VOLHYNIAN MICROFAUNA IN BLEJEŞTI AREA (CENTRAL-SOUTHERN PART OF THE MOESIAN PLATFORM)

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Abstract. This paper presents the microfaunal assemblages of lower Sarmatian (Volhynian) deposits intercepted by 10 hydrocarbon wells from the Blejești hydrocarbon field, S Romania. The identified microfaunas are typically for two Volhynian foraminifera zones: *Varidentella reussi* Zone and *Elphidium reginum* Zone. At the contact with the underlying Cretaceous or Middle Miocene (= Badenian) units, the Sarmatian studied samples, containing foraminiferal assemblages with abundant *Ammonia beccarri*, may not be assigned to a certain biozone. Besides, the identified ostracod assemblages were assigned to the NO 11 Cytheridea hungarica – Aurila mehesi. The composition and the abundance of microfaunal assemblages allow us to advance paleoecological considerations for the lower Sarmatian deposition interval of the studied area.

Key words: early Sarmatian, foraminifera, ostracods, biozones, paleoecology, S Romania

1. INTRODUCTION

The studied area is located N of the Danube river and belongs to the central-southern region of the Moesian Platform, tectonically framed in the Roşiori - Alexandria Depression. The Moesian Platform (Fig. 1) is a major tectonic unit, bordered in the N by the Getic Depression, the Central Dobrogea towards NE, the Balkan Mountains in the S and the Black Sea in the E (Săndulescu, 1984).

The Moesian Platform is divided (Săndulescu, 1984) in: (i) the western part, namely Wallachian platform that extends up to the Danube; (ii) the eastern part, *i.e.*, the Southern Dobrogea platform, bordered by the Danube to the West and the Black Sea towards East. The Wallachian part of the Moesian Platform contains many hydrocarbon wells that still produce nowadays and therefore it was intensively studied since the beginning of the Romanian oil industry, due to its high potential (Paraschiv, 1979; Beca & Prodan, 1983).

Within the Miocene, the western Moesian Platform was included in the Dacian Basin, part of the Central Paratethys. Since the Upper Miocene (*i.e.*, Sarmatian stage) the Dacian Basin was included in the Eastern Paratethys, due to paleogeographic changes (Popov *et al.*, 2004; Jipa & Olariu, 2009).

The Paratethyan Domain occurs since the Oligocene, as a result of the tectonic movements Alps and Carpathian, following the African-Arabian Plate collision with the Eurasian one (Royden *et al.*, 1982; Steininger & Wessely, 2000). Starting with Middle-Late Miocene the Paratethys was divided in several domains grouped in Central Paratethys, that included Vienna, Pannonian and Transylvanian basins and the Eastern Paratethys with Dacian, Euxinian and Caspian basins (Papp *et al.*,1974; Marinescu, 1978; Popov *et al.*, 2004; Piller *et al.*, 2007) (Fig. 2). Since the Late Miocene and later, in the Pliocene-Quaternary interval, the original Oligocene extension of the Paratethys Sea significantly decreased, and isolated basins, *i.e.*, including the present day Black Sea, along with the Caspian and Aral ones, occurred. Therefore, the paleogeographic changes mirrored the significant uplift of the Carpathians and Caucasus mountains (Popov *et al.*, 2004; Schmid *et al.*, 2008).

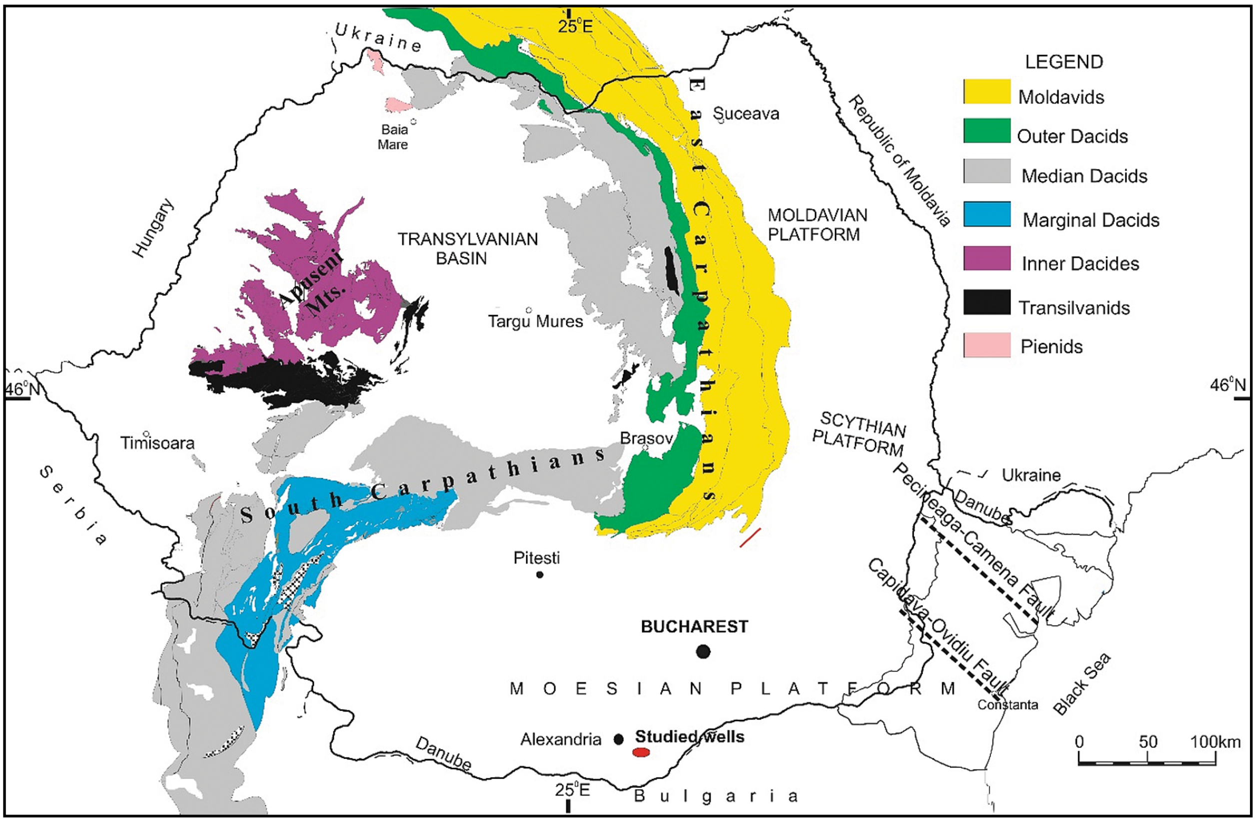


Fig. 1. Geological map of Romania (simplified after Săndulescu, 1984) showing the location of the investigated wells.

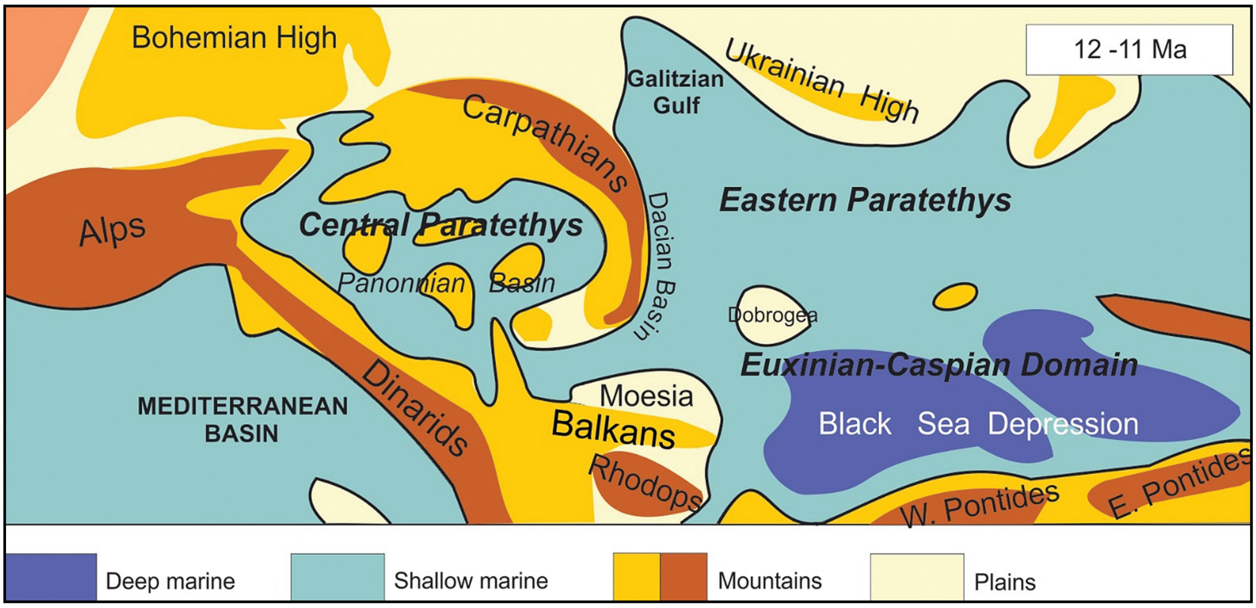


Fig. 2. Paleogeography of the Paratethyan Domain and surrounding areas during the Sarmatian (modified after Popov *et al.*, 2004, Jipa & Olariu, 2009 and Briceag *et al.*, 2018).

This paper is focused on the Middle Miocene, *i.e.*, Sarmatian *senso lato* (*s.l.*) stage, from wells of the W Moesian Platform. The Sarmatian regional stage was named by Suess (1866) and supported over time many discussions regarding its chronostratigraphic division. In the Central Paratethys, the Sarmatian *senso stricto* (*s.s.*) proposed by Suess (1866) is in used (Piller *et al.*, 2007); there, the Sarmatian stage (containing two substages, the Volhynian and the Bessarabian) overlies the Badenian stage and it is followed by the Pannonian; in the Eastern Paratethyan Domain, the Sarmatian *s.l.*, comprised between the Badenian and Meotian stages, is used. There, the Sarmatian is divided into three substages (Fig. 3), namely Volhynian, Bessarabian and Khersonian (Andrusov, 1917; Marinescu, 1978; Popov *et al.*, 2004; Brânzilă & Chira, 2005; Jipa & Olariu, 2009, 2013; Briceag *et al.*, 2018).

2. MATERIAL AND METHODS

Qualitative and quantitative foraminiferal and ostracod analysis have been performed. In all, 73 samples have been collected from cores belonging to 10 wells from the Blejești hydrocarbon field, situated between 60 and 80 km SE from Bucharest, in the Teleorman County (Fig. 4). Each collected sample weighs about 100 grams. For microfaunal analysis, the material was processed by standard micropaleontological methods: the material was soaked in water containing 30% hydrogen peroxide, boiled and passed through 63 µm sieve. All the specimens have been examined under a binocular Olympus microscope and microphotographs have been taken with an Olympus camera. The most common encountered taxa are illustrated in Plates 1-4.

To assign biostratigraphically the identified assemblages, we used the Central Paratethys biozonation (Grill, 1941; Papp, 1974, Rögl, 1998; Görog, 1992) along with the biozonation schemes defined in various regions of Romania, *i.e.*, Ionesi, 1968; Popescu, 1995; Filipescu & Silye, 2008 (Fig. 3). All the data, including samples, thickness of Volhynian formations intercepted by wells, age, number of taxa along with the lithology have been used for making graphics. To note that the figure given to each of the studied well has been attributed by the authors, does not match with the real number of the wells.

3. RESULTS AND DISCUSSION

In the studied wells, the stratigraphic interval assigned to the early Volhynian reaches almost 100 m in thickness. Predominantly type of sediments are: medium to low compacted argillaceous limestones with horizontal laminae (in some places commonly containing pyrite and organic matter), argillaceous marls with carbonized plant remains, sands (fine grained, subangular to subrounded, moderately to well sorted), calcareous marls (medium compacted, fine micaceous), sandstones (fine-medium grained, coarse at places, subangular to subrounded, moderately sorted, low to medium cemented with mixed binder, fine micaceous) and slightly argillaceous limestones with oolites (well compacted and containing fossil debris).

The Volhynian deposits overlies the Badenian sediments (only in Well Blejești 3) or the Cretaceous ones (in 6 wells); the base of the Volhynian contains very scarce microfaunal assemblages. In the claystones of Well Blejești 3, above the

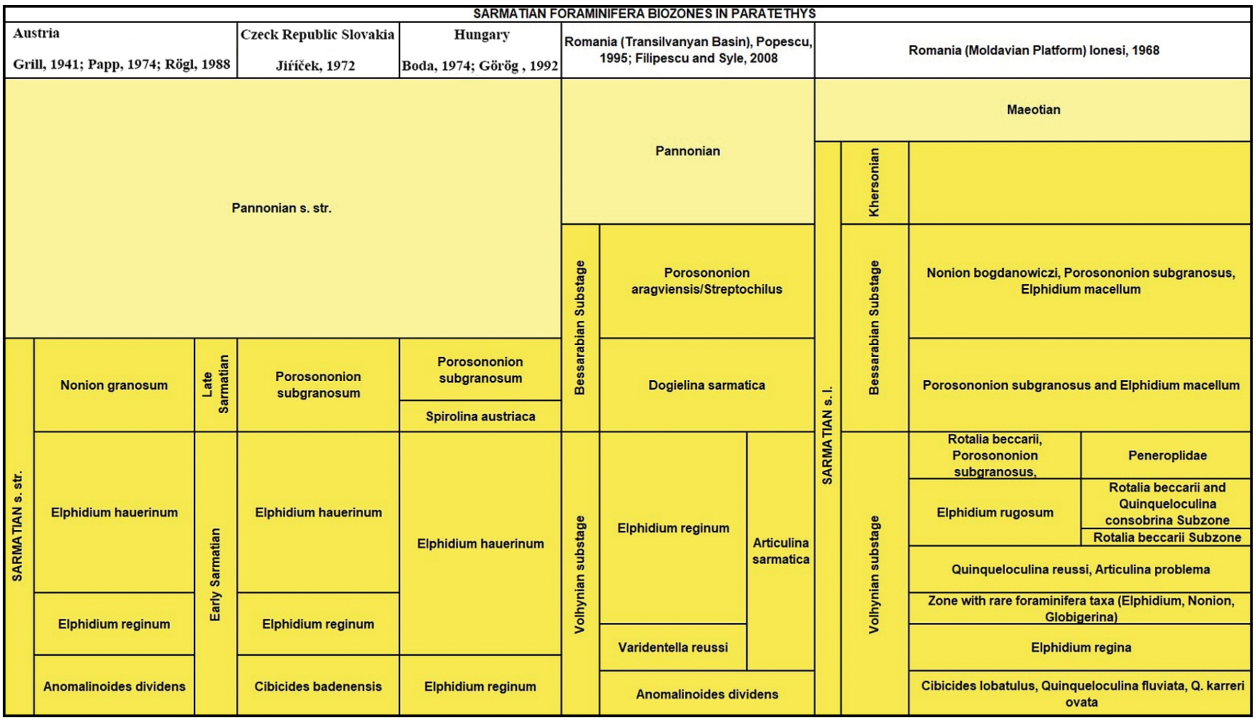


Fig. 3. Central and Eastern Paratethys Sarmatian substages and correlation based on foraminifers.

Fig. 4. The location of the Blejeşti studied wells (map from www.google.com/maps)

Badenian deposits, the argillaceous limestones are very abundant in macrofossils, while the microfaunas are missing or are inconclusive: sponge spicules and rare *Charophyta* algae fragments along with the benthic foraminifera species *Ammonia beccarii* (Linnaeus). Similar fossil assemblages collected from the deposits overlaying the top of the Badenian were described in a nearby area, in wells belonging to the Cartojani oil field (Ioniță *et al.*, 2016).

Above this basal level, the rest of the cores, assigned to the early Volhynian, contains very fine polymictic sands with scarce microfaunal assemblages, composed of sponge spicules, few benthic foraminifera, such as *Elphidium rugosum* (d'Orbigny), *Elphidium aculeatum* (d'Orbigny), *Nonion bogdanowiczi* Voloshinova, rare ostracods specimens of *Cytheridea hungarica* (Zalányi), *Charophyta* algae fragments and reworked Cretaceous foraminifera (many of them with pyritized test). We assume that a brackish paleoenvironment prevailed within the lower part of the Volhynian, based on the aforementioned benthic foraminifers.

The overlaying deposits contain microfaunas with very abundant *Ammonia beccarii*, between 100 – 1400 taxa/sample). The tests of this species are small-sized and most of them are filled with pyrite (Fig. 5), suggesting low oxygenation in the marine bottom water. This assemblage is completed by few specimens of benthic foraminifers *Elphidium macellum* (Fichtel & Moll) and *Cycloforina* sp., along with ostracods such as *Aurila mehesi* (Zalányi), *Cytheridea hungarica* and *Miocyprideis sarmatica* (Zalányi); rarely, mysidae statoliths occur. Besides *in situ* taxa aforementioned, Cretaceous and Miocene reworked foraminifer species were observed.

The above-mentioned ostracod assemblage argues for the presence of the Central Paratethys Cytheridea hungarica - Aurila mehesi ostracod zone (Fig. 6), early Sarmatian in age (Jiříček & Říha, 1991; Filipescu *et al.*, 2014). This biozone is described also from extra Carpathian regions, *i.e.,* the Dacian Basin extending on the Moldavian Platform (Ionesi & Guevara, 1993; Dumitriu *et al.*, 2017), occurring in fact in the lower Sarmatian depositional interval around the whole Paratethyan Domain (Zelenka, 1990).

The foraminifer *Ammonia beccarii,* commonly present in the studied samples, is an euryhaline species, adapted to high salinity fluctuations (Koubová & Hudáčková, 2010). Some authors (Gross, 2004; ter Borgh *et al.*, 2014) indicate that the ostracod species *Cytheridea hungarica* is indicative for an epineritic, brackish to normal marine setting. Other authors suppose that this taxon is more related to a shallow littoral to sublittoral settings, requiring well aerated brackish waters, with depth no more than 30 m and a warm climate, *i.e.*, tropical to subtropical (Jiříček, 1985; Olteanu & Jipa, 2006). Assemblages with dominant *Elphidium* spp. and *Ammonia beccarii* are currently present in brackish waters all over the world, at salinity above 4-5 ‰ (Murray, 1991). According to Reinhardt *et al.* (1994), the domination of *Ammonia* is linked, in terms of paleosetting, to a transitional zone between lagoon and open marine conditions. Debenay *et al.* (1998) indicate that *Ammonia beccarii* is common in marine environments with salinities greater than 33‰. On the other hand, *Ammonia beccarii* is present nowadays in the Black Sea, including near the Danube mouth, at salinities around 5-8 ‰ and in some Pleistocene-Holocene intervals known to have had salinity strong fluctuations (Melinte-Dobrinescu & Ion, 2013; Briceag *et al.*, 2016a, 2016b, 2019).

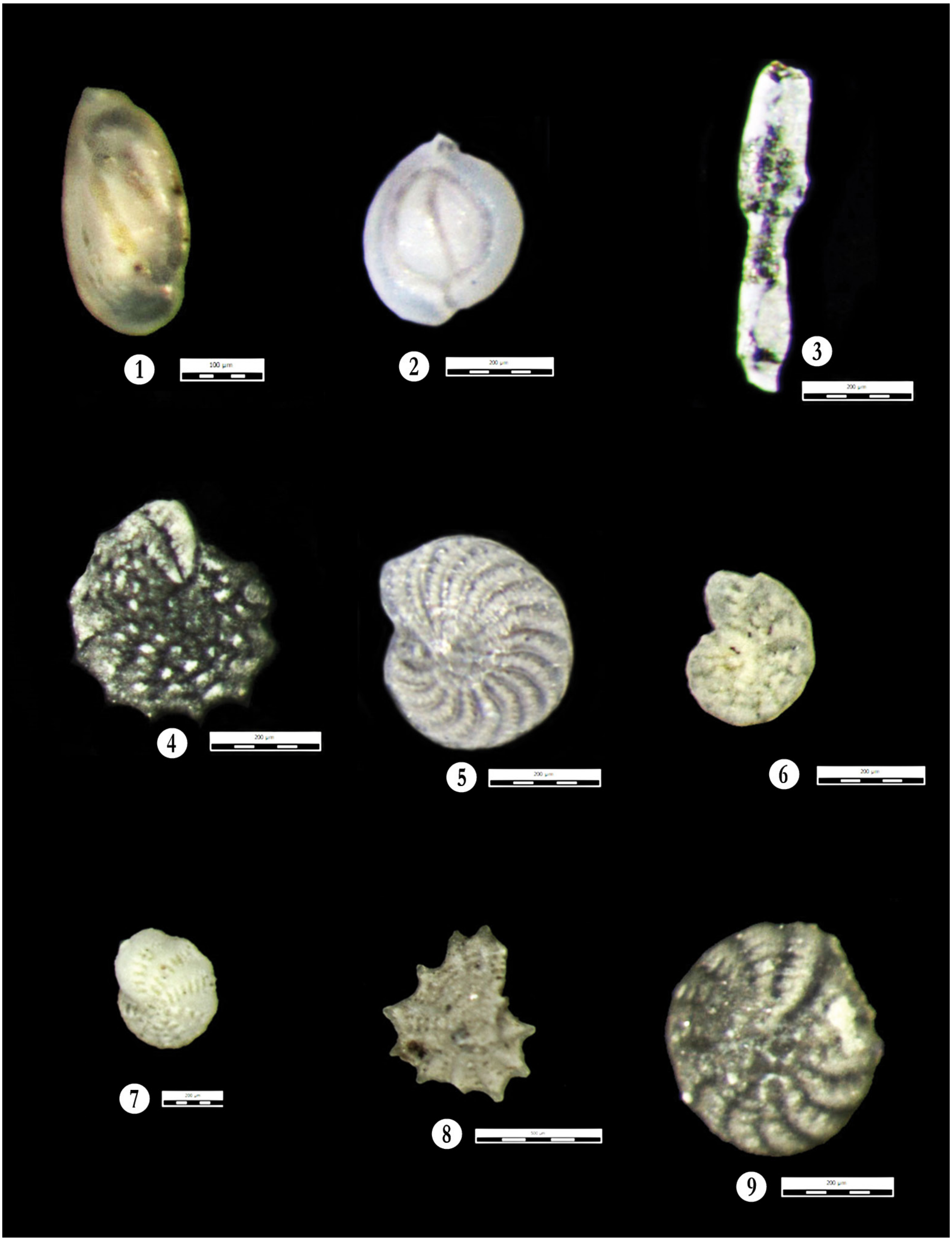


Plate 1. Volhynian foraminifera from Blejeşti area. **1**. *Cycloforina* sp. – side view, **2**. *Vatridentellla reussi* Bogdanowicz – side view, **3**. *Articulina problema* Bogdanowicz – side view, **4**. *Elphidium aculeatum* (d'Orbigny) – spiral view, **5**. *Elphidium crispum (*d'Orbigny) – spiral view, **6**. *Elphidium fichtelianum* (Linnaeus) – spiral view, **7**. *Elphidium* hauerinum (d'Orbigny) – spiral view, **8**. *Elphidium josephinum (*d'Orbigny) – spiral view, **9**. *Elphidium macellum macellum (*Fichtel & Moll) – spiral view.

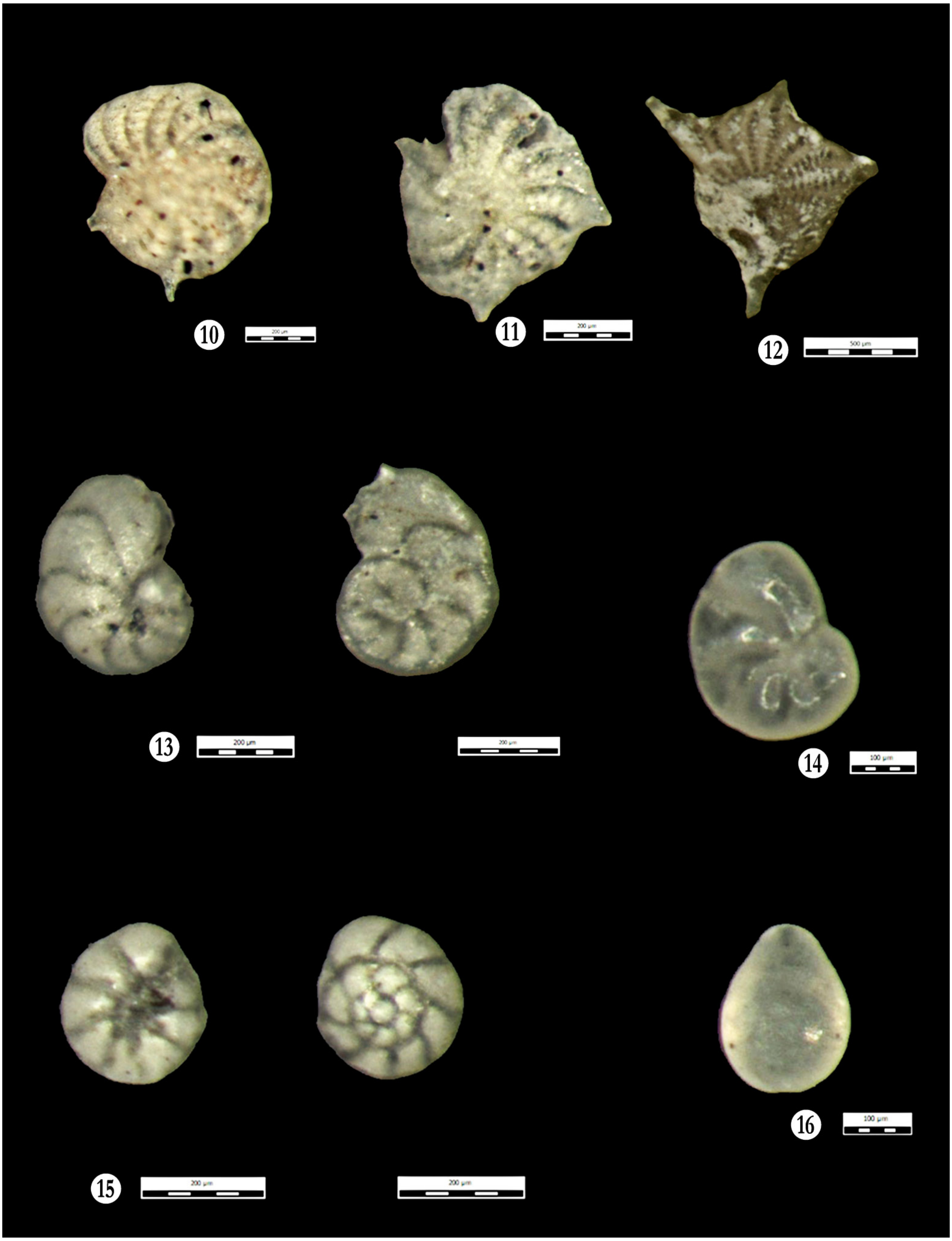


Plate 2. Volhynian foraminifera from Blejeşti area. **10**. *Elphidium macellum aculeatum* (Silvestri) – spiral view, **11**. *Elphidium reginum* (d'Orbigny) – Blejești 3 well, spiral view, **12**. *Elphidium reginum* (d`Orbigny) – Blejești 2 well, spiral view, **13**. *Lobatula lobatula* (Walker and Jakob) – umbilical view (left) and spiral view (right), **14**. *Nonion bogdanowiczi* Voloshinova – spiral view, **15**. *Ammonia beccarii (*Linnaeus) – umbilical view (left) and spiral view (right), **16**. *Fissurina* sp. – side view.

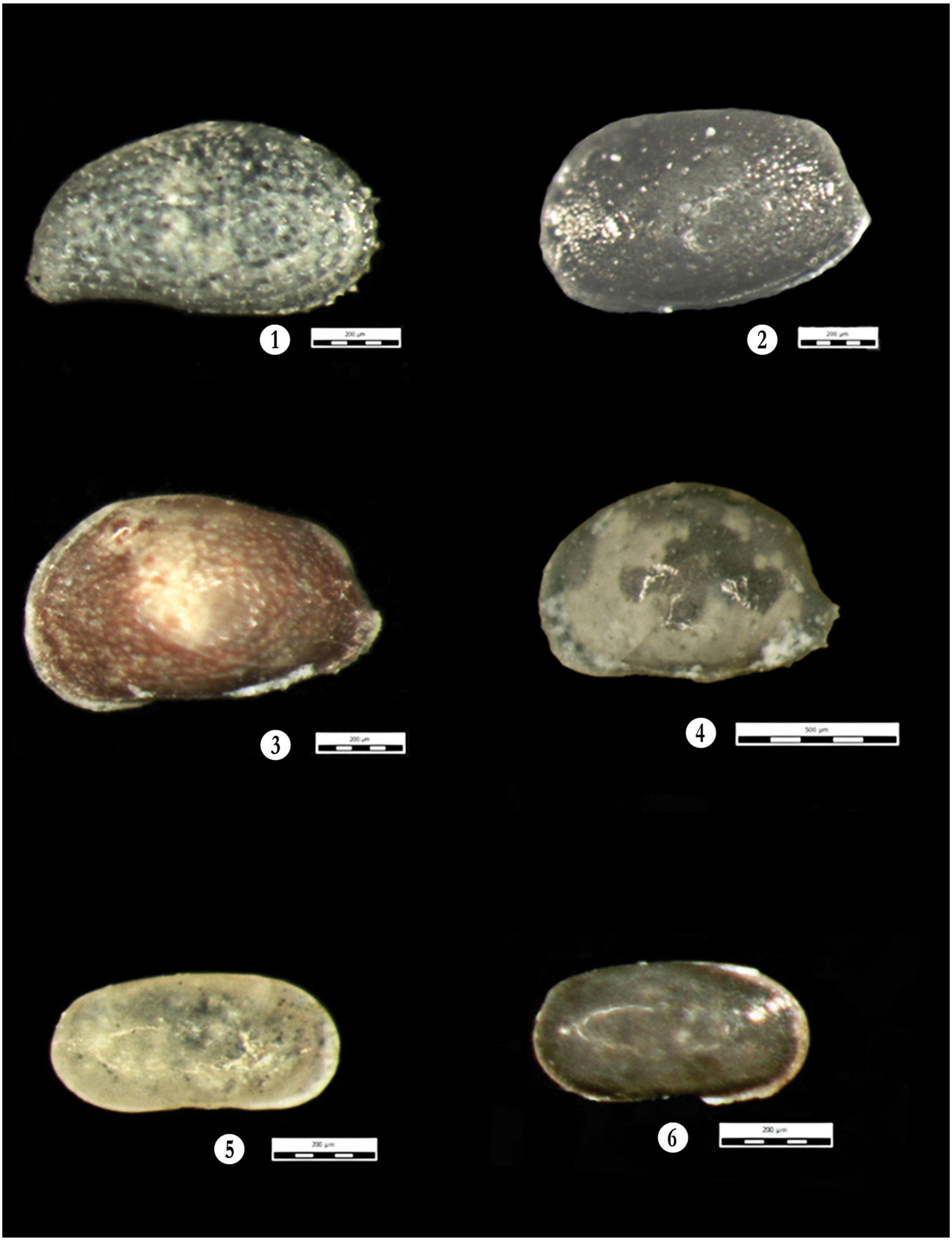


Plate 3. Volhynian ostracods from Blejeşti area. All valves are in external lateral view. LV = left valve, RV = right valve. **1.** *Cytheridea hungarica* (Zalányi) – RV, **2.** *Aurila mehesi* (Zalányi) – with pyritized, LV, **3**. *Aurila mehesi* (Zalányi) – LV, **4.** *Aurila merita* (Zalányi) – LV, **5.** *Amnicythere tenuis* (Reuss) – RV, **6.** *Amnicythere tenuis* (Reuss) – infiled with pyrite, RV.

Plate 4. Volhynian ostracods from Blejești area. All valves are in external lateral view. LV = left valve, RV = right valve. **7**. *Callistocythere incostata* Pietrzeniuk – RV, **8**. *Callistocythere egregia (*Méhes) – LV, **9**. *Euxinocythere diafana* (Stancheva) – LV, **10**. *Cytherois sarmatica (*Jiřiček) – RV, **11**. *Loxoconcha curiosa* Schneider – LV, **12**. *Loxocorniculum schmidi (*Cernajsek) – LV, **13**. *Xestoleberis elongata* Schneider – RV, **14**. *Xestoleberis fuscata* Schneider – RV.

The foraminifera species *Ammonia beccarii* is seen by many authors as an opportunistic taxon. Hence, its dominance in the assemblages is most probably indicative for a low degree or even absence of competition with other taxa (Murray, 1991).

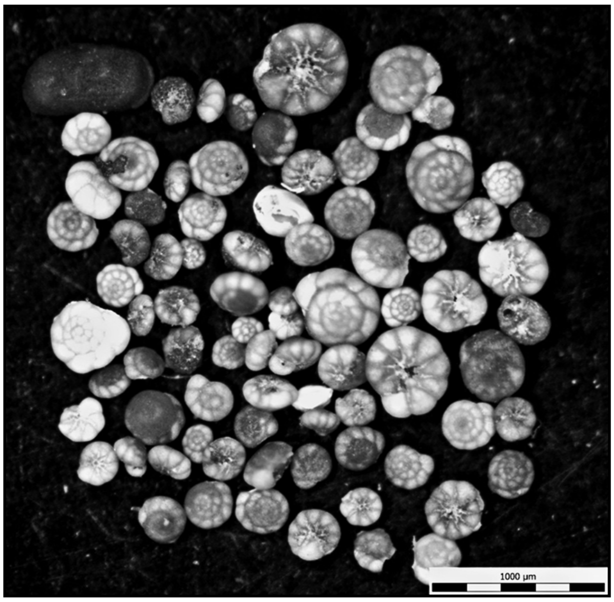


Fig. 5. Numerous specimens of *Ammonia beccarii* from Blejești 3 associated with few *Cycloforina* fragments and *Miocyprideis sarmatica* ostracod species.

In the identified ostracod assemblage of the studied samples, *Cytheridea hungarica* is the dominant ostracod species. Its common presence, along with the significant abundance of foraminifer *Ammonia beccarii*, constituting monospecific assemblages, indicates a brackish to shallow marine paleoenvironment, located close to the shoreline.

This assumption is also supported by the presence of *Charophyta* algal fragments, possible transported by rivers from the adjacent land. Along with the aforementioned assemblages, gastropods, bivalve fragments, rare fish bones and worm tubes suspension feeder *Serpula* are present. The common presence of *Serpula* taxa in the various Paratethyan Sarmatian deposits was interpreted to be linked to a progressive basin desalting and hence the dominance of more brackish conditions, but a marine shallow paleosetting is not excluded (Saint-Martin & Pestrea, 1999; Cornée *et al.*, 2009). Nowadays, the presence of abundant *Serpula* shows an enclosed and sheltered environment with no turbulent water, mainly in a marine setting, frequently associated with reefs (Short & Neckles, 1999).

The overlaying sediments are represented by very fine polymictic sands with scarce microfaunal assemblages, including sponge spicules and few benthic foraminifera taxa: *Elphidium rugosum* (d'Orbigny), *Elphidium aculeatum* (d'Orbigny) and *Nonion bogdanowiczi* Voloshinova, rare ostracods belonging to the species *Cytheridea hungarica* (Zalányi), *Charophyta* algae fragments and various reworked foraminifera, many of them with pyritized test (Plates 1-4). The above-described microfaunal assemblages are most probably related to a brackish paleosetting.

The overlaying deposits of the studied cores contain foraminiferal assemblages characteristic for *Varidentella reussi* Zone that includes many miliolid taxa, such as *Cycloforina fluviata* Venglinskin, *Quinqueloculina akneriana akneriana* (d'Orbigny), *Varidentella reussi* (Bogdanowicz), *Pseudotriloculina consobrina* (d'Orbigny) and ostracods, *i.e.*, *Aurila mehesi* (Zalanyi), *Aurila merita* (Zalanyi), *Callistocythere egregia* (Méhes), *Loxoconcha curiosa* Schneider and *Xestoleberis fuscata* Schneider. Similar microfaunal association was mentioned from boreholes of the Moldavian Platform – NE Romania (Dimitriu *et al.*, 2017).

The Varidentella reussi Foraminiferal Zone extends from immediately above (5 m stratigraphically) the association with abundant *Ammonia beccarii*. Because of the foraminifer index species absence in the studied wells, the oldest Sarmatian biozone Anomalinoides dividens Zone (Papp *et al.*, 1974; Popescu, 1995; Hartzhauser & Piller, 2004; Filipescu & Silye, 2008) was not identified, thus we may assume that the lower Volhynian depositional interval is lacking due to the erosion or nondeposition.

SARMATIAN OSTRACODES ZONES FROM PARATETHYS (Slovakia, Czech Republic, Bulgaria)					
AGE		ZONE	Jiříček & Riha, 1991	Zelenka, 1990	Stancheva, 1990
SARMATIAN	Late	NO14	Hemicytheria hungarica - C. pokornyi	Aurila notata	
		NO 13	N. janoscheki - C. vindobonensis		
	Middle	NO 12	N. kollmanni - A. notata		Euxinocythere grave odessosensis
	Early	NO 11	Cytheridea hungarica - Aurila mehesi	Cytheridea hungarica - Aurila mehesi	Euxinocythere turpe
					Cytheridea hungarica - Aurila mehesi

Fig. 6. Central and Eastern Paratethys Sarmatian substages and correlation based on ostracods.

Another possibility is that the first 5 m of sediments overlaying the Badenian ones, with abundant *Ammonia beccarii*, represent the entire interval of Anomalinoides dividens biozone in the Central Moesian Platform. Taking into account the later statements, we believe that the oldest foraminiferal zone that might be highlited in the studied area is Varidentella reussi Zone, Early Volhynian in age (except the basal part of this substage).

The following identified biozone is Elphidium reginum Zone that has a large development in the studied area, being observed in all analyzed wells. The microfaunal assemblages of the Elphidium reginum Zone show differences in abundance related to the type of sediments enclosing them. Hence, the siliciclastic sediments contain in general scarce assemblages with only few foraminifers and ostracods, while in the carbonate rocks the foraminifers and ostracods abundance increases.

The most characteristic species present in the late Volhynian Elphidium reginum Zone are:

(i) In siliciclastic rocks, the found foraminiferal assemblages contain *Ammonia beccarii* (Linnaeus), *Elphidium fichtelianum* (d'Orbigny), *Elphidium macellum aculeatum* Silvestri, *Elphidium macellum macellum* (Fichtel & Moll), and *Elphidium reginum* (d'Orbigny);

(ii) In carbonate rocks, the foraminifer assemblages are represented by *Pseudotriloculina consobrina* (d'Orbigny), *Varidentella reussi* (Bogdanowicz), *Articulina problema* Bogdanowicz, *Cycloforina karreri ovata* Serova, *Nonion bogdanowiczi* Voloshinova, *Porosononion subgranosus subgranosus* (Egger), *Buliminella elegantissima* (d'Orbigny), *Bolivina moldavica* Didkowski, *Fursenkoina sarmatica* (Vengkinski), *Fissurina* sp., *Elphidium aculeatum* (d'Orbigny), *Elphidium hauerinum* (d'Orbigny), *Elphidium josephinum* (d'Orbigny), and *Elphidium reginum* (d'Orbigny), accompanied by the ostracods *Cytherois sarmatica* Jiricek, *Cytheridea hungarica* (Zalanyi), *Euxinocythere diafana* (Stancheva), *Euxinocythere naca* (Mehes), *Callistocythere egregia* (Mehes), *Amnicythere tenuis* Reuss, *Aurila merita* (Zalanyi), *Aurila mehesi* (Zalanyi), *Loxocorniculum hastatum* (Reuss), *Loxocorniculum schmidi* (Cernajsek), *Loxoconcha porosa* Mehes, *Loxoconcha punctatella* (Reuss), *Xestoleberis elongata* Schneider, and *Xestoleberis fuscata* (Schneider), along with serpulids, mysid statoliths, gastropods, bivalves and *Charophyta* algae.

Some of the aforementioned representative taxa are illustrated in Plates 1-4. The distribution of samples in each well and the occurrence of species are presented in the Chronocharts (Figs. 7-15).

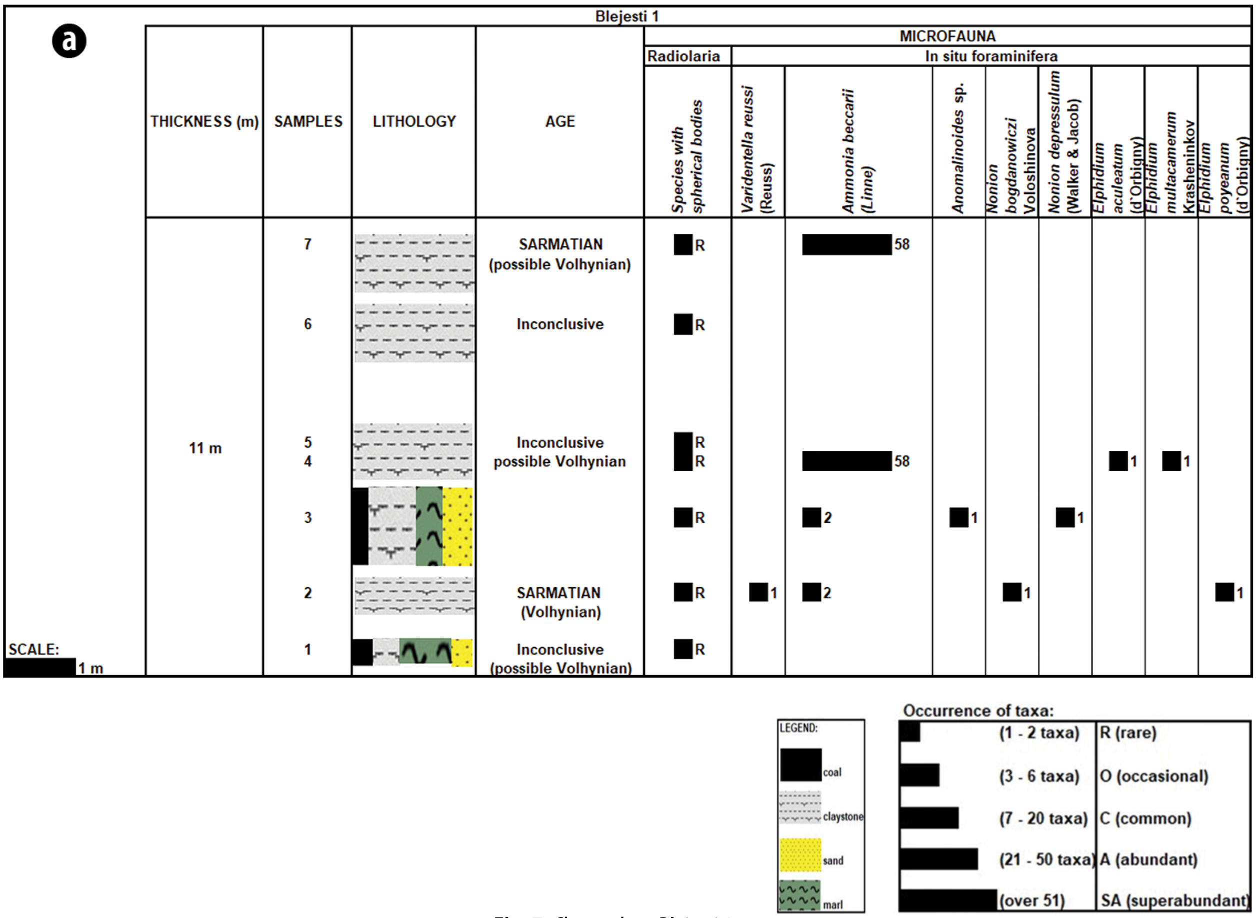
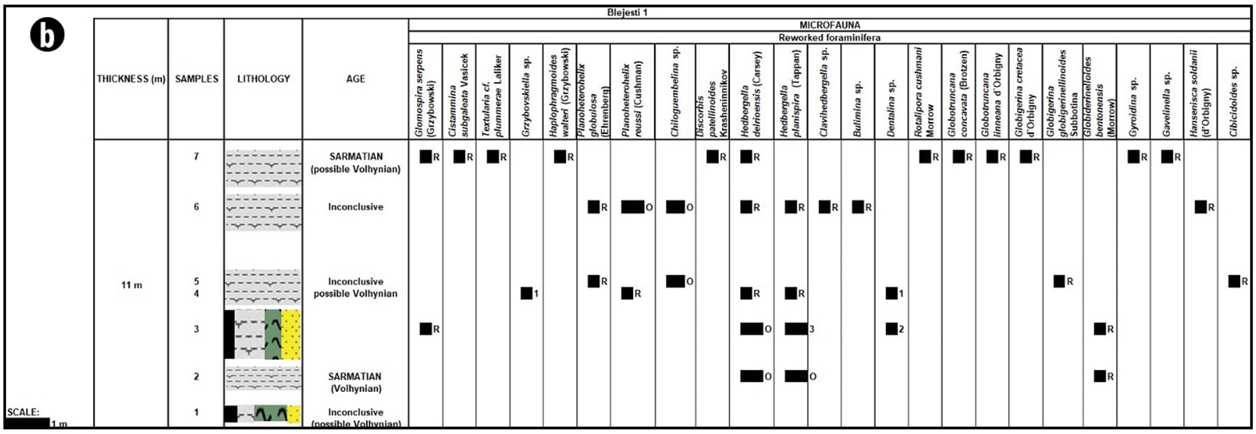
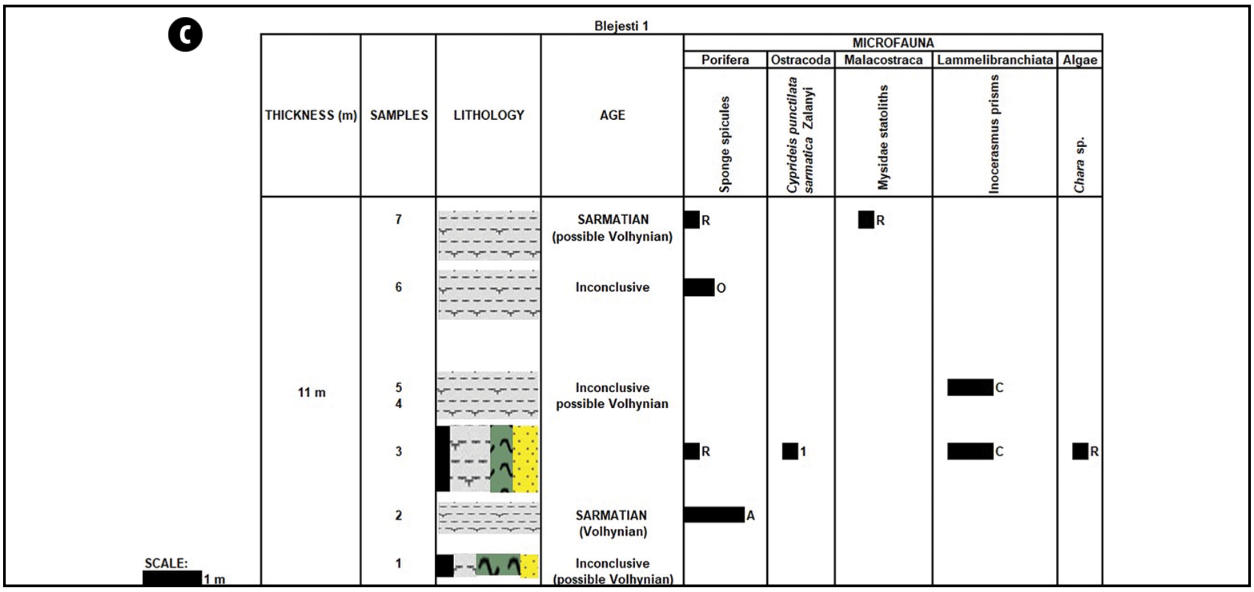


Fig. 7. Chronochart Blejești 1 - **a**.





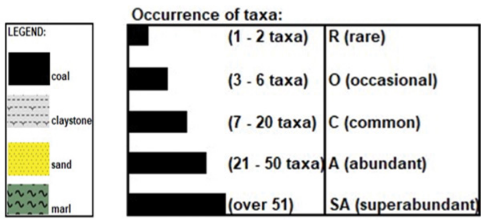
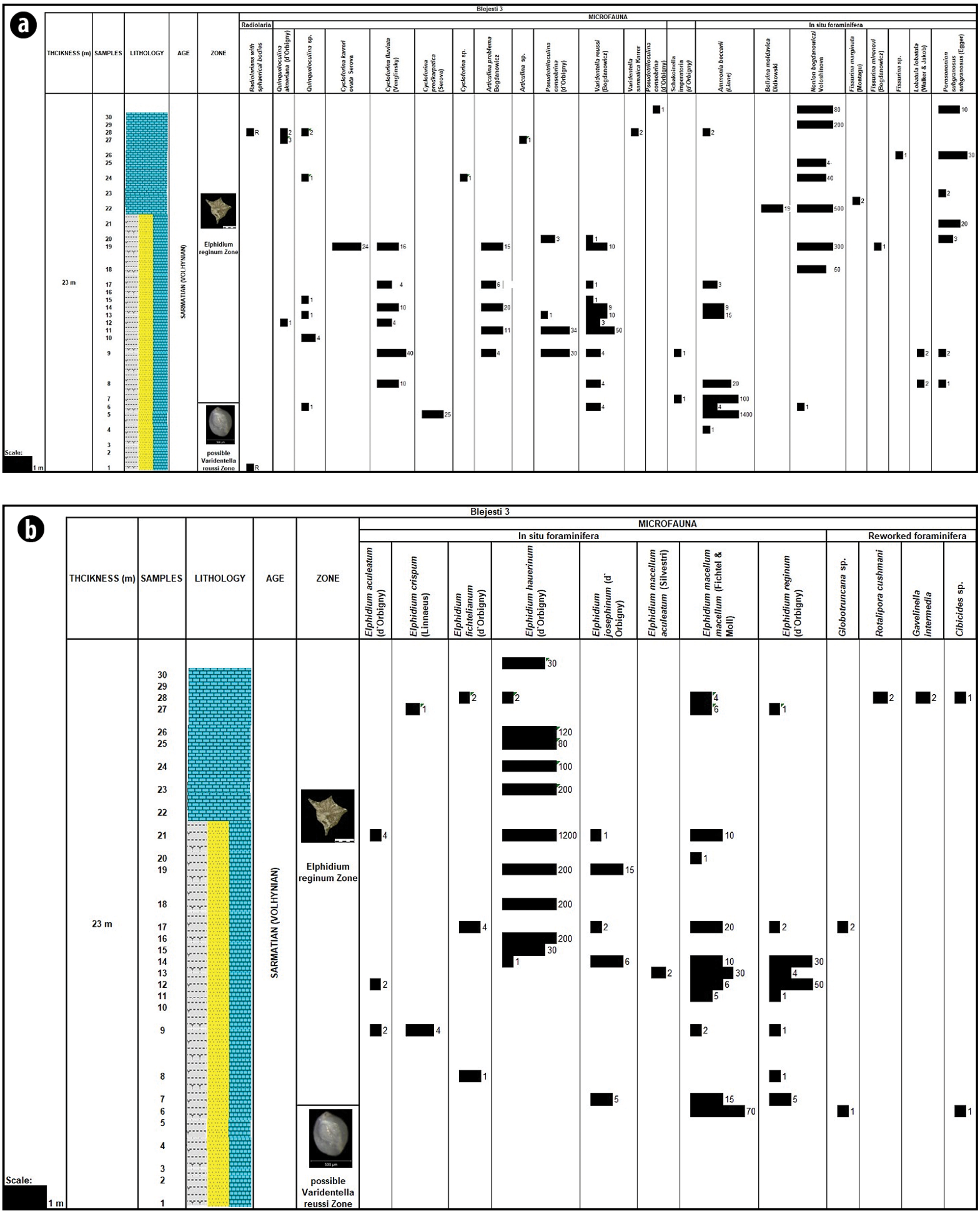


Fig. 7. Chronochart Blejeşti 1 - **b** and **c**.



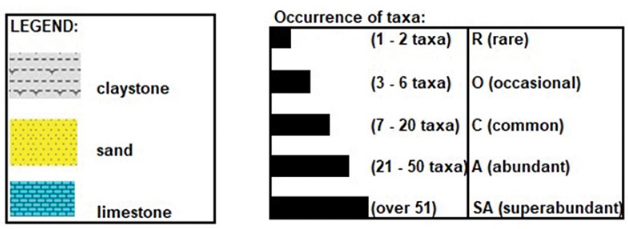
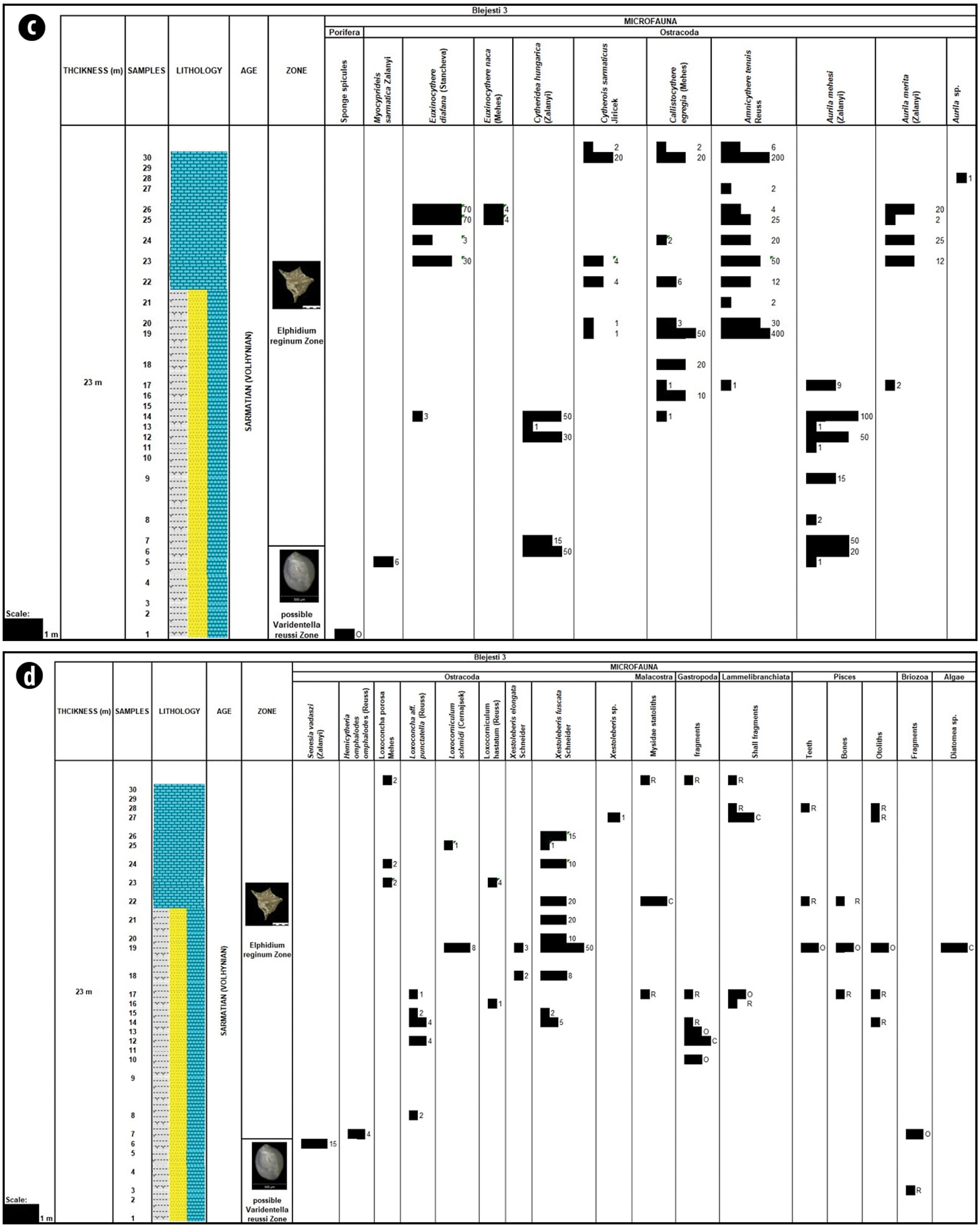


Fig. 8. Chronochart Blejești 3 - **a** and **b**.



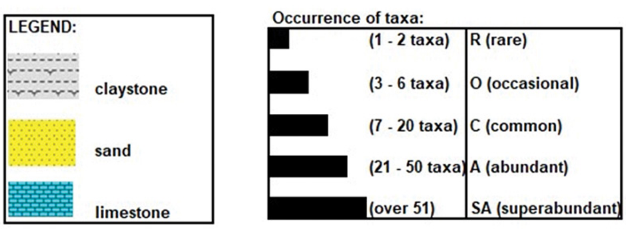


Fig. 8. Chronochart Blejești 3 - **c** and **d**.

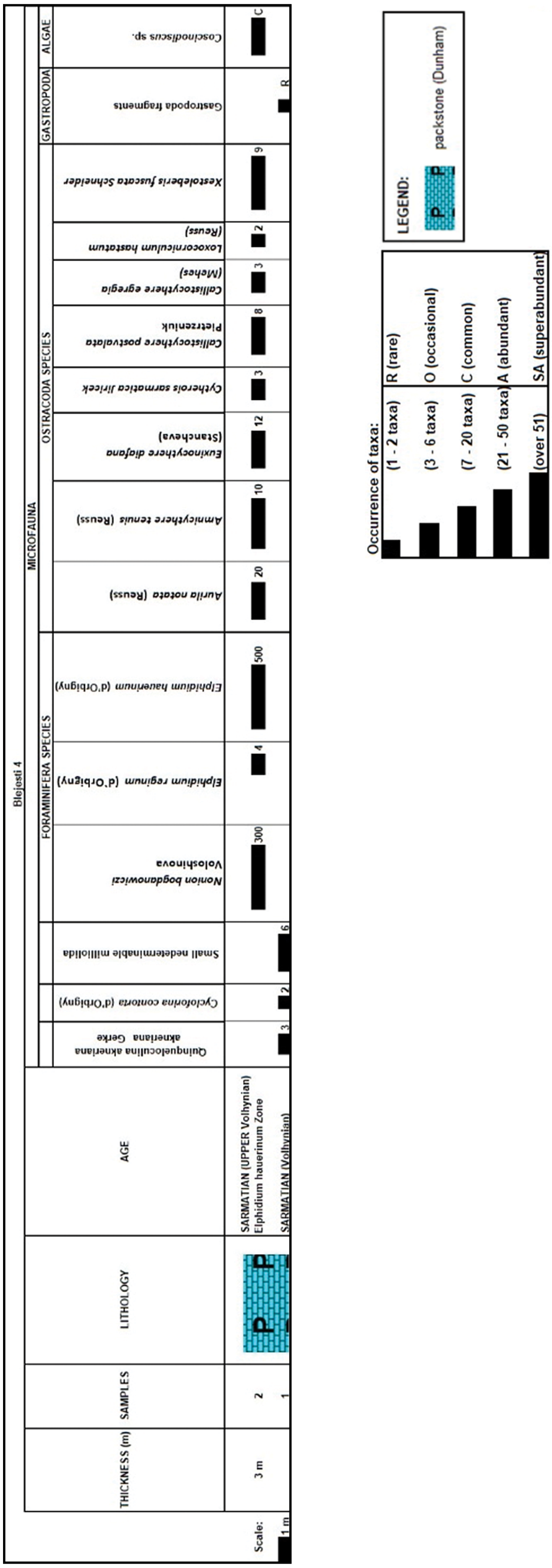


Fig. 9. Chronochart Blejești 4.

BLEJESTI 5

				MICROFAUNA: FORAMINIFERA			OSTRACODA SPECIES			GASTROPODA
THICKNESS (m)	SAMPLES	LITHOLOGY	AGE	Cycloforina sp.	*Ammonia beccarii* (Linne)	Broken indeterminable species	*Miocyprideis sarmatica* (Zalanyi)	*Aurila merita* (Zalanyi)	*Broken indeterminable species*	Gastropoda fragments
1 m	1		SARMATIAN (VOLHYNIAN)	6	1	R	1	3	2	R

SCALE: 1 m

Occurrence of taxa:	
(1 - 2 taxa)	R (rare)
(3 - 6 taxa)	O (occasional)
(7 - 20 taxa)	C (common)
(21 - 50 taxa)	A (abundant)
(over 51)	SA (superabundant)

LEGEND: Sandy limestone

Fig. 10. Chronochart Blejești 5.

Blejesti 6

				MICROFAUNA: FORAMINIFERA SPECIES				OSTRACODA
THICKNESS (m)	SAMPLES	LITHOLOGY	AGE	*Fissurina sp*	*Nonion bogdanowiczi* (Voloshinova)	*Porosononion subgranosus subgranosus* (Egger)	*Elphidium hauerinum* (d'Orbigny)	*Candona* sp.
2 m	1		SARMATIAN (VOLHYNIAN)	1	9	2	5	1

SCALE: 2 m

Occurrence of taxa:	
(1 - 2 taxa)	R (rare)
(3 - 6 taxa)	O (occasional)
(7 - 20 taxa)	C (common)
(21 - 50 taxa)	A (abundant)
(over 51)	SA (superabundant)

LEGEND: Sandy limestone

Fig. 11. Chronochart Blejești 6.

Blejesti 7

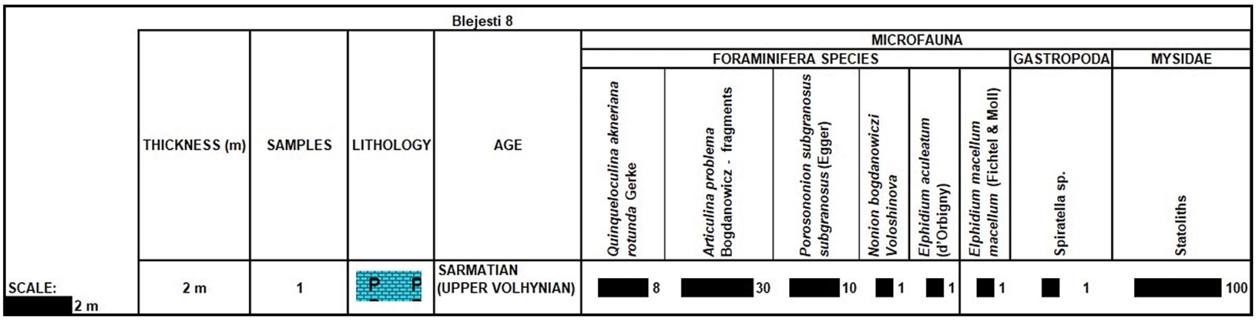
				MICROFAUNA: FORAMINIFERA SPECIES				OSTRACODA SPECIES				
THICKNESS (m)	SAMPLES	LITHOLOGY	AGE	*Quinqueloculina seminula* (Linnaeus)	*Pseudotriloculina angustioris* (Bogdanowicz)	*Ammonia beccarii* (Linne)	*Porosononion subgranosus subgranosus* (Egger)	*Aurila mehesi* (Zalanyi)	*Hemicytheria* sp.	*Amnicythere tenuis* Reuss	*Loxoconcha punctatella* (Reuss)	*Xestoleberis fuscata* Schneider
2 m	1	W W	SARMATIAN (VOLHYNIAN)	5	3	1	20	20	1	14	1	1

SCALE: 2 m

Occurrence of taxa:	
(1 - 2 taxa)	R (rare)
(3 - 6 taxa)	O (occasional)
(7 - 20 taxa)	C (common)
(21 - 50 taxa)	A (abundant)
(over 51)	SA (superabundant)

LEGEND: W W Wackestone

Fig. 12. Chronochart Blejești 7.



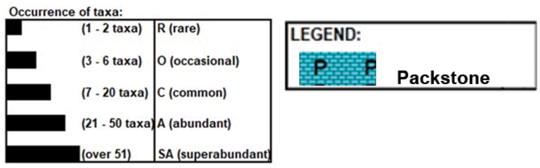
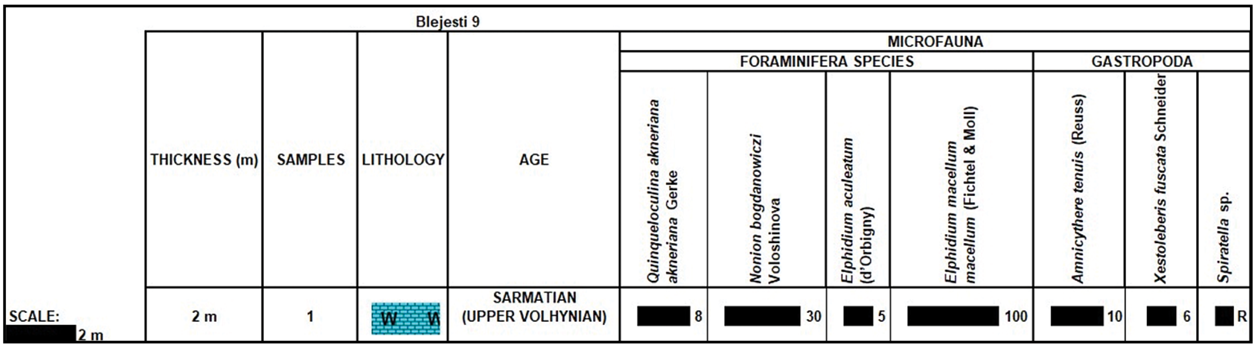


Fig. 13. Chronochart Blejeşti 8.



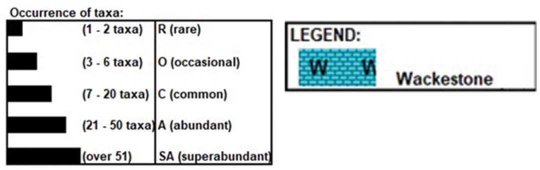
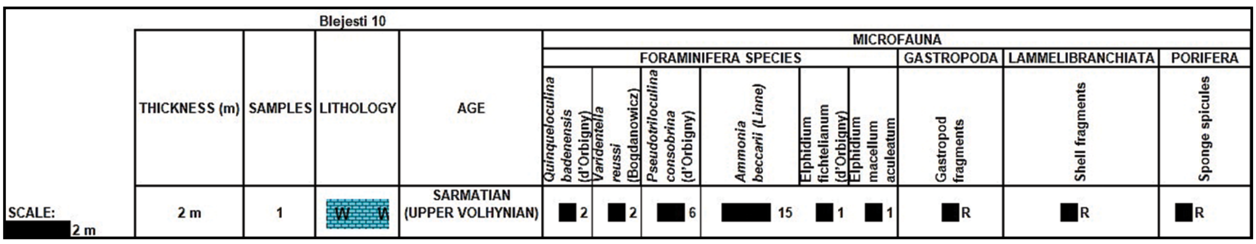


Fig. 14. Chronochart Blejeşti 9.



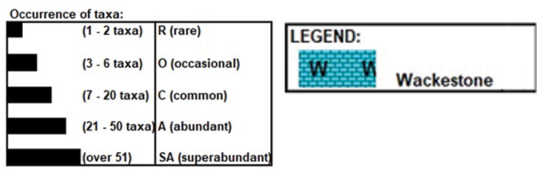


Fig. 15. Chronochart Blejeşti 10.

4. CONCLUSIONS

Based on the micropaleontological data from 10 drillings located in the south-central part of the W Moesian Platform, we were able to separate the following assemblages:

(i) Just above the Badenian deposits or overlaying the Cretaceous ones, a transitional zone, lacking foraminifera marker to assign a certain biozone, but with very abundant specimens of the *Ammonia beccarii* foraminifer species, was observed. Possibly, this interval corresponds to the Anomalinoides dividens Zone defined by Popescu (1985). This assumption is argued by the identification in the aforementioned interval of the studied wells of the NO 11 Cytheridea hungarica - Aurila mehesi ostracod zone, which starts at the base of the Sarmatian (=early Volhynian), overlapping the time interval of Anomalinoides dividens Foraminiferal Zone.

(ii) The Varidentella reussi Zone was observed in the studied deposits based on the presence of index species, along with other foraminiferal and ostracod taxa present in the identified microfaunal assemblages. This biozone is indicative for the presence of the lower Volhynian depositional interval in the studied area.

(iii) The upper Volhynian depositional interval has been pointed out based on the identification of Elphidium reginum Foraminiferal Zone. This biozone was identified in two types of sediments. In the siliciclastic deposits intercepted by the wells, the assemblages are very scarce, but contain the index foraminifera taxon, while in the carbonate sediments more diversified and abundant assemblages were identified.

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