THE MESOZOIC CARBONATE DEPOSITS FROM THE BOREHOLE 6042 DELENI (TRANSYLVANIAN DEPRESSION)

IOAN I. BUCUR¹, MARCEL-ADRIAN PITEIU² & EMANOIL SĂSĂRAN¹

ABSTRACT. The borehole 6042 Deleni is among the few wells located in the central part of the Transylvanian Depression that crossed the rocks in the basement. Among these, the Mesozoic deposits were cross-cut along 916 m. Based on the investigations carried out on core samples from the Mesozoic deposits three carbonate units attributed to the Late Oxfordian -Tithonian (?Neocomian) have been separated. A preliminary evaluation of the terrigenous and carbonate-terrigenous deposits overlaying the carbonate ones indicated an Aptian-Albian, respectively Senonian age. Considerations on the paleoenvironment of the Mesozoic deposits studied are also presented.

Keywords: Carbonate rocks, biostratigraphy, Mesozoic, Transylvanian Depression

INTRODUCTION

The borehole 6042 Deleni crossed carbonate deposits on a total thickness of 916 m (between m. 3664 and m. 4580). Seventy six meters were sampled (Figs.1A-B, 2A-D) and 147 samples were investigated. Based on lithological features, three carbonate rock units have been separated as follows (from the base to the top, Fig.2):

1. Dolomitic limestones with *Cladocoropsis* (2 m thick, between m. 4580-4578);
2. Dolomites (427 m total thickness, between m. 4578-4151, of which 66 m were effectively sampled);
3. Limestones with cyanobacteria and *Clypeina* (487 m, between m. 4151-3664, of which 9.5 m were effectively sampled).

The limestones and dolomites are overlaid by terrigenous and carbonate-terrigenous rocks (sandstones, siliceous shales, clayey-silty limestones) (253 m thick, between m. 3595-3342, of which 9 m were effectively sampled). Fourteen samples were investigated in this interval.

Data concerning the general structural features of the Transylvanian Depression were published by Săndulescu & Visarion (1978) and Săndulescu (1984).

¹ Babeș-Bolyai University, Department of Geology, str. M. Kogălniceanu nr.1, 400084 Cluj-Napoca, Romania. E-mails: ibucur@bioge.ubbcluj.ro; esasaran@bioge.ubbcluj.ro

² SNGN "Romgaz" S. A. Medias, Str. Unirii No 4, 3125 – Medias. E-mail: marcel.piteiu@medias.romgaz.ro

Fig. 1A – B – Sampled intervals with Mesozoic deposits from the borehole 6042 Deleni.

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II. LITOSTRATIGRAPHY

1. Dolomitic limestones with *Cladocoropsis*.

The interpretation is based on 24 investigated samples (Fig.2D). The limestones consist of packstone, packstone-wackestone or dolomitised wackestone. The abiotic components are represented by micritic peloids of various sizes, as a result of either micritisation of bioclasts, or of the reworking of carbonate sediment. The dolomitisation process was undifferentiated – it affected both the matrix and the clasts, and lead to the formation of dolosparitic aggregates usually consisting of partially outlined rhombohedra that build-up in average 10-20% of the bulk rock. Locally, dolomitisation was more intense (30-40%). The secondary nature of the dolomitisation process is also indicated by the screening effect of some bioclasts upon the Mg carbonate-rich solutions. The rock is locally characterised by the presence of diachases filled with microdolosparitic material.

The bioclasts consist of frequent fragments of sclerospongia (*Cladocoropsis mirabilis* FELIX) (Pl.I, figs. 1-4) that give the specific feature of these limestones. Besides fragments of bivalves, (rare) gastropods, foraminifers and calcareous algae are present. The microbial structures are represented by rivulariaceean type cyanobacteria (Pl.I, figs. 7-8), bacinelloid-type nodules (Pl.I, figs. 5-6), sometimes ending with a *Lithocodium*-type stage (Pl.III, fig. 4), *Lithocodium*-type nodules (Pl.III, fig.5), *Hormathonema*-type microbial deposits (Pl.III, figs. 7-8) accompanied by small micritic aggregates and thin micritic crusts within the internal space of *Cladocoropsis* (Pl.III, fig. 6), micritic microbial crusts around the *Cladocoropsis* and mollusc fragments.

Except for the cyanobacteria, the carbonate algae are relatively scarce. However, the most frequent species is *Thaumatoporella parvovesiculifera* (RAINERI) (Pl.3, fig.3) while dasyclad fragments are very rare.

Foraminifers are abundant, represented both by agglutinated forms, as well as miliolids and involutinids. The following species were identified: *Redmondoides lugeoni* (SEPTFONTAINE) (Pl.II, fig.6), *Alveosepta jaccardi* (SCHRODT) (Pl.II, figs.1-2), *Neokilianina rahonensis* (FOURY & VINCENT) (Pl.II, figs. 3-4), *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATI-MORANO (Pl.II, fig.5; Pl.III, fig.1), "*Trocholina*" sp., *Andersenolina* gr. *alpina* (LEUPOLD) (Pl.II, figs. 7-8), *?Everticyclammina* sp., *Pseudocyclammina* sp., *?Protopeneroplis* sp., *?Arenobulimina* sp., various agglutinated forms of textulariid-type, miliolids (Pl.III, fig.2).

2. Dolomites

The study was performed on 96 samples (Fig.2B-D). The dolomites consist of medium- to coarse grained dolosparites (Pl.IV, figs. 3-5). The dolomitisation affected a pre-existing carbonate sediment, as proven by the frequent bioclast and peloid "phantoms" identified in some rock varieties (Pl.IV, figs.1-2). The process shows variable intensities, in some cases leading to a total overprint on the previous substrate. The shape of the dolomite rhombohedra ranges from anhedral to euhedral, and their sizes from 0.10 to 0.60 mm. Occasionally crystals larger than 1 mm have been noticed. It is highly probable that the original carbonate clasts played the role of nucleation centres for the dolomite rhombohedra, as suggested by the darker nuclei including relic carbonate material.

Many crystals show growth zonation pattern during subsequent nucleation stages, with lighter external bands (Pl.IV, figs. 4, 6). When the original sediment included

porous spaces of a fenestral-type, the dolomite crystals developed around these voids, in a centripetal display (Pl. IV, fig. 5). The pores left empty by the dolomitisation process were subsequently filled-in with a late, poikilitic-type sparite cement. Sometimes the fenestral space was occupied by geopetal sediments mainly consisting of fine- to medium-granular dolomitic detritus. Frequently the rocks are fissured; sometimes they reached the brecciation stage (Pl.IV, figs. 7-8). As in the case of fenestral spaces, the fissures were filled with fine dolomite detritus. Opaque, dark-coloured iron oxi-hydroxides and/or organic matter represent other types of materials often identified in the studied dolomites (less than 1% of the volume in some rock varieties). Some of the rhombohedra are intensely fissured, most probably along the twinning planes; this process might have thus provided the fine filling material for the voids and fissures.

The bioclasts that could be identified in the dolomite matrix are first of all represented by foraminifers, such as "*Trocholina* " sp. (Pl.IV, fig.1), *Redmondoides lugeoni* (SEPTFONTAINE), *Neokilianina rahonensis* (FOURY & VINCENT), miliolides, various agglutinated foraminifers. Fragments of *Thaumatoporella parvovesiculifera* (RAINERI) are also present. Among the dasyclads, only *Salpingoporella annulata* CAROZZI has been determined (Pl.IV, fig.2).

3. Limestones with cyanobacteria and *Clypeina*

Twenty seven samples were collected from this unit (Fig.2A-B). In the 4151-3924 m. interval the succession is represented mainly by wackestone-packstone and wackestone, with cyanobacteria and foraminifers. Rare echinoderm plates, bivalve and gastropod fragments, crustacean coprolites, as well as fragments of dasyclads and *Thaumatoporella* are also noticeable. The cyanobacteria nodules range between 1 and 9-10 mm; in general they are the major component of the rock. The nodules' structure is of a bacinelloid-type; however, some nodules consist of rivulariacean-type structures (Pl.V, fig.8). Most of them suffered an intense micritisation process that finally led to the complete overprint of the original structure. The micrite peloids, usually 0.05-0.20 mm in size and showing rounded or oval shapes most probably originate from micritised bioclasts. Rare coarse grainstone interbeddings mainly consist also of cyanobacteria nodules, in principal of bacinelloid-type. Fragments of gastropods, foraminifers, fragments of dasyclad and *Thaumatoporella* are also present. The rock was subject to dolomitisation processes to a lesser extent. Rare rhombohedral crystals of reduced size (0.10-0.13 mm) subsequently most probably affected by dedolomitisation have been noticed. The wackestone-type facies including cyanobacteria nodules, foraminifers and *Thaumatoporella* dominates the top of this unit. Locally this facies is very scarce in foraminifers, and is characterised by the abundance of bacinelliform or micritic microbialitic nodules; the latter sometimes consist of small peloids of microbial-type. Such varieties indicate a very shallow facies, possibly even supratidal small ponds. Locally, the rock shows fenestrate features, the voids being filled with a fine granular dolomitic material.

In other cases the wackestone-type facies is dominated by *Thaumatoporella*-type structures (Pl.V, fig.7). The sequence ends with peloidal grainstone / packstone with foraminifers and rare dasyclads, accompanied by fragments of bivalves, gastropods and crustacean coprolites. The micritic peloids consisting 50-60% of the rock show variable sizes, between 0.05 and 1.1 mm, most of them resulting from bioclast micritisation. Foraminifers are the most abundant bioclasts.

In the interval 3804-3801 m. the succession consists of packstone and wackestone with ostracods, fragments of bivalves, foraminifers and fragments of dasyclads. The micritic peloids range between 0.10-0.20 mm; miliolids are frequent in general.

Finally in the interval 3665-3664 m. the deposits are represented by boundstone dominated by hermatypical recrystallized corals of thamnasterioid-type. Besides, sclerospongia of *Chaetetopsis*-type were noticed. The peloidal intrareef sediment contains fragments of bivalves and gastropods, foraminifers and "Tubiphytes". Within the same interval also coarse packstone-grainstone deposits with *Bacinella* and *Lithocodium* nodules, abundant echinoderm plates, fragments of bivalves and large recrystallized coral fragments (perireef sediment) were identified. In addition, annelid tubes and foraminifers (including *Lenticulina*) are present.

The following genera and species were identified in the succession: *?Everticyclammina* sp., *?Gaudryina* sp., *Belorusiella* sp., *Patellovalvulina* sp., *Nautiloculina* sp., *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATI MORANO (Pl.VI, figs.1-3), *Redmondoides lugeoni* (SEPTFONTAINE) (Pl.VI, fig.4), *Andersenolina* sp. (Pl.VI, fig.5), *Lenticulina* sp., *Meandrospira* sp. (Pl.VII, fig.1), *?Protopeneroplis* sp. (Pl.VII, fig.2), *Neotrocholina* sp. (Pl.VI, fig.6), *Clypeina sulcata* (ALTH) (Pl. V, fig. 5), *?Salpingoporella* sp. (Pl.V, fig.6), *?Selliporella* sp. (Pl.V, figs. 1-4), *Thaumatoporella parvovesiculifera* (RAINERI) (Pl.V, fig.7), *Bacinella irregularis* RADOIČIĆ, *Lithocodium aggregatum* ELLIOTT (Pl.VII, fig.3), and *Favreina salevensis* (PAREJAS) (Pl.VI, figs.7-8).

4. Terrigenous and carbonate-terrigenous deposits

On the top of the carbonate rocks, the borehole from Deleni crossed a terrigenous and carbonate-terrigenous succession.

Sandstones and sandy limestones are the corresponding rocks identified in the 3595-3587 m interval. The sandstones belong to the quartzo-lithical type (Q = 30-40 %; micas - 15-20 %) and they show a dominant siliceous cement (partly carbonate-rich, dolomitised). The bioclasts are represented by numerous sponge spicules, foraminifers and fragments of red algae. The foraminifers are mainly represented by species of the *Hedbergella* – *Globigerinelloides* and *Gavelinella* genera. The sandy limestones (3592-3591 m interval) consist of silty to fine arenitic quartz (20-25%), bioclasts (fragments of bivalves, foraminifers, fragments of red algae) (20-25 %), and micas (3-5 %). *Gavelinella* and *Hedbergella* – *Globigerinelloides* are still dominant among foraminifers and rare nodosariides and *Sabaudia minuta* (HOFKER) (Pl.VII, figs.4-5) are also present.

The 3492-3489 m interval is represented by siliceous shales with radiolarians. Quartz is present in relatively reduced amounts (10-15%, up to 30-40% in interbeddings showing a more pronounced terrigenous character). Micas range between 5-15%. Films of opaque minerals (iron oxides-hydroxides) were frequently noticed. The cement is siliceous, microcrystalline. The biophase mainly consists of radiolarians, rare sponge spicules and rare foraminifers (including heterohelicides).

Samples of silty-clayey to fine arenitic limestones have been recovered from the 3347-3342 m interval, with quartz grains ranging between 5-20%, and bioclasts between 15-20 %. The cement has a carbonate nature, being intimately mixed with microcrystalline silica. Bioclasts are mainly represented by foraminifers, besides which radiolarians, sponge spicules and calcispherulides have been noticed. The dominant foraminifera are *Hedbergella* – *Globigerinelloides*, *Globotruncana* (Pl.VII, fig.6-8) and *Heterohelix*, while most of the calcispherulides belong to *Pithonella*.

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Fig. 2A

Fig. 2A – D – Lithologic succession of the Mesozoic deposits from the borehole 6042 Deleni.

Fig. 2B

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Fig. 2C

Fig. 2D

II. BIOSTRATIGRAPHIC REMARKS

The foraminiferal assemblage identified in the Limestones with *Cladocoropsis* includes 4 species that are characteristic for the Tethyan Late Jurassic: *Redmondoides lugeoni* (SEPTFONTAINE), *Alveosepta jaccardi* (SCHRODT), *Neokilianina rahonensis* (FOURY & VINCENT) and *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATI-MORANO. Among them, *Alveosepta jaccardi* is stratigraphically restricted to the Late Oxfordian-Early Kimmeridgian (Maync, 1960; Hottinger, 1967; Septfontaine et al., 1991). The lower limestone unit can be thus attributed to this time-interval (Fig.3).

Regarding the dolomites, among the “phantom”-foraminifers that could have been identified, two species belong to the same Late Jurassic group: *Redmondoides lugeoni* (SEPTFONTAINE) and *Neokilianina rahonensis* (FOURY & VINCENT) (Bassoullet, 1997). Based on these species, the dolomite unit can be assigned to the Kimmeridgian-Late Tithonian interval, characterized by the presence of the species *N. rahonensis*.

The limestones with cyanobacteria include, starting with sample 7638 (m. 4150-4148), the species *Parurgonina caelinensis* having the upper limit restricted to the Middle Tithonian (Bassoullet, 1997). At about 125 m above, the limestones in this unit include *Clypeina sulcata* (ALTH) accompanied by *Redmondoides lugeoni* (SEPTFONTAINE), and *Favreina salevensis* PAREJAS. This association indicate the Late Tithonian. Starting with m. 3804 till m. 3664, where the carbonate succession ends, the foraminiferal and algal association does not provide any clue for age assignments. However, some of the foraminifers attributed to genera *Protopeneroplis* and *Meandrosira* resemble *Protopeneroplis ultragranulata* (GORBACHIK), and *Meandrosira favrei* (CHAROLLAIS, BRÖNNIMANN & ZANINETTI). Based on these arguments, we assigned the last 100-140 m of limestones to the Early Cretaceous (Berriasian-?Valanginian) (Altiner, 1991; Bucur et al., 1995); this assignment is however questionable.

The terrigenous rocks on the top of the succession belong to the Cretaceous. The sandstones and sandy limestones in the 3595-3587 m interval contain foraminifers of the *Hedbergella*, *Globigerinelloides* and *Gavelinella* genera, besides which *Sabaudia minuta* (HOFKER) has been identified. Keeping into account that the latter species does not have a post-Albian extension (Chiocchini et al., 1983; Arnaud-Vanneau & Chiocchini, 1985), the whole unit may be assigned to the Aptian-Albian. There are no clear arguments for dating the shales with radiolarians in the 3492-3489 m interval. However, based on the fact that they contain species of the genus *Heterohelix* with the first species occurring at the end of the Albian, we can assign a Late Cretaceous (probably the lower part of Late Cretaceous) age to these rocks. Finally, the globotruncanids identified in the latter investigated interval (m. 3347-3342) indicate a Late Cretaceous (Senonian) age.

III. PALEOENVIRONMENTAL INTERPRETATION

The carbonates studied were deposited in a shallow environment (carbonate platform), that evolved from an external platform facies with *Cladocoropsis* and foraminifers (the limestones with *Cladocoropsis*) to an internal one (shallow subtidal, intertidal to supratidal) dominated by cyanobacteria (the Limestones with cyanobacteria), followed by a platform margin (reef and para-reef environments) (the

Fig. 3 – Biostratigraphic repartition of the main microfossils identified in the Mesozoic deposits from the borehole 6042 Deleni.

coral limestones at the top of the succession). It is difficult to define the environment of deposition for the limestones that evolved in the dolomitic unit. However, dolomitisation was for sure a secondary process that probably affected the limestones during successive stages of their formation, from the penecontemporaneous (quasi-simultaneous) stage to late diagenesis. The source of magnesium for the CaMg (CO₃) is not obvious. Its transport was anyway provided by solutions circulating through the areas of minimum resistance in the sediment (pores, fissures, diaclasses).

The terrigenous deposits mark the transition to deep waters facies with pelagic foraminifers accompanied in the lower part by benthic elements (Aptian-Albian with *Sabaudia*), the pelagic feature becoming dominant towards the top (radiolarians, pithonellas, globotruncanids).

IV. CONCLUSIONS

The borehole 6042 Deleni crossed Mesozoic deposits along 916 m thickness. Three carbonate units were separated: 1) limestones with *Cladocoropsis*; 2) dolomites and 3) limestones with cyanobacteria and *Clypeina*. Based on the microfossils identified in thin sections, the three carbonate units were attributed to the Late Oxfordian-Tithonian (?Neocomian). The terrigenous and carbonate-terrigenous deposits at the top of the limestones were assigned partly to the end of the Early Cretaceous (Aptian-Albian), and partly to the Late Cretaceous.

The Jurassic limestones and dolomites formed within a carbonate platform that evolved from an external to an internal environment. Both the facies and the micropaleontological content of these deposits are similar to the Oxfordian-Tithonian carbonate deposits in the Transylvanian units of the Southern Apuseni Mountains. The terrigenous and carbonate-terrigenous deposits at the top of the succession indicate a deep water environment.

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PLATES

Plate I

- Fig. 1-4 – *Cladocoropsis mirabilis* FELIX. 1-3: oblique sections; 1-sample 26/03, x 6.2; 2-sample 7491, x 6.2; 3-sample 7491, x 12.5; 4: longitudinal section, sample 7494, x 6.2.
- Fig. 5-6 – *Bacinella*-like nodules. 5: sample 26a/03, x 12.5; 6: sample 7491, x 12.5.
- Fig. 7-8 – Rivulariacean-like cyanobacteria. 7: sample 26/03, x 25; 8: sample 7496, x 12.5.

Plate II

- Fig. 1-2 – *Alveosepta jaccardi* (SCHRODT). 1: equatorial section, sample 25/03, x 50; 2: axial section, sample 26/03, x 50.
- Fig. 3-4 – *Neokilianina rahonensis* (FOURY & VINCENT). Longitudinal sections. 3: sample 26/03, x 25; 4: sample 7491a, x 25.
- Fig. 5 – *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI MORANO. Oblique section, sample 7496, x 25.
- Fig. 6 – *Neokilianina rahonensis* (FOURY & VINCENT) and *Redmondoides lugeoni* (SEPTFONTAINE). Oblique and longitudinal-oblique sections, sample 7480(D), x 25.
- Fig. 7-8 – *Andersenolina* gr. *alpina* (LEUPOLD). Subaxial sections. 7: sample 26/03, x 50; 8: sample 7491, x 50.

Plate III

- Fig. 1 – *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI MORANO. Detail of the wall structure, sample 7491a, x 50.
- Fig. 2 – Miliolid foraminifer. Sample 7493, x 50.
- Fig. 3 – *Thaumatoporella parvovesiculifera* (RAINERI). Sample 7491a, x 25.
- Fig. 4 – *Bacinella irregularis* RADOIČIĆ-*Lithocodium aggregatum* ELLIOTT. Sample

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7497, x 12.5.

Fig. 5 – *Lithocodium* nodule. Sample 7480(D), x 25.

Fig. 6 – Microbial sediment inside on open space of *Cladocoropsis mirabilis* skeleton. Sample 7495, x 50.

Fig. 7-8 – Microbial structures of *Hormathonema* type inside the internal spaces of *Cladocoropsis* (8 = enlargement of fig.7). Sample 7483(D); 7 x 50; 8 x 100.

Plate IV

Fig. 1-2 – Dolomite with phantome-like clasts, including some well preserved biosclasts: “*Trocholina*” sp. (fig.1) and *Salpingoporella annulata* CAROZZI (fig.2). 1: sample 7488(D), x 50; 2: sample 7486a(D), x 50.

Fig. 3 – Medium-grained dolomite. Sample 7628, x 12.5.

Fig. 4, 6 – Coarse-grained dolomite with zoned rhombohedra. 4: sample 7610/2, x 25; 6: sample 7661, x 12.5.

Fig. 5 – Open space in a coarse-grained dolomite filled with poikilitic sparry calcite. Sample 7612, x 12.5.

Fig. 7-8 – Brecciated dolomite. 7: sample 7498(D), x 6.2; 8: sample 7616, x 6.2.

Plate V

Fig. 1-4 – ?*Seliporella* sp. Tangential sections through laterals. 1: sample 7535, x 25; 2, 3: sample 7630, x 25; 4: sample 7631, x 25.

Fig. 5 – *Clypeina sulcata* (ALTH). Tangential section through a verticil, sample 7641/2, x 50.

Fig. 6 – ?*Salpingoporella* sp. Transverse section, sample 7644, x 50.

Fig. 7 – *Thaumatoporella parvovesiculifera* (RAINERI) with small protuberances (?reproductive structures). Sample 7640, x 50.

Fig. 8 – Rivulariacean-like cyanobacteria. Sample 7634, x 25.

Plate VI

Fig. 1-3 – *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI MORANO. Subaxial sections, sample 7638, x 25.

Fig. 4 – *Redmondoides lugeoni* (SEPTFONTAINE). Subaxial section, sample 7639, x 25.

Fig. 5 – *Andersenolina* sp. Subaxial section, sample 7636, x 50.

Fig. 6 – *Neotrocholina* sp. Subaxial section, sample 7648, x 50.

Fig. 7-8 – *Favreina salevensis* (PAREJAS). 7: sample 7631, x 25; 8: sample 7635, x 25.

Plate VII

Fig. 1 – *Meandrospira* sp. Transverse section. Sample 7646, x 50.

Fig. 2 – ?*Protopeneroplis* sp. Oblique section, sample 7647, x 50.

Fig. 3 – *Lithocodium aggregatum* ELIOTT. Sample 7647, x 25.

Fig. 4-5 – *Sabaudia minuta* (HOFKER). 4: transverse section; 5: longitudinal section through the embrionar apparatus, sample 7652/2, x 50.

Fig. 6-8 – *Globotruncana* div. sp. 6: sample 7657, x 50; 7: sample 7658, x 50; 8: sample 7659, x 50.

Plate I

Plate II

Plate III

Plate IV

Plate V

Plate VI

Plate VII