THE AGE OF THE GURA ȘOIMULUI FORMATION FROM THE PLEȘU ANTICLINE (MOLDAVIAN SUBCARPATHIANS, ROMANIA) BASED ON PALEOICHNOLOGY

Titus BRUSTUR[1], Andrei BRICEAG[1]

[1]National Institute of Marine Geology and Geo-Ecology (GeoEcoMar), 23-25 Dimitrie Onciul St., 024053 Bucharest, Romania
e-mail: tbrustur@geoecomar.ro

Abstract. The presence of *Mammillichnis* ichnogenus in the Gura Șoimului Formation, cropping out in the Pleșu Anticline axis, represents the first paleoichnological argument that confirms the Early Miocene age of this unit. This argument broadens the distribution areal from Vrancea half-window at south, to Bistrița half-window at north. The regional expansion of *Arthrophycus* (=*Sabularia*) paleoichnocenosis, which is often associated with *Mammillichnis*, indicates that the Gura Șoimului Formation has the same age with Vinețișu and Podu Morii units located on the external flysch of the Eastern Carpathians (i.e., Tarcau and Vrancea nappes). Based on the paleoichnological content, the Almașu Formation (=Almașu Sandstone) does not represent the stratigraphic equivalent of the Gura Șoimului Formation; the Almașu Sandstone ichnofauna is continental, while the Gura Șoimului Formation ichnofauna is marine.

Key words: *Mammillichnis*, trace fossils, Gura Șoimului Formation, Pleșu Anticline, Subcarpathian Nappe

1. INTRODUCTION

The Gura Șoimului Formation, defined by Stoica (1953) cropping out in the Bistrița Half-Window (Tazlăul Mare Basin), covering the Oligocene-Miocene boundary interval (Mirăuță, 1969), shows both molasse and flysch features (Grasu *et al.*, 1998; 1999). This formation was the subject of brief petrographic investigations (Joja, 1952), followed by more detailed ones (Grasu *et al.*, 1988; 1999), including lithostratigraphic (Mirăuță, 1969; Ionesi & Florea, 1984; Ionesi & Bogatu, 1986), sedimentological (Grasu *et al.*, 1988; Ionesi & Popescu, 1994; Ionesi *et al.*, 1994; Ionesi & Popescu, 2000; Popescu, 2005), and biostratigraphical. The later ones allowed determining an Early Miocene age based on foraminifers and calcareous nannofossils assemblages. Thus, according to Ionesi & Popescu (2000), the planktonic foraminifers (i.e., *Globigerinoides primordius*, *G. trilobus* and *G. sicana*) indicates the late Aquitanian – early Burdigalian interval (Ionesi & Gheța, 1978) or early Burdigalian (Ionesi & Bogatu, 1986), while the calcareous nannofossils assemblages comprising the species *Helicosphaera kampteri*, *H. ampliaperta*, *H. carteri*, *Sphaenolithus belemnos* and *Discoaster druggi*, among other taxa are interpreted either to be late Aquitanian – early Burdigalian in age (Ionesi & Gheța, 1978), or early Burdigalian – the NN2 Biozone (Dicea & Dicea, 1980; Mărunțeanu, 1992) and respectively early to late Burdigalian – NN3 Biozone (Ionesi & Meszaros, 1995; Popescu, 2005). According to Ionesi (1977, 1979), Ionesi & Grasu (1986), the Gura Șoimului Formation is a lithostratigraphic unit characteristic of the Vrancea Nappe, which crops out in half-windows, windows and splays of the Eastern Carpathians external flysch zone.

In this paper, the presence of *Mammillichnis* ichnogenus is for the first time reported in Gura Șoimului Formation from Pleșu Anticline that belong to the Subcarpathian Nappe. The presence of this ichnogenus confirms the Early Miocene age of these deposits and offers the possibility of correlation with synchronous formations from the external flysch of the Eastern Carpathians, based on ichnofaunas.

2. GEOLOGICAL SETTING

In the Moldavian Subcarpathians that include the study area, the Neamțului Depression is bordered to the north by the Pleșu Hill, which represents an anticline containing Miocene formations that are Burdigalian conglomerates with green schist elements. From the petrographic point of view, these green schist elements are specific to the Subcarpathian Nappe located north of the Trotușului Valley (Tufescu, 1966). Towards N of the Lunca Village, the Catrinei Spring (= *pârâul Chitan* – Popescu-Voitești, 1945; = *pârâul Adânc* – Grasu *et al.*, 1999), has its catchment basin in the Cetățuia Mare Hill and confluences with Nemțișor Spring; this spring cuts the Upper Eocene deposits of the Bisericani Formation, the Lower Oligocene sediments of the Bituminous Marls and Lower Menilitic units, as well as Upper Miocene sediments of the Gura Șoimului and Pleșu units (the latter being firstly described as the Pleșu Conglomerates). Both Gura Șoimului and Pleșu units crop out in the axis of the Pleșu anticline (Fig. 1) located in the Subcarpathian tectonic unit.

The Miocene deposits of the Moldavian Subcarpathians (comprised between Râșca and Agapia valleys) were subject of general geological investigations (Athanasiu, 1916; Popescu-Voitești, 1945) and of detailed studies of Joja (1952). Without paleontological arguments, Joja (1952) has separated three horizons (members):

(i) The lower subconglomerate horizon (Aquitanian);
(ii) The middle conglomerate horizon (Burdigalian) and
(iii) The upper horizon ("Helvetian").

Afterwards, Polonic & Polonic (1968) noted the multifacial character of these units. The authors, based on the geometry of the formations located between Lower Salt Formation and Perchiu Gypsum units, separated the following formations: Topolița, Pleșu, Drăceni, Solca, Valea Catrinei and Valea Mare. All these units where described as 'Beds', except Pleșu and Valea Mare that were described as conglomerates.

Mirăuță & Mirăuță (1964 – *fide* Micu, 1976) considered that the Upper Almașu Conglomerates represent a western equivalent of the Pleșu Conglomerates; therefore, the Valea Catrinei unit represents the stratigraphic equivalent of the Almașu Sandstone, which contains a rich ichnofauna of birds and mammals (Panin, 1965; Brustur, 2015) that can be found in Cracăului Valley in the Cuejdiului Valley Basin. Săndulescu *et al.* (1980) identified the Valea Catrinei unit below the Lower Salt Formation and considered it as an equivalent of the Gura Șoimului Formation. This opinion was also sustained by Grasu *et al.* (1999) based on petrographic data and by Popescu (2005), taking into account the lithological and biostratigraphical features.

According to Grasu *et al.* (1999), the presence of the gypsum in both lithological entities (Valea Catrinei and Gura Șoimului units) gives them the identity; hence, is not any more necessary keeping the name of Valea Catrinei Formation. The interpretation of the Pleșu Conglomerates, Almașu Sandstone and Moișa Sandstone sedimentology at the stratotype (Grasu *et al.*, 1999), suggests that the first aforementioned unit is very similar with Lower Almașu Conglomerates, while Almașu and Moișa Sandstones are possibly the same unit. According to Grasu *et al.* (1999), the base of the Gura Șoimului Formation, exposed in the Catrinei Spring, is made by breccia with green schist clasts, followed by a turbidite succession, with mm to dm layers of fine greenish sandstones, silts and shales. In the upper half of the studied section, the rhythmites are interrupted by parabreccia and green sandstones with argillaceous clasts, along with fine laminated gray-green shales that in some places are replaced by black shales, similar with Oligocene dysodile shales. These lithological aspects are common to Gura Șoimului Formation from Vrancea Nappe.

From the tectonic point of view, the Eocene-Oligocene Formations cropping out in the axis of the Pleșu Anticline (located in the Subcarpathian Nappe) were considered to be either in a normal position (Joja, 1952; Macovei & Atanasiu – *fide* Băncilă, 1958), or inserted in splays (Popescu-Voitești, 1945), olistoliths (Polonic & Polonic, 1967) or even diapir structures (Joja *et al.*, 1968). The fact that the Bisericani and Gura Șoimului units from the Catrinei Spring are included in a splay is confirmed by drilling data and their particular structural features, in relation to Pleșu Conglomerates (Grasu *et al.,* 1999).

3. RESULTS

3.1. Lithology

Recent investigations of the Catrinei Spring section (Brustur, 2015), in an outcrop exposing the Gura Șoimului Formation from the Subcarpathian Nappe (Fig. 2), offer the first argument to assign the Early Miocene age of this formation based on paleoichnological data, and allows for its supposed equivalence to Almașu Sandstone. In the outcrop exposed on the Catrinei Spring banks, gray-green sandstone layers, medium coarsed with rare rounded green schists were observed (Fig. 2a$_1$). Above these layers, a thin alternation of green turbidites, composed of thin sandstones (max. 3-4 cm thick), green pelitic sediments and gray siltic sediments that contain the ichnospecies *Mammillichnis aggeris* occur (Fig. 2a$_2$). In this outcrop, cm-thick intercalations of breccia with green schists angular clasts and conglomerates with green clasts, and rarely reddish sandstones and black silicolites were also observed (Fig. 2b). In some intervals, the green pelitic sediments are tectonized, being comprised between thin layers of hard siliceous sandstones (Fig. 2c). At approximately 10 m upstream from this outcrop, dm beds of hard green-gray sandstones, with parallel lamination and tendency to detach in fine parallel layers, occur (Fig. 2d).

3.2. Paleoichnology

We have the chance to identify a low calcareous silt clast, yellowish gray-green, very thin (6 mm), which conserves on one stratification surface approximately 60 specimens of

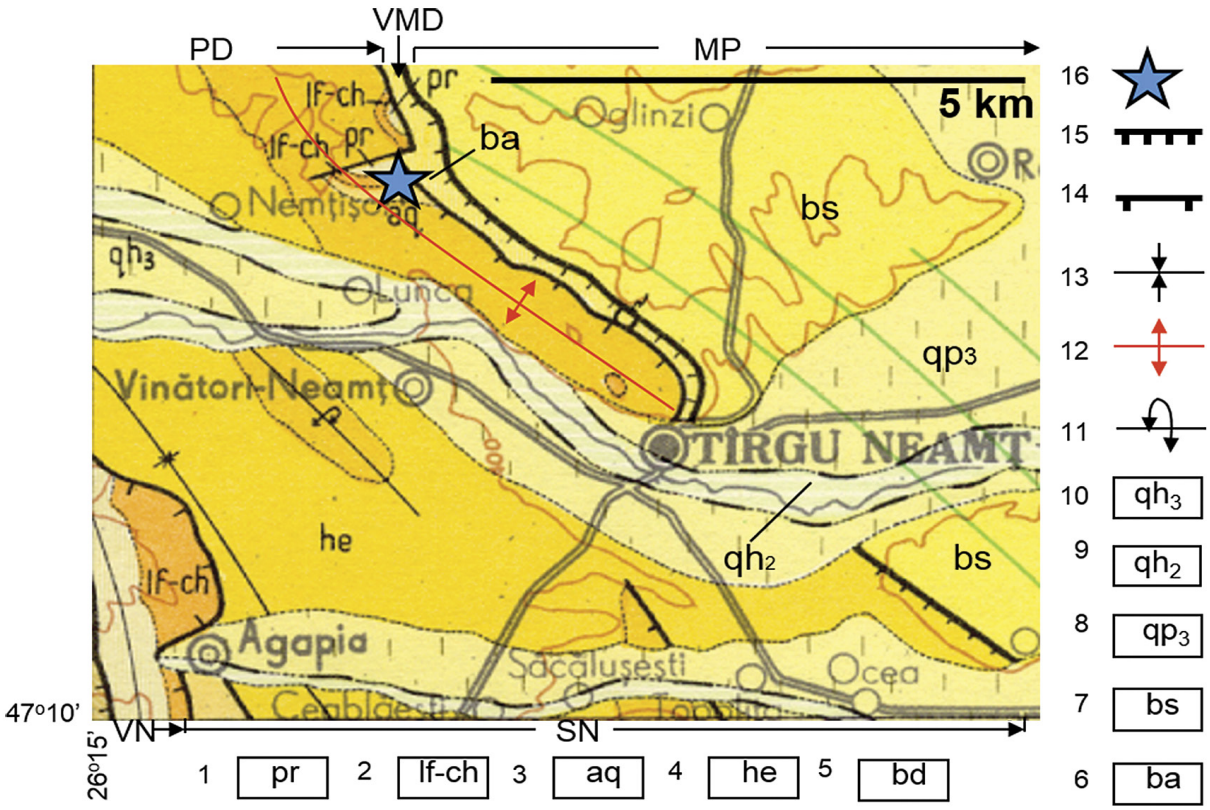

Fig. 1. Geological map of the Tg. Neamț–Lunca region (from the Geological Map of Romania, scale 1: 200,000, sheet 13 Piatra Neamț, 1968). Legend: **Upper Eocene** – **1**. Bisericani Formation; **Oligocene** – **2**. Lower Menilite and Bituminous Marls units; **Miocene**: Aquitanian – **3**. Gura Șoimului Formation; Burdigalian – **4**. Gray Formation; **5**. Pleșu Conglomerates; **6**. Badenian; **7**. Sarmatian (Bassarabian); **Quaternary** – **8**. Upper Pleistocene; **9**. Middle Holocene; **10**. Upper Holocene; **11**. Reverse anticline; **12**. Pleșu Anticline; **13**. Syncline; **14**. Reverse fault, **15**. Overthrusting (=Pericarpathian Fault); **16**. Gura Șoimului Formation cropping out in the Catrinei Valley. **VN** - Vrancea Nappe, **SN** - Subcarpathian Nappe (PD Pietricica Digitation, VMD Valea Mare Digitation); **MP** - Moldavian Platform.

Mammillichnis (Fig. 3), leading to an important paleoichnological argument that confirms the Lower Miocene age of Gura Șoimului Formation from the Pleșu anticline axis. As can be seen, in good light conditions, natural (Fig. 3a) or artificial (Fig. 3b), significant details of *Mammillichnis* ichnogenus occur. This ichnogenus is characterized by a hemispheric structure, more or less flattened, with an obvious apical depression that contains inside a small cylindrical protrusion. Some specimens may have an elliptical or circular contour. On a 25 cm^2 of the studied sample (12x7 cm), approximately 40 hypichnial specimens of *Mammillichnis aggeris* (Fig. 3a) were identified.

These specimens were assigned to two dimensional classes: (i) one with the diameter comprised between 2 and 3.5 mm and (ii) another with bigger diameter, comprised between 4.5 and 9-11 mm (Fig. 3d). In some specimens, there is a small circular depression (Fig. 3a$_1$, 3c$_1$), with a cylindrical sub-millimeter tubercle, and in two specimens a radial symmetry, poorly shaded (Fig. 3b$_2$) exists. Most of the *Mammillichnis* specimens are flattened due to subaerial alterations that obliterate the central depression and the cylindrical tubercle.

The ichnogenus *Mammillichnis* described by Chamberlain (1971), highlights a hemispherical shape with an apical depression containing a cylindrical protuberance. To explain the formation of this biogenic structure, the aforementioned author proposes three possibilities: (i) trace of rest, (ii) eggs housing, or (iii) part of an organism body that explored the substrate. Based on the radial symmetry of one specimen of *Mammillichnis* identified in the Carpathian flysch from Poland, Ksiazkiewicz (1977) assigned it to Anthozoa, an opinion shared by Crimes *et al.* (1981). Contrary to this interpretation, Seilacher (2007) excludes this ichnogenus from *Coelenterata* traces category.

According to Uchman (1998), the ichnospecies *Mammillichnis aggeris* could rather be a funnel type trap produced by another organism in a muddy, cohesive substrate. This biogenic sedimentary structure can be confused with sand volcanoes, but these have a larger diameter (3-5 cm), with sand laminae concentrically arranged around a small crater (cf. Crimes, 1977, p. 83). The *Mammillichnis* ichnogenus was

Fig. 2. Lithology and sedimentology of the Gura Șoimului Formation, Catrinei Valley outcrop

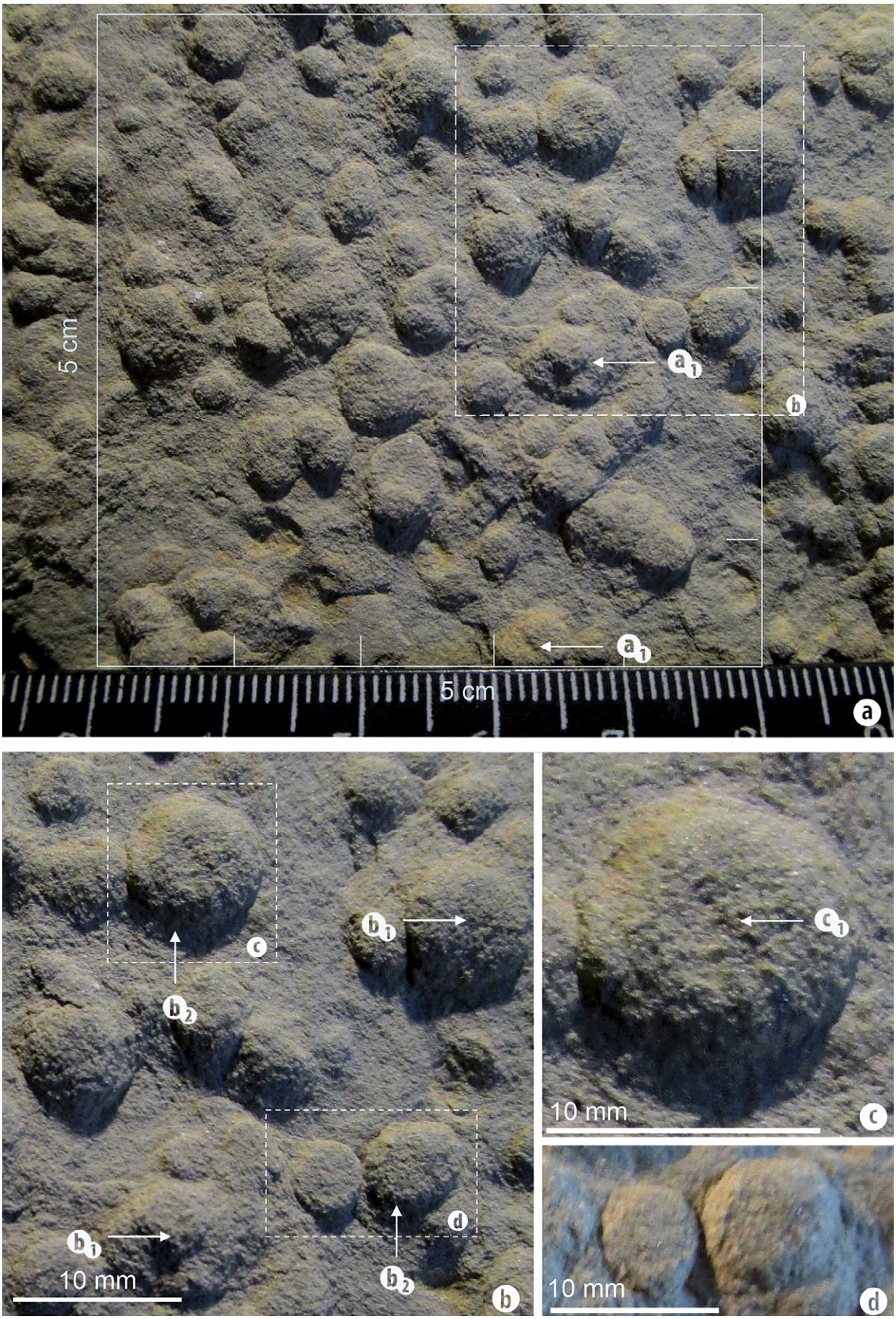

Fig. 3. *Mammillichnis aggeris* Chamberlain 1971

described from Paleozoic, e.g., Cambrian, and Ordovician, as well as Paleogene (Oligocene), while its last occurrence cited by Uchman (1998, p. 109), extended in the Early Miocene, as shown by Alexandrescu *et al.* (1993). Likewise, the *Arthrophycus tenuis* ichnospecies (=*Sabularia tenuis – in* Alexandrescu & Brustur, 1984; Alexandrescu, 1986; Alexandrescu *et al*., 1993), frequently associated with *Mammillichnis*, may be found in the Early Cretaceous (Valanginian) – Early Miocene interval. According to Uchman (1998), this ichnogenus characterizes deep sea deposits, but may be found also in deltaic or shallow marine water sediments.

4. DISCUSSION

The identification of *Mammillichnis* ichnogenus, associated with *Arthrophycus* (=*Sabularia*), *Planolites* isp. and *Helminthopsis* isp., in the Podu Morii Formation (Izvoarele Member) from the Pucioasa Formation (i.e., Puciosa Marl interbedded) with Fusaru Sandstones belonging to the Tarcău Nappe of the Romanian Carpathians bend, exposed between Teleajenului and Buzăului valleys), was made by Alexandrescu *et al.* (1993). Brustur (1996) reported *Mammillichnis*, associated with *Arthrophycus* (=*Sabularia*), *Rhizocorallium*, *Scolicia*, *Ophiomorpha* and *Zoophycos,* in the Podu Morii Formation from the Vrancea Nappe, cropping out in the central part of the Eastern Carpathians, between Coza and Mișina valleys.

In the Tarcău Nappe occurring in the Buzău Valley basin, a paleoichnocoenosis with *Arthrophycus (=Sabularia)* was identified (Alexandrescu & Brustur, 1984) along with *Taphrhelminthopsis* and *Helminthopsis* (Alexandrescu, 1986; Alexandrescu & Brustur, 1984), in the Vinețișu Formation and its external corresponding, i.e., the Podu Morii Formation.

In the Buzăului Valley basin, successions described as 'hieroglyphic beds', located towards the base of Vinețișu Formation (above the Vinețișu Tuff), N to the Nehoiu locality (Tarcău Nappe, southern Eastern Carpathians) contain many specimens of *Mammillichnis*, which in the lower part of Podu Morii Formation, are part of *Athrophycus* (=*Sabularia*) paleoichnocoenosis (Brustur, 1995 – personal obs.). According to Melinte (1988) and Melinte & Brustur (2008), which studied the calcareous nannofossil associations, both formations enclosing the *Mammillichnis* ichnogenus belong to the NN1-NN2 calcareous nannoplankton zones, Early Miocene (Aquitanian-Burdigalian) in age. The occurrence of *Mammillichnis aggeris* ichnospecies in the Gura Șoimului Formation cropping out in the Pleșu Anticline, widen the spreading area of this ichnofossil to the north of Bistriței half-window, also certifying an Early Miocene age of this unit.

The presence of these biogenic structures shows, taking into account the frequency of ichnogenus *Arthrophycus (=Sabularia)* along with *Memmillichnis*, the existence of an intense synchronous benthonic activity at the change of geochemical facies, indicating the modification of the paleosetting, from the anoxic Oligocene to the Early Miocene oxic one (Alexandrescu *et al.*, 1993).

5. CONCLUSIONS

Based on the paleoichnological investigation carried out on Gura Șoimului Formation exposed in the Pleșu Anticline (Subcarpathian Nappe), the conclude:

(i) The presence of *Mammillichnis* ichnogenus represents the first paleoichnological argument that confirms the Early Miocene age of Gura Șoimului Formation cropping out in the Pleșu Anticline axis.

(ii) The Valea Catrinei unit (= Valea Catrinei Beds, *sensu* Polonic & Polonic, 1968) represents the Gura Șoimului Formation from Pleșu Anticline, as stated by Săndulescu *et al.* (1980) based on its geometrical position. A similar setting was attributed bu Grasu *et al.* (1999) based on the petrographical and sedimentological features and Popescu (2005), arguing the litho- and biostratigraphic data (calcareous nannofossils).

(iii) The Almașu Sandstone is not the stratigraphic equivalent of Gura Șoimului Formation, as the paleoichnological content of the two lithostratigraphic entities is quite distinct; the first unit of the above-mentioned unit contains a continental ichnofaunas, while the second one is characterized by marine ones. For solving the assumed equivalence between the Almașu unit (= The Almașu Sandstone) and the Moișa one (Grasu *et al.*, 1999), it is necessary to perform detailed paleoichnological investigation of the Moișa Sandstone, in order to identify a possible presence of continental ichnofaunas enclosing traces of vertebrates.

ACKNOWLEDGMENTS

The financial support of this paper was given by the Project Nucleus (Program Nucleu) of the Ministry of Research and Innovation, PN 18 16 02 02. The comments of Academician Nicolae Panin, Dr. Corneliu Dinu, and Dr. Mihaela C. Melinte-Dobrinescu are gratefully acknowledged.

REFERENCES

Alexandrescu Gr., 1986. *Ichnofacies à Sabularia dans les couches de Vineţişu et de couches de Podu Morii de la vallée de Buzău (Carpathes Orientales)*. D. S. Inst. Geol. Geof., **70–71**/3: 5–8, Bucureşti.

Alexandrescu Gr., Brustur T., 1984. *Ichnofaciesul cu Sabularia în stratele de Vineţişu din partea de nord a Carpaţilor Orientali*. D. S. Inst. geol. geofiz., **68/3**: 17–22, Bucureşti.

Alexandrescu Gr., Brustur T., Frunzescu D., 1993. *Sabularia paleoichnocenoses between the Teleajen and Buzău Valleys (East Carpathians).* Bul. Soc. Geol. Rom., ser.4, **14**: 15–21, Bucureşti.

Athanasiu S., 1916. *Formaţiunea saliferă miocenă din bazinul Cuejdului şi al Almaşului din districtul Neamţu şi raporturile sale cu flişul*. D. S. Inst. Geol., **VII**: 397–404, Bucureşti.

Băncilă I., 1958. *Geologia Carpaţilor Orientali*. 367 p., Edit. Ştiinţifică, Bucureşti.

Brustur T., 1995. *Studiul paleoichnologic al formaţiunilor cretacic-miocene din Moldavidele externe*. Rezumatul tezei de doctorat, 24 p., Universitatea Bucureşti.

Brustur T., 1996. *Sabularia paleoichnocoenosis from the East Carpathians Bend Area (Vrancea).* Rom. J. Paleontology, **77**: 1–10, Bucureşti.

Brustur T., 2015. *Raport de fază: Investigarea paleoichnologică a Miocenului din Culmea Pleşu (zona Tg. Neamţ).* Programul Nucleu (etapa III), Arh. GeoEcoMar, Bucureşti.

Chamberlain C. K., 1971. *Morphology and ethology of trace fossils from the Ouachita Mountains, southeast Oklahoma*. J. Paleontology, **45/2**: 212–246.

Crimes T. P., 1977. *Trace fossils on an Eocene deep-sea sand fan, northern Spain*. In: Crimes T. P. & Harper J. C. (eds.) Trace fossils 2, Geological Journal Special Issue, **9:** 71–88, Liverpool.

Crimes T. P., Goldring R., Homewood P., Stuijvenberg J., Winkler W., 1981. *Trace fossil assemblages of deep-sea fan deposits, Gurnigel and Schlieren flysch (Cretaceous-Eocene), Switzerland*. Eclogae geol. Helv., **74/3**: 953–995, Basle.

Dicea O., Dicea M., 1980. *Stratigraphic correlations on nannoplancton basis n the external flysch of the East Carpathians.* D. S. Inst. Geol. Geofiz., **LXV**/4: 185-188, Bucureşti.

Grasu C., Catană C., Grinea D., 1998. *Flişul carpatic. Petrografie şi consideraţii economice*. 208 p., Edit. Tehnică, Bucureşti.

Grasu C., Catană C., Miclăuş C., Boboş I., 1999. *Molasa Carpaţilor Orientali*. 227 p., Edit. Tehnică, Bucureşti.

Ionesi L., 1977. *Prezenţa stratelor de Gura Şoimului în semifereastra Humorului*. Anal. Univ. "Al. I. Cuza" din Iaşi, secţ. II, b. Geol., **XXIII**: 35-38, Iaşi.

Ionesi L., 1979. *Dovezi noi în sprijinul "Semiferestrei Humorului"*. Anal. Univ. „Al. I. Cuza", s. II b, **XXV**: 5-12, Iaşi.

Ionesi L., Gheţa N., 1978. *Vîrsta stratelor de Gura Şoimului din semifereastra Humorului*. An. Muz. Şt. Nat. Piatra Neamţ, **IV**: 125-131, Piatra Neamţ.

Ionesi L., Grasu C., 1986. *Unité de Vrancea entre la vallée du Tazlău et la vallée de la Suceava*. An. Muz. Şt. nat. Piatra Neamţ, geol.-geogr., **V**: 43-50, Piatra Neamţ.

Ionesi L., Popescu L., 2000. *Formation de Gura Şoimului. Lithologie et sédimentologie*. Rev. Roum. Géologie, **44** : 77-91, Bucureşti.

Joja Th., 1952. *Cercetări geologice între valea Rîşcei şi valea Agapiei*. An. Com. Geol., **XXIV**: 95-193, Bucureşti.

Joja Th., Mirăuţă E., Alexandrescu Gr., 1968. *Notă explicativă. Harta geologică a României, foaia 13 Piatra Neamţ*, 45 p., Inst. Geol., Bucureşti.

Ksiazkiewicz M., 1977. *Trace fossils in the flysch of the Polish Carpathians.* Palaeontologia Polonica, **36**, 208 p., Warszawa-Krakow.

Mărunţeanu M., 1992. *Distribution of the Miocene calcareous nannofossils in the intra- and extra-Caparpathian areas of Romania*. Knihovincka ZPN, 14b, **2**: 247-261, Praga.

Melinte M., 1988. *Stabilirea limitei Oligocen/Miocen în bazinul Vaii Buzăului, pe baza nannoplanctonului calcaros*. Romanian Journal of Stratigraphy, **75/4**: 91-97.

Melinte-Dobrinescu, M.C., Brustur T., 2008. *Oligocene-Lower Miocene Events in Romania*. Acta Palaeontologica Romaniae **VI**: 203-217.

Micu M., 1976. *Flişul extern şi miocenul subcarpatic dintre valea Agapiei şi valea Almaşului.* D. S. Inst. Geol. Geofiz. **LXII/5**: 53-75, Bucureşti.

Micu M., Gheţa N., Tăutu E., Bratu E., 1984. *Contributions to the stratigraphy of the Tazlău basin Paleogene Bistriţa half-window (Eastern Carpathians)*. D. S. Inst. Geol. Geof., **LXVIII**: 105-118, Bucureşti.

Mirăuţă O., 1969. *Stratigrafia şi structura Miocenului subcarpatic din regiunea Moineşti-Tazlău*. D. S. Com. Geol., **LIV**/3: 172-211, Bucureşti.

Panin N., 1965. *Coexistence de traces de pas de vertébrés et de mécanoglyphes dans la molasse miocène des Carpaţes Orientales*. Rev. Roum. Géol., Géophys., Géogr., Géologie, **9**/2: 141-163, Bucarest.

Polonic P., Polonic G., 1967. *Miocenul subcarpatic dintre valea Moldovei şi valea Cracăului.* D. S. Com. Geol., **LII/3**: 39-61, Bucureşti.

Polonic P., Polonic G., 1968. *Direcţii de transport în molasa helveţiană dintre valea Sucevei şi valea Trotuşului.* D. S. Com. Geol., **LIV**, 205-215, Bucureşti.

Popescu L. Gh., 2005. *Studiul geologic al Formaţiunii de Gura Şoimului din Pânza de Vrancea (Sectorul Valea Moldovei-Valea Tazlăului).* 120 p., Edit. Sedcom Libris, Iaşi.

Popescu-Voiteşti I., (1945*) L'âge des conglomerats de Pietricica, de Gârcina et de Pleşul des Subcarpates Orientales.* C. R. Acad. Sci. Roum., **VII**, 312-319, Bucureşti.

Rusu A., Popescu Gh., Melinte M., 1996. *Oligocene-Miocene transition and main geological events in Romania*. IGCP Project 326, Field Symposium, A. Excursion Guide, Rom. J. Paleontology, **76**, suppl. 3: 3-47. Inst. Geol. Rom., Bucureşti.

Săndulescu M., Micu M., Popescu B., 1980. *La structure et la paléogeographie des formations miocènes des Subcarpates Moldaves.* Procc. XI Congr. Carp.-Balk. Geol. Assoc., Tectonics, p. 186-197, Kiev.

Seilacher A., 2007. *Trace fossil analysis*. 226 p., Springer Verlag.

Stoica C., 1953. *Stratele de Gura Șoimului-Tazlău*. Rev. Univ. C.I. Parhon și Polit. Bucuresti, St. Nat., **2**: 171-176, București.

Uchman A., 1998. *Taxonomy and ethology of flysch trace fossils: revision of the Marian Ksiazkiewicz collection and studies of complimentary material*. Ann. Soc. Geol. Polon., **68**: 105-218.

Tufescu M., 1966. *Subcarpații*. 250 p., Edit. Științifică, București.