BIOSTRATIGRAPHY AND PALAEOGEOGRAPHY OF LOWER DEVONIAN CHITINOZOANS, FROM EAST AND WEST MOESIA, ROMANIA

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(2 figures, 1 table, 3 plates)

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ABSTRACT. The knowledge on the biostratigraphy of Moesia has been supplemented based on chitinozoan assemblages in two boreholes, one from East Moesia and the second one from West Moesia. Previous contributions on chitinozoans, acritarchs and miospores, using only the optical microscopy corroborated by macrofaunal data have been already published. An Upper Lochkovian succession could be identified and a more accurate position of the Lower - Middle Devonian boundary is proposed in the borehole from East Moesia. The Emsian is documented in the borehole from West Moesia. The geographical position of East Moesia and possibly West Moesia during the Lower Devonian is similar to those from Northern Gondwanan localities as demonstrated by the chitinozoan assemblages recognized in the present work. Systematic notes, including biometric investigations and SEM images are provided for selected taxa of taxonomic significance and palaeogeographical distribution.

KEYWORDS. chitinozoans, biostratigraphy, Lower Devonian, palaeogeography, Moesia, Northern Gondwana

1. Introduction

The Moesian Platform on the territory of Romania has two sectors, East and West Moesia, separated by the Intra-Moesian Fault (IMF). The Peceneaga Camena Fault (PCF) and Capidava Ovidiu Fault (COF) are other important faults affecting Moesia (Fig. 1). Traditionally the biostratigraphy of the Moesian Terrane was established using palynological studies with optical microscopy. The identification of palynomorphs was made according to the classification available at those times. The old palynological assemblages as well as macrofauna did not display an obvious palaeogeographical affinity. Core samples from two boreholes have been studied in this work. The 5082 Mangalia borehole was drilled in East Moesia, while the 1111 Gârla Mare borehole is located in West Moesia (Figs 1, 2a & 2b). The purpose of this study is to refine the biostratigraphy in this

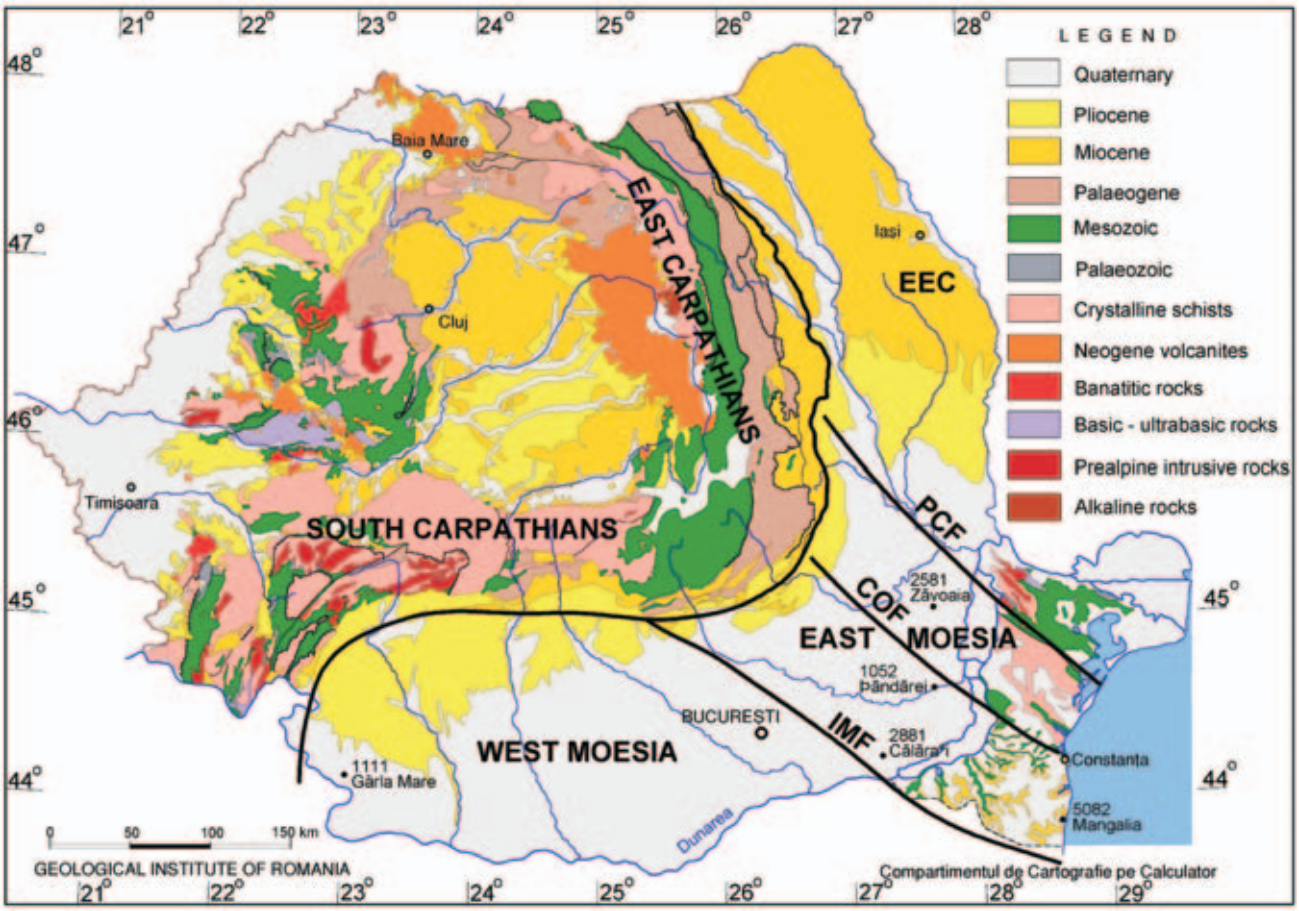

Figure 1. Schematic geological map of Romania with the location of the Moesian Platform and the larger tectonic units; the location of important boundary faults. Abbreviations: *PCF*-Peceneaga-Camena Fault; *COF*-Capidava-Ovidiu Fault; *IMF*-Intra-Moesian Fault; *EEC*-East European Craton.

area and establish new arguments concerning the palaeogeographical position of Moesian Terrane during the Palaeozoic based on chitinozoans.

2. Previous contributions

2.1. The 5082 Mangalia borehole

The 5082 Mangalia borehole is located in East Moesia and penetrates Jurassic and Palaeozoic deposits. The sediments which are encountered include limestones (570.00 m to 652.00 m), supposed to be Upper Devonian (Frasnian), limestones and dolomites (652.00 m to 747.00 m) (Middle Devonian), argillites (747.00 m to 800.00 m) (Middle Devonian), sandstones and quartzites (800.00 m to 917.00 m) (Middle Devonian) and argillites (917.00 m to 1203.00 M) (Lower Devonian) (Fig. 2b, modified after Iordan, 1981).

Because there is such a large amount of palynological data, we mention below only the previous contributions relevant to the Silurian/Devonian boundary, Lochkovian and Pragian.

The 5082 Mangalia borehole was stopped at the depth of 1204 m. In the interval 951 m to 1204 m, where the Silurian/Devonian boundary was defined, the following macrofossils were identified: *Lingulella paliformis, Dalmanela cf. orbicularis, Rensselaeria robustela, Anastrophia verneuilli, Camarotechia daleydensis, Spirifer (Delthyris) infans, S. (Quadrifarius) dumintianus, Strophaeodonta aff. virgata, Strophonella headleyana, Tentaculites ornatus, T. gyracanthus, Uniconus glaber, Multiconus sp., Novakia acuaria, Ctenodonta maureri varicosa, Sphaenotus compactus, Nuculites sp., Bellerophon sp., Asteropyge (Metacanthus) prostellans, A. (Rhenops) pictinata, A. aff. rotundiformis,* etc. (Răileanu *et al.*,1965; Iordan, 1967).

Some sub-zones for the Devonian have been established by Beju (1972), but only three of them are described here. The D1a sub-zone contains spores like *Leiotriletes sp., L. simplex, L. laevis, Punctatisporites sp., P. debilis, Retusotriletes sp., R. simplex, Emphanisporites minutus* and *Ambitisporites sp*. The chitinozoans are represented by: *Angochitina devonica, A. bifurcata, Urochitina simplex, Ancyrochitina tumida, A. tomentosa* and *A. ancyrea minor.* Acritarchs are also present: *Baltisphaeridium simplex, Veryhachium remotum, V. josefae, V. thyrae, Polyedrixium multifrons* and *Pterospermopsis martinii* (Beju, 1972). In the 5082 Mangalia borehole, East Moesia, the conodont *Icriodus woschmidti* was identified (Răileanu *et al*., 1965; Paraschiv, 1974). Its age was established as Lochkovian.

The D1b sub-zone consists of *Anapiculatisporites ventae, Acanthotriletes inferus, A. espinositus, Apiculiretusispora sp., Emphanisporites rotatus, E. robustus, Perforosporites robustus, Retusotriletes communis, R. semizonalis, R. rotundus, Punctatisporites sp., P. irrarus* and *Calamospora sp*. Acritarchs are represented by *Veryhachium robiosum, Baltisphaeridium molinum, B. pilaris, Onondagella deunffii* and *Cymatiosphaera canadense* (Beju, 1972). The age was determined as Pragian.

The D1c sub-zone is characterized by miospores like *Lycospora culpa, Auroraspora minuta, Hymenozonotriletes sp., Perotriletes mutabilis, Cingulatisporites sp., Apiculatisporites toriensis, Anapiculatisporites burtonensis, Retusotriletes triangulates, Emphanisporites radiatus, E. anulatus* and *E. mcgregori*. Acritarchs and chitinozoans are also mentioned by Beju (1972). The age is determined as Emsian.

2.2. The 1111 Gârla Mare borehole

The 1111 Gârla Mare borehole was drilled in East Moesia. It penetrates Cenozoic, Cretaceous, Upper Jurassic, and Triassic rocks. The Palaeozoic succession occurs between 1370.00 m to 4251.00 m and it is represented by three systems: Carboniferous (1370.00 m to 2020.00 m), Devonian (2020.00 m to 3540.00 m), and Silurian (3540.00 m to 4251.00 m). In the interval 1370.00 m to 2020.00 m, Carboniferous strata are represented by sandstones (1370.00 m to 1440.00 m) and limestones and dolomites (1440.00 m to 2020.00 m). Sediments having a thickness of 1520 m are assigned to the Upper and Middle Devonian, consisting of limestones and dolomites (2020.00 m to 3333. 80 m), lower Middle Devonian (Eifelian), sandstones (3338.00 m to 3448.00 m) and the Lower Devonian (Pragian-Emsian), orthoquartzitic sandstones (3448.00 m to 3540.00 m). The strata between 3540.00 m to 4251.00 m are assigned to the Silurian and they consist of black argillites, graptolite shales, and green siltstones, which, according to their organic content, belong to the Přídolí, Ludlow, Wenlock and possibly Llandovery (Fig. 2a, modified after Iordan *et al.*, 1985). They include from bottom to top the following sediments and palaeontological content.

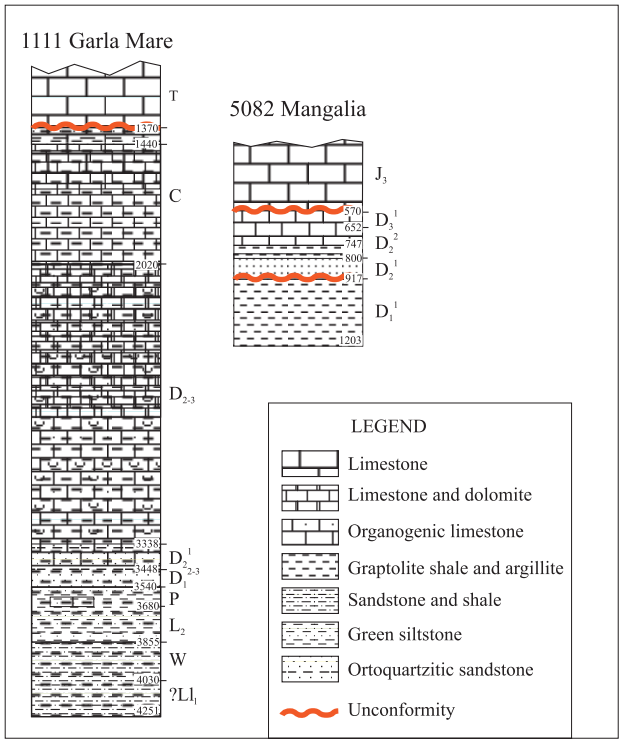

Figure 2. Simplified stratigraphic column of the Palaeozoic in the 1111 Gârla Mare borehole and 5082 Mangalia borehole. *2a*. The 1111 Gârla Mare borehole (modified after Iordan, 1981); *2b*. The 5082 Mangalia borehole (modified after Iordan *et al.*, 1985). Abbreviations: Ll_1–Lower Llandovery (Rhuddanian); *W*-Wenlock; L_2–Ludlow (Ludfordian); *P*- Přídolí; D_1^{2-3}-Lower Devonian (Pragian-Emsian); D_1^3-Emsian; D_2^1-Eifelian; D_{2-3} -Middle–Upper Devonian; D_3–Upper Devonian; D_2^2-Givetian; D_3^1 - Frasnian; *C*-Carboniferous.

Green siltstones appear at 4030.00 m with interbeds of fine calcareous sandstones. The macrofauna consists of fragments trilobites, brachiopods, corals, crinoids and possibly bivalves and gastropods. Unfortunately, the macrofauna present is not relevant to establish the age of these sediments. The palynological content is represented by acritarchs (95%) and some chitinozoans, while miospores appear sporadically and, based on these, the sediments are assigned to the Llandovery (Iordan *et al*. 1985).

The identified acritarchs are *Baltisphaeridium cf. duplex, B. molinum, B. brevispinosum, var. wenlockensis, Leiofusa algerensis, Macropticha cf. uniplicata, Pterospermopsis cf.*

guapita, Dictyopsophosphaera polygonia, Acantho-diacrodium sp., etc. The chitinozoans present in association are *Lagenochitina brevicolis, Cyathochitina kuckersiana, C. cylindrica, Linochitina erratica, Ancyrochitina sp.* etc. The miospore *Ambitisporites avitus* was recognized.

The 1111 Gârla Mare borehole penetrated grey or greenish argillites interlayered with black argillaceous limestones in the interval within 3855.00 m to 4030.00 m. Also present are bands of grey or greenish fine sandy limestones and sometimes sandstones with silica cement. The macrofaunal association consists essentially of brachiopods and sporadically of trilobite and crinoid fragments. The palynological content is represented predominantly by acritarchs, a small number of chitinozoans, some miospores (10%), and sporadically scolecodont remains. The common occurrence of the observed macrofauna and microfauna point to a Wenlock age (Iordan *et al*. 1985).

The macrofaunal species *Lissostrophia cf. cooperi, Mesopholidostrophia sp., Leptaena rhomboidalis, Isorthis aff. clivosa, Morinorhynchus cf. orbignyi* and *Atrypa aff. reticularis* have been identified at this level. The acritarchs *Veryhachium trispininflatum, V. downiei, V. lairdi, V. europaeum, Neoveryhachium neocarminae, Baltisphaeridium microfurcatum, B. echinodernum, B. arbusculiferum, B. ravum, B. trifurcatum, B. cariniosum, B. malum, Michristridium stellatum, Pterospermopsis bernadinae, P. onodagensis, Cymatiosphaera cf. mirabilis, Leiofusa cf. banderilla, L. cantabrica, Onondagella cf. deunffi, O. assymetrica, Gorgoniosphaeridium wenlockium, Duvernaysphaera sp.* were recognized at this depth. The chitinozoans present in assemblage are *Conochitina cf. gordonensis, Lagenochitina macrostoma, Ancyrochitina tumida,* etc. Some miospores, *Ambitisporites cf. avitus, Leiotriletes sp., Retusotriletes sp.* and *Archaeozonotriletes sp.* have been found too.

Black argillites, micaceous shales, and sometimes calcareous sandstones were penetrated in the interval between 3680.00 m and 3855.00 m. The macrofauna is represented by bivalves, tentaculites, crinoids and brachiopods. The assemblage of acritarchs, chitinozoans and miospores indicate a Ludlow age (Iordan *et al*. 1985).

As macrofaunal species *Nuculites sp., Ctenodonta sp.* and *Palaeoneilo sp.* were found. The acritarchs *Baltisphaeridium sanpetrensis, B. cf. echinodernum, Veryhachium mucronatum, Leiofusa cantabrica, Cymatiosphaera sp., Tasmanites sp.,* etc., the chitinozoans *Lagenochitina prussica, L. macrostoma, Ancyrochitina fragilis harpagie, A. moldavica, Clathrochitina cf. clathrata, Conochitina lagenomorpha, C. filifera, C. brevis conica, Angochitina valentinii aspera,* etc., and the miospores *Leiotriletes cf. dissimilis, Archaeozonotriletes divellomedium, A. chulus nanna, Emphanisporites cf. protophanus, Ambitisporites sp., Calamospora sp.,* were recognized in this assemblage.

Black argillites and bands of green sandstones were found in the interval assigned to the Přídolí (3540.00 m to 3680.00 m). The macrofauna is represented by tentaculites, trilobites, corals, bivalves, echinoderms and ostracods. The microfauna consist of miospores (about 80%), chitinozoans, and acritarchs (Iordan *et al*. 1985).

The species *Mesodouvillina subinterstrialis, Eospirifer sp. cf. E. schmidti, Leptostrophia sp., Tentaculites tenuis, Uniconus sp., Leptotrypella sp., Heliolites sp., Ctenodonta sp., Palaeoneilo sp.,* etc. are recognized at this depth as macrofauna. The identified miospores are *Leiotriletes confertus, L. cf. marginalis, Calamospora cf. microrugosa, Retusotriletes waringtonii, R. cf. semizonalis, Archaezonotriletes divellomedium, Stenozonotriletes cf. furtivus, Phyllothecotriletes densicorpus, Camptozonotriletes cf. aliquantus, Emphanisporites neglectus, E. rotatus, Grandispora sp., Auroraspora sp.,* etc. The chitinozoans *Lagenochitina elegans, Ancyrochitina diabolo, Fungochitina sp.* and the acritarchs *Micrhystridium stellatum, Veryhachium trispinosum, Baltisphaeridium cf. malum, Cymatiosphaera sp.,* etc. complete the assemblage of this depth.

Sandstones and black argillites were recovered from depths 3448.00 m to 3540.00 m. The macrofauna is fragmentary and sparse, represented by bivalves, crinoids, and *Hyenia sp.* The palynological content is represented by miospores (80%), acritarchs, and sporadically chitinozoans (in part as fragments). Miospores such as *Leiotriletes pagius, Punctatisporites obesus, Cyclogranisporites plicatus, Archaeozonotriletes divellomedium, Tholisporites cf. densus, Phyllothecotriletes elegans, Samarisporites cristatus, Ambitisporites dilutus, Calamospora pannucea, Emphanisporites neglectus, Perforosporites robustus, Reticulatisporites sp.* and *Convolutispora sp.,* were found. Acritarchs present in the assemblage are *Tasmanites huronensis, Baltisphaeridium uncinatum,* and *Leiosphaeridia voigti*. The chitinozoans are represented by only two genera *Lagenochitina* and *Desmochitina*. Based especially on the palynological assemblage, these deposits are assigned to the Lower Devonian (Pragian-Emsian) (Iordan *et al.,* 1985).

The macrofaunal species *Paracyclas rugosa, Orthonota triplicata, Grammysia mangalica* (very diagnostic species), *G. aff. armorica, Grammysioidea inaequalis, Cypricardella gosseleti, Leptostrophia index, Schellwienella umbracullum, Fimbrispirifer trigeri, F. daleidensis, Najadospirifer najadum, Schizophoria multistriata, Actinopteria costata, Nuculites elipticus,* etc.(Iordan *et al.,* 1987, unpublished, GIR archive).

The succession lying in the interval from 3338.00 m to 3448.00 m have been assigned to the Eifelian. Here, black argillites and bioturbated siltstones which contain corals, crinoids, tentaculites, brachiopods, spores and acritarchs were found (Iordan *et al.,* 1985).

The spores are represented by the following species: *Anapiculatisporites lanceolatus, Cyclogranisporites plicatus, Calamospora microrugosa, C. pannucea, Apiculiretusispora arenorugosa, Geminospora svalbardinae, Emphanisporites rotatus, E. neglectus, Hymenozonotriletes endemicus, Reticulatisporites emsiensis* and *Retusotriletes communis*. The palynological assemblage of this level is completed by some acritarchs, *Veryhachium trispinosum, V. reductum, Baltisphaeridium ravum, B. arbusculiferum* and *Lophosphaeridium cf. citrinopellatum,* etc.

The macrofaunal species *Cupressocrinus cf. crassus, Hexacrinus cf. elongates, Ripidocrinus cf. crenatus, Ripidomella penelope, Leptostrophia rotunda, Markitoechia marki,* tentaculites of *Novakia maureri* Zone have been identified too at this depth (Iordan *et al.,* 1987, unpublished, GIR archive).

The 2020.00 m to 3338.00 m interval comprises carbonate deposits with tentaculites, brachiopods, crinoids, undeterminable trilobites, corals, ostracods, bryozoans, spores and acritarchs. These deposits were assigned to the Middle-Upper Devonian (Iordan *et al.,* 1985).

At this depth, there were identified as macrofauna the specimens *Tentaculites conicus, T. bellulus potomacensis, Strophodonta aff. demisia, Amphipora ramose, Iridistrophia sp.* and *Hermannina sp.* The species *Tentaculites conicus* and *T. bellulus potomacensis* attest the presence of the Givetian. The palynological content is poor and consists of some spores, *Leiotriletes, Punctatisporites, Acanthotriletes* types, acritarchs, belonging to the genera *Baltisphaeridium* and *Trachysphaeridum,* as well as unidentifiable chitinozoan fragments.

3. Method and material studied

A total of 16 samples were collected from cores of two boreholes: 14 from 5082 Mangalia (East Moesia) and the other two from 1111 Gârla Mare borehole (West Moesia).

The investigated intervals from the 5082 Mangalia borehole are:

- 917.00 m to 927.00 m (A, B)
- 917.90 m to 921.90 m (A, B): one of them contains some chitinozoan fragments, the other one is barren
- 936.30 m to 937.80 m
- 945.90 m to 948.60 m
- 1004.00 m to 1010.70 m (A, B)
- 1010.00 m to 1013.10 m (A, B)
- 1010.80 m to 1013.10 m
- 1020.60 m to 1022.60 m
- 1180.00 m to 1181.00 m: barren
- 1200.00 m to 1201.00 m (contains only one chitinozoans)

The 1111 Gârla Mare borehole has been investigated in the interval within 3466.00 m to 3470.00 m (samples A, B). For those intervals where there are two samples for each, the palynological components will be presented in common assemblage without other specification.

The processing technique used, was described by Paris (1981a). Twenty grams per sample have typically been used in the specialized laboratory of Liège University. Digital pictures have been taken by S.E.M. type JEOL (JSM) 6400, at Research Unit Palaeontology, Department of Geology and Pedology, Ghent University.

4. Results and analyses

4.1. The 5082 Mangalia borehole

4.1.1. Assemblage A – Upper Lochkovian

Assemblage A has been recorded at 917.00 m and 927.00 m (samples A and B) of the 5082 Mangalia borehole. It is characterized by the common occurrence of *Eisenackitina bohemica* (Eisenack, 1934), *Cingulochitina plusquelleci* Paris, 1981b, ?*Pterochitina sp. A,* (Middle Ordovician-Lower Devonian), *Armoricochitina sp. A* (Plate 1, fig. c), and ?*Calpichitina sp. A* (Plate 1, fig. a), *Calpichitina sp. B* (Plate 1, fig. d) (Ordovician-Lower Devonian).

The range of *Eisenackitina bohemica* (Eisenack, 1934) defines a global Devonian biozone and covers nearly exactly Lochkovian (Paris *et al.,* 2000). It has been recorded in Bohemia, Czech Republic, France, Armorican Massif (Paris, 1981a), Morocco (Rahmani, 1983); Podolia, Ukraine (Paris & Grahn, 1996); Spain (Schweineberg, 1987); Algeria, Tunisia, Libya, Poland (Paris *et al.,* 2000), West Moesia, Bulgaria (Lakova 1989, 1993, 1999; Paris *et al.,* 2000) and East Moesia, Romania (Vaida *et al.,* 2004, Vaida & Verniers, 2004, Vaida *et al.,* in press).

Cingulochitina plusquelleci Paris, 1981a (Plate 1, fig. b) was observed in the Lochkovian of the Armorican Massif (Paris, 1981a), the Armorique Formation (uppermost Lochkovian) (Paris, 1980), the Mehaiguéne Formation, Algeria (Boumendjel, 1987) and the Moesian Platform, West Moesia, Bulgaria (Lakova, 1985, 1989, 1995a, 1995b, 1999) and East Moesia, Romania (Vaida *et al.,* 2004, Vaida & Verniers, 2004, Vaida *et al.,* in press).

4.1.2. Assemblage B

This assemblage was identified in the interval between 936.30 m to 937.80 m. The presence of *Cingulochitina plusquelleci* Paris, 1981a, *Armoricochitina spp.* (Plate 1, fig. e-h), *Eisenackitina bohemica* (Eisenack, 1934) are characteristic for the Upper Lochkovian. The assemblage is complemented by *Ancyrochitina sp. A* (Plate 2, fig. d), *Ancyrochitina spp.,* and ?*Armoricochitina spp.* (Plate 2, fig. a-c) (Middle Ordovician-Lower Devonian).

4.1.3. Assemblage C

This assemblage consists of *Cingulochitina plusquelleci* Paris, 1981a (Plate 1, fig. j), *Eisenackitina bohemica* (Eisenack, 1934), *Cingulochitina serrata* (Taugourdeau & de Jekhowsky, 1960), *Ancyrochitina sp. B* (Plate 1, fig. i), (Upper Ordovician-Upper Devonian), ?*Anthochitina sp. A* (Plate 1, fig. k), *Anthochitina sp. B* (Upper Silurian-Lower Devonian), *Pterochitina sp. A* (Plate 1, fig. o), *Armoricochitina spp.* (Plate 1, fig. p-u), *Bursachitina sp.* (Plate 1, fig. l) (Ordovician (?) - Middle Devonian) and *Bursachitina cf. oviformis* (Eisenack, 1972) (Plate 1, fig. m, n) in the interval of 945.90 m to 948.60 m. It should be noted that the conodont *Icriodus woschmidti,* the type species of the biozone was found at the depth of 951 m (Răileanu *et al.,* 1968, Paraschiv, 1974).

Cingulochitina serrata (Taugourdeau & de Jekhowsky, 1960) occurs in the Algerian Sahara (Taugourdeau & de Jekhowsky, 1960), Spain (Cramer, 1964), Florida (Cramer, 1971), Portugal, France (Přídolí and Lochkovian) (Paris, 1981), Libya (Jaglin & Paris, 2002), Moesian Platform, Bulgaria (Lakova 1985, 1989, 1993, 1995), Moesia, Romania (Vaida *et al.,* 2004, Vaida *et al.,* in press).

4.1.4. Assemblage D

This assemblage is identified at the level of 1004.00 m – 1010.70 m of the 5082 Mangalia borehole: *Fungochitina lata* Taugourdeau & de Jekhowsky, 1960 – biozone, *Margachitina catenaria* Obut 1973, *Cingulochitina plusquelleci* Paris 1981a (Plate 2, fig. f), *Cingulochitina ervensis* (Paris, 1979 in Babin *et al.,* 1979), *Cingulochitina sp. A, Ancyrochitina sp. C* (Plate 2, fig. h), *Ancyrochitina sp. D* (Plate 2, fig. i), *Ancyrochitina sp. E* (Plate 2, fig. j), *Ancyrochitina spp., Fungochitina sp. A* (Plate 1, fig. g) and *Fungochitina spp.* The joint occurrence of the chitinozoans present in this association characterizes mid Lochkovian.

Fungochitina lata (Taugourdeau & de Jekhowsky, 1960) (Plate 2, fig. e) is defined as an index fossil of the global Devonian biozone (Paris *et al.,* 2000). Its presence in the borehole is a good stratigraphic marker for the middle part of Lochkovian. The last was recorded in northern Gondwana areas (Armorican Massif, north-western Spain, Algeria, Tunisia, Romania) (Paris *et al.,* 2000) including Bulgaria (Lakova, 1993).

Margachitina catenaria Obut 1973 (Plate 2, fig. k, t) appears in the *Fungochitina lata* biozone. It is known in the Lochkovian of Podolia (Obut 1973), Algerian Sahara (Taugourdeau & de Jekhowsky, 1960), Spain (Diez & Cramer, 1978), Armorican Massif (Paris, 1981a), Montagne Noire, France (De Bock, 1982), in the Lochkovian type, Czech Republic (Chlupáč *et al.,* 1985), Algeria (Boumendjel, 1987), Bulgaria (Lakova, 1995a, 1999).

Cingulochitina ervensis (Paris, 1979 in Babin *et al.,* 1979) occurs in France (Paris, 1979 in Babin *et al.,* 1979), Algerian Sahara (Boumendjel, 1987), Podolia, Ukraine (Paris & Grahn, 1996), Libya (Jaglin & Paris, 2002), Moesia, Romania (Vaida *et al.,* in press, Vaida *et al.,* 2004, Vaida & Verniers, 2004) and Moesian Platform, Bulgaria (Lakova, 1985, 1989, 1995b).

4.1.5. Assemblage E

The assemblage described in the interval 1010.00 m - 1013.10 m contains *Cingulochitina plusquelleci* Paris, 1981a (Plate 2, fig. p), *Cingulochitina ervensis* (Paris, 1979 in Babin *et al.,* 1979) (Plate 2, fig. l, m), *Eisenackitina bohemica* (Eisenack, 1934), *Ancyrochitina sp. G* (Plate 2, fig. n), *Angochitina chlupaci* Paris & Laufeld, 1980 (Plate 2, fig. o), *Eisenackitina sp. A* (Plate 2, fig. r, s) (Middle Ordovician-Middle Devonian), *Angochitina spp.* and *Ancyrochitina spp.*

4.1.6. Assemblage F

At the depth of 1020.60 m -1022.60 m an association has been identified that contains the chitinozoans: *Margachitina catenaria* Obut 1973 (Plate 2, fig. t), *Eisenackitina bohemica* (Eisenack, 1934) and *Ancyrochitina spp.*

In the interval of 1200.00 m – 1201.00 m only *Margachitina sp. A* (Plate 2, fig. u) (Silurian – Lower Devonian) was found, which does not allow to establish this age for the present interval, but we can suppose that the age is Upper Lochkovian, based on the data mentioned above and old data which assigned this depth to Lochkovian.

The chitinozoans *Angochitina devonica, A. tomentosa, Ancyrochitina ancyrea,* the acritarchs, *Baltisphaeridium simplex, B. arbusculiferum, Veryhachium josefae* and the miospores *Leiotriletes simplex, L. cf. laevis, L. marginatus, Punctatisporites punctatus, Retusotriletes simplex, R. pichovii, Archaeozonotriletes chulus var. chulus, Ambitisporites dilutus, A. avitus, Emphanisporites minutus* are components of the assemblage of the level of 1200.00 m to 1201.00 m (Iordan *et al*., 1987, unpublished, GIR archive) and it inscribes in the D_{1a} Zone defined by Beju (1972).

The Lochkovian age is supported also by the following macrofauna species: *Nowakia acuaria, Tentaculites ornatus, T. gyracanthus, T. straeleni, Prolationus praelongus, Multiconus macarovici* and *Heteroctenus sp*. (Iordan *et al*., 1987, unpublished, GIR archive).

4.1.7. The stratigraphical significance of the 5082 Mangalia borehole data

The joint occurrence of the chitinozoans identified in the 5082 Mangalia borehole, in part very diagnostic species like *Cingulochitina plusquelleci* Paris, 1981a, *Cingulochitina serrata* (Taugourdeau & de Jekhowsky, 1960), *Cingulochitina ervensis* (Paris 1979 in Babin *et al*., 1979), *Eisenackitina bohemica* (Eisenack, 1934), *Margachitina catenaria* Obut, 1973, *Fungochitina lata* (Taugourdeau & de Jekhowsky, 1960), indicates an Upper Lochkovian age for all of the interval within 917 m to 1201 m of the 5082 Mangalia borehole. In addition ?*Pterochitina sp. A.,* ?*Calpichitina sp. A,* ?*Anthochitina sp. A, Cingulochitina sp. A, Armoricochitina spp., Angochitina spp., Margachitina spp., Fungochitina spp*. and *Ancyrochitina spp*. are present in this assemblage.

Considering the biostratigraphical arguments, the identified chitinozoan assemblages A to F of the 5082 Mangalia borehole, could be grouped into three main assemblages:

Assemblage 3 – E + F: *Eisenackitina bohemica* Zone, lower part of Lochkovian;

Assemblage 2 – D: *Fungochitina lata* Zone, mid Lochkovian; with the accompanying species *Cingulochitina plusquelleci* and *Margachitina catenaria;*

Assemblage 1 – A + B + C: *Cingulochitina plusquelleci, Eisenackitina bohemica, Armoricochitina sp., Ancyrochitina sp*. suggesting an uppermost Lochkovian – lowermost Pragian.

In the light of the present results in the 5082 Mangalia borehole, the boundary between the Lower and the Middle Devonian is to be situated above 917 m, instead of 920 m like it was considered to be until now.

4.2. The 1111 Gârla Mare borehole

4.2.1. Assemblage A

At depths between 3466 m and 3470 m in the 1111 Gârla Mare borehole there were identified mainly chitinozoans like *Bulbochitina bulbosa* Paris 1981a, *Bursachitina riclonensis* Paris 1981b (well represented with more than 50 specimens), some unidentified spores and possibly acritarchs. Their joint occurrence indicates an age of early Emsian (Lower Devonian) for the interval mentioned above.

Bulbochitina ?*bulbosa* Paris 1981a (Plate 3, fig. r-u) was defined to characterize a Devonian biozone (Paris *et al.,* 2000). It was described in the Armorican Massif (La Lézais area) where its range is demonstrated as the Upper Pragian-Lower Emsian, based on brachiopods (Paris, 1981a). The *Bulbochitina bulbosa* biozone is documented in Northern Gondwana (Bohemia, Armorican Massif, western Algeria, Tindouf basin) (Paris *et al.,* 2000).

Bursachitina riclonensis Paris 1981b (Plate 3, fig. a-p) is characterized by the *Bursachitina bursa* biozone (Paris *et al.,* 2000). The first atypical *Bursachitina riclonensis* Paris 1981b are recorded toward the top of the mentioned biozone (Paris, 1981a) and is a good marker for the Emsian-Eifelian transition. *Bursachitina riclonensis* Paris 1981b was described in the Armorican Massif, the Upper Emsian of the La Lézais section. It was also identified in Spain, in the Upper Emsian of the Mariposas Formation (Aragon), as well as in the Cantabrian Mountains, the La Vid Formation (zones 17 and 18, Diez & Cramer, 1978; Cramer, 1964). It was recognized in Libya (Paris, 1981a), Algerian Sahara, Lower and Middle Devonian (zone 7 - Taugourdeau & de Jekhowsky, 1960) and in the Alrar Formation, Illizi Basin (Boumendjel, 1987). Besides, the *Bursachitina bursa* biozone to which *Bursachitina riclonensis* Paris 1981b belongs, is documented by Paris *et al*. (2000) in Northern Gondwana (Bohemia, Armorican Massif, north-western Spain, Algeria).

This assemblage is characteristic for the Emsian. The previous palaeontological data document the Pragian - Emsian age in the interval 3488.00 m to 3540.00 m. The present study indicates that the interval 3466.00 m to 3470.00 m is assigned now to Emsian, and possibly could be assigned to the interval 3448.00 m to 3470.00 m. The Pragian-Emsian boundary could now be situated in the interval 3470 m to 3540 m.

5. Palaeogeography

Iordan (1967), used lithological and macrofauna criteria of the 5082 Mangalia borehole to suggest that the deposits therein present an affinity with the macrofauna identified in the Bosfor area (Bithynia), i.e. in those basins where sedimentation was marine and continuous across the Silurian/ Devonian boundary. The trilobites and tentaculites contained in the interval 1092 m to 1204 m are also comparable to those from the Armorican Massif (Méricourt shale formation), the Ardennes (Mondrepuits shale Formation), shales from the Bohemian Massif, Vosges Mountains, Pireneas Mountains, Carnic Alps, Bosfor area, Ural Mountains and North America. The lithostratigraphy of Bosfor as well as the Devonian fauna have been reconsidered by Haas (1967), who has shown that the Marmara Formation and the upper part of Akviran Formation are similar to the argillitic formation (Devonian) of Moesia and are characterized by a joint facies, Rhenan and Hercynic type. Most of the goniatites and trilobites of Sogonli Beds are similar to those of the Pragian of Bohemia and Morocco. In addition, the conodont *Icriodus wochmidti* was identified in the Akviran Formation. The last was also found in the 5082 Mangalia borehole, East Moesia as well as in the West Moesia (Răileanu *et al.,* 1966, Paraschiv, 1974).

In the present study, two of the palynological components of the 5082 Mangalia borehole, East Moesia, respectively *Cingulochitina plusquelleci* and *Fungochitina lata* (Devonian global biozone), are only quoted in one palaeocontinent, Northern Gondwana (Paris *et al.,* 2000). *Fungochitina lata* is supposed to be found in Bolivia; however, this is not yet documented. The other components are fairly often cited for Northern Gondwana: *Eisenackitina bohemica, Cingulochitina ervensis* and *Margachitina catenaria*.

These arguments which show a North Gondwana provenance, supplement the palaeogeographical evidence provided by the other three boreholes from East Moesia, 2881 Călăraşi, 2581 Zăvoaia and 1052 Ţăndărei (Vaida *et al.,* in press, Vaida & Verniers, unpublished).

The Northern Gondwana palaeogeographical affinity of the Lochkovian chitinozoans has also been demonstrated in Northwest Bulgaria, West Moesia (Lakova,

1995b). This is in contrast with the results from miospores studied by Steemans & Lakova (2004), who support a Baltic affinity for Moesia at that time. During the Early Devonian in a closing and therefore narrower Rheic Ocean the Baltic or Gondwanan affinity was probably waning. The difference in conclusions might arise from the difference in environment between the producers of miospores living on the continent or shallow shelf and the chitinozoans living more in the deeper shelf to continental slope.

6. Conclusions

The present study documents a Lochkovian age based on chitinozoans, for the whole 917 m to 1201 m interval of the 5082 Mangalia borehole, East Moesia. According to the new dating, a correction to the depth of the boundary Lower/Middle Devonian is imposed, this now being above 917 m instead of 920 m as a previously considered.

A new assemblage identified in the 1111 Gârla Mare borehole, West Moesia, consists mainly of chitinozoans, arguing for an Emsian age for the interval between 3466.00 m to 3470.00 m. The old palaeontological data had suggested a Pragian-Emsian age for the interval 3488.00 m to 3540.00 m where the studied interval (3466.00 m to 3470.00 m) is included. Consequently, we might speculate that the Emsian begins at the depth of 3488.00 m (to 3470.00 m) but that it is not at all certain that the horizon at depth 3470.00 m is the boundary between Emsian/Pragian or if the Emsian continues down to 3540.00 m depth.

Based on the new data, we cannot exclude a Northern Gondwana affinity for the whole of Moesia. New studies are urgently needed in West Moesia as well as in East Moesia, in order to refine the biostratigraphy of these areas and to document new evidence regarding the palaeoaffinity of the Moesian Terrane in the Ordovician and Silurian.

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Appendix

Only the species *Bursachitina riclonensis* will be described and/or discussed here. The generic and suprageneric classification proposed by Paris *et al*. (1999) has been adopted. The following abbreviations have been used for the biometric studies: *L* – length of the vesicle; D_p – diameter of chamber; D_c – diameter of neck. All the corresponding values are expressed in μm. The dimensions have been restored by a coefficient of correction of 0.8 for D_p and D_c.

Order OPERCULATIFERA Eisenack, 1931

Family DESMOCHITINIDAE Eisenack, 1931, emend. Paris, 1981a

Subfamily DESMOCHITININAE Paris, 1981a

Genus BURSACHITINA, Taugourdeau, 1966 restrict. Paris, 1981a

Type species: *Desmochitina bursa* Taugourdeau & de Jekhowsky, 1960

Bursachitina riclonensis Paris, 1981 b (Plate 3, fig. a-p)

Synonymy:

? 1960 *Conochitina cf. lagenomorpha* Eisenack: Taugourdeau & de Jekhowsky, p. 1223, fig. 5, 6, pl. IV.
1964 *Conochitina cf. Conochitina cf. lagenomorpha* Eisenack; Cramer, p. 343, fig. 18, pl. 22.
1978 *Conochitina pachygaster* Taugourdeau & de Jekhowsky; Paris, pl. 1, fig. 11.
1978 *Conochitina pachygaster* Taugourdeau & de Jekhowsky; Diez & Cramer, p. 209, pl. 1, fig. 34-35.
1981 a *Bursachitina riclonensis* Paris; p. 139, pl. 36, fig. 5,6.
1981 b *Bursachitina riclonensis* Paris; p. 61, pl. 3, fig. 1-6, 9, 10, 12.
1987 *Bursachitina riclonensis* Boumendjel; p.38, pl. 19, fig. 3, pl. 20, fig. 3, 8, 11.

Material: 56 flattened and three-dimensional specimens recovered in the cores (from 3466.00 m to 3470.00 m).

Dimensions: means based on 56 flattened or three-dimensional specimens from 3466.00 m to 3470.00 m (Plate 3, fig. a-p, Tab 1).

Biometrics of *Bursachitina riclonensis* (measurements in µm)

	L	D_p	D_c	L/D_p	D_p/D_c
Mean	92.00	58.76	52.01	0.88	1.20
Min.	57.60	52.80	26.40	0.54	0.76
Max.	116.00	108.00	64.00	1.28	1.66

Discussion: the determined specimens are well enough preserved in order to be recognized. From a total of 56 specimens, only a few there are three-dimensional, in the rest they are flattened, but maintaining their structure. In general, their features are as described by Paris (1981a, 1981b) and Boumendjel (1987). The maximal values of the parameters are very close to those described before.

Occurrence: this species occurs in Emsian-Eifelian (pro part) and is a good stratigraphic marker (Paris *et al*., 2000). It is possible to be geographically more widespread than we mentioned above but, due to its resemblance with other species, i.e. *Armoricochitina panzuda*, it could elsewhere be described under different name.

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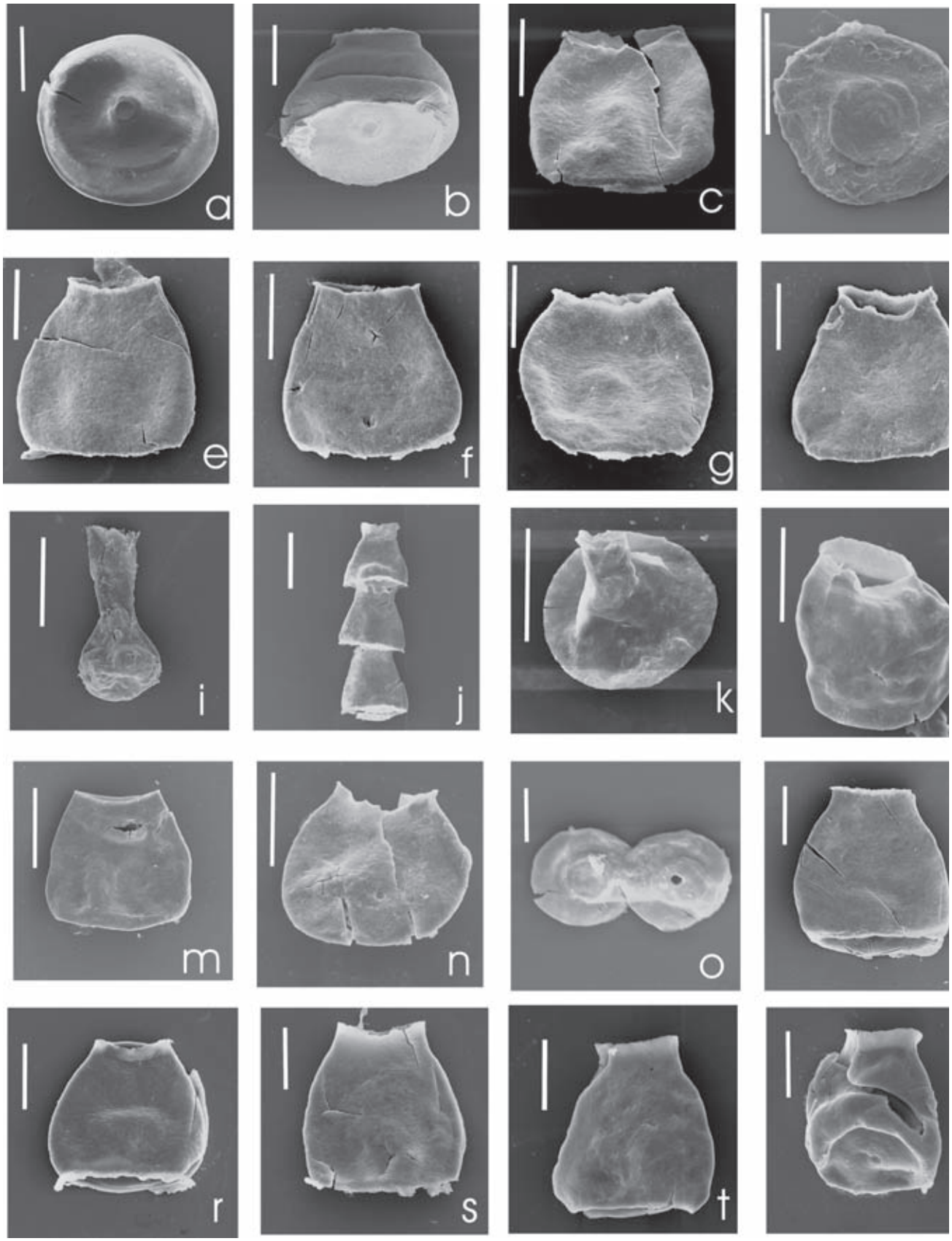

Plate 1 –Chitinozoans from 5082 Mangalia borehole (figures *a-d,* depth 917.00 m – 927.00 m; figures *e-h*, depth 936.30 m–937.80 m; figures *i-u*, depth 945.90 m-948.60 m). Upper Lochkovian-and remaining part of the Lower Devonian.

a. ?*Calpichitina sp. A* – b, j. *Cingulochitina plusquelleci* Paris, 1981 – c. *Armoricochitina sp. A* – e-h, j, p-u. *Armoricochitina spp.* – d. *Calpichitina sp. B* – i. *Ancyrochitina sp. B* – k. ?*Anthochitina sp. A* – l. *Bursachitina sp.* – m, n. *Bursachitina cf. oviformis* (Eisenack, 1972) – o. *Pterochitina sp. A*

The scale bar for all figures is 50 μm

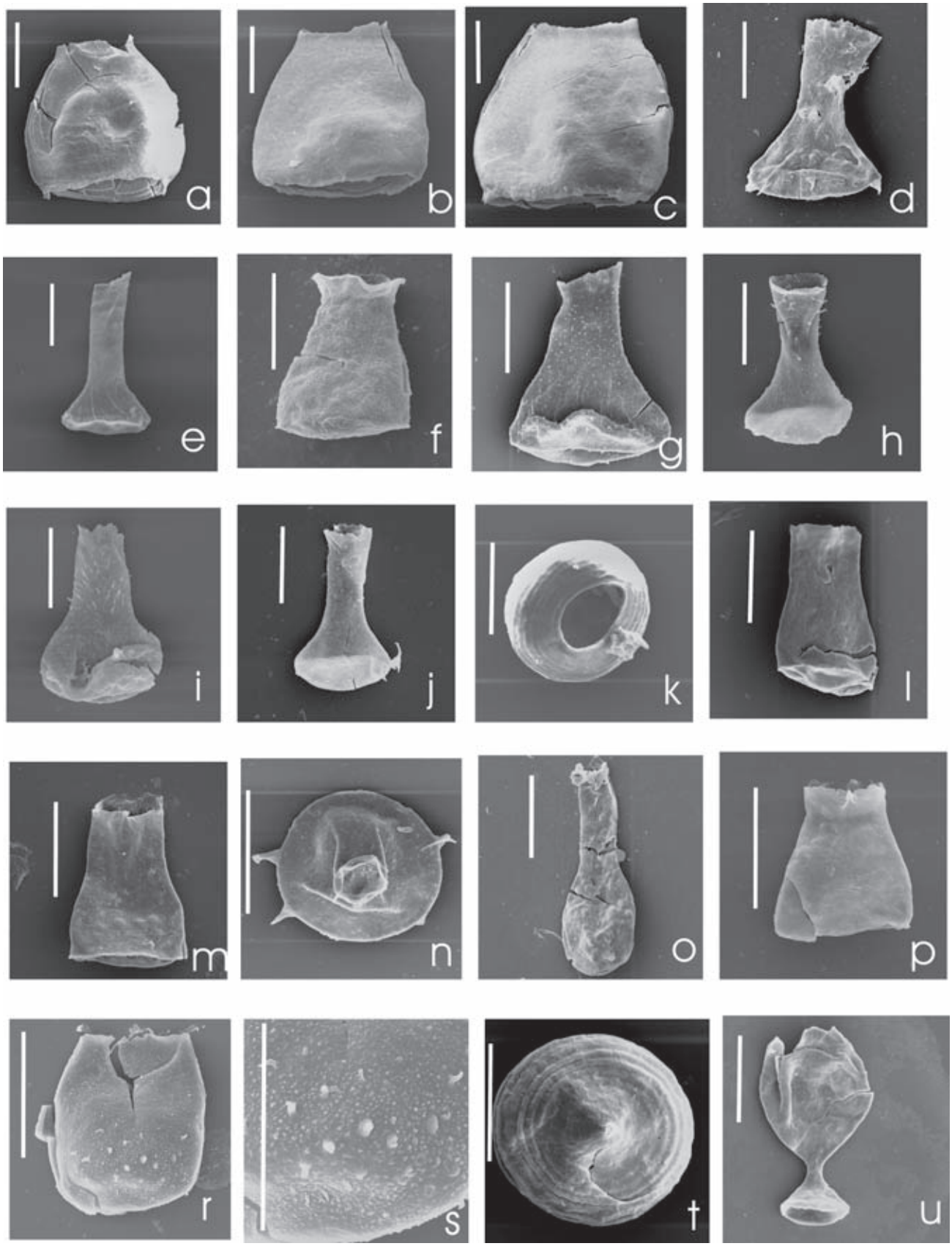

Plate 2 – Chitinozoans from 5082 Mangalia borehole (figures a-d, depth 936.30 m-937.80m; figures e-k, depth 1004.00 m – 1010.70 m; figures l-s, depth 1010.00m -1013.10 m; figure t, depth 1020.60 m - 1022.60 m; figure u, depth 1200.00 m -1201.00 m). Upper Lochkovian, Lower Devonian.

a-c. ?*Armoricochitina spp*. – d. *Ancyrochitina sp. A* – e. *Fungochitina lata* (Taugourdeau & de Jekhowsky, 1960) – f. *Cingulochitina plusquelleci* Paris, 1981 – g. *Fungochitina sp. A* – h. *Ancyrochitina sp. C* – i. *Ancyrochitina sp. D* – j. *Ancyrochitina sp. E* – k, t. *Margachitina catenaria* Obut 1973 – l, m. *Cingulochitina ervensis* (Paris, 1979 in Babin *et al*., 1979) – n. *Ancyrochitina sp. G* – o. *Angochitina chlupaci* Paris & Laufeld, 1980 – p. *Cingulochitina plusquelleci* Paris, 1981 – r. *Eisenackitina sp. A* – s. Detail of structure of fig. r – u. *Margachitina sp. A*

The scale bar for all figures is 50 μm.

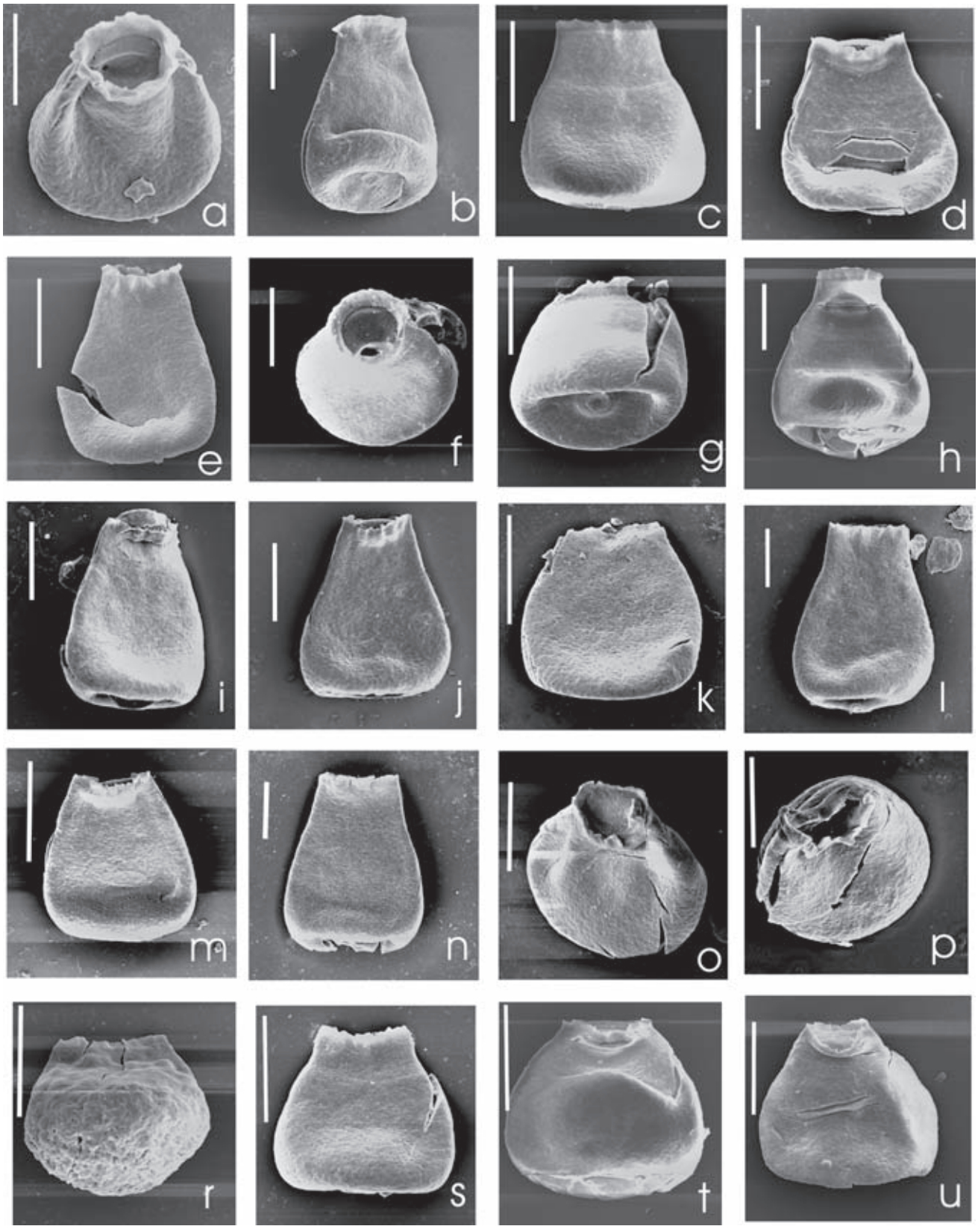

Plate 3 – Chitinozoans from 1111 Gârla Mare borehole, 3466.00 m – 3470.00 m depth. Emsian, Lower Devonian.

a-p. *Bursachitina riclonensis* Paris, 1981b
r-u. *Bulbochitina bulbosa* Paris, 1981a

The scale bar for all figures is 50 μm.