late Tithonian–Berriasian age. In addition to this marker taxon, other foraminifera species recorded were *Mohlerina basiliensis, Earlandia* sp., *Glomospira* sp., *Dobrogelina* sp., *Haplophragmoides joukowskyi, Charentia cuvillieri, Nautiloculina cretacea - broennimanni, Pseudocyclammina lituus, Rumanoloculina robusta, Andersenolina alpina, A. odukpaniensis, A. campanella, A. delphinensis, A. elongata, A. sagittaria*, and *Neotrocholina valdensis*. In spite of the rich forams assemblage from the interval of this zone, the stratigraphic value or range

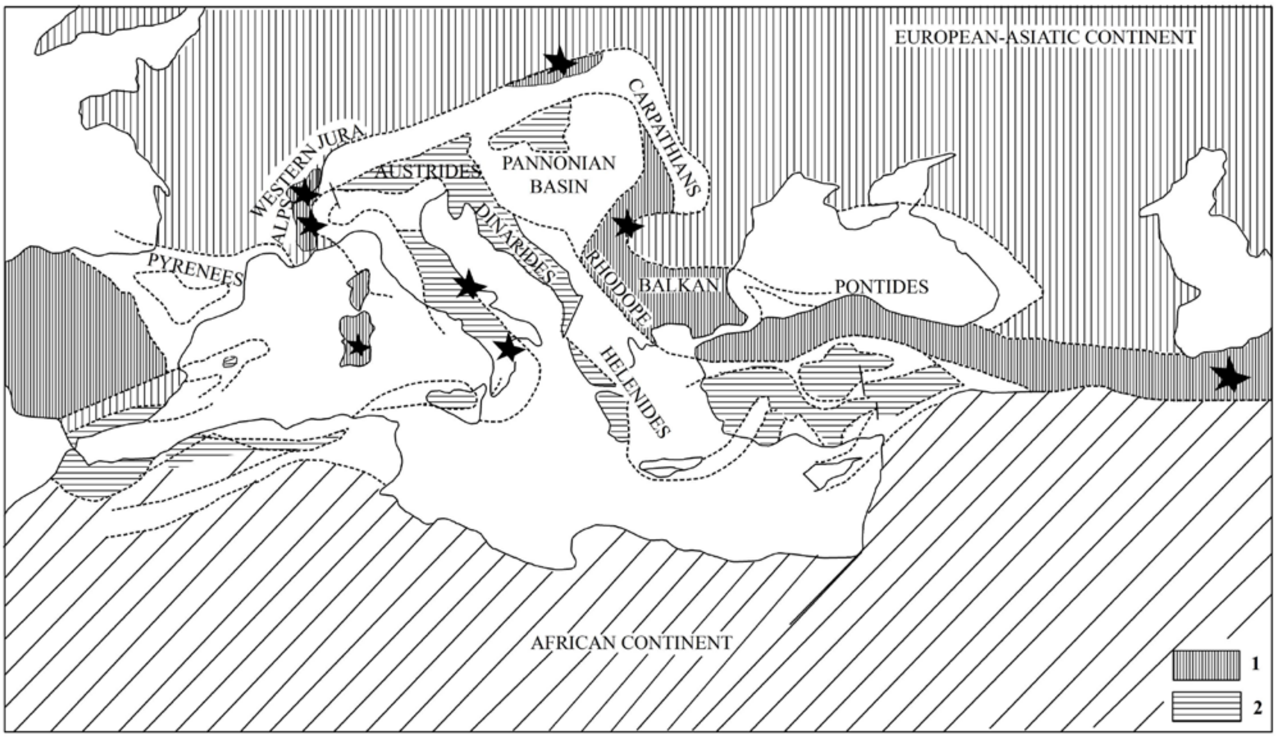

Figure 8. The paleogeographic distribution and occurences of *Protopeneroplis ultragranulata* in the Tethyan realm (paleogeography from Ricou et al. 1986, in Sotak 1987; **1**. Northern Tethyan shelf, **2.** Southern Tethyan shelf, modified).

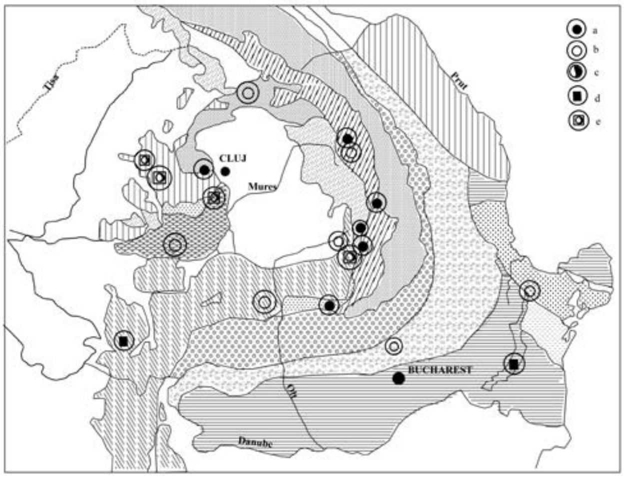

Figure 9. Distribution and occurences of species of the genus *Protopeneroplis* on the Romanian territory: **a**. *P. striata*, **b**. *P. ultragranulata*, **c.** *P. striata* and *P. ultragranulata*, **d.** *P. ultragranulata* and *P. banatica*, **e.** *P. striata*, *P.ultragranulata* and *P. banatica*; (after Bucur 1997, 1997a, Dragastan 1975, 2010, Bucur & Săsăran 2011.

of some taxa is more extensive; taxa like *Andersenolina, Neotrocholina* and *Nautiloculina* have a Berriasian–lower Valanginian range, or even Barremian in the case of *Rumanoloculina robusta.*

Bucur (1997, 1997a) presents the occurrences of several Late Jurassic–Early Cretaceous species of the genus *Protopeneroplis* (*P. striata, P. ultragranulata, P. banatica* n. sp. Bucur) identified in the South Carpathians, Getic carbonate platform and recently by Dragastan (2010) in the Upper Berriasian of Cernavodă-lock, South Dobrogea (Fig. 9).

On the Romanian territory *P. ultragranulata* was reported by Bucur (1985, 1986) and illustrated by Bucur and Oros (1987) from Berriasian–Valanginian allodapic limestones from the Reşiţa-Moldova Nouă Zone, Getic carbonate platform, South Carpathians. Bucur (1997a) mentioned *P. ultragranulata* from the upper Berriasian of the *Marila Limestones*, but also from the uppermost Berriasian and lower Valanginian *Crivina Marls*, in this later case the age of the deposits being calibrated according to calpionellid and ammonite associations.

According to Septfontaine (1974), *P. striata* was reported from Aalenian to Tithonian deposits, while *P. ultragranulata* was mainly reported from the Berriasian–Valanginian and up to Barremian (Bucur 1993, 1997) (Fig. 10). We consider the specimens reaching the Barremian is a new taxon.

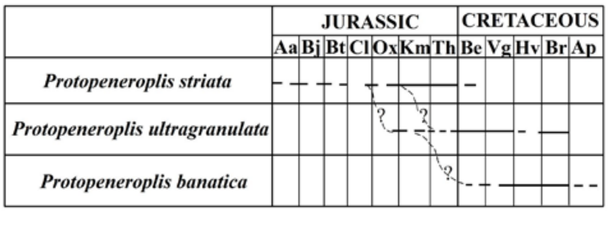

Figure 10. Possible stratigraphical range of some *Protopeneroplis* species (after Bucur 1997a, modified in this paper).

P. banatica n. sp. Bucur 1997 with a range from the Valanginian to the Aptian covers a large stratigraphical interval, but we consider this species more stratigraphically restricted, being probably a good marker for the Hauterivian.

In the Northern Calcareous Alps, Schalgintweit & Ebli (1999) described and illustrated from the Plassen Formation an assemblage with *Charentia cuvillieri, Mohlerina basiliensis, Neotrocholina infragranulata, Protopeneroplis ultragranulata* and *P.* aff. *banatica*, an assemblage also assigned to the upper Berriasian.

Summary: The *Protopeneroplis ultragranulata* biozone from the Cernavodă-lock section, South Dobrogea, has a position at the basal part of the profile and corresponds to the lowermost part of the upper Berriasian.

Biozone II with Andersenolina elongata, middle part of the upper Berriasian, Hinog Member, Cernavodă Formation.

A. elongata is as species frequently cited from the Berriasian–Valanginian interval, sometimes in association with *A. alpina.*

The zone is identified as the interval between the first occurrence of *A. elongata* (Pl. 1, Fig. 2) as lower boundary, and the first appearance of the foraminifer *Dobrogelina anastasiui* as upper boundary.

In addition, this zone contains *Andersenolina cherchiae* (Pl. 1, Fig. 7), *Scythiolina camposaurii* (Pl. 1, Fig. 8), S. *cuneata, Scythiloculina confusa, Histerolina ellipsiformae, Kaminskia acuta* (Pl. 1, Fig. 5), *Protopeneroplis ultragranulata, Mohlerina basiliensis, Pseudocyclammina lituus, Axiopolina granumfestucae, Decussoloculina granumlentis* (Pl. 1, Fig. 6) and *Earlandia brevis.*

Dasycladalean algae are represented by dismembered verticils of primary or only secondary branches of *Rajkaella subtilis*.

Arnaud-Vanneau et al., (1988) presents a synthesis and a revision regarding the Cretaceous taxa of *Trocholina*, with a new stratigraphic scheme for the different taxa from the Jurassic–Cretaceous boundary up to the Albian–Cenomanian; they recognized a gap, without species being present, during the Aptian–Albian interval (Fig. 11 A).

In fact, this gap is only apparent, because certain taxa such as *Neotrocholina aptiensis* and others do occur in this interval. A geographical distribution of the main *Andersenolina* (former *Trocholina*) species during the Berriasian and Valanginian is presented by the authors (Fig. 11 B, C).

In another revision of this Early Cretaceous group and some related genera from Romania, Neagu (1994) introduced the new genus *Andersenolina* for several former Cretaceous *Trocholina* species, also maintaining the genera *Trocholina* (s.str.), *Neotrocholina* and *Ichnusella.*

In case of the different *Andersenolina* species, Cretaceous stratigraphic intervals and biozones can be distinguished using first occurrence dates of the taxa as lower boundary, together with abundance factors.

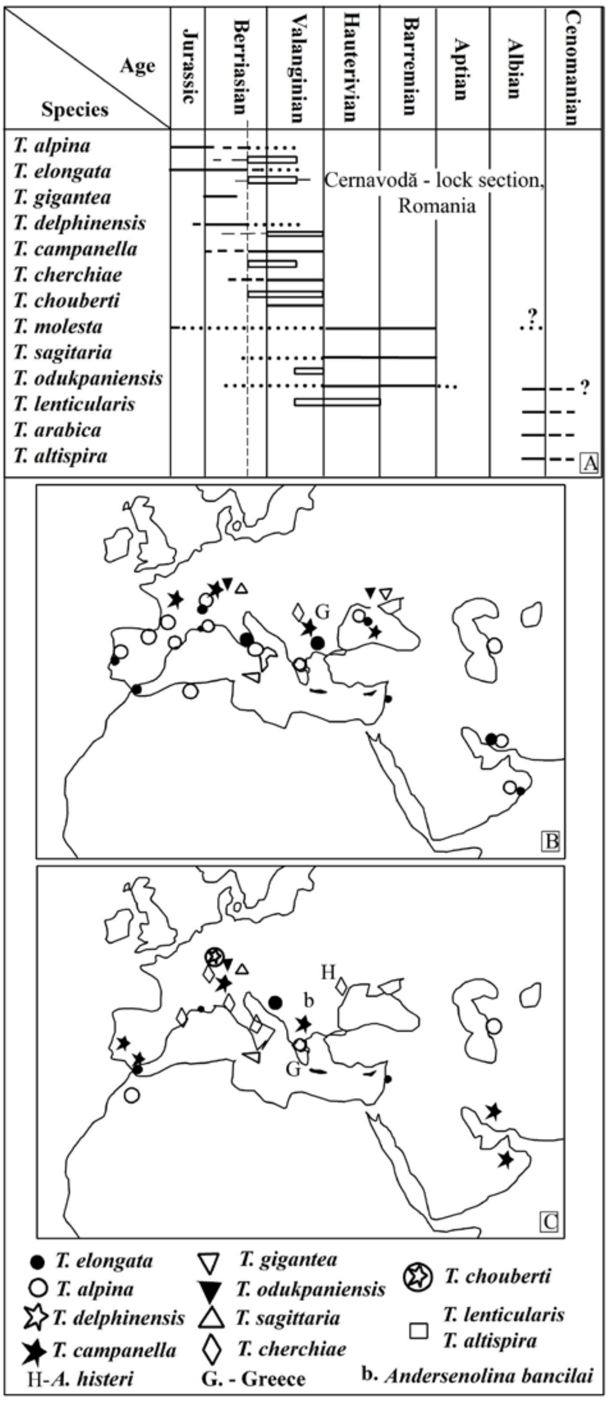

Figure 11. A. Stratigraphic range for the main Cretaceous *Trocholina* species, in parallel with the range of species from Cernavodă-lock, Romania, B-C. Geographical distribution of *Trocholina* species in the Berriasian and Valanginian, with data from Greece (G), as symbols, b. *Andersenolina bancilai* and H. *A. histeri.* (after Arnaud-Vanneau et al., 1988, Dragastan et al., 1998, Dragastan 2010, modified).

PLATE I

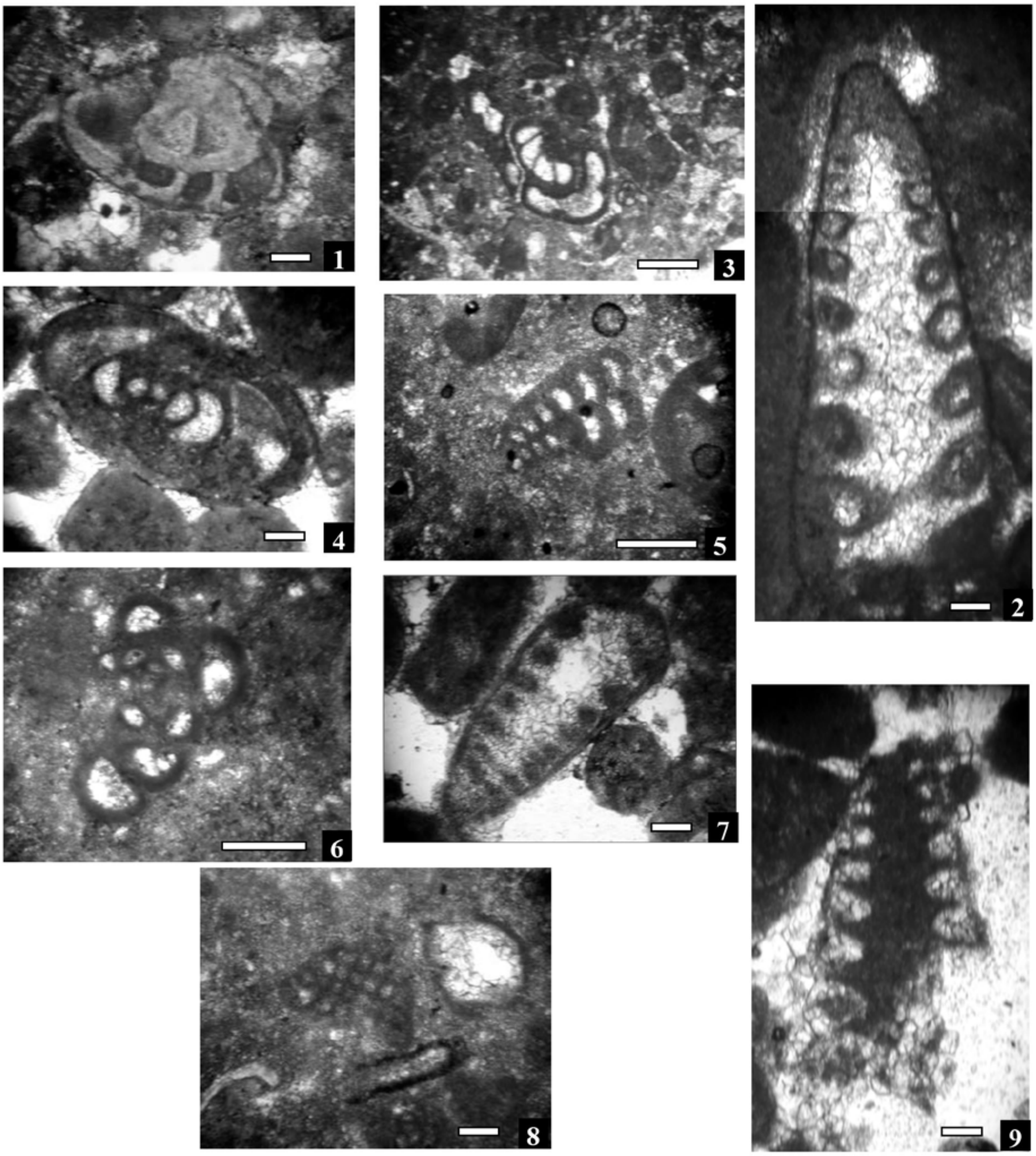

Plate I. Upper Berriasian, Hinog Member, Cernavodă Formation.

Figure 1 – ***Protopeneroplis ultragranulata*** (Gorbatchik) Septfontaine et al., 1991; Figure 2 – ***Andersenolina elongata*** (Leupold), Neagu 1994; Figure 3- ***Dobrogelina anastasiui*** Neagu, 1979; Figure 4 – *Nautiloculina cretacea* (Arnaud-Vanneau & Peybernes); Figure 5 – *Kaminskia acuta* Neagu 1999b; Figure.. 6 – *Decussoloculina granumlentis* Neagu 1984; Figure 7 – *Andersenolina cherchiae* (Arnaud-Vanneau et al., 1988) Neagu 1994; Figure 8 – *Scythiolina camposaurii* (Sartoni & Crescenti) Neagu 2000a and *Earlandia inconstans* Radoicic; Figure. 9 – *Andersenolina bancilai* Neagu, 1994., Scale bar: 0.1 mm.

Arnaud-Vanneau et al. (1988) identified the followings characteristic assemblages:

- for the lower Berriasian: abundant *Neotrocholina molesta*, together with *Andersenolina alpina*, *A. elongata* and *A. delphinensis*, which mark in the Jura Mts. the boundary between the Purbeckian and the Berriasian in carbonate platform facies;

- for the lower Berriasian (upper part) and the basal part of the upper Berriasian (*Paramimounum* Zone), *A. alpina* (with small test), *A. elongata* and *A.*

delphinensis, all these three taxa being very frequent;

- the upper Berriasian, overlying the major discordance D1 inside the *Picteti* Zone (Fig. 11 A), an assemblage containing *A. campanella*, *A.* cf. *alpina* and *A. alpina* (with large test); this latter taxon is considered here to represent *A. elongata*;
- for the Valanginian, characteristic species are: *A. cherchiae*, *A. chouberti* and *A. campanella*;
- for the Hauterivian and Barremian, characteristic taxa are represented by abundant *A. odukpaniensis*, along with *A. sagittaria* and *Neotrocholina molesta*.

During the upper Albian and the lower Cenomanian, the involutinids reappear on the Atlantic Coast with several species such as *Andersenolina odukpaniensis*. Ornamented species, like *Trocholina lenticularis*, which belongs to the genus *Bancilina* Neagu 1994, *T. altispira*, and *T. arabica*, occur in Iraq, Iran and Oman.

In the Plassen Formation of the Northern Calcareous Alps (Austria), the species *Andersenolina cherchiae* was found in the lower Berriasian (Schlagintweit et al., 2003). In Asprovouri Mts., Methana (Greece), the species *A. elongata*, *A. alpina*, *A. cherchiae* and *A. campanella* occur in the upper Berriasian–lower Valanginian limestones, while taxa such as *A. bancilai*, *A. histeri*, *A. sagittaria*, are recorded in the upper Valanginian (Dragastan & Richter 2003).

On the Romanian territory, involutinids have been found in the Lower Cretaceous of different geological units (Fig. 12). Thus, in the Hăghimaş Mts. (Bicaz Gorges, Fig. 12, point 1) *Andersenolina alpina*, *A. elongata*, *A. delphinensis*, *A. cherchiae* and *Neotrocholina infragranulata* occur in Berriasian–Valanginian limestones (Dragastan 1975, 2010, 2011, Bucur & Săsăran 2011).

In the Getic carbonate platform, corresponding to the Eastern (pars) and South Carpathians, the species *A. elongata*, *A. delphinensis*, *A. sagittaria* and *Neotrocholina valdensis* have been recorded in the upper Berriasian–Valanginian deposits from Piatra Mare-Bunloc massifs (Fig. 12, point 4). The upper Valanginian–lower Hauterivian deposits from Postăvaru Mts. and Râşnov area (Fig. 12, point 5) yielded *A. elongata* and *A. odukpaniensis*, in association with *Protopeneroplis ultragranulata* (Dragastan, 2010).

In the Codlea-Vulcan area (Fig. 12, point 3), *Andersenolina alpina* (rare), *A. elongata* and *A. delphinensis* were reported from Valanginian deposits, while *Neotrocholina valdensis* appear in the lower Hauterivian. The limestone olistholiths from Şinca Nouă (Fig. 12, point 2) *Andersenolina odukpaniensis* appears frequently in the Valanginian.

In the southern and southeastern part of the Getic carbonate platform, in the Piatra Craiului Mts. (Fig. 12, point 6), the species *A. elongata*, *A. delphinensis* and *A. sagittaria* are recorded in upper Berriasian-lower Valanginian deposits, while *Neotrocholina valdensis* occurs in the upper Valanginian of the Bran Member of the Braşov Marls Formation. Similarly, in the Dâmbovicioara Basin (Fig. 12, point 7) *A. campanella* occurs in the Berriasian at Colţii Ghimbavului, together with *Protopeneroplis ultragranulata*, and *Andersenolina alpina, A. elongata* and *A. campanella* in the lower Valanginian. In the Mateiaş Mts. (Fig. 12, point 9), the species *Andersenolina delphinensis* and *A. odukpaniensis* were recorded in Valanginian limestone deposits.

Figure 12. Distribution of *Andersenolina, Neotrocholina* and *Bancilina* in the Lower Cretaceous deposits of Romania: 1. Hăghimaş Mts. (Bicaz Gorges) - Transylvanian carbonate platform, Eastern Carpathians, 3. Codlea-Vulcan, 4. Piatra Mare-Bunloc, 5. Postăvaru, Eastern Carpathians; 2. Şinca Nouă olistolites, 6. Piatra Craiului Mts., 7. Dâmbovicioara Basin, 8. Bucegi-Lespezi Mts., 9. Mateiaş Mts., 10. Vânturariţa Mts., 11. Reşiţa- Moldova Nouă Zone-Getic carbonate platform, South Carpathians, 12. Trascău Mts., South Apuseni, 13. Bihor carbonate platform, Northern Apuseni and 14. South Dobrogea.

On the western slope of the Bucegi Mts., in the Lespezi Massif (Fig. 12, point 8) *Neotrocholina valdensis* and *N. infragranultata* occur in the upper Valanginian.

In the median southern part of the Getic carbonate platform, in the Vânturariţa Massif (Fig. 12, point10) an assemblage with *Andersenolina elongata*, *A. perconigi* and *A. odukpaniensis* were reported in the Arnota Member of the of Vâturariţa Formation, of late Berriasian–Valanginian, and possibly also early Hauterivian age (Dragastan 2010).

In the western part of the Getic carbonate platform, in the Reşiţa-Moldova Nouă Zone (Fig. 12, point 11), Bucur (1997) mentioned the species *A. alpina*, *A. elongata, Neotrocholina valdensis, N.* cf. *infragranulata* from the upper Berriasian–lower Valanginian, as well as *N.* cf. *aptiensis* of Lindinei Valley, from Hauterivian deposits.

A largely similar assemblage, with *Andersenolina* and *Neotrocholina*, is mentioned in the Berriasian–Valanginian deposits from the Bihor carbonate platform (Fig. 12, point 13) and from the Trascău Mts., South Apuseni area (Fig. 12, point12).

A rich Berriasian–Valanginian and Hauterivian microfauna are reported from drills and outcrops from the Moesian Platform, also including South Dobrogea (Fig. 12, point 14), with different species of *Andersenolina, Neotrocholina* and *Bancilina* described from the Cernavoda-Aliman area by Neagu & Dragastan (1984), Neagu (1994, 1995) and Dragastan (1975, 2001).

Summary: The *Andersenolina elongata* biozone from the Cernavodă-lock section, South Dobrogea, corresponds to the middle part of the upper Berriasian.

Biozone III with Dobrogelina anastasiui, uppermost part of the upper Berriasian, Hinog Member, Cernavodă Formation.

The lower boundary of this zone corresponds to the first occurrence of the miliolid species *Dobrogelina anastasiui*, while its upper boundary is marked by the first occurrence of *Haplophragmoides joukowski* (Fig. 7).

Neagu (1979) described the index species of the biozone in the upper Berriasian deposits from the classical outcrop situated on the right bank of the Danube, at Cernavodă. The zone contains diverse foraminifers: *Protopeneroplis ultragranulata, Danubiella cernavodensis, Dobrogelina ovidii, Decussoloculina granumlentis, Kaminskia dissimile, K. exigua, Andersenolina delphinensis, A. campanella, A. elongata, Verneuilinoides danubiensis, Neotrocholina valdensis* and *Neotrocholina* sp.

Dasycladalean calcareous algae are represented by *Rajkaella subtilis*, mentioned by Dragastan & Bucur (1993) from the Berriasian–lower Valanginian of Bicaz Gorges-Ghilcoş Massif, Hăghimaş Mts., East Carpathians, as well as by *Clypeina parasolkani*, a species described by Farinacci and Radoicic (1991) from Berriasian deposits of the Western Pontides, Turkey.

Several foraminifera taxa from this assemblage have been described from the classical profile of Cernavodă by Neagu (1979, 1984, 1985, 1994, 1999a, 1999b, 2000a, 2000b), by Dragastan et al., (1998), and from Berriasian deposits of different massifs of the Getic carbonate platform, South Carpathians (Dragastan 2010).

Danubiella cf. *anastasiui* was recorded in the upper part of the Berriasian Marila Limestone Formation, Reşiţa- Moldova Nouă Zone and Getic carbonate platform by Bucur (1988), together with *Andersenolina delphinensis* and *A. elongata*.

The species *A. delphinensis* and *A. campanella* were also mentioned in the Western Pontides, Turkey. Here they occur in the assemblage of Subzone IIIa with *Haplophragmoides joukowskyi*, considered by Altiner (1991) an Acme zone, characteristic only for the Berriasian stage, a conclusion we disagree with, since the index species *H. joukowskyi* was mainly found in the lower Valanginian.

Summary: The *Dobrogelina anastasiui* biozone from the Cernavodă-lock profile, South Dobrogea, has a position in the basal part of the profile and corresponds to the uppermost part of the upper Berriasian. These three biozones (I, II, III) from the Cernavodă-lock section confirmed the late Berriasian age of the Hinog Member of the Cernavodă Formation.

Biozone IV with Haplophragmoides joukowskyi, lowermost part of the lower Valanginian, Aliman Member, Cernavodă Formation.

This zone was defined as the interval between the first occurence of *Haplophragmoides joukowskyi* as lower boundary, and the first occurence of *Montsalevia salevensis*, as upper boundary (Fig. 7).

The species *H. joukowskyi* (Pl. II, Figs. 1-2) has a different stratigraphic range. The species was described by Charollais et al., (1966) from the upper Valanginian of Mont Saléve. Subsequently, Darsac (1983) reported the same taxon from the upper Berriasian–lower Valanginian of the southern Jura Mts. (Ain, Savoie), while Bucur (1988) mentioned it from Hauterivian limestones of Lindinei Valley, in the Reşiţa-Moldova Nouă Zone, Getic carbonate platform. Moreover, Altiner (1991) introduced a *Subzone* IIIa *with H. joukowskyi* in the frame of *Zone III with Protopeneroplis ultragranulata*, which covers the uppermost Tithonian–Berriasian interval in carbonate facies from the western Pontides (Turkey).

The lower and upper boundaries of the subzone, as defined by Altiner, are similar to those adopted and recorded for this zone in the Cernavodă- lock succession, South Dobrogea.

According to Altiner, most taxa already cited in the *P. ultragranulata* Zone, including this subzone, are *Neotrocholina valdensis* and different *Andersenolina* species.

The biozone contains a characteristic foraminifera assemblage with large-tested *Ammocyclolоculina erratica*, sometimes occurring as broken debris, *Barkerina dobrogiaca* (Pl. II, Fig. 3), *Protopeneroplis ultragranulata* (Pl. II, Fig. 4), *Andersenolina elongata*, *A. cherchiae*, *Gerochella cylindrica*(Pl. II, Fig. 7) and *Kaminskia acuta*.

Dasycladalean algae are represented by *Rajkaella alpina* and *R. subtilis*, as broken thalli verticils occurring with maximum frequency, and *Acicularia elongata* (Pl. II, Fig. 6). Between the mudstone and grainstone levels, algal nodules of *Tubiphytes morronensis* and small oncoid nodules also occur with low frequency (Pl. II, Fig. 5). The large foraminifers, such as *Ammocycloloculina erratica*, were recorded in the Cernavodă profile on the right bank of the Danube and in the Aliman profile (Dragastan, 1978). Often this taxon was confounded with orbitolinids, leading to erroneous age determinations based on which parts of the limestone deposits from the Cernavodă-Aliman area were assigned to Barremian or to lower Aptian.

Maync (1958) mentioned this species from the *Infravalanginian of Natica leviathan Limestone*; subsequently, Charollais et al., (1966) and Schroeder (1968) assigned this species to the lower Valanginian.

PLATE II

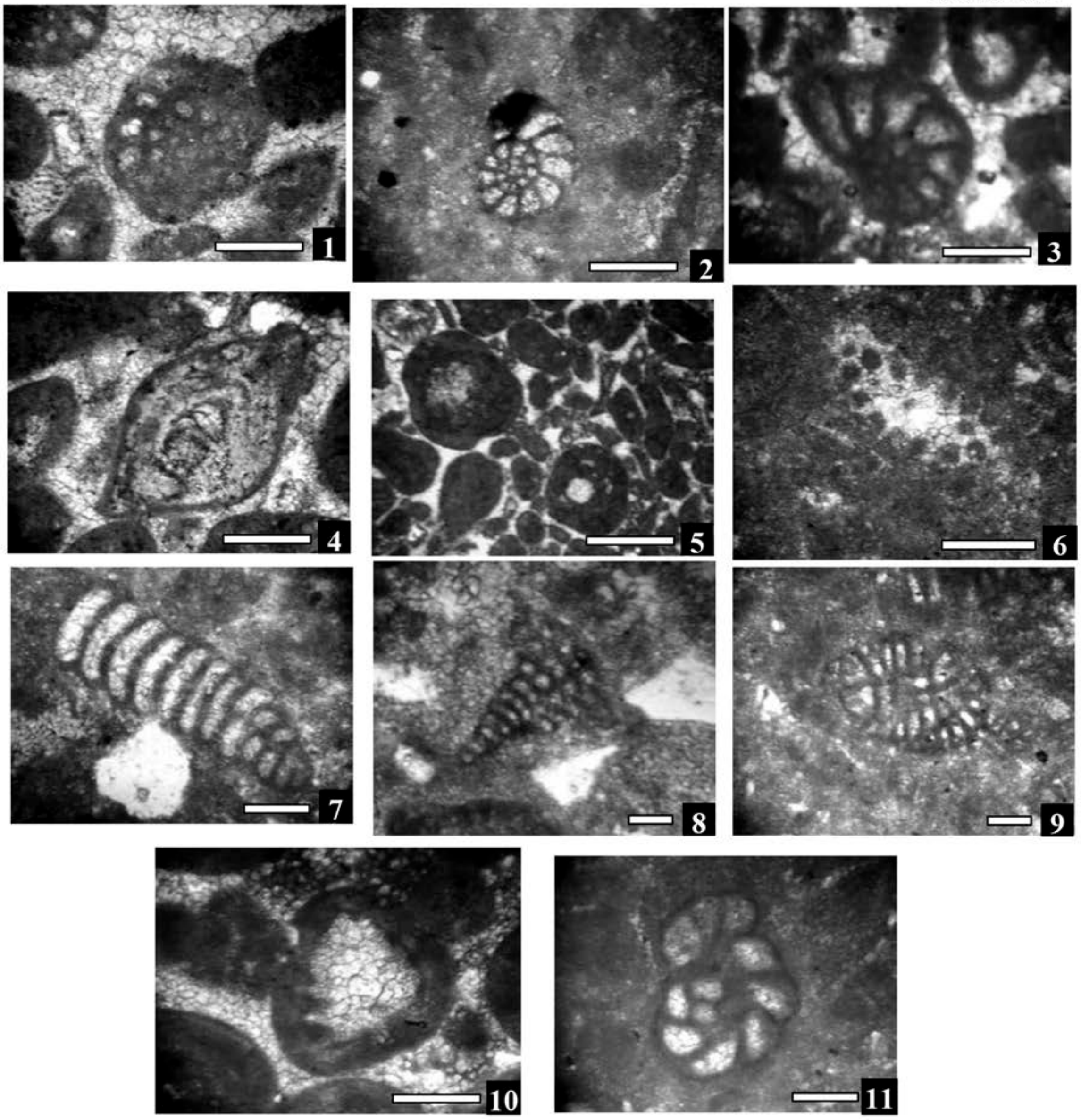

Plate II. Lower Valanginian, Aliman Member, Cernavodă Formation.

Figure 1, 2 – ***Haplophragmoides joukowski*** Charollais, Brönnimann & Zaninetti 1966; Figure 3 – *Barkerina dobrogiaca* Neagu; Figure 4 – *Protopeneroplis ultragranulata* (Gorbatchik) Septfontaine et al., 1991; Figure 5 – Grainstone with *Tubiphytes morronensis* Crescenti; Figure 6 – *Acicularia elongata* Carozzi; Figure 7 – *Gerochella cyclindrica* Neagu 1997; Figures 8, 9 – ***Montsalevia salevensis*** Charollais, Brönnimann & Neumann; Figure 10 – *Neotrocholina valdensis* Reichel; Figure 11 **–** ***Carasuella cylindrica*** Neagu 2000b. , Scale bar: 0, 1 mm

In the lower Valanginian, an assemblage composed of *Charentia cuvillieri, Mohlerina basiliensis, Neotrocholina valdensis, Protopeneroplis ultragranulata, P.* aff. *banatica* and *Troglotella incrustans* was recorded, which is more or less comparable with the assemblage found in the Cernavodă-lock section, South Dobrogea.

In the Getic carbonate platform area from the Piatra Mare-Bunloc massifs, Dragastan (2010) reported an upper Berriasian–lower Valanginian assemblage with *Andersenolina delphinensis, Kaminskia cuneata* and *K. exigua*. In the Postăvaru-Râşnov massifs, *Haplophragmoides joukowskyi* is associated with *Andersenolina elongata, A. odukpaniensis, Kaminskia cuneata, Neotrocholina valdensis, Patellina turriculata* and *Earlandia brevis*.

In the Dâmbovicioara Basin, an assemblage with *Protopeneroplis ultragranulata, Andersenolina elongata, Istriloculina emiliae, Decussoloculina barbui, D. mirceai* and *Axiopolina granumfestucae* occurs in the lower Valanginian, while in the Giuvala Massif the species *Kaminskia exigua* and *K. acuta* were reported.

From the Hăghimaş Mts. (Bicaz Gorges), the three members or subunits (SU I, SU, II and SU III) of the Lapoş Formation yielded, according to Dragastan (2011), Bucur et al., (2011) and Bucur & Săsăran (2011), an upper Berriasian–lower Valanginian assemblage composed of *Anchispirocyclina lusitanica, Everticyclammina virguliana, E. kelleri, E. greigi, Pseudocyclammina lituus P. sphaeroidalis, Andersenolina campanella, A. cherchiae, Neotrocholina molesta, Pseudocyclammina transylvanica, Streptocyclammina orientalis*, associated with the algae *Rajkaella alpina, Salpingoporella annulata* and with callpionelids.

Summary: The *Haplophragmoides joukowskyi* biozone indicates the lowermost part of the lower Valanginian, Aliman Member, Cernavodă Formation.

Biozone V with Montsalevia salevensis, middle part of the lower Valanginian, Aliman Member, Cernavodă Formation.

The lower boundary of this biozone corresponds with the first occurrence of *Montsalevia salevensis* (Pl. II, Figs. 8-9), while its upper boundary with the first occurrence of *Carasuella cylindrica* (Pl. II, Fig. 11).

In addition, the biozone contains other foraminifer species such as *Neotrocholina valdensis* (Pl. II, Fig. 10), *Gerochella cylindrica, Danubina obtusa, Pseudocyclammina transylvanica, Earlandia conradi* and *Microtubus cristatus*.

In the western Pontides (Turkey), Altiner (1991) distinguished and described a *Zone IV with Montsalevia salevensis*, defined as the interval between the first occurrence of *M. salevensis* and the first occurrence of *Meandrospira favrei.* Several forams species have been mentioned from this zone: *Protopeneroplis ultragranulata, Mohlerina basiliensis, Earlandia* sp., *Haplophragmoides joukowskyi, Charentia cuvillieri, Pseudocyclammina lituus, Scythiolina scarcellai, Andersenolina delphinensis, A. sagittaria* and *Neotrocholina valdensis*. The authors also established a detailed calibration scale based on calpionellid zonation (Altiner & Ozkan 1991) and *M. salevensis* is considered a reliable marker for the Valanginian, although not covering the uppermost part of this stage.

Montsalevia salevensis was also considered a good marker for the Valanginian in western-central and Eastern Europe (Charollais et al., 1966, Benest et al., 1973, Azema et al., 1977, Darsac 1983, Chiochini et al., 1988, Velič 1988, Bucur, 1993, Dragastan 2010, 2011, Bucur et al., 2011 and Bucur & Săsăran, 2011).

Montsalevia salevensis was recorded in the lowermost part of the lower Valanginian in the Diniş Formation from Pojoga area, Southern Apuseni Mts., and was considered a marker for this substage (Burza & Dragastan 2003).

Bucur (1997), cited *M. salevensis* from limestones outcropping in Lindinei Valley, Reşiţa-Moldova Nouă Zone, but with a different stratigraphic range, considered to range from the upper Valanginian to the Hauterivian.

Summary: The *Montsalevia salevensis biozone* is a marker for the middle part of the lower Valanginian, Aliman Member, Cernavodă Formation.

Biozone VI with Carasuella cylindrica, upper part of the lower Valanginian, Aliman Member, Cernavodă Formation.

The lower boundary of the zone is defined by the first occurrence of *Carasuella cylindrica*, and its upper boundary corresponds to the first occurrence of *Danubiella gracillima*, an index species for the upper Valanginian.

The marker species *Carasuella cylindrica* belongs to Family Haplophragmoidiidae and was described by Neagu (2000a) from upper Berriasian–Valanginian deposits of the classical Cernavodă profile, on the right bank of the Danube.

The microfaunal assemblage of this zone includes *Kaminskia cuneata, K. acuta, Scythiloculina confusa, Scythiolina cuneata, S. camposaurii, Andersenolina cherchiae, Mohlerina basiliensis* and *Streptocyclammina orientalis*. Most of these taxa were described by Neagu (1985, 1999a, 2000b) from the upper Berriasian-Valanginian of the Cernavodă profile, and others are known from the Valanginian of the Lapoş Formation, Bicaz Gorges, Hăghimaş Mts., East Carpathians (Dragastan 2011, Bucur et al., 2011).

A sponge patch- reef (P-R 3i or lower, levels 17-17a-b) occurs in the basal part of the biozone, being covered by ostreid coquina limestones, and with clastic breccia containing organic debris and oolitic grainstone accumulated on the reef slopes (Pl. II, Fig. 5).

PLATE III

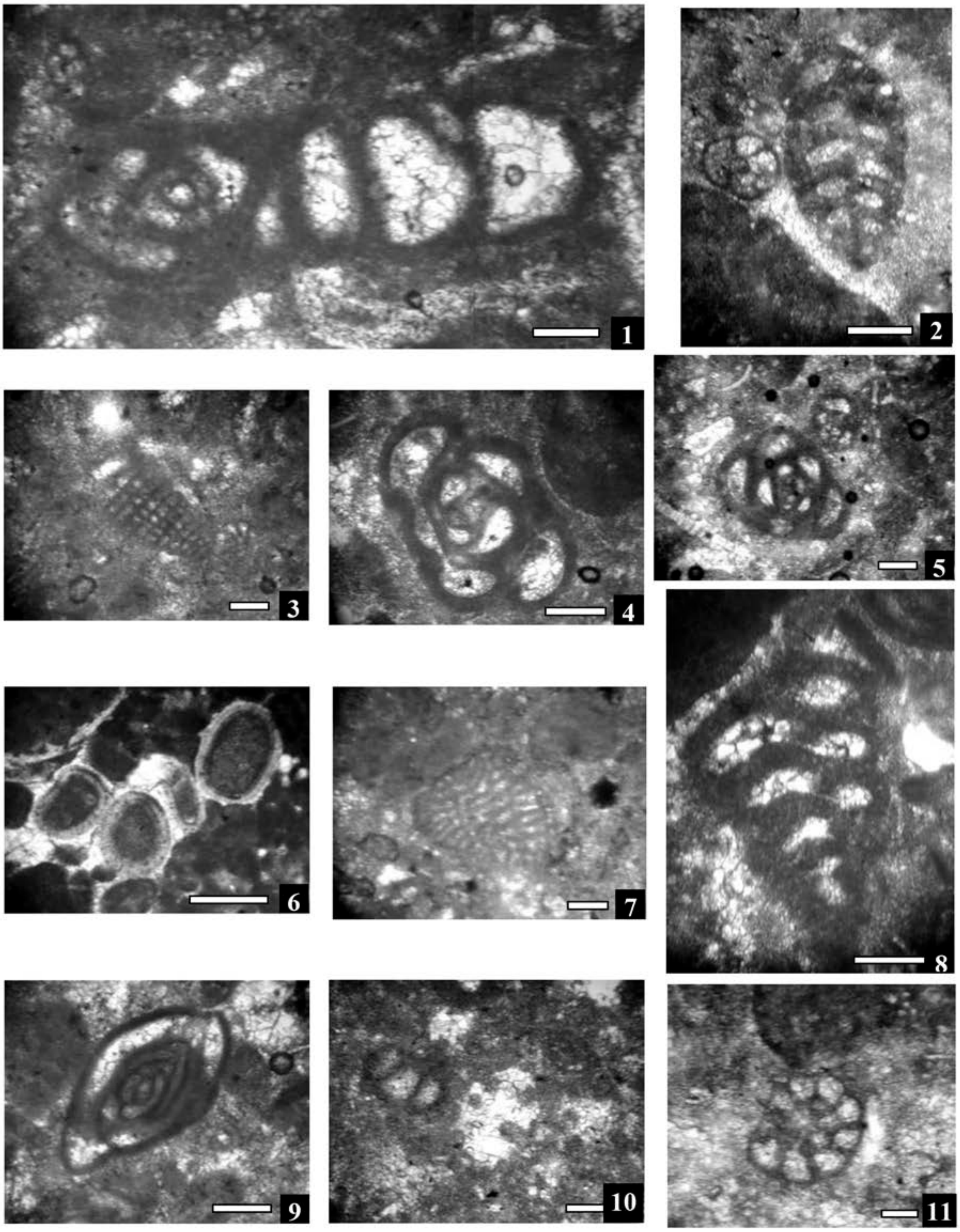

Plate III. Upper Valanginian, Aliman Member, Cernavodă Formation.

Figure 1 - ***Danubiella gracillima*** Neagu 1984; Figures 2, 8 – *Kaminskia cuneata* Neagu 1999b; Figure 3, 7 – *Scythiolina cuneata* Neagu 2000b; Figures 4, 5 – *Scythiloculina confusa* Neagu 1985; Figure 6 – Grainstone oolitic; Figure 9 – ***Rumanoloculina robusta*** (Neagu 1968) Neagu 1986; Figure 10 – *Russoella iginiodieni* Dragastan & Richter 2003; Figure 11 - ***Meandrospira favrei*** (Charollais, Brönniman & Zaninetti) Salvini Bonnard, et al., 1984., Scale bar: 0.1 mm

Summary: The *Carasuella cylindrica biozone* is a marker for the upper part of the lower Valanginian, Aliman Member, Cernavodă Formation.

Biozone VII with Danubiella gracilima, lowermost part of the Upper Valanginian, Aliman Member, Cernavodă Formation (Fig. 7).

This zone was defined by the interval between a lower boundary corresponding to the first occurrence of *Danubiella gracilima* (Pl. III, Fig. 1) and an upper boundary that coincides with the first occurrence of *Rumanoloculina robusta.*

In addition to the index taxon, this biozone also contains foraminifers such as *Scythiloculina confusa, Kaminskia dissimile, K. cuneata, Rumanoloculina pseudominima, Neotrocholina valdensis* (a rare taxon), *N. infragranulata, Istriloculina emiliae, Patellovalvulina patruliusi, Protopeneroplis ultragranulata, Montsalevia salevensis, Mohlerina balcanica, Andersenolina bancilai, A. histeri, Earlandia brevis-inconstans* and, rarely, *Haplophragmoides joukowskyi.*

Dasycladalean calcareous algae are represented by dismembered verticils of *Praturlonella danilovae* and thalli debris of *Salpingoporella annulata*.

The index species *Danubiella gracillima* was described from the upper Berriasian–Valanginian deposits at Cernavodă Bridge, on the right bank of the Danube, associated with *Scythiloculina confusa, Andersenolina bancilai, A. histeri* and *Istriloculina emiliae* by Neagu (1984, 1994).

The species *Kaminskia cuneata* and *K. dissimile* have a large stratigraphic range, extending from the uppermost Berriasian to the Hauterivian (Neagu, 1999b), but these taxa reach a peak of individual abundance in the Cernavodă-lock profile during this biozone interval.

Certain species, such as *Neotrocholina valdensis, N. infragranulata* and *Montsalevia salevensis* also occur in the Valanginian of the Latium-Abruzzi carbonate platform, central Italy (Chiocchini et al., 1988).

An upper Valanginian assemblage composed of *Andersenolina bancilai, A. histeri, Mohlerina balcanica, Decussoloculina barbui, Pseudocyclammina lituus, Everticyclammina minuta* and *Scythiloculina confusa* was mentioned from Methana Peninsula, Asprovouni Mts., Greece (Dragastan & Richter 2003).

From Valanginian or upper Valanginian deposits of the Getic carbonate platform (South Carpathians), advancing from its eastern to western parts, Dragastan (2010, 2011) mentioned the following different foraminifera-algae assemblages:

-in the Piatra Mare - Bunloc massifs, *Andersenolina sagittaria, A. delphinensis, Kaminskia cuneata, Earlandia conradi, Nautiloculina cretacea, Istriloculina emiliae* and *Neotrocholina valdensis*;

- in the Postăvaru - Râşnov massifs and the Codlea Basin, the upper Valanginian assemblages contain *Andersenolina elongata* (rare), *A. odukpaniensis* and an abundance of *Neotrocholina valdensis* specimens;

- in the Piatra Craiului Mts., the upper Valanginian association includes *Neotrocholina valdensis, Nautiloculina cretacea, Charentia cuvillieri* and *Andersenolina odukpaniensis.* In the Măgura-Bran olistholiths, the Valanginian deposits yielded *Danubiella cernavodensis, Montsalevia salevensis* and the calcareous algae *Salpingoporella annulata, Hedstroemia villosa* and *Rivularia pumili*.

Summary: The *Danubiella gracilima* biozone is a marker for the lowermost part of the upper Valanginian, Aliman Member, Cernavodă Formation.

Biozone VIII with Rumanoloculina robusta, middle part of the upper Valanginian, Aliman Member, Cernavodă Formation (Fig. 7).

The zone was defined as interval between the first occurrence of *Rumanoloculina robusta* (Pl. III, Fig. 9), as lower boundary, and the first occurrence of *Meandrospira favrei*, defining its upper boundary.

The species *Rumanoloculina robusta* was described initially by Neagu (1968), under the name *Quinqueloculina robusta* and was transferred by the same author in 1986 to the newly erected genus *Rumanoloculina.* It was described from the carbonatic deposits of Cernavodă-Hinog, Aliman and Ostrov-Dumbrăveni area, in South Dobrogea. According to its author, *Rumanoloculina robusta* has a large stratigraphic range, from the upper Berriasian to the lower Aptian.

In addition to its index taxon, the *R. robusta* zone yielded an assemblage with *Decussoloculina mirceai, D. granumlentis, Dobrogelina* sp., *Kaminskia cuneata* (Pl. III, Fig. 2), *Scythiolina cuneata* (Pl. III, Figs. 3, 7), *S.confusa* (Pl. III, Figs. 4, 5), *Earlandia inconstans*. In the same zone, the dasycladalean algae are represented by *Russoella iginiodieni* (Pl. III, Fig. 10), a species described by Dragastan & Richter (1999, 2003) from the upper Valanginian of Methana (Greece). This taxon shows a maximum concentration in microlevels of the carbonate spicules only within this biozone.

It is to mention that the species *Rumanoloculina robusta* (Neagu 1968) was also described by Altiner (1991) from the Anatolian carbonate platform, from within *Zone III* with *Protopeneroplis ultragranulata* (syn. *P. trochoangulata*), under the name *Quinqueloculina robusta.* Here it occurs in association with *Mohlerina basiliensis*, *Dobrogelina* sp., *Pseudocyclammina lituus* and *Derventina* sp., assigned to the upper

Tithonian–Berriasian interval. It is not excluded that *Q. robusta* from the Tithonian–Berriasian belongs to a different species, possibly to *Q. semisphaeroidalis* from the Oxfordian–Kimmeridgian–Tithonian (?). In the same paper, Altiner (1991) mentioned that *Q. robusta* in the association of *Zone IV* with *Montsalevia salevensis* being considered a good marker for the Valanginian, not only in Anatolia, but also in Western Europe.

PLATE IV

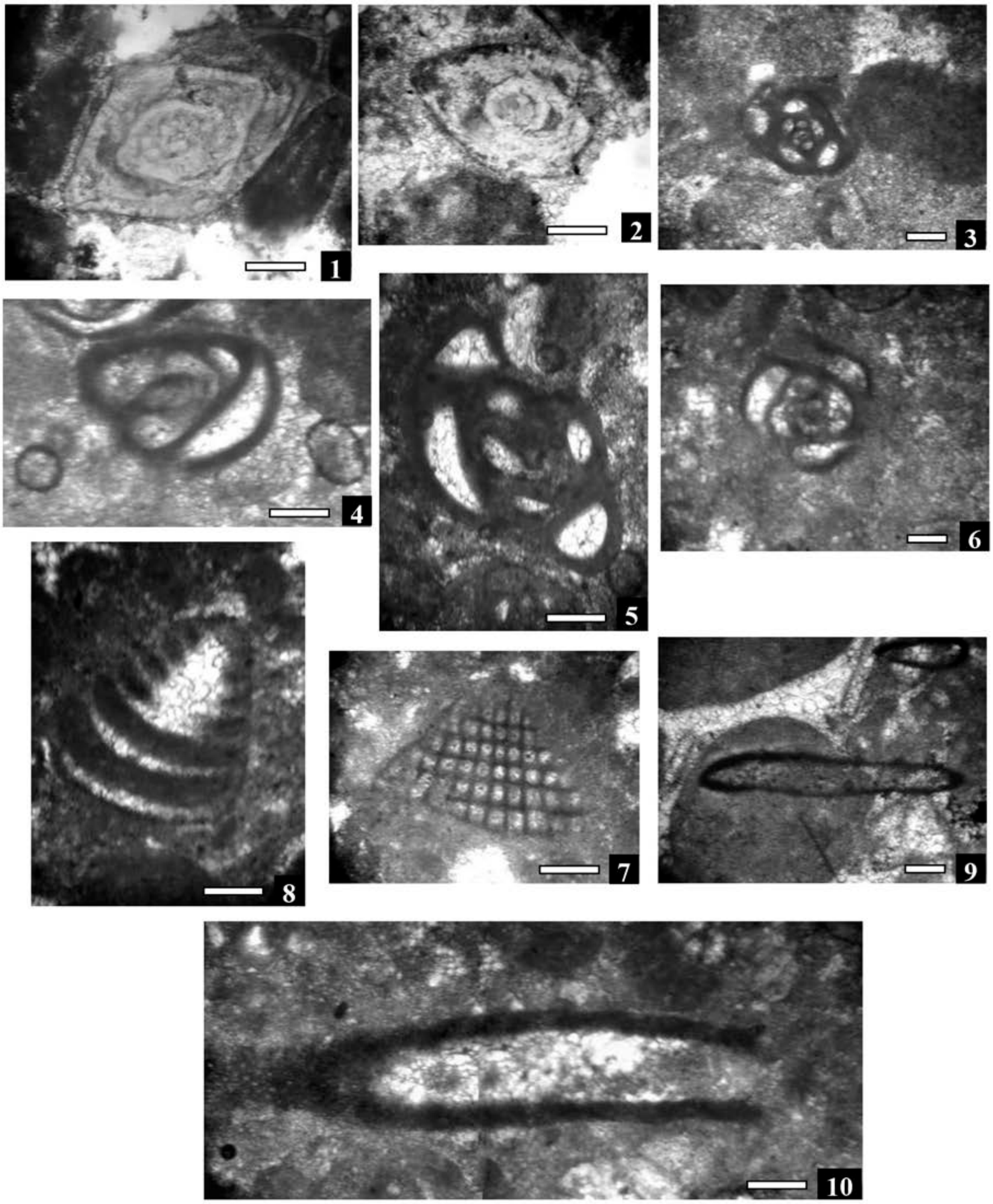

Plate IV. Lower Hauterivian, Vederoasa Member, Cernavodă Formation.
Figures 1, 2 – ***Protopeneroplis banatica*** Bucur 1993; Figure 3 – *Decussoloculina mirceai* Neagu 1984; Figure 4 – *Istriloculina emiliae* Neagu 1984; Figure 5 – *Decussoloculina barbui* Neagu 1984; Figure 6 – *Axiopolina granumfestucae* Neagu 1984; Figure 7 - *Histerolina pileiformae* Neagu 2000a; Figure 8 – *Andersenolina sagittaria* (Arnaud-Vanneau, Boisseau & Darsac) Neagu 1994; Figure 9 - *Earlandia inconstans* Radoicic; Figure10 – *Microtubus cristatus* Dragastan 1999., Scale bar: 0.1 mm.

In the calcareous deposits of the Getic carbonate platform (Dragastan, 2010), *Rumanoloculina robusta* appears during the Barremian–lower Aptian in the Postăvaru-Râşnov Massif, in the Hauterivian–Barremian in the Codlea Basin, or in the Barremian–lower Aptian in the Piatra Craiului Mts., Dâmbovicioara Basin (Colţii Ghimbavului-Vârtoapele-Dragoslavele), Vânturariţa Massif and Cioclovina-Pui.

Summary: The *Rumanoloculina robusta biozone* is a marker for the middle part of the upper Valanginian, Aliman Member, Cernavoda Formation.

Biozone IX with Meandrospira favrei, uppermost part of the upper Valanginian, Aliman Member, Cernavodă Formation (Fig. 7).

This zone was defined by the first occurrence of *Meandrospira favrei* (Pl. III, Fig. 11), a bioevent that corresponds to its lower boundary, while the upper boundary of the zone can be traced at the first occurrence of *Protopeneroplis banatica.*

In addition, the assemblage of this zone contains *Istriloculina emiliae*, *Decussoloculina barbui*, *Axiopolina granumfestucae*, *Gerochella* sp., *Kaminskia cuneata*, *Rumanoloculina robusta*, *Patellina turriculata* and *Neotrocholina* sp. Also present within this biozone are the green algae *Acicularia elongata* (Dasycladaceae) and *Felixporidium balcanicus* Dragastan & Richter, 2003 (Protohalimedaceae), described from the upper Valanginian deposits of Methana region, Asprovouni Mts. (Greece). The same interval includes two intercalated levels with ostreid shells (samples 25 and 26) covered by laminitic algal crusts, microbialites (Pl. VI, Fig. 4) and, in its lower part, borings of *Troglotella incrustans* Werlni and Fookes sensu Schlagintweit & Ebli (1999).

Charollais et al., (1966) cited the taxon *Meandrospira favrei* from upper Valanginian–Hauterivian deposits of the Geneva region (Switzerland).

Bucur (1988) recorded this index species also from the Hauterivian limestones of Lindinei Valley, Reşiţa-Moldova Nouă, in the western part of the Getic carbonate platform (Romania). In 1997, the same author cited, besides the index species, an assemblage with *Protopeneroplis banatica*, *Melathrokerion praesigali*, *Nautiloculina* cf. *broennimanni*, *Montsalevia salevensis*, *Lenticulina* sp., *Patellina* sp., *Spirillina italica* and *Neotrocholina* cf. *infragranulata* from the lowermost part of the Lindinei Formation, which corresponds to the uppermost Valanginian (p. 70, Fig. 21).

Altiner (1991) distinguished the *M. favrei* zone in the Anatolian carbonate platform (Turkey), using the first occurrence of this index species as lower boundary, up to the first occurrence of the planktonic foraminifera index species *Globuligerina hoterivica* as a maker for its upper boundary. In addition, other frequently occurring taxa within this zone include *Bolivinopsis* sp., *Haplophragmoides joukowskyi*, *Everticyclammina* sp., *Pseudocyclammina* sp., *Montsalevia* sp., *Spirillina* sp. and *Patellina* sp. It was also mentioned that the last occurrence of *Haplophragmoides joukowskyi* might be significant for this range zone.

The author concluded that the upper boundary can be drawn at the first occurrence of the late Hauterivian marker *Globuligerina hoterivica* and thus the chronostratigraphic position of the *Meandrospira favrei* zone was calibrated as having a late Valanginian to early Hauterivian age.

Dragastan(2010, 2011) recorded *Meandrospira favrei* in limestones of late Valanginian–early Hauterivian age in the Piatra Mare-Bunloc massifs, in the Şinca Nouă olistholiths, in the Dâmbovicioara Gorges, the Mateiaş Mts. and in the Ohaba-Ponor region from the Getic carbonate platform (Southern Carpathians).

Summary: The *Meandrospira favrei biozone* is an index for the uppermost part of the upper Valanginian, Aliman Member, Cernavodă Formation.

Biozone X with Protopeneroplis banatica, lowermost part of the lower Hauterivian, Vederoasa Member, Cernavodă Formation (Fig. 7).

This biostratigraphic unit has a lower boundary which corresponds with the first occurrence of *Protopeneroplis banatica* (Pl. IV, Figs. 1, 2) and an upper boundary marked by the first occurrence of *Vercorsella tenuis.*

P. banatica Bucur (1993) was described as new species from the Reşiţa-Moldova Nouă Zone, part of the Getic carbonate platform, having a wide stratigraphic range from the uppermost Berriasian–Valanginian–Hauterivian and probably continuing up to Barremian and Aptian (Fig. 10). In our opinion, the Barremian–Aptian specimens belong to a new, different species. The taxon was reported also from Valanginian limestones in southeastern France (Blanc et al., 1992) and in Berriasian–Valanginian deposits at Jerma, Eastern Serbia. Bucur (1997) presented a synthesis concerning the occurrences of the different *Protopeneroplis* species in the Jurassic–Lower Cretaceous deposits of Romania, including the regional distribution of *Protopeneroplis striata, P. ultragranulata, P. striata* together with *P. ultragranulata, P. ultragranulata* with *P. banatica* and *P. striata,* respectively *P. ultragranulata* and *P. banatica* (Fig. 9).

P. banatica was found in the Valanginian–Hauterivian Lindinei Valley Limestones, in the Reşiţa-Moldova Nouă Zone, South Carpathians.

In the Cernavodă-lock section, it appears that this index species occurs in the lowermost part of the lower Hauterivian deposits.

The assemblage zone contains a diversified foraminifera assemblage with *Decussoloculina mirceai*, *D. barbui*, *Gerochella* sp., *Axiopolina granumfestucae*, *Histerolina pileiformae*, *Andersenolina sagittaria*, *Earlandia inconstans* and *Microtubus cristatus* (Pl. IV, Figs. 3, 5, 6-10).

PLATE V

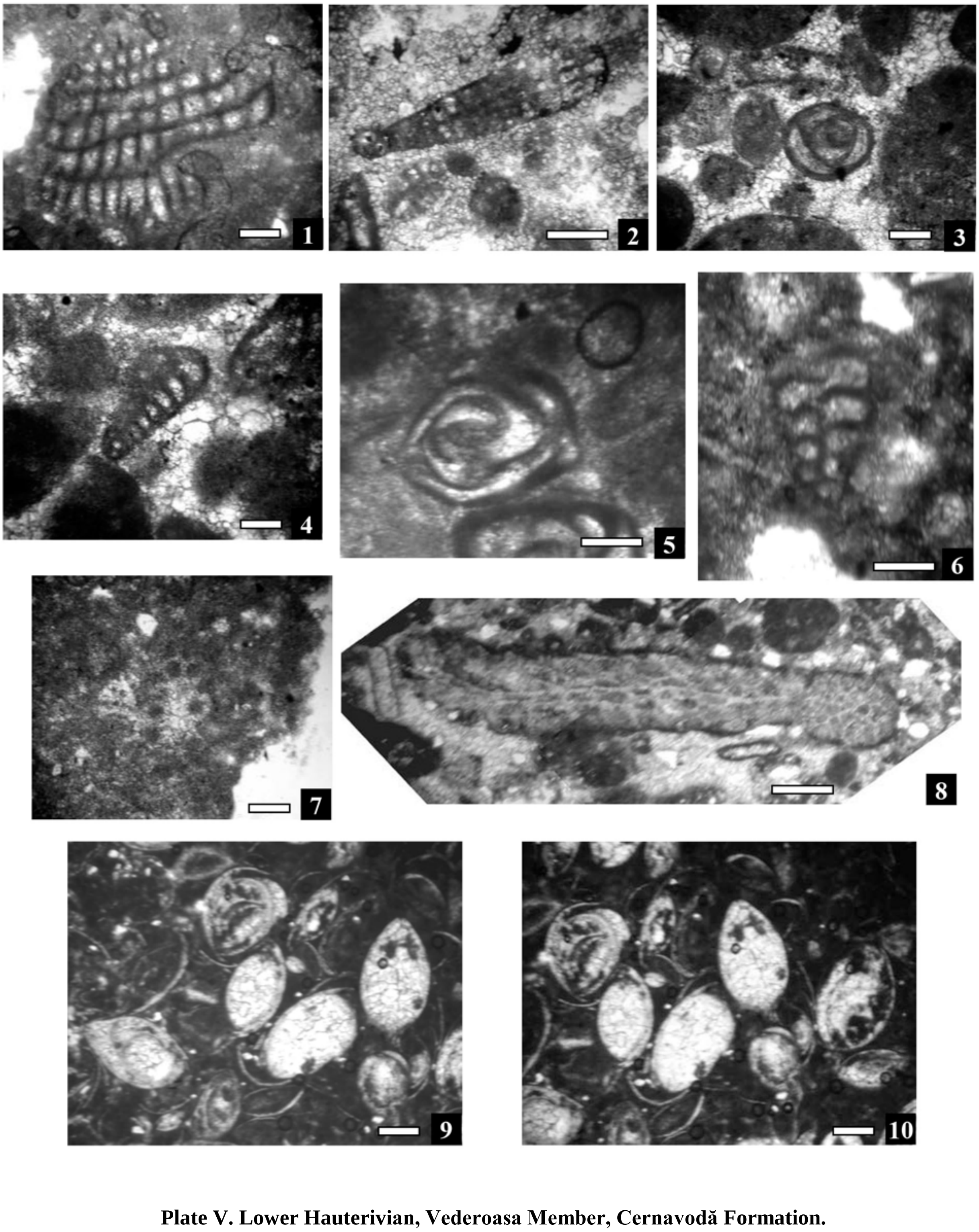

Plate V. Lower Hauterivian, Vederoasa Member, Cernavodă Formation.

Figure 1 - *Histerolina pileiformae* Neagu 2000a; Figure 2 – *Gerochella* sp.; Figure 3 – *Istriloculina alimanensis* Neagu 1984; Figure 4 – ***Vercorsella tenuis*** (Velic & Gusic, 1973) Aranaud-Vanneau, 1980; Figure 5 - ***Moesiloculina danubiana*** Neagu, 1984; Figure 6 – *Kaminskia dissimile* Neagu 1999b; Figure 7 – *Russoella circularis* Dragastan & Richter 2003; Figure 8 – Bryalgal facies; Figures. 9, 10 - Ostracods microbeds accumulation., Scale bar: 0.1 mm.

PLATE VI

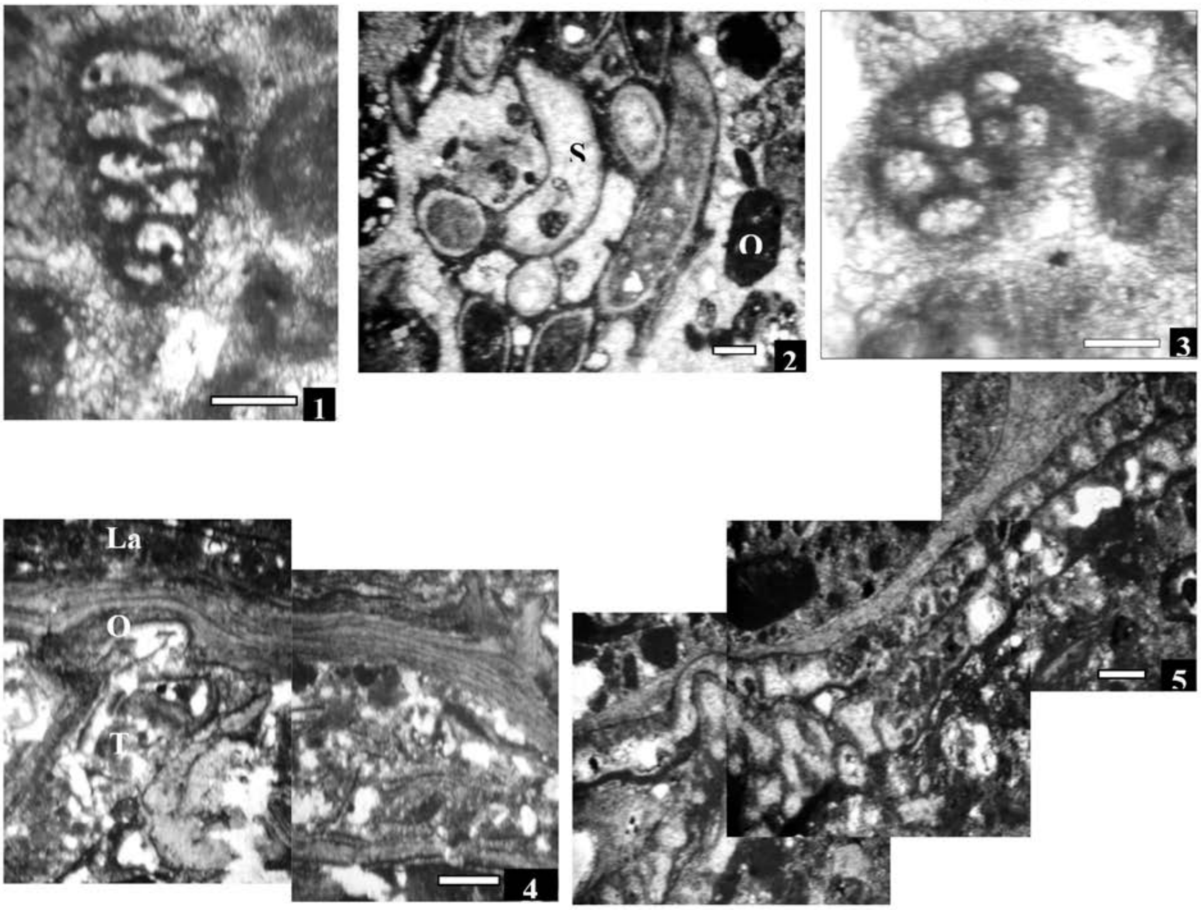

Plate VI. Lower Hauterivian, Vederoasa Member, Cernavodă Formation.
Figure 1 - *Kaminskia exigua* Neagu 1999b; Figure 2 - Serpulid (S) with oncoidal nodule (O); Figure 3 - *Barkerina* sp.; Figure 4 - Oysters shells (O), *Trogotella* sp. (T) and laminitic algal crusts (La); Figure 5 - Algal crust with *Lithocodium aggregatum* Elliott and *Bacinella* microbialites sensu Schlagintweit & Bover Arnal, 2012, Scale bar: 0.1 mm

Several taxa from this association, such as *Kaminskia cuneata, Istriloculina emiliae* (Pl. IV, Fig. 4) and *Meandrospira favrei*, occurs in the lower Hauterivian deposits from the Piatra Mare-Bunloc Massif, the Postăvaru-Râşnov Massif and the Şinca Nouă olistholiths, all parts of the Getic carbonate platform, South Carpathians (Dragastan, 2010).

Sporadically appearing dasycladalean algae represented by *Dissocladella hauterivica*, a Hauterivian species.

Summary: The *Protopeneroplis banatica biozone* is a marker for the lowermost part of the lower Hauterivian, Vederoasa Member, Cernavodă Formation.

Biozone XI with Vercorsella tenuis, middle part of the lower Hauterivian, Vederoasa Member, Cernavodă Formation (Fig. 7).

The species *Vercorsella tenuis* was initially described as new species under the name *Cuneolina tenuis* by Velič & Gusic (1973), being recorded in the *Clypeina cenozone*, type-stratum of the Neocomian (probably Hauterivian) from Ogulin region, Central Croatia. Velič & Sokac (1978) introduced for the Neocomian a *Clypeina?solkani* cenozone sensu Velič (1977) from the same region, with dasyclad algae and foraminifers, allowing the separation of the Valanginian and Hauterivian stages.

In the Hauterivian, the assemblages include *Clypeina*? *solkani*, *Salpingoporella annulata*, *S. pygmaea*, *Epimastopora*?*cekici*, *Montsalevia salevensis*, *Cuneolina camposaurii*, *C. tenuis*, *Sabaudia minuta*, *Orbitolinopsis capuensis* and *Favreina salevensis.*

Subsequently, Arnaud-Vanneau (1980) transferred this species from *Cuneolina* to *Vercorsella* nov. genus Arnaud-Vanneau. Meantime, a new species, *Vercorsella arenata,* was also described, with a large stratigraphic range from the upper Hauterivian up to the Bedoulian; this taxon is recorded in southeastern France, Italy and Serbia.

The interval of this zone is defined between the first occurence of *Vercorsella tenuis* (Pl. V, Fig. 4, a vertical-radial section) as its lower boundary, and the first occurence of *Moesiloculina danubiana*, a species referred initially to *Quiqueloculina* by Neagu (1968). Subsequently, Neagu (1984) transferred this taxon to the new genus *Moesiloculina*, after a detailed study based on a large collection including several thousand specimens, regarding the systematics and nomenclature of the agathisteg miliolids of the Mesozoic.

Velič (1988) defined a biozone with *Montsalevia salevensis* and *Cuneolina tenuis* characteristic for the Valanginian, but mentioned that their stratigraphic range could exetend also in the Hauterivian.

This biozone yielded several species of foraminifers, such as *Scythiolina camposaurii, S. scarcellai*, *Histerolina pileiformae* (Pl. V, Fig. 1), *Protopeneroplis banatica, Kaminskia dissimile* (Pl. V, Fig. 6), *Istriloculina alimanensis* (Pl. V, Fig. 3), *Rumanoloculina robusta, R. pseudominima*, *Moesiloculina deformata, M. dobrogiaca*, and *Bancilina rumana.*

The species *Bancilina rumana* was described by Neagu (1995) from Hauterivian deposits of Aliman quarry on the right bank of Vederoasa Lake and can represent a marker for this stage, when it is represented by a large number of specimens. Here is not the case in the lower Hauterivian from the Cernavodă-lock section.

The dasycladalean algae are represented in this zone by fragmentary thalli of *Anisoporella cretacea*, *Russoella circularis* (Pl. V, Fig. 7) and, rarely, by small algal nodules of *Tubiphytes morronensis*.

In the middle part of this biozone (samples 32-33), a common occurrence is represented by the 3.0 millimeter thick crusts of *Lithocodium aggregatum* Elliott (Pl. VI, Fig. 5), a heterothichale filamentous-septatae calcareous green algae, possibly from Order Ulotrichales, crossed by borings of the ichnogenus *Entobia* Bronn. This ichnogenus corresponds to traces of calcareous boring sponges, following new interpretations of the *Lithocodium* crusts given by Schlagintweit (2010). Towards the top of this biozone (sample 34), a 1.0 cm thick microbed formed through accumulation of serpulid tubes and *Tubiphytes morronensis* algal nodules (Pl. VI, Fig. 2/o) can be observed.

Summary: The *Vercorsella tenuis biozone* is a marker for the middle part of the lower Hauterivian, Vederoasa Member, Cernavodă Formation.

Biozone XII with Moesiloculina danubiana, uppermost part of the lower Hauterivian, Vederoasa Member, Cernavoda Formation.

This biozone is defined as the interval between the first occurrence of *Moesiloculina danubiana* (Pl. V, Fig. 5) which corresponds with the lower boundary of the unit and an upper boundary marked by the contact with the markedly different lithology of the Lipniţa Member of the Ostrov Formation, a unit of Bedoulian age, with *Palorbitolina lenticularis* and pars and by the Ramadan Formation. The Lipniţa Member follows transgressively after an upper Hauterivian–Barremian hiatus on top of the lower Hauterivian Vederoasa Member of the Cernavodă Formation (Fig. 5). It is possible that this index species can also be identified in the Aliman section, approximately 23 km south from Cernavodă, where the Hauterivian deposits contain a complete succession of this stage**.**

The index species *Moesiloculina danubiana* was initially described as a new species of the genus *Quinqueloculina* by Neagu (1968), at this time identified with a large stratigraphic range, from the upper Berriasian to the lower Aptian. Having at his disposal a large amount of specimens, Neagu (1984) subsequently redefined this taxon, also including a new description, and transferred it to *Moesiloculina* nov.genus. Following 1984, the same author identified several new taxa that belong to this genus and reconsidered the stratigraphic range of *M. danubiana* as upper Valanginian–Hauterivian (Neagu personal communication). In association with *Moesiloculina danubiana* (Neagu 1968), the following taxa were identified: *M. dobrogiaca*, *M. angulare*, *Protopeneroplis banatica*, *Meandrospira favrei*, *Rumanoloculina pseudominima*, *R. robusta*, *Kaminskia dissimile*, *K. exigua* (Pl. VI, Fig. 1), *Istriloculina alimanensis*, *Barkerina* sp. (Pl. VI, Fig. 3) and *Lenticulina* sp.

In the basal part of this biozone a bryozoan level covered by a crust with microbialites (sample 35) was recorded, which together generated a milimetric bryalgal crust (Pl. V, Fig. 8).

Similarly, in the terminal part of the zone (sample 42), a patch-reef (P-R 5) appears in the succession, built predominantly by the sponge *Actinostromaria coacta*, characterized by a massive, slightly bulbous coenosteum, having both radial and vertical growth, with orthogonal microstructure and a concentric reticulum of hexactinellid type. The presence of this built level is significant since a comparable level with a rich association of different sponge taxa was found in the Hauterivian deposits of the Aliman quarry, 23 km to the south from Cernavodă (Dragastan et al., 1998).

In the Bicaz Gorges region (Hăghimaş Mts., East Carpathians), the Hauterivian deposits of the Lapoş Formation (Transylvanian carbonate platform) yielded *Neotrocholina molesta, Decussoloculina barbui, Rumanoloculina pseudominima, Scythiloculina* *confusa* and *Earlandia* sp. (Dragastan, 2011).

In the different sectors of the South Carpathians, within the Hauterivian of the Getic carbonate platform Dragastan (2010) identified the following associations progressing from the eastern towards the western parts of this unit:

- in the Piatra Mare-Bunloc sector, the species *Kaminskia cuneata, Patellina turriculata* and a high frequency of the cyanophycean alga *Rivularia theodori*;
- in the Postăvaru- Râşnov sector, the species *Neotrocholina valdensis, Istriloculina emiliae, Scythiolina scarsellai*, and *P. turriculata*;
- in the Codlea Basin, the species *N. valdensis, P. turriculata, Rumanoloculina robusta,* frequent *Lithocodium aggregatum,* the dasyclad alga *Anisoporella cretacea*, but also intercalations with the planktic foraminifer *Globuligerina hoterivica*. This planktic taxon is also recorded in the Appenini Mts. as well as in the Pontides of northwestern Anatolia (Turkey), as a distinct biozone VI, for Hauterivian age (Altiner, 1991);
- in the Piatra Craiului Mts., the benthic species *Meandrospira favrei, P. turriculata, Ichnusella trocholinaeforme*, associated with *Globuligerina hoterivica*, a planktic index taxon;
- in the Dâmbovicioara Basin the species *Scythiolina camposaurii, Patellina turriculata, Istriloculina emiliae, Scytiolina scarsellai*, and *Globuligerina hoterivica*, a planktic index species for the Hauterivian according to Chiocchini et al., (1988) and Altiner (1991);
- in the Lespezi Massif, on the western slope of the Bucegi Mts. the species *Meandrospira favrei, Patellina turriculata, Neotrocholina valdensis* and *Globuligerina hoterivica*;
- in the Vânturariţa Massif, the species *Meandrospira favrei, Montsalevia salevensis, Andersenolina histeri, Pfenderina flandrini* and *Lithocodium aggregatum,* a heterotrichale filamentous septatae calcareous green alga, crossed by borings of ichnogenus *Entobia* with traces of excavating sponges;
- in the Ciclovina-Pui region, the species *Scythiolina scarsellai, Rumanoloculina robusta* and algal crusts of *Lithocodium aggregatum*; and
- in the western part of the Getic carbonate platform, in the Reşiţa-Moldova Nouă Zone, Bucur (1988, 1997) recorded the following assemblages from Hauterivian deposits: *Patellina turriculata, Ichnusella trocholinaeformis, Earlandia conradi-brevis, Charentia cuvillieri, Nautiloculina* cf. *broennimanni, Everticyclammina hedbergi, Meandrospira favrei, Vercorsella scarsellai* and *Spirillina italica.* The age of this association, found in the Lindinei Formation, was calibrated using the ammonite *Acanthodiscus radiatus.*

Summary: The *Moesiloculina danubiana* biozone is an index zone for the uppermost part of the lower Hauterivian, Vederoasa Member, Cernavodă Formation.

It is worth mentioning, that the upper Hauterivian and Barremian deposits are missing in the Cernavodă-lock profile. The entire Hauterivian–Barremian succession have been not recorded from Cernavodă Bridge and the classical profiles on the right bank of the Danube, Dragastan et al., (1998) considered that this time interval is missing and corresponds to a stratigraphic gap; this conclusion appears to be partially upheld here.

7. CONCLUSIONS

The new stratigraphic scheme proposed here for the Lower Cretaceous deposits of the Cernavodă Formation (upper Berriasian–Valanginian and lower Hauterivian) is based on the successions recognized in the Cernavodă-lock profile, South Dobrogea, taking into account the benthic foraminifera assemblages. No levels with planktic foraminifers were identified. Up to now, no investigations are available for the nannoplancton, although this is certainly present.

Twelve biozones (I-XII, Fig. 7) have been identified using the different benthic foraminifers as marker or index species, and first occurences of these taxa were employed to establish the lower boundary for each biozone. Meantime, the associated microfauna are also recorded for each biozone, and the occurrence of dasycladaleans and other calcareous algae is also noted.

The biozones previously described from different areas (Alps, France, Carpathians, Appenines, Dinarides, Pontides and Hellenides), and also identified in the Cernavodă-lock profile, such as those based on *Protopeneroplis ultragranulata, Haplophragmoides joukowskyi, Montsalevia salevensis, Meandrospira favrei*, and *Vercorsella tenuis* (Fig.7), showed a comparable stratigraphic position and age, although occasionally small differences are also present. Accordingly, the stratigraphic scheme proposed for Cernavodă-lock should be considered a good marker for regional correlations in the Tethys realms.

Seven new biozones have been defined and redefined using the following taxa: *Andersenolina elongata, Dobrogelina anastasiui, Carasuella cylindrica, Danubiella gracilima, Rumanoloculina robusta, Protopeneroplis banatica*, and *Vercorsella tenuis* (Fig. 7), with the lower and upper boundaries of these zones drawn at the first occurences of the respective marker species.

The Lower Cretaceous (upper Berriasian–Valanginian–lower Hauterivian) biozones of the new stratigraphic scheme corresponds to Partial-Range Zones according to the International Stratigraphic Guide, and they also take into account the overall assemblages for each biozone.

The most important groups used in this biostratigraphic scheme of Lower Cretaceous carbonate shelf deposits are the Involutinidae (with species of the genera *Andersenolina* and *Neotrocholina*), the miliolid family Quinqueloculinidae (with the genera *Scythiloculina, Decussoloculina, Rumanoloculina, Danubiella, Istriloculina* and *Moesiloculina*, described by Neagu, 1968, 1984, 1985), the Textulariidae (Subfamily Kaminskiinae Neagu 1999b), the Cuneolinidae (*Scythiolina*, *Cuneolina*, *Histerolina* and *Vercorsella*), the Haplophragmoidiidae (*Freixialina, Carasuella*) (Neagu 2000 a, 2000b) and the Endothyridae (genus *Protopeneroplis*).

Several calcareous algae, especially the dasycladaleans (such as *Rajkaella, Salpingoporella, Anisoporella, Zergabriella, Clypeina, Russoella)*, occur in the Berriassian–Valanginian, while other taxa such as *Meagaporella fluegeli* and *Bancilaporella filipescui*, are mainly restricted to the Hauterivian deposits (Dragastan et al., 1998).

The high diversity of foraminifers and calcareous algae, also combined with the presence of a rich macrofauna with pachyodonts, sponge patch-reefs with rare scleractinian corals, bivalves, gastropods, nautiloids, echinoids and sparse vertebrates (fishes of the genera *Lepidotus* and *Gyrodus* or dinosaurian vertebrae and teeth) makes the Lower Cretaceous of the Cernavodă area a very important paleontological, stratigraphical and geological site that allows detailed comparisons with other sites from the Alps, Carpathians, Dinarides, Appennines, Hellenides and Taurides.

The entire upper Berriasian–Valanginian–lower Hauterivian spectrum of organisms indicates a progradant shelf passing from the continental area (represented by the Central Dobrogean land) to marine conditions, ranging from tidal flat (supratidal-intertidal) environments to an inner shelf carbonate platform, with small and large lagoons and a high biological diversity (Neagu et al., 1997).

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