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STATISTICAL ANALYSIS OF MIDDLE JURASSIC BIVALVE ASSEMBLAGES FROM ROMANIA: A PRELIMINARY REPORT WITH PALEOECOLOGICAL SIGNIFICANCE

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Abstract. The application of similarity coefficients is helpful in comparative analysis between different fossil assemblages and it permits observations with regard to the degree of clustering reported to occurrence and lithofacies. Statistical and paleoecological analysis, were performed for bivalve assemblages occurring in Anina, Bucegi, Central Dobrogea, Codlea, Haghimas, Rarau, Rosia (Padurea Craiului Mountains). The binary (presence – absence) similarity coefficients used in this paper is the Jaccard, Dice and Kulczynski II coefficients. The similarity between the studied fossil assemblages was calculated and presented graphically using rectangular cladograms obtained with the Free Tree Software.

Keywords: Statistical analyses, Bivalves, Jurassic, Romania.

INTRODUCTION

Numerous statistical indices were used for the systematic analysis of the quantitative, qualitative and binary "presence-absence" data belonging to a representative unit such as a fossil assemblage. Cheetham A. H. & Hazel J. E. (1969) show that the translation of these coefficients, in order to express relationships between bioassociational units, has generated conceptual and nomenclatorial difficulties. They specify which are the conceptual relationships and the properties of the coefficients that express similarity or differences between different units in the way they were defined by the binary data. They showed that these coefficients are highly important in systematic biology and paleontology, due to the large spectrum of binary data, such as morphological characteristics that are present or absent for many individuals of he same species. Such species were recording as having both various stratigraphic ranges and occurrences.

The binary coefficients that used for this study are Jaccard, Dice and Kulczynski II.

The Jaccard coefficient: $C / (N_1 + N_2 - C)$, calculates the number of taxa, common for two associations, reported to the number of total taxa belonging to two fossiliferous sites (N_1 and N_2), pointing to the differences between the associations.

The Dice coefficient $2C / N_1 + N_2$ and II Kulczynski Coefficient: $C(N_1 + N_2) / 2N_1N_2$ point to the similarity between the two associations.

Statistical, population or taxonomic comparisons between associations was based generally by the quality of the published scientific papers approaching the relative species abundance, and by the facies types containing these associations. In the same time, scientific papers show different opinions of various authors with regard to the species variation, incomplete descriptions, mixed and contradictory synonymy lists, poor or un-existing illustrations, and they generate serious difficulties for objective comparative studies.

The quantity analysis of fossiliferous sites, done by calculating the relative species abundance, is highly important for identifying the significant ecological groups, and for reconstructing several paleocommunity features. Harper (1978) discussed the statistical significance of analyses grouping fossiliferous sites in paleoecological communities, reported to the species content of each site. These approaches in quantity paleoecology were used here in the case of paleoecological analysis of Romanian bivalve associations, collected or studied from previous paleontological titles. Connections between the studied taxa and the main ecological groups were established by assessing the functional morphology of the shells, the degree of preservation, the relationships within the food chain, and by comparing our data with already published data.

The statistical study was focusing on the comparison between different Romanian Middle Jurassic bivalve associations, for understanding the stratigraphic trends, and the facies affinities of bivalve species. The studied areas are Anina (Resita Basin), the western part of the Bucegi Mountains, Central Dobrogea, Codlea, Rarau (Tarnita – Rarau – Breaza, Campulung – Pojărata), Haghimas, and Rosia (Padurea Craiului Mountains). The aspects considered for selecting the studied areas are the following:

-the high degree of geological and biostratigraphical knowledge;

-the published systematic content (described, illustrated species, or at least published species lists). Anina, Central Dobrogea, Codlea, Campulung - Pojărata, Haghimas, Rarau, Rosia – Padurea Craiului areas were already studied and paleontological data were already published;

-the quality of the original systematic,

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paleoecological and taphonomic data (Bucegi, Anina, Codlea);

-the revision of fossil material, previously collected and found within the collections of Faculty of Geology and Geophysics, University of Bucharest.

The coefficient values were obtained using the binary data (Presence/Absence) for 177 bivalve species collected from seven areas with Middle Jurassic outcrops (Annex 1). The degree of similarity for fossils assemblages studied was calculated and graphic represented by rectangular cladograms with Free Tree Program. The similarity matrix (Table 1, 2, 3) and the cladograms permitted to obtain the degree of clustering, with regard to the localities versus the lithofacies.

The western part of the Bucegi Mountains represents one of the most important outcropping areas of Middle Jurassic deposits. The large outcropping of this area and the rich faunal content give the importance of this section. Numerous paleontologists studied this famous area, since the beginning of the XIX-th Century: Herbich (1888), Popovici-Hatzeg (1898, 1905), Simionescu (1905), Jekelius (1916), Patrulius (1957, 1964, 1969, and 1980), Stoica (1997), and Lazar (2000 - 2003).

Patrulius et al. (1980) assigned Middle Jurassic deposits outcropping in the western slope of the Bucegi Mountains to two formations: the Strungulita Formation (Bajocian) and the Strunga Formation (Bathonian - Lower Callovian).

The bivalve species diversity of these deposits is very high, 77 bivalve species being described and illustrated (Lazar, 2000, 2001, 2002). Based on detailed paleoecological studies, Lazar (2000) emphasized three types of assemblages:

a. associations included in silty interlayers from the lower part of the Strungulita Formation, Bajocian in age;

b. associations included in the calcareous sandstone and calcarenites of the middle part of the Strungulita Formation;

c. associations from the "bed with brachiopods", with a hard ground surface to its top of the Strunga Formation, Bathonian - Lower Callovian in age.

Stoica (1997) gave the facies influence on the percentage distribution on bivalve ecological groups for these assemblages.

Numerous geologists intensively studied the geology of the **Anina** region since 1855. Badaluta (1965-1976), Bucur (1997), and Popa (2000) detailed the history of the geological research in this area. The molluscan associations are recorded as Middle Liassic (Pliensbachian-Toarcian) to Middle Callovian, and they were studied by Badaluta (1965, 1976), Bucur (1997). These assemblages are remarkable by the very high number of species and individuals. The study of the molluscan faunas of these sequences was re-initiated by Lazar, Barbu & Popa in 2001, and the detailed results in systematic will be published soon. Middle Jurassic deposits that outcrop in this area are predominantly silty and pellitic. In the Anina zone, the Middle Jurassic (Aalenian, Bajocian, Lower and Middle Bathonian) is different from Bucegi Mountais considering the type of facies. Although rich fossiliferous clays and sandy marls represent the Middle Jurassic deposits from Anina, these deposits contain a series of common species with the Bajocian deposits of the Pasul Strunga - Pasul Strungulita (Bucegi area): *Grammatodon (G.) concinnus* (Phillips), *Protocardia (P.) stricklandi* Morris & Lycett, *Modiolus imbricatus* (Sowerby), *Gervillella acuta* (Sowerby), *Liostrea acuminata* (Sowerby), *Rollierella minima* (Sowerby). The Upper Bathonian of the Anina area is represented mainly by marls and limestones that include a rich molluscan association having in common with the Bajocian deposits of the Bucegi Mountains only the species *Entolium (E.) corneolum* Young & Bird and *Chlamys (Aequipecten) fibrosus* (Sowerby). In spite of this, within the last 10 meters of the Upper Bathonian, occurs the facies with *Bositra buchi* (Roemer) that were not recorded in the Bucegi Mountains. Badaluta et al., 1969, discussed the occurrence of the facies with *Bositra buchi* in detail. The Lower Callovian deposits of the Anina area include a rich association occurring in a sequence of marls alternating with clays, and rare calcareous sandstones, to the topmost sequence.

The first citations regarding the Mesozoic fauna of the **Codlea area** (South Carpathians) belong to Jaekelius (1916). Valceanu (1960) records a Middle Jurassic bivalve and ammonite association occurring in the Breitbach Valley. Sandulescu (1967) mapped the Middle Jurassic deposits of the region and cited the occurrence of the "*Posidonia* level". Manoliu-Negreanu (1969) completed the list of species, describing some genera and species marking the Bajocian - Bathonian - Lower Callovian age. Barbulescu, Gradinaru & Stoica (1997) studied in detail the paleontology and paleoecology of the Lower Bathonian molluscan association of the Valea Lata Formation (Dragastan and Popa, 1997), separating two molluscan paleocommunities associated to two depositional environments: a. shallow marine (proximal shelf), with sandy sediments and b. distal shelf with muddy sediments.

Comparing the bivalve species of the two paleocommunities with those of the Bucegi area, a low number (10) of common species was recorded. Only two of them, *Grammatodon (G.) concinnus* (Phillips) and *Protocardia (P.) stricklandi* (Morris & Lycett) occur in the pellitic level with arenitic interlayers of Pasul Strungulita, while all other common species occur in Bucegi in calcareous sandstones.

The Middle Jurassic deposits of the Codlea and Anina areas are different from a lithological point of view, and the molluscan associations have a low

number of common elements. In the Codlea region, *Bositra buchi* occurs in the Upper Bathonian - Lower Callovian deposits (occurring in the deposits of the same age from the Anina region), while in Western Bucegi, Rarau and Padurea Craiului Mountains this species were yet recorded.

The Middle Jurassic deposits of **Central Dobrogea** represented by detritic and carbonatic deposits were dated as Upper Bathonian - Callovian. In these sequences were separated the Tichilesti Formation (Draganescu, 1985), Upper Bathonian - Lower Callovian and the Gura Dobrogei Formation (Draganescu, 1979), Middle-Upper Callovian. Dragastan et al., 1998, present the history of research in this area in detail. The richest fossiliferous deposits of this region occur in Hârşova - Topalu – Baltagesti – Galbiori – Stupina – Tichilesti sector (western part of the Central Dobrogea) and Mireasa – Cheia – Casian – Piatra – Valea Sartorman - Valea Visterna sector (eastward). The molluscan faunas of these formations were recorded for the first time by Cardas (1907b), and then described and illustrated by Simionescu (1910). Detailed studies on these faunas were accomplished by Barbulescu (1961a, 1961b, 1963a, 1974), Barbulescu and Gradinaru (1969), and Barbulescu (in Dragastan et al., 1998). These papers are used here for statistic comparisons. Bucegi and Central Dobrogea share numerous common species (38) included in Bajocian calcareous sandstones and biocalcarenites. The highest similarity regards families Mytilidae, Pectinidae, Limidae, Pholadomyidae and Pleuromyidae.

The bivalve association from the Lower Bathonian - Callovian "bank with cephalopods" from Bucegi, although it is less species diverse, shares a series of common species with central Dobrogea (having similar facies), such as: *Inoperna plicata* (Sowerby), *Chlamys (C.) textoria* (Schloteheim), *Eopecten spondyloides* (Roemer), *Pseudiolimea duplicata* (Sowerby), *Limatula cerealis* Arkell, *Astarte modiolaris* Lamarck, *Pholadomya angustata* (Sowerby).

An interesting aspect is the fact that the bivalve species occurring in the Bajocian pellitic level with arenitic interlayers from Pasul Strungulita (Bucegi) cannot be founding in the Bathonian coarser deposits of Central Dobrogea. The species *Eonavicula minuta* (Sowerby), *Grammatodon (G.) concinnus* (Phillips), *Nicaniella (Trautscholdia) andriacensis* (Fischer), *Pleuromya tenuistria* (Münster), *Pleuromya subelongata* (d'Orbigny) show affinities with higher turbulent environments, marked by clayey material deposited in shallow waters, where more nutrients occurred for infaunal suspension feeders and detritus feeders.

The stratigraphic range of these species is not significant for comparing the two associations, as the species where recorded also from other outcropping areas of Bathonian deposits of Romania and Europe.

The Jaccard coefficient calculated for Jurassic bivalve associations from Bucegi and central Dobrogea is 0.33% for species, 0.53% for genera, and 0.85% for families. The low Jaccard species coefficient is triggered by the dominance of the epifaunal species (of families Pectinidae, Rhombopteriidae, Oxytomidae) from Central Dobrogea, while in Bucegi the association is dominated by infaunal and semi-infaunal species (of families Pholadomyidae, Pleuromyidae, Ceratomyidae, Mytilidae, Bakevellidae). In the same time, this difference could be explaining by the age difference between the two assemblages, the pectinids from Dobrogea being mainly Callovian, while the infaunal or semi- infaunal species from Bucegi are Middle Bajocian.

The Jaccard coefficient values for genera and families are high, making the compared associations very similar. This aspect demonstrates the capacity of these mollusks to span long time intervals and to adapt to varied sedimentary conditions.

Numerous researchers who contributed a lot to the geological knowledge of the area studied the Mesozoic deposits of Haghimas Mountains (Eastern Carpathians). In Haghimas, Lower and Middle Jurassic deposits are detritic and they were well developed on both sides of the Haghimas syncline (Preda, 1976). These deposits include a continuous sequence between Hettangian and Bathonian, with a Pliensbachian sedimentary gap. The Middle Jurassic deposits of the western flank outcrop well around the Red Lake, along the Ucigasul Creek and on the Suhard Mountain and they are represented by grey calcareous sandstones, sandy limestones, ferruginous oolithic limestones, and red argillite shales with jasper interlayers to their top. The Middle Jurassic deposits of the eastern flank are less developed, and the main fossiliferous outcrop occurs north of Piatra Liciului, where black limestones and grey sandy limestones (Preda, 1976) represent the sedimentary deposits. These deposits yield a rich bivalve fauna, together with corals, brachiopods and rare cephalopods. For comparing the bivalve associations were used the papers of Pelin (1969), Grasu (1971) and Preda (1976), as these papers include descriptions and illustrations of the fauna.

The Bajocian-Bathonian bivalve faunas of this region share a high number of species (19) with those of Bucegi. These species belong to both regions in the same types of rocks, in calcareous sandstones and ferruginous oolithic limestones. The common species belong to Entoliidae, Pectinidae, Pholadomyidae şi Pleuromyidae.

Mutihac (1965) studied the Middle Jurassic deposits of the Rarau-Breaza syncline, along the outcrops from Valea Tatarca and Izvorul Rece,

considering a few species of bivalves as Middle Jurassic in age. Later, Stanoiu (1967) dated the sedimentary deposits as Bathonian-Lower Callovian (reddish, sandy and oolithic limestones, with brachiopods, ammonites and pectinids).

Turculet (1998, 1999-2000) described and illustrated a rich bivalve fauna belonging to the families Posidoniidae, Oxytomidae, Chlamyidae, Entoliidae collected from calcareous sandstones and limestones from the Tarnita – Rarau – Breaza area.

Turculet (1968) also studied the Middle Jurassic deposits of the Câmpulung - Pojorata area, re-finding the fossiliferous site described previously by other researchers. This outcrop is located by this author on the left shore of the of the Fundul Pojoratei creek, 400 m upstream of the confluence with Moldova creek. Turculet dated these deposits (calcareous, grey, compact, very fossiliferous sandstones overlained by tough, grey marls with belemnites) based on the molluscan fauna as Lower Bajocian (*humphersianum* zone). Turculet described and illustrated only a part of the collected fauna with belemnites, brachyopods, bivalves, and ammonites. The species of bivalves are common with Bucegi associations, and they were collected from deposits with similar facies. It is very possible that the bivalve associations will be higher, but this comparison is biased by the published number of species from this area.

Rosia (Padurea Craiului Mountains)

Preda (1962, 1968) described the most abundant Lower and Middle Jurassic bivalve species from the Rosia zone, from the following sites: Strungarului creek, Lazuri creek, Gorunaş Hill, Cuților creek.

This association shares only few species with that of Bucegi Mountains: *Entolium (E.) corneolum* Young & Bird, *Placunopsis fibrosa* Laube, *Trigonia costata* Parkinson, *Astarte modiolaris* Lamarck, *Pholadomya murchisoni* Sowerby, *Chlamys (C.) textoria* (Schlotheim). These species were collected from oolithic, ferruginous limestones.

	BUCEGI	CENTRAL DOBROGEA	CODLEA	HAGHIMAS	RARAU	PADUREA CRAIULUI	ANINA
BUCEGI		0.50000	0.30088	0.36364	0.20619	0.11429	0.26772
CENTRAL DOBROGEA	0.50000		0.33043	0.32143	0.18182	0.16822	0.26357
CODLEA	0.30088	0.33043		0.32787	0.20833	0.25000	0.33333
HAGHIMAS	0.36364	0.32143	0.32787		0.31111	0.18868	0.26667
RARAU	0.20619	0.18182	0.20833	0.31111		0.20000	0.22581
PADUREA CRAIULUI	0.11429	0.16822	0.25000	0.18868	0.20000		0.17143
ANINA	0.26772	0.26357	0.33333	0.26667	0.22581	0.17143	

Table 1. Dice coefficient - The similarity matrix

	BUCEGI	CENTRAL DOBROGEA	CODLEA	HAGHIMAS	RARAU	PADUREA CRAIULUI	ANINA
BUCEGI		0.50007	0.37056	0.46828	0.37423	0.16204	0.28972
CENTRAL DOBROGEA	0.50007		0.41133	0.41878	0.33547	0.24172	0.28719
CODLEA	0.37056	0.41133		0.32866	0.23438	0.25521	0.34443
HAGHIMAS	0.46828	0.41878	0.32866		0.33944	0.19037	0.28111
RARAU	0.37423	0.33547	0.23438	0.33944		0.20833	0.29484
PADUREA CRAIULUI	0.16204	0.24172	0.25521	0.19037	0.20833		0.19022
ANINA	0.28972	0.28719	0.34443	0.28111	0.29484	0.19022	

Table 2. Kulczynski II coefficient - The similarity matrix

	BUCEGI	CENTRAL DOBROGEA	CODLEA	HAGHIMAS	RARAU	PADUREA CRAIULUI	ANINA
BUCEGI		0.33333	0.17708	0.22222	0.11494	0.06061	0.15455
CENTRAL DOBROGEA	0.33333		0.19792	0.19149	0.10000	0.09184	0.15179
CODLEA	0.17708	0.19792		0.19608	0.11628	0.14286	0.20000
HAGHIMAS	0.22222	0.19149	0.19608		0.18421	0.10417	0.15385
RARAU	0.11494	0.10000	0.11628	0.18421		0.11111	0.12727
PADUREA CRAIULUI	0.06061	0.09184	0.14286	0.10417	0.11111		0.09375
ANINA	0.15455	0.15179	0.20000	0.15385	0.12727	0.09375	

Table 3. Jaccard coefficient - The similarity matrix

The Jaccard, Dice, Kulczynski II coefficients point to the following conclusions:

- the similarity between bivalve associations from Bucegi and Central Dobrogea with Dice (Tab. 1, Fig.

1A) and Kulczynski II (Tab. 2, Fig. 1B) coefficients of 0.51 obtained from the similarity matrix is influenced by the facies in which these associations occur (calcareous sandstones interlayered with biocalcarenites). Ecological groups that dominate these associations point out this aspect. These ecological groups are infaunal and semi-infaunal species belonging to Pleuromyidae, Pholadomyidae, Ceratomyidae, Mytilidae, Pinnidae). The similarity between the two associations is confirmed also by the low value of the Jaccard coefficient (0.44) (Tab. 3, Fig. 1C), this coefficient showing the differences between the assemblages. This difference was triggered by the byssate infaunal species of families Arcidae, Cucullidae, Paralellodontidae and Bakewellidae, occurring in a pellitic facies of the western Bucegi Mountains, lower part of the Strungulita Formation respectively.

- the Haghimas associations are similar to the Bucegi and Central Dobrogea associations due to the same type of facies, sharing 14 common species belonging to the families Mytilidae, Oxytomidae, Rhombopteriidae, Entoliidae, Pectinidae, Pholadomyidae, Pleuromyidae. The Jaccard coefficient value (0.18), indicating the minimal differences between the three associations, is influenced by the low number of species recorded until now from Haghimas area.

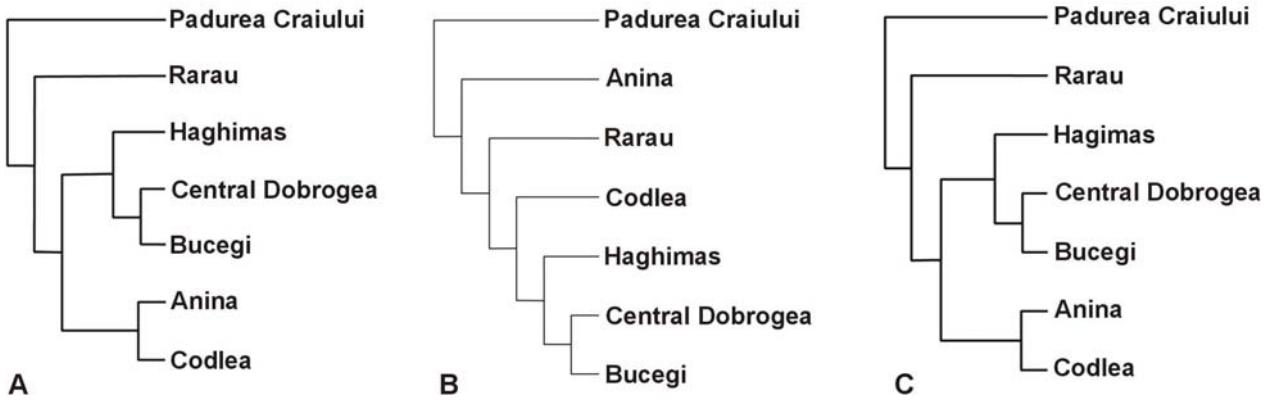

Figure 1. Rectangular cladograms using
the Dice (A), Kulczynski II (B) and Jaccard (C) coefficients

- the associations from Rarau and Rosia zones (Padurea Craiului Mountains) have the lowest values of similarity coefficients, due to the low number of species described in the literature, with only two common species.

- the associations from Anina and Codlea have a high similarity rank (according to the Dice coefficient), with little differences (according to the Jaccard coefficient). The similarity of these two assemblages is evident when considering the relative dominance related to the species number, of Bivalvia Class' subclasses. In this way, the subclasses Pteriomorphia, Anomalodesmata and Heterodonta show a high number of common species.

The results obtained in this study are very useful for paleoecological and paleobiogeographical reconstructions. However, these results are preliminary, as the primary data are significant only for the Anina, Bucegi, Codlea, Central Dobrogea areas, while for other areas such as Rarau, Haghimas, Rosia – Padurea Craiului Mountains, the data were provided only from previous literature, without quantity information. Completing these data may lead to high similarity coefficient values between these associations and those studied in detail by the authors.

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REFERENCES

Badaluta, A. & Năstaseanu, A. 1965, Geologia regiunii Anina cu privire speciala asupra Jurasicului – zona Resița – Banat. Teza de doctorat (Autoreferat), 33 p., Bucureşti.

Badaluta, A., Barbulescu, A., Manoliu, E., Mutiu, R., 1969, Asupra faciesului cu Bositra buchi (Romer) in Romania. *Anuarul Universitatii Bucuresti*, an XVIII – 1969, extras p. 65-77.

Badaluta, A. 1976, Precisious biostratigrafiques sur la Serie Mesojurassique d' Anina (zona Reşița, Banat). *Just. Geol – Geof*, Dări de seama, vol. LXII (1974-1975), extras p. 73-84.

Barbulescu, A. 1961a, Contribuții la studiul Jurasicului din Valea Tichileştilor (R. Hârşova). Studii şi cercetări de Geologie, extras, Tom VI, vol. 4, p. 700 – 708, Editura Academiei, R.P.R.

Barbulescu, A. 1961b, Fauna callovianǎ din Dealul Baroi – Hîrşova. (Notă preliminară). *Analele Universității C. I. Parhon, Ser. Ştiințele Naturii, Geologie-Geografie,* Extras, vol. 27, anul X, p. 81-89.

Barbulescu, A. 1963a, Contribuții la studiul faunei de lamellibranchiate jurasice din Dobrogea. *Studii şi cercetări de Geologie*, extras, Tom VIII, vol. 1, p. 45-63, Editura Academiei, R.P.R.

Barbulescu, A. 1974, Stratigrafia Jurasicului din Vestul Dobrogei Centrale. Editura Academiei, R.S.R., Bucureşti, p. 9-161, Pl. XXI – XXXI.

Barbulescu, A. & Grădinaru, E. 1969, Studiul faunei de moluşte din formațiunile Bathonian – Calloviene inferioare din Valea Tichileştilor (Dobrogea Centrală). *Analele Universității Bucureşti*, Geologie, Anul XVIII, p. 79-115.

Barbulescu, A., Grădinaru, E. and Stoica, I. 1997, Paleoecology of early Bathonian molluscan faunas in the Codlea area (South Carpathians, Romania). *Acta Paleontologica Romanie*, vol. 1. p.45 – 56.

Bucur, I, I., 1997, Formatiunile Mezozoice din zona Resita – Moldova Noua (Muntii Aninei si estul Muntilor Locvei), 214 p., *Presa Universitara Clujeana*, Cluj – Napoca.

Cardas, A., 1907b, Nore sur le bivalves trouvées dans l'Oxfordien de Hirsova – Topal (Dobrogea), *An. St. Universitatea Iasi*, IV, 3-4.

Cheetham, A. H. and Hazel, J. E. 1969, Binary (Presence-Absence) similarity coeficients. *Journal of Paleontology*, vol. 43, Nr. 5, p. 1130-1136, sept. 1969.

Dodd, J. R. & Stanton, J. R. 1981, Paleoecology – Concepts and Applications Bloomington, Indiana; College Station, Texas, p. 383-440.

Dragastan, O., Neagu, Th., Barbulescu, A., Pana, I. 1998, Jurasicul şi Cretacicul din Dobrogea Centrală şi de Sud (Paleontologie şi Stratigrafie). S.C. SuperGraph Tipo S.R.L., Cluj-Napoca, 1998.

Grasu, C. 1971, Recherches geologiques dans le sedimentaire Mesozoique du bassin superieur de Bicaz (Carpates Orientales). *Lucr. Stațiuni de Cercet.Biol., Geol., Geograf., "Stejarul".*

Harper, C. W. Jr. 1978, Groupings by locality in community ecology and paleoecology: test of significance. *Lethaia*, Vol. 11, p. 251-257, Oslo.

Herbich, Fr. 1885 (1888), Données paléontologiques sur les Carpathes Roumaines. *Anuarul Biroului Geologic*, anul III, nr. 1, Bucureşti, p. 12-339, pl. I – XXIX.

Jekelius, E. 1916, A Brassói Hegyek Mezozoós Faunája III-VII. A Brassói Dogger- ÉS Malmfauna, Budapest.

Lazar, I. 2000 (1999), Middle Jurasic Anomalodesmatan Bivalves from Strunga – Tataru, Bucegi Mountains. *Acta Palaeontologica Romaniae* V.2, p. 237-250, Presa Universitara Clujeana, 2000.

Lazar, I. 2002 (2001), Bivalves (Subclass Anomalodesmata) from Middle Jurassic deposits of the western flank of Bucegi Mountains. *Acta Palaeontologica Romaniae* V.3, p. 241-256, Ed. Vasiliana '98, Iasi, 2002.

Manoliu – Negreanu, E., 1969, Contribuții la studiul paleontologic al Jurasicului mediu (Bajocian-Bathonian-Callovian inferior) din regiunea Codlea. *Bul. Inst. de Petrol, Gaze şi Geol.*, vol. XVII, 1969, p. 37-62.

Mutihac, V. 1965, Considerații asupra Doggerului din Sinclinalul Marginal (Rarău – Breaza), *Studii şi Cercetări de Geologie, Geofizică şi Geografie*, seria Geologie, Tom 10, nr. 1, Editura Academiei RSR, p. 247-252.

Patrulius, D. 1957, Corelarea doggerului superior şi malmului din Carpații Orientali, *Bul. Şt. Acad. R.P.R., Secț. Geol.-Geogr.*, vol. II, , nr. 2, p. 261-273.

Patrulius, D. 1962, Affinités provinciales et voies de migration de quelques faunes jurassiques des Carpates roumaines et de l'avant-pays carpatique. Colloque du Jurassique, Luxembourg, 1962, volume de Comptes Rendus et Mémoires, l'Institut grand-ducal, Section des Sciences naturelles, physiques et mathématiques, p. 519-525.

Patrulius, D. 1964, Faunele mezozoice din Masivul Bucegi. *Ocrotirea Naturii*, Tomul 8, nr.1, p. 41-53, Editura Acad. R.P.R., Bucureşti.

Patrulius, D. 1969, Geologia Masivului Bucegi şi a Culoarului Dîmbovicioara. Editura Acad. R.S.R., Bucureşti.

Patrulius, D., Popa, E., Avram, E., Baltreş, A., Pop, G., Iva, M., Antonescu, E., Dumitrică, P., Iordan, 1980, M., Studiul petrologic şi biostratigrafic complex al formațiunilor jurasice şi neocomiene din Carpații Românești şi Dobrogea în vederea evaluării potențialului de resurse minerale. Sectorul Leaota-Braşov-Munții Perşani. Raport I.G.G. – Tema Nr. 47/1979.

Pelin, M., 1969, Asupra depozitelor liasice si doggeriene de pe flancul estic al sinclinalului Haghimas – Culmea Piatra Liciului (Carpatii Orientali), Analele Universitatii Bucuresti, Geologie, Anul XVIII, p. 55-64, Bucuresti, 1969.

Popa, M.E., 2000. Early Jurassic land flora of the Getic Nappe, University of Bucharest, Bucharest, unpublished PhD thesis, 258 pp.

Popovici-Hatzeg, V. 1898, Étude géologique des environs de Câmpulung et de Sinaia (Roumanie). Fac. Science Paris, Thèses, ser. A, nr. 31, Nr. 968, Paris.

Popovici-Hatzeg, V.1905, Les Céphalopodes du Jurassique moyen du Mont Strunga (Massif de Bucegi, Roumanie). *Mém. de la Soc. Géol. de France*, Paléontologie, Tome XIII, Fascicule 3, Nr. 35, p. 5 – 27, Pl. I – XIV.

Preda, I., 1962, Studiul geologic al regiunii Rosia – Meziad (Muntii Padurea Craiului), 108 p., 17pl., Editura Academiei R.P.R, Bucuresti.

Preda, I. 1968, Lamellibranchiatele jurasice de la Roşia (Munții Pădurea Craiului). An. Univ. Buc., seria Şt. Nat., an. XVII, nr. 1, p. 9-16, extras, 1968.

Preda, I. 1976, Contribuţii la cunoaşterea Liasicului şi Doggerului din M-ţii Haghimaş (Carp. Or.). *Anuarul Muz. de Şt. Nat. Piatra-Neamţ*, seria Geologie-Geografie, III, Extras p. 19-40.

Sandulescu, M. 1967, Structura geologică a terenurilor mezozoice de la exteriorul masivului cristalin al Făgăraşului. *Dări de Seamă ale Şedinţelor Comitetului Geologic*, Vol. LII / 2, p. 177 – 208, Bucureşti.

Simionescu, I. 1899, Über die Kelloway – fauna von Valea Lupului in den Südkarpathen Rumäniens. – Verh. K. K. geol. Reichsanst., Wien, Nr. 18: 410 –415; Viena.

Simionescu, I. 1905, Studii geologice şi paleontologice din Carpaţii Sudici, IV. Fauna Jurasică din Bucegi. *Publ. Fond. Adamachi*, No. XIII, p. 223-263, Pl. I-IV, Academia Română, Bucureşti.

Simionescu, I. 1910, Studii geologice şi paleontologice din Dobrogea, II. Lamellibranchiatele, Gastropodele, Brachiopodele şi Echinodermele din păturile Jurasice de la Hârşova. – Academia Română Publs., Nr.25: 109 p.; Bucureşti.

Stanoiu, I. 1967, Noi date privind stratigrafia Jurasicului din regiunea Valea Tătarca – Valea Lucava (partea de nord a sinclinalului Rarău; Carpaţii Orientali). *Dări de Seamă ale Şedinţelor*, Vol. LIII / 1, p. 465 – 470, Bucureşti.

Stoica, I. 1997, Palaeoecology of Middle Jurassic bivalve communities from Strunga - Strungulița, western side of Bucegi Mountains, Romania. *Acta Palaeontologica Romaniae. The First Romanian National Symposium on Palaeontology*, Bucharest, p. 101-106, pl. 11.I.

Turculet, I. 1968, Contribuţii la cunoaşterea Jurasicului mediu de la Pojorâta (Cuveta Rarăului). *Buletin Soc. de Şt. Geol.*, R.S.R., vol. X, p. 145-161.

Turculet, I., 1998, Sur des Pectinacées du Jurassique Bucovinique de la zone Tarnita – Rarau – Breaza (Carpates Orientales), I. Entoliidae, *Revue Roumanine de Géologie*, Editura Academiei Romane, Tome 42, p. 91-100, pl. I – VI, 1998, Bucuresti.

Turculet, I., 1999-2000, Sur des Pectinacées du Jurassique Bucovinique de la zone Tarnita – Rarau – Breaza (Carpates Orientales), II. Posidoniidae, Oxytomidae, Chlamyidae, *Analele Stiintifice ale Universitatii "Al. I. Cuza" Iasi*, Geologie, Tom XLV – XLVI, p. 173 – 179, pl. I – II.

Vîlceanu, P. 1960, Contribuţii la cunoaşterea geologică a regiunii Codlea. *Studii şi Cercetări Geologice*, Vol. 1, p. 119 – 134, Bucureşti.

Annex 1. Stratigraphical distribution of the Middle Jurassic bivalve fauna from studied areas.

Annex 1. Stratigraphical distribution of the Middle Jurassic bivalve species from studied areas.

Families	Species	Western Bucegi Mts. **Baj - Bth.**	Central Dobrogea **Bth. – Clv.**	Codlea (South Carpathians) **Bth.**	Hăghimaş (Eastern Carpathians) **Baj. - Bth.**	Câmpulung – Pojorâta (Mts. Rarău) – **Baj.**	Rogoz (Pădurea Craiului) **Baj. - Clv.**	Anina **Aal. - Clv.**
1	2	3		5	6	7	8	9
NUCULIDAE Gray, 1824	*Palaeonucula menkei* (Roemer)	✓						
	Nucula variabilis Sowerby	✓						
ISOARCIDAE Kenn	*Isoarca bajociensis* d'Orb.	3						
POLIDEVCIIDAE Kunpera et al., 1960	*Dacryomya lacrima* (J.C. Sowerby)							★
ARCIDAE Lamarck,1809	*Eonavicula minuta* (Sow.)	✓						
CUCULLAEIDAE Stewart, 1930	*Cucullaea inaequivalvis* Goldfuss							★
	Cucullaea diana (d'Orbigny)	✓						
PARALLELODONTI-DAE Dall, 1898	*Grammatodon (G.) concinnus* (Phillips)	✓		▲				★
	Grammatodon (G.) clathratus (Leckemby)	✓						
	Grammatodon (G.) balkhanensis (Pcelincev)			▲				
	Grammatodon (Cosmetodon) keyserlingii (d'Orbigny)			▲				
MYTILIADE Rafinesque, 1815	*Arcomytilus bathonicus* (M.& L.)	✓	ϖ					
	Modiolus imbricatus (Sow.)	✓	ϖ	▲				★
	Modiolus anatinus (Smith)		ϖ	▲				
	Modiolus gibbosus Sow.	3	ϖ		•			
	Modiolus (M.) bipartitus Sow.	3						
	Modiola cuneata Sow.				•			★
	Modiola cf. borrjisiaki Roemer				•			
	Inoperna plicata (Sow.)	3	ϖ	▲				
	Mytilus (F.) tumidus M. & L.		ϖ					
	Mytilus suprajurensis	3						
	Mytilus petatus	3						
	Mytilus linceus	3						
BAKEVELLIDAE King, 1850	*Gervillella ferruginea* Beneke	3						
	G. aviculoides (Sow.)	3				7		
	G. lanceolata (Munster)							★
	G. acuta (Sow.)	✓						★
	G. monotis (Deslongchamps)			▲				
	Bakevellia (B.) waltoni (Lycett)	✓						
ISOGNOMONIDAE Dall, 1895	*Isognomon archiachi* (Rig. & Sauv.)		ϖ					
	I. (I.) isognomoides (Stahl.)	3						
	I. promytiloides							★
PINNIDAE Leach, 1819	*P. ampla* (Sow.)	3						
	Pinna cuneata							★
	P. (Pinna) lanceolata Sow.		ϖ					
	Pinna cancelata M. & L.							★
OXYTOMIDAE Ichikawa, 1958	*Oxytoma inequivalve* (J. Sow.)	✓	ϖ		•			★
	Oxytoma censoriensis (Cotteau)		ϖ				♦	
RHOMBOPTERIIDAE Korobkov, 1960	*Bositra buchi* (Roemer)	✓	ϖ	▲	•	7		★
ENTOLIIDAE Korobkov, 1960	*Entolium (E.) corneolum* Y. & B.	✓	ϖ	▲	•	7	♦	★
	Entolium (E.) lunare (Roemer)						♦	
	Cingentolium (C.) cingulatum (Goldfuss)		ϖ	▲	•	7	♦	★
PECTINIDAE Rafinesqe, 1815	*Chlamys (C.) textoria* (Schlotheim)	✓	ϖ	▲	•	7	♦	★
	Chlamys (C.) valonensis Defrance						♦	
	Radulopecten fibrosus (J. Sow.)	✓	ϖ		•			★
	Radulopecten vagans (Sow.)	✓	ϖ		•			

1	2	3	4	5	6	7	8	9
PECTINIDAE Rafinesque, 1815	*Radulopecten fibrosodichotomus* (Kasansky)		ϖ					★
	Radulopecten scarburgensis (Young & Bird)		ϖ					
	Camptonectes (Camptonestes) laminatus (Sow.)	✓				7		
	Camptonectes (C.) subulatus (Munster)						♦	
	Camptonectes (C.) aratus (Waagen)		ϖ			7		
	Camptonectes (C.) auritus (Schlot.)	3	ϖ	▲	•	7		★
	Camptonectes (Camptochlamys) obscurus (Sow.)	3						★
	C. (Camptochlamys) clathratus (Roemer)	✓	ϖ	▲				
	Eopecten spondyloides (Roemer)	✓	ϖ					
	Eopecten tegulatus (M. & L.)		ϖ					
	Eopecten abjectus (Phill.)		ϖ					
	Pseudopecten (P.) equivalvis (J.Sow.)						♦	
PROPEAMUSIIDAE Tucker Abott, 1954	*Propeamusium (Parvamusium) pumilum* (Lamarck)			▲			♦	
TERQUEMIIDAE Cox, 1964	*Placunopsis fibrosa* Laube	3	ϖ				♦	★
	Placunopsis jurensis (Roemer)		ϖ					★
	Placunopsis socialis M. & L.		ϖ	▲				
	Placunopsis oblongus Laube		ϖ				♦	
LIMIDAE Rafinesque, 1815	*Plagiostoma leesbergi* (Branco)	3						
	P. mincinhamptonesis C. & A.		ϖ					
	P. strigillata Laube						♦	
	P. bellulla M. & L.	3						
	P. hellica Cosm. et d'Orb.	✓	ϖ					
	P. bynei Cox & Arkell	✓	ϖ					
	P. cardiiformis Sow.	✓	ϖ					
	Lima (P.) subcardiiformis Greppin		ϖ					
	L. (P.) schimperi Branco		ϖ					
	L. (P.) complanata Laube		ϖ					
	L. (P.) lycetti Laube		ϖ					
	L. (P.) goyoni Fischer		ϖ					
	Lima gigantea Desl.						♦	
	Pseudolimea duplicata (Sow.)	✓	ϖ					
	Limatula cerealis Arkell	3	ϖ		•	7		
	L. helvetica (Oppel)	✓	ϖ					
	Ctenostreon rugosum (Smith)		ϖ					
	Ctenostreon cf. proboscideum Sow.	3	ϖ	▲				★
PLICATULIDAE Watson, 1930	*Plicatula fistulosa* Morris et Lycett			▲	•		♦	
OSTREIDAE Rafinesque, 1815	*Gryphaea cymbium* Lamarck						♦	
	Gryphaea (Bilobissa) dilobotes Duff							★
	Gryphaea (G.) ex. gr. arcuata Lamarck							★
	Liogryphaea calceola Goldfuss					7		★
	Lopha marshii (Sow.)		ϖ					
	Lopha (Rastellum) eruca (Defr.)	✓	ϖ					
	Lopha costata (Sow.)	3	ϖ	▲				
	Liostrea acuminata (Sow.)	3						★
	Liostrea subrugulosa M. & L.							★
	Lopha (Rastellum) gregarea (Sow.)	✓						
	L. hebridica (Forbes)		ϖ					★
	Catinula matisconensis (Lissaj.)		ϖ	▲				
	"Ostrea" knori Voltz							★
	Exogyra crassa (Smith)		ϖ					
	Nanogyra nana (Sow.)		ϖ					

TRIGONIIDAE Lamarck, 1819	*Trigonia ex. gr. siliceum* Quensted	✓						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
TRIGONIIDAE Lamarck, 1819	*Trigonia (Lyriodon) aff. praecasiope* Lebk.		ϖ					
	Trigonia costata Parkinson	✓	ϖ			7	♦	
	Myophorella (M.) signata (Ag.)		ϖ		•			
	M. (M.) cf. eichwaldi Sow.					7		
	M. (M.) cf. clavellulata (Strand)			▲				
	M. duplicata (Sow.)	✓						
MACTROMYIDAE Cox, 1929	*Mactromya cognata* (Phillips)	✓	ϖ		•			
	Mactromya varicosa (J. Sowerby)		ϖ					
	Mactomya gibbosa (M. & L.)		ϖ					
CARDIIDAE Lamarck, 1809	*Protocardia (P.) stricklandi* (M. & L.)	✓	ϖ	▲				★
	Protocardia (P.) lycetti Rollier			▲				
ASTARTIDAE d' Orbigny, 1844	*Astarte modiolaris* Lamark	3	ϖ				♦	
	A. cf. robusta Ettalon							★
	A. parkinsoni							★
	A. elegans Zietten					7		
	A. integra Munster				•			
	A. aff. obliqua Lamarck						♦	
	A. aff. rhomboidalis Phillips						♦	
	A. pulla Röemer		ϖ					
	Neocrassina (Pressastarte) ungulata (Lycett)			▲				
	Nicaniella (T.) andriacensis Fischer	✓						
	Nicaniella (T.) carinata (Phillips)			▲				★
	Opis lucensis d'Orbigny						♦	
ARCTICIDAE Newton, 1891	*Rollierella minima* (Sow.)	✓	ϖ			7		★
	Pseudotrapezinum cordiforme (Deshayes)		ϖ					
	Anisocardia gibbosa Munst.	3			•			
	Anisocardia (A.) loweana (M. & L.)	3		▲				
PHOLADOMYIDAE Gray, 1840	*Pholadomya angustata* (Sow.)	3	ϖ		•			
	P. (Bucardiomya) lyrata (Sow.)		ϖ					
	P. murchisoni Sow.	3	ϖ	▲	•		♦	
	P. reticulata Ag.	3	ϖ					
	P. (P.) ovalis (Sow)	✓	ϖ	▲	•			
	P. crassa Ag.				•			
	P. hemicardia Roemer			▲			♦	★
	P. frickensis Moesch				•			
	P. cordata Quenstd.					7		
	P. ambigua (Sow.)	✓						
	P. deltoidea (Sow.)	✓						
	P. cf. exaltata Agassiz			▲				
	Homomya inornata (Sowerby)		ϖ					
	Homomya gibbosa (Sowerby)	3	ϖ					
	Pachymya (Arcomya) calceiformis (Philips)	✓	ϖ					
	Pachymya (Arcomya) crassiuscula (M. & L.)		ϖ					
	Goniomya sulcata (Ag.)		ϖ					
	G. (G) hemicostata M. & L.		ϖ					
	G. trapezicostata Pusch.						♦	★
	G. (G.) intersectans Smith	✓	ϖ	▲	•			★
	G. proboscidea Agassiz	3			•	7		
	Osteomya dilatata (Phillips)							★
CERATOMYIDAE Arkell, 1934	*Ceratomya similis* (Lycett)		ϖ					
	C. striata (Sow)	✓	ϖ					
	C. columba (Laube)		ϖ					
	C. calloviensis (Kasansky)		ϖ					
	Gresslya gregaria (Zieten)	✓			•			
	G. peregrina rostrata Agassiz	✓						

	G. abducta intermedia Wetzel	✓						
	G. major Agassiz							★
	G. concentrica Agassiz		ϖ					
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
PLEUROMYIDAE Dall, 1900	*Pleuromya caudata* Terq. et Jourdy	✓	ϖ		•			
	P. tenuistria (Munster) Agassiz	3			•			
	P. uniformis (Sow.)	3	ϖ	▲	•			★
	P. aff. rhenana Brogniart							★
	P. aff. goldfussi Rollier	3						
	P. alduini (Bongniart)	✓	ϖ					
	P. subelongata (d' Orbigny)	✓	ϖ		•			
QUENSTEDTIDAE Cox, 1929	*Quenstedtia mactroides* (Ag.)	3						
	Quenstedtia oblita Phillips				•			
TANCREDIIDAE Meek, 1864	*Tancredia (Isotancredia) extensa* Lycett		ϖ					
	Tancredia donaciformis						♦	
PETRICOLIDAE Deshayes, 1839	*Lucinopsis trigonalis*							★
LUCINIDAE Fleming, 1828	*Lucina bellona*							★
	Lucina despecta Phillips							★
	Lucina pisiformis Terquem							★
	Lucina cf. laevigata Greppin							★
LATERNULIDAE Hedley, 1918	*Cercomya (C.) undulata* (J. C. Sowerby)	✓	ϖ	▲				
THRACIIDAE Stolicza, 1870	*Thracia lata* (Goldfuss)	✓						
CUSPIDARIIDAE Dall, 1886	*Cuspidaria ibbetsoni* (Morris)	✓						