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NEW DATA ON TYPICAL ACRITARCH ASSEMBLAGE FROM THE UPPER FORMATION (TG4) FROM TULGHEŞ GROUP, BĂLAN AREA, EASTERN CARPATHIANS (ROMANIA)

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KEY WORDS: Acritarchs, Biostratigraphical Correlation, Tremadocian, Ordovician, Tulgheş Group, Eastern Carpathians, Romania

Introduction. For the crystalline geological formations, the acritarchs and the chitinozoans represent very important argumentations in the palynological studies and for the biostratigraphical correlations. Their value within the biostratigraphical correlations increases very much when there is a lack of other micro- or macrofossil remains, such as the case of the crystalline formations from Eastern Carpathians.

Thus, in the present study we tried to have a comparison and a biostratigraphical correlation of Bălan and Sandominic metamorphic Formations, which belong to the upper part (Tg 4) of Tulgheş Group. Therefore, we realized a thorough study on the acritarch assemblages coming from the analyzed geological formations, which we correlated with the chitinozoan assemblage, yielded from the same samples and previously studied. We compared and correlated the results with palynological data from sedimentary formations from classic regions, where also we could have biozonations both on macrofloristic arguments and on microfaunistic arguments (trilobites, graptolites, conodonts).

Previous studies on Tulgheş Group. The previous palynological studies (acritarchs and chitinozoans) on Tulgheş Goup from Eastern Carpathians are few, but their importance for the biostratigraphy of the metamorphic formations is huge; besides, they served in numerous geological studies for useful mineral substances prospecting. Among these studies we remind: Iliescu, Mureşan (1972, 1975, 1976), Iliescu, Kräutner (1975), Vodă *et al.* (1976), Iliescu *et al.* (1983), Olaru, Gruia (1988), Olaru, Horaicu (1989), Olaru (1991), Olaru, Apostoae (1995), Olaru (2001). Also two doctoral dissertations include references on Tulgheş Group: Horaicu (1999) and Vaida (1999). In

Bălan area, recent studies (Olaru, Apostoae, 2003-2004) had thorough biostratigraphical researches on the metamorphic formations, proving some valuable chitinozoan assemblages.

Material and working method. The analyzed samples for this study come from Bălan and Sândominic Formations, both also representing structural-tectonic units of Upper Formation (Tg 4) of Tulgheş Group from Bălan area. We mention that in this study there were analyzed the same samples coming from the same lithologic columns (geological cross-sections) which were used for the previous chitinozoan studies (Olaru, Apostoae, 2003; Olaru, Apostoae, Apostoae, 2003-2004).

Bălan Formation. Lithologically, this formation is represented by Arama Oltului Member, with 800-900 m thickness. This lithologic member prevails, represented by chloritic-sericitous schists, graphitous quartzites, with intercalations of quartzites, metaconglomerates, green schists, rhyolitic metatuffs with disseminated pyrite levels (Figure 1). The samples for the palynological analysis were yielded from chloritic-sericitous and graphitous schists (samples 10, 11).

Sândominic Formation. The lithology of this formation is much larger than Bălan's one (Figure 2). It includes Fundu Moldovei Member (300-400 m thickness), Braşca Member (600-200 m) and Pârâul Crucii Member (100-1500 m). Lithologically, within these members, grey sericitous-chloritic phyllites prevail. Subordinately or intercalated, there are green schists and metabazites, black quartzites, white quartzites, graphitous phyllites, metaconglomerates. Also, there are intercalations of rhyolitic metavulcanites and limestones.

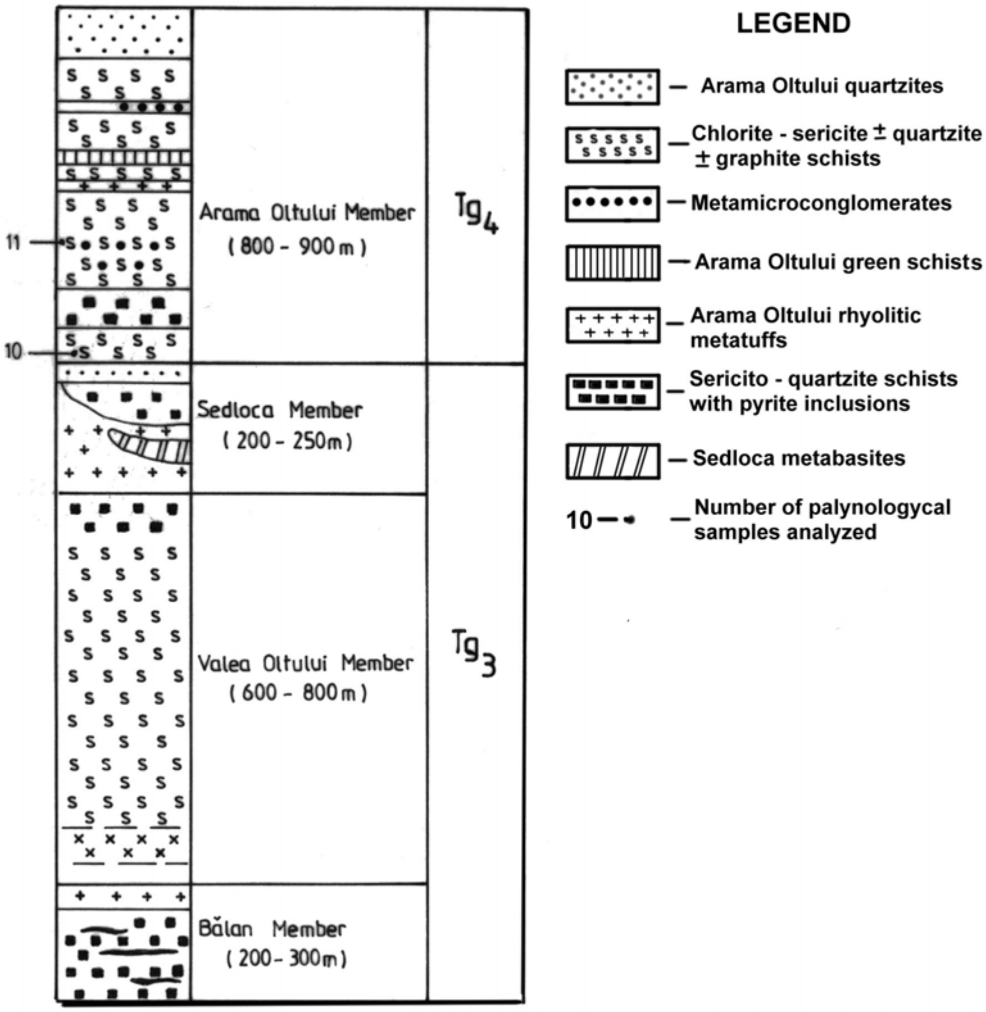

Fig. 1. Geological column of the Upper Formation (Tg. 4) Tughes Group from the Balan Formation (after Kräutner & Bindea, 1995)

The samples for the palynological analyses were yielded from the grey chloritic-sericitous phyllites, graphitous phyllites, and black quartzites.

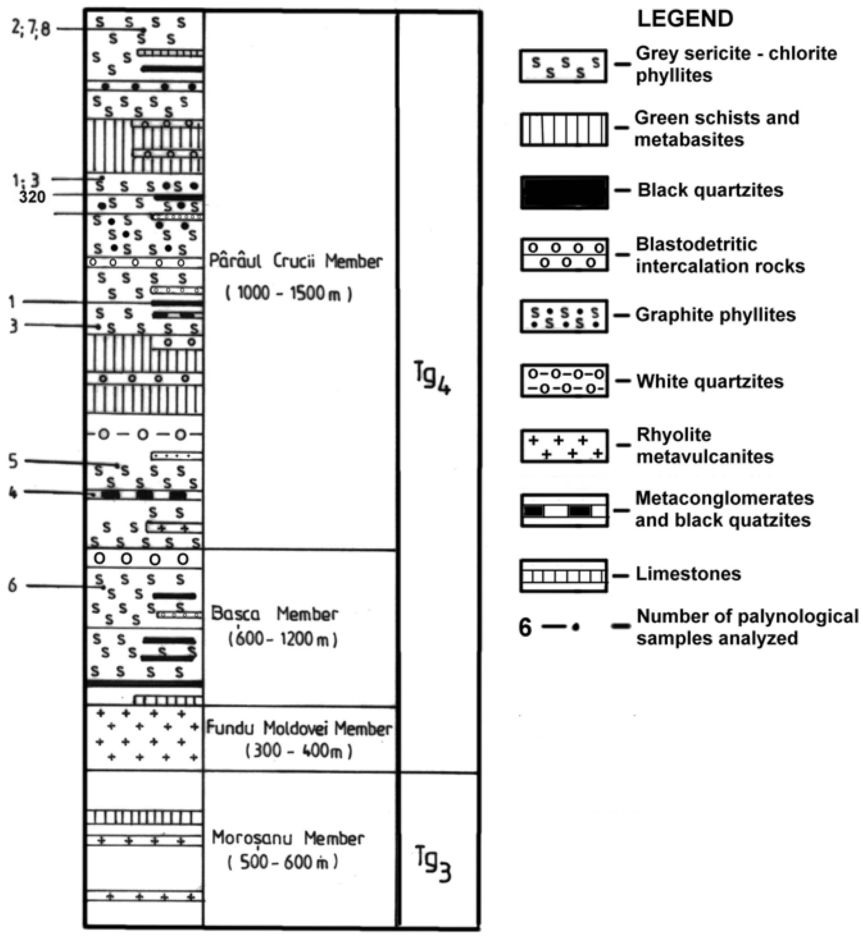

Fig. 2. Geological column of the Upper Formation (Tg. 4) Tulghes Group from the Sândominic Formation (after Kräutner & Bindea, 1995).

From Pârâul Crucii Member there were analyzed the samples 1, 2, 3, 4, 5, 7, 8, 9, 13, 320, and from Başca Member, only the sample 6.

From the all 13 samples yielded for the palynological analyses, the best and the more concluding results came from the samples 1, 3, 4, 5, 6, 9, 10, 11.

All the samples were prepared in the Palynological Laboratory, using the standard methodology for metamorphic rocks: physical disintegration, chemical maceration using HCl, HF acids, than the sample washing; KOH oxidation; heavy liquid (CdI + KI) centrifugation; microscopic slide preparation with gelatin-glycerin fastener. The microscope study included establishing of the acritarch taxa, using the sample representation statistic, comparison between taxa from other acritarch assemblages from clastic sedimentary formations, zonation, comparison between biozones based on trilobite, graptolites, conodonts and chitinozoans. At the end, we interpreted all these results, also counting on the structure and the tectonics of the region.

We must mention that the condition of many of the taxa was not sufficiently good, a typical problem for all the metamorphic formations. Thus, the taxa are small, deformed due to the metamorphic compression, torn or broken due to the dynamic tectonic and metamorphic phenomena. All taxa are decolorized due to metamorphism, resulting in a careful oxidation procedure in the laboratory. All these impediments meant important difficulties in establishing, correlating and biostratigraphical interpreting of taxa and of the palynological assemblages.

Characterization of the acritarch assemblage. The acritarch assemblage established on the yielded samples (Table 1) includes 46 taxa. It represents a complex assemblage, formed by groups or sub-assemblages of acritarch genera and species. This mixture of taxa is the result of the initial sedimentation processes and, subsequently, of the tectonic and metamorphic ones, which affected all the analyzed geological formations.

Table 1. Range chart showing of stratigraphic distribution of acritarch assemblage in the Upper Formation (Tg.4) of the Tulgheş Group, Balan Zone (East Carpathians).

TAXONOMIC UNITS	**ANALYSED SAMPLES**								**CHRONOSTRATIGRAPHIE**		
	1	**3**	**4**	**5**	**6**	**9**	**10**	**11**	**Cb.3**	**Trem.**	**Aren.**
1	2	3	4	5	6	7	8	9	10	11	12
Acantodiacrodium angustum (Dow.) Comb.	●	●	●	●	●	●	●			▬▬	▬▬
Leiosphaeridia sp. A.	●	●	●	●	●	●	●	●	▬▬		
Baltisphaeridium crinitum Martin						●			▬▬	▬▬	
Acantodiacrodium snookense Parsons & Anderson	●	●				●			▬▬		

Table continuation

TAXONOMIC UNITS	ANALYSED SAMPLES								CHRONOSTRATIGRAPHIE		
	1	**3**	**4**	**5**	**6**	**9**	**10**	**11**	**Cb.3**	**Trem.**	**Aren.**
1	2	3	4	5	6	7	8	9	10	11	12
Acantodiacrodium golubii Fensome et al.	•	•				•	•		———	———	- - -
Leiosphaeridia sp. B.	•	•	•	•	•	•	•	•	———		
Veryhachium dumontii Vang.		•	•	•		•	•	•	———		
Baltisphaeridium aciculare (Tim.)	•									———	
Lunulidia lunula (Eis.) Eis.	•	•			•		•			———	
Leiofusa stoumonensis Vang.			•		•		•	•	———		
Acanthodiacrodium lanatum (Tim.) Martin	•		•						———	———	- - -
Orthosphaeridium extensum Parsons & Anderson			•						———		
Saharidia cf. *fragilis* (Dow.) Combaz.			•	•	•				———	———	
Polygonum minimum (Tim.) Volkova			•						———		
Impulviculus bibulbulus Parsons & Anderson				•					———	———	
Tasmanites sp.				•			•	•	———	———	

Table continuation

TAXONOMIC UNITS	ANALYSED SAMPLES								CHRONOSTRATIGRAPHIE		
	1	**3**	**4**	**5**	**6**	**9**	**10**	**11**	**Cb.3**	**Trem.**	**Aren.**
1	2	3	4	5	6	7	8	9	10	11	12
Elenia armilata (Vanderflit) Volkova				•		•			—	—	
Polygonum sexradiatum (Tim.) Volkova				•					—		
Vulcanisphaera tuberculata (Downie) Eis.				•					—	—	
Cristallinium cambriense (Slavikova) Vanguestaine				•	•				—	—	
Buedingisphaeridium tremadocum Rasul				•				•	—	—	
Izhoria angulata Golub et Volkova					•				—	—	
Cymatiogalea gorkae Rauscher					•				—	—	
Acanthodiacrodium sp.					•	•			—	—	—
Pirea orbicularis Volkova					•		•	•	—		
Dactylofusa squama (Deunff) Martin	•					•				—	
Baltisphaeridium setaceum (Tim.)	•									—	

TAXONOMIC UNITS	ANALYSED SAMPLES								CHRONOSTRATIGRAPHIE		
	1	**3**	**4**	**5**	**6**	**9**	**10**	**11**	**Cb.3**	**Trem.**	**Aren.**
1	2	3	4	5	6	7	8	9	10	11	12
Arbusculidium ornatum (Deunff) Martin	●									—	
Cristallinium pilosum Golub. et Volkova							●		—		
Vulcanisphaera capillata Jardiné			●						—	—	
Dactylofusa velifera Cocchio	●			●			●			—	
Poikilofusa squama (Deunff) Martin	●						●	●		—	
Stelliferidium cf. *stelligerum* (Gorka) Deunff et al.			●				●			—	
Timofeevia estonica Volkova						●	●		—		
Cristallinium cf. *randomense* Martin Fensom et al., Ribb. & Vang.							●		—	- - -	
Ooidium cf. *rossicum* Timofeev							●		—		
Ooidium timofeevii Loeblich							●		—		
Leiofusa sp.	●		●				●	●	—	—	

TAXONOMIC UNITS	ANALYSED SAMPLES								CHRONOSTRATIGRAPHIE		
	1	3	4	5	6	9	10	11	Cb.3	Trem.	Aren.
1	2	3	4	5	6	7	8	9	10	11	12
Trachydiacrodium coarctatum Tim.								•			
Ooidium cf. *clavigerum* Parsons & Anderson			•					•			
Trichosphaeridium annovaelense Tim.								•			
Lophodiacrodium valdaicum(Tim.) Defl. et Defl.-Rigaud.								•			

Within this assemblage, firstly stands up an Upper Cambrian taxa group, which disappears or reduces at the end of this epoch. Among these taxa we mention: *Acanthodiacrodium snookense*, *Veryhachium dumontii*, *Leiofusa stoumonensis*, *Orthosphaeridium extensum*, *Pirea orbicularis*, *Cristallinium* cf. *randomense*, *Ooidium* cf. *clavigerum*, *Trichosphaeridium annolovaense*. From these taxa, a few are Upper Cambrian zone types, from Random Island, Newfoundland, Canada (Parsons and Anderson, 2000). We mention the followings: *Orthosphaeridium extensum*, *Acanthodiacrodium* sp., typical for RA5 microfloristic assemblage, equivalent to the trilobite zone with *Peltusa praecursor* and *Peltura minor*. The taxa of *Acanthodiacrodium snookense* and *Calyxiella izhoriensis* (the last one missing from our samples) represent RA6 microfloristic assemblage, corresponding to *Peltura scarabeoides*, also typical for Upper Cambrian.

The taxa group of *Poikilofusa squama* and *Ladogella rotundiformis* (the last one missing from our samples) is characteristic for RA7 microfloristic assemblage, equivalent to the upper part of *Acerocare* zone, also possible representing a subzone of *Peltura scarabeoides* zone, recognized in Scandinavia, and also appearing in the eastern side of Newfoundland region in Canada (Parson and Anderson, 2000).

Taxa of *Ooidium* cf. *clavigerum* and *Striatotheca randomensis* (the last one missing from our samples) are typical for RA8 microflora (Newfoundland, Canada), equivalent to the middle part of *Acerocare* zone, and the taxa group of *Ooidium rossicum* and *Nellia acifera* (the last one missing from our samples) define RA9 microflora from the upper part of *Acerocare* zone.

From the brief presentation of the typical Upper Cambrian assemblages it comes out that it also partially was found in the metamorphic formation studied by us. Moreover, enlarging the view, we tried a biozonation, considering the classic region of Newfoundland from Canada, where the comparison also supports the zones with trilobites, which miss in our location.

Another important category of taxa from our established acritarch assemblage belongs to Upper Cambrian-Tremadocian age or just Tremadocian (76%). Among these interval species we mention: *Leiosphaeridia* sp. A, *Leiosphaeridia* sp. B, *Baltisphaeridium crinitum*, *Acanthhodiacrodium golubii*, *Acanthodiacrodium lanatum*, *Saharidia* cf. *fragillis*, *Polygonium minimum*, *Impulviculus bibulbulus*, *Vulcanisphaera tuberculata*, *Cristallinium cambriense*, *Izhoria angulata*, *Cymatiogalea gorkae*, *Arbusculidium* cf. *destombesii*, *Cristallinium pilosum*, *Poikilofusa squama*, *Ooidium* cf. *rossicum*, *Ooidium timofeevii*, *Leiofusa* sp., *Laphodiacrodium valdaicum*, *Cymatiogalea* cf. *cuvillierii*, *Cymatiogalea velifera*.

Some species from presented assemblage were characteristic only for Tremadocianstage. From these specis we notice: *Acanthodiacrodium angustum*, *Baltisphaeridium aciculare*, *Lunulidia lunula*, *Elenia armillata*, *Polygameru sexradiatum, Buedingüsphaeridium tremadocum, Dactylofusa squama, Dactylofusa velifera, Baltisphaeridium setaceum, Vulcanisphaera* cf. *britannica, Stelliferidium*cf. *stelligerum*, *Vulcanisphaera* cf. *capillata*.

A very good representation of these taxa is shown in UK4B and OT1, OT2, OT3 acritarch assemblages from Eastern-European Platform, Baltic province (Volkova, 1995) and from Moscow Syneclise (Volkova, 1999).

Comparing and correlating our assemblage to acritarch assemblages from Eastern-European Platform and Moscow Syneclise, it results:

From UK4B acritarch assemblage ("the acritarch complex") equivalent to the zone with *Peltura scarabeoides* and *Acerocare* (Upper Cambrian) and with conodonts (*Protoconodontus* and *Cordylodus andresi*), we met in our samples the following species: *Cristallinium cambriense*, *Cristallinium pilosum*, *Ooidium rossicum*, *Elenia armillata*. This acritarch assemblage represents the limit between Upper Cambrian and Tremadocian.

OT1 acritarch assemblage ("the acritarch complex") (Lower Tremadocian, Estonia) begins with the acritarch representatives from *Diacromorphita* family, as a Lower Tremadocian feature in our samples. It is equivalent to zone with *Acerocare* (trilobites) and *Rhabdinipora flabelliformis* (graptolites), as well as to the zone with conodonts (*Cordylodus proavus* and *Cordylodus intermedius*). In the region of Moscow Syneclise, VK4B-1 acritarch assemblage from the lower part of OT1 assemblage, equivalent to the conodonts zone with *Cordylodus andresi* also marks the Cambrian-Ordovician (Lower Tremadocian) limit. The content of OT1 acritarch assemblage also includes species established by us such as: *Acanthodiacrodium angustum*, *Izhoria angulata*, *Cristallinium pilosum*, *Ooidium rossicum*, *Ooidium timofeevii* a.o.

The second typical assemblage for Lower Tremadocian in Eastern-European Platform, Baltic region (Estonia) is represented by species of OT2 assemblage ("the acritarch complex"). This assemblage is equivalent to the zone of graptolite *Rhabdinipora flabelliformis* and to the zones of the conodont species *Cordylodus lindstroemi* and *Cordylodus rotundatus* - *Cordylodus angulatus*. The acritarch species established by us, belonging to this assemblage, are the following: *Vulcanisphaera britannica*, *Baltisphaeridium setaceum*, *Baltisphaeridium aciculare*, *Elenia armillata*, *Lunulidia lunula*, *Dactylofusa squama*, *Saharidia* cf. *fragillis*, *Acanthodiacrodium angustum* a.o.

The typical OT3 acritarch assemblage for Upper Tremadocian ("the acritarch complex") from Estonia is equivalent to the graptolite zone with *Clonograptus-Didymograptus* and to the conodonts zone with *Drepanoistodus dellifer pristinus*. Here are represented fewer acritarch species from our assemblage, such as: *Acanthodiacrodium angustum*, *Baltisphaeridium aciculare*, *Baltisphaeridium setaceum*, *Leiosphaeridia* sp. A, Leiosphaeridia sp. B.

At the end, a few acritarch species from our assemblage pass the Tremadocian-Arenigian limit, continuing their evolution besides typical Arenigian taxa. Among these species we remind: *Acanthodiacrodium angustum*, *Acanthodiacrodium lanatum*, *Acanthodiacrodium* sp., *Dactylofusa squama*, *Poikilofusa squama*, *Leiofusa* sp., *Leiosphaeridia* sp. A, *Leiosphaeridia* sp. B.

The species *Coryphidium bohemicum* Vavrdova represents a special case where Arenigian starts in Prague Basin, by Klabava Formation (Vavrdova, 1965), and characterizing the whole Arenigian-Llanvirnian stratigraphical interval from Peri-Gondwanaland region. The establishing of this species in our samples is difficult especially due to the poor preserving conditions of its typical external ornamentation elements (spins). In spite of all these difficulties, we found exemplars of this species, typical in the samples 4 and 8 from the graphitous phyllites of Pârâul Crucii Member from Sândominic Formation, Bălan area, Eastern Carpathians, and previously in the Ordovician (Arenigian) formations of Bugeac Group from Northern Dobrogea (Olaru, 1998).

Biostratigraphical correlations. The biostratigraphical correlations represent for each study the scientific conclusions with the greatest value and practical importance. As we showed in the present study, the biostratigraphical correlations are difficult mainly due to the poor preservation conditions of the acritarch taxa, and also to the structure and the complicate tectonics of the analyzed metamorphic formations.

From the beginning we must underline that, generally, in the metamorphic formations and, especially, in the formations of Tulgheş Group, besides acritarchs and chitinozoans, there are no other organic rests useful for the comparisons within the biostratigraphical correlations and the biozonations. In this case, for the comparison and the correlation, we employed the biozones with trilobites, graptolites and conodonts, established in other classic regions, with the sedimentary formations, where the lithological succession is not tectonically affected, and the succession of the palynological and macrofaunistic assemblages is distinct, used for biostratigraphical zonations and correlations. As example, we could cite Eastern-European Platform, with Baltic province and Moscow Syneclise, Newfoundland region – Canada, Southern Turkey, and other well studied areas and regions. In our analyzed samples, we did not find all the zone taxa, or we established them in intense degraded or diagenized stages, fact that did not allow a proper recognition.

In this situation we based our study on many assemblage or cenozone species, which accompany the typical zone taxa and which we recognized in the analyzed formations.

In order to appreciate the chronostratigraphical terms of correlation, we used the Geological Time Scale for Phanerozoic, elaborated by F.M. Gradstein and J.G. Ogg (1997) where Tremadocian is considered as the lower stage for Lower Ordovician (495-485 m.y.), followed by Arenigian (485-470 m.y.) which represents the upper stage of Lower Ordovician. Thus, at the limit of Upper Cambrian-Lower Ordovician there is no intermediary or transitional stage between Cambrian and Ordovician, as Tremadocian was considered in other older chronostratigraphical scales.

The correlation between acritarch and chitinozoan assemblages from Bălan and Sândominic Formations of the upper formations (Tg 4) of Tulgheş Group, Bălan area. Between the two assemblages coming from the same samples of the analyzed formations we could have a parallel and a correlation, but also there are some seeming differences of biostratigraphical correlation.

From the results of the present study over our established acritarch assemblage (Table 1) it stands out that some species some typical for Upper Cambrian-Lower Tremadocian interval, others are typical for Tremadocian, and others, several, "rise up" to Arenigian. This situation is normal for older organisms which evolved and extended within newer formations, considering the environmental, sedimentary and tectonic conditions.

The chitinozoans mainly show the Arenigian age, meaning the stage of their explosive start in biostratigraphy. We have to mention that many of the chitinozoan species, established as: *Lagenochitina esthonica*, *Conochitina symmetrica*, *Conochitina raymondii*, *Fustichitina grandicula*, *Clavachitina decipiens* a.o. are typical for Lower Arenigian (Lower Ordovician, the upper part), meaning the limit with Tremadocian (Lower Ordovician, the lower part). Moreover, the appearance for the first time of the chitinozoans is mentioned in Upper Cambrian, but their real explosive biostratigraphical start is mentioned in Arenigian. From this correlation and from the comparison with the micro- and macrofauna assemblages from other regions (trilobites, graptolites and conodonts) it follows that biostratigraphically Tremadocian stays as a transitory substage between Cambrian and Ordovician, the time when there are changes in the microflora assemblages (acritarchs, chitinozoans), and micro- and macrofauna (trilobites, graptolites and conodonts). We have to mention that chronostratigraphically Tremadocian is considered the lower substage of Early Ordovician, thus Arenigian becomes the upper substage of Early Ordovician. Therefore, the limit between Cambrian and Ordovician stands at the base of Tremadocian.

Eastern-European Platform. For Eastern-European Platform, considering the correlation possibilities, there are two distinguished regions: Moscow Syneclise (Volkova, 1999) and Baltic region (Estonia) (Volkova, 1995).

For Moscow Syneclise, Marino-1 drill (North of Yaroslavl) passed through a pack of Ordovician and Upper Cambrian argillaceous sandstones, sandy sandstones, siliceous sandstones and clays. For Tremadocian, the analyzed samples came from 2141-2147 m depth, yielded from the argillaceous sandstones of Ukhra Formation, and for Ordovician, the samples were yielded from 2118-2127 m depth, from argillaceous and sandy sandstones of Sementsovo Formation. Upper Cambrian was found between 1785-1793 m depth, including argillaceous and siltic sandstones from Bugino Formation. Besides Marino-1 drill, there were analyzed Rybinsk-1 and Tolbukhino-1 drills.

UK4B (lower) and UK4B-1 (upper) acritarch assemblages belong to Upper Cambrian and are equivalent to the zones with trilobites *Peltura scarabeoides* and *Acerocare* and to the zones with conodonts *Protoconodontus*, *Cordylodus andresi* and *Cordylodus proavus*.

UK4B assemblage does not include *Cristallinium pilosum*, *Veryhachium dumontii*, *Polygonum sexradiatum*, *Baltisphaeridium capillatum*, *Cymatiogalea cuvillieri*, *Cymatiogalea velifera*, *Izhoria angulata*, *Saharidia fragilis* a.o. This assemblage is older than OT-1 assemblage from Estonia, marking the limit of Cambrian-Ordovician (the base of Tremadocian).

Another important assemblage for biozonation comes from Sementsovo Formation from Marilo-1 drill. It is equivalent to the zone with the conodonts *Cordylodus proavus* and with OT-1 acritarch assemblage from Estonia. It is considered to be Lower Tremadocian, at its base standing the limit between Cambrian-Ordovician. This assemblage is represented by *Diacromorphitae*, among them we established only *Acanthodiacrodium angustum* and *Acanthodiacrodium* sp. Within the acritarch assemblage from Marino-1 drill (Moscow Syneclise) there are also mentioned species such as *Acanthodiacrodium comptulum* and *Acanthodiacrodium striatulum* that we have not found them.

Another assemblage with value in the biostratigraphical correlation from Sementzovo Formation, upper than the first assemblage, corresponds to the zone with the graptolite *Rhabdinipora flabelliformis* and to the zones with the conodonts *Cordylodus lindstroemi* and *Cordylodus rotundatus / Cordylodus angulatus*. This assemblage is similar with OT-2 acritarch assemblage from Estonia which includes *Vulcanisphaera britannica*, *Acanthodiacrodium angustum* and other species. These two species were also established in our analyzed samples. This assemblage is considered as Lower Tremadocian (OT-2) and it is upper than the first assemblage (OT-1), which is also Lower Tremadocian. The Lower Tremadocian acritarch assemblages from Moscow Syneclise, Baltic region, as well as our analyzed samples from Bălan area, Eastern Carpathians, are abundantly represented by species such as *Diacromorphitae* and *Hekomorphitae*, which will be better represented in Ordovician. This acritarch assemblage is typical for the cold water environment from Peri-Gondwanaland region. In a special way, the Tremadocian acritarch assemblage from East of China (Yin, 1986) and Canada (Martin, 1992) belongs to warm water province. The warm water taxa from Peri-Gondwanaland region (with cold water) are the result of their migration into the temperate latitudinal regions. This situation also appears in Eastern Carpathians in the formation we analyzed, where the mixture of taxa is both the result of their migration in the basin of the initial deposited sediments, and the result of the subsequent tectonic and metamorphic processes of the geological formations.

In Baltic Sea region, the drills that gave the samples for the analysis were placed in Estonia – East of Tallin, and in Russia – South of Sankt Petersburg. Generally, that microflora has a lager diversity than that from Moscow Syneclise and is very much alike the acritarch assemblage established by us in Eastern Carpathians.

UK4B Upper Cambrian acritarch assemblage includes species such as: *Cristallinium pilosum*, *Ooidium rossicum*, *Ooidium timofeevii* a.o., being equivalent to the zone with *Peltura minor* (spatially), *Peltura scarabeoides* and *Acerocare* (partially). Similarly, it has correspondence with the zones with conodonts, *Protoconodontus* and *Cordylodus andresi*. This acritarch assemblage gradually passes into Lower Tremadocian assemblage, also with *Baltisphaeridium capillatum*, *Izhoria angulata*, *Elenia armillata* and other species. A similar assemblage was found in Öeland Islands, Sweden (Di Milia *et al.*, 1989; Tongiorgi, Ribecai, 1990). At the end of Cambrian is also mentioned a cosmopolite species, *Cristallinium cambriense*. At the end of Cambrian the established flora is of cold type, also mentioned in Newfoundland region (Martin, Dean, 1981, 1988), towards it warm species from North-East of China migrated (Yin, 1986).

Lower Tremadocian microflora represented by OT-1 assemblage is equivalent to the zone with *Acerocare* (partially) and to the zone with *Rhabdinipora flabelliformis*, as well as to that with *Cordylodus proavus* and probably with *Cordylodus intermedius* (Volkova, 1995).

This typical assemblage for the lower part of Lower Tremadocian (at the limit contact with Upper Cambrian) includes more acritarch species equivalent to those we established: *Acanthodiacrodium angustum*, *Arbusculidium* sp., *Baltisphaeridium capillatum*, *Ooidium rossicum*, *Ooidium timofeevii*. It also represents a cold water assemblage and it was mentioned in many other Tremadocian areas such as: England (Downie, 1958; Rasul, Downie, 1974), France (Martin, 1973), Belgium (Vanguestaine, 1974; Martin, 1977), Spain (Wolf, 1980), Italy (Pittau, 1990), North Africa (Combaz, 1967; Jardiné *et al.*, 1974), North Iran (Gavidel-Syooki, 1992), Eastern Newfoundland (Martin, 1982), North-West of Argentina (Bultynek, Martin, 1982).

More recent studies on the extent of Tremadocian and of the typical acritarch assemblages are cited for East of Newfoundland region (Parson and Anderson, 2000), North Africa, Hassi R'Mel region and Rhadames Basin (Vecoli, 1999), South of Turkey (Dean, Martin, 1972), England (Molyneux, Dörning, 1989), North Africa (Vecoli, Tongiorgi, Farida-Fatma Abdessalem-Ronghi, 1999).

OT-2 (at the upper part of Lower Tremadocian) is the second important acritarch assemblage, comparable with our established species in Eastern Carpathians. She includes species such as: *Vulcanisphaera britannica*, *Baltisphaerdium setaceum*, *Baltisphaeridium aciculare*, *Elenia armillata*, *Izhoria angulata*, *Lunulidia lunula*. This assemblage corresponds to the zone with *Rhabdinipora flabelliformis* (partially) and *Clonograptus-Didymograptus* (partially). Also, it is equivalent to the zones with conodonts: *Cordylodus lindstroemi* and *Cordylodus rotundatus-Cordylodus angulatus*.

This assemblage was also mentioned in Tremadocian formations from England (Rasul, 1979), as well as in Morrocco (Elaouad-Debbaj, 1988), and Belgium, France, Spain, Algeria, Sweden, Northern Norway (Bagnoli *et al.*, 1988). The microflora is also of cold type with warm type migratory influences from North-Eastern China (Yin, 1986) and Alberta, Canada (Martin, 1992).

OT-3 Upper Tremadocian acritarch assemblage corresponds to the zone with *Clonograptus-Didymograptus* (graptolites) and to the zone with conodonts *Drepanoistodus deltifer pristinus.* Within this assemblage we established only *Baltisphaeridium aciculare* and *Baltisphaeridium setaceum* well as *Acanthodiacrodium* sp. In this case, it is difficult to have a biostratigraphical correlation.

Southern Turkey. A few possibilities of biostratigraphical correlation are interesting, between Eastern Carpathians and Taurus Mountains Massif from South of Turkey.

Early *Tremadocian* appears here within the limestone intercalations from the clastic sediments of Seydişehir Formation, Sultan Dag area (Western Taurus) where European and Asian species were established, trilobites such as *Macropyge*, *Niobella*, *Parakoldinia*, which prove the Tremadocian age of this geological formation. Within the same formation, Seydişehir, but from the central region of Taurus Mountains, a rare acritarch assemblage was established, with *Cymatiogalea cuvillieri*, *Cymatiogalea simplex*, *Cymatiogalea cristata* (*Herkomorphitae*), indicating undifferentiated Tremadocian (Dean, Martin, 1992). From these species, only *Cymatiogalea cuvillieri* and *Cymatiogalea* sp. were found in our analyzed samples.

Ordovician from Taurus Mountains, the southern central area (Mediteranean seaside) was pointed out in the same Seydeşehir Formation, by a fauna with trilobites (*Niobe* and *Taihungshania*), which suggests an Early Arenigian age), with an analogy with other regions from Turkey and France (Dean, Martin, 1992). The mentioned authors established an acritarch assemblage, which includes *Coryphidium bohemicum*, *Cristallinium dentatum*, a.o., species that allow a better correlation with Eastern Carpathians. *Coryphidium bohemicum* species, typical for the beginning of Arenigian, also found in our samples, is classic for Early Arenigian from Prague Basin, Klabava Formation (Vavrdova, 1965).

These species were also found in the eastern region of Newfoundland, Canada, within Bell Island Group, suggesting Later Tremadocian-Early Arenigian (Dean, Martin, 1978).

Conclusions. In the present study it is analyzed the content of the acritarch assemblage from Bălan and Sândominic Formations from Upper Formation (Tg 4) of Tulgheş Group, Bălan area, Eastern Carpathians.

Within this study we completed a comparison and a biostratigraphical correlation with the previous results offered by the previous studied chitinozoan assemblage from the same geological formations (Olaru, Apostoae, 2003; Olaru, Apostoae, Apostoae, 2003-2004).

In the biostratigraphical analyzing, comparing and correlating process, it stood out that many acritarch species are poorly preserved, broken or deteriorated, and the microflora is mixed due to the initial sedimentation conditions, and subsequently to the tectonic and metamorphic events which affected the studied geological formations.

Another obvious remark is the lack of the rests of micro- or macrofauna also due to the action of the sedimentary and tectonic processes on the analyzed geological formations.

All these troubles created important difficulties in the biostratigraphical correlation of the acritarch assemblages and of the involved geological formations.

In spite of all these difficulties, the biostratigraphical correlation could be realized using the comparative analysis of the acritarch assemblage, separated from the studied geological formations, with the acritarch assemblages from the classic regions with sedimentary rocks, where they were preserved by fossilization and faunistic rests of conodonts, graptolites and trilobites, very useful organisms for correlation and biozonation.

Thus, there were possible biostratigraphical correlations with regions such as Newfoundland from Canada, Moscow Syneclise and Baltic province from Eastern-European Platform, Southern Turkey, Peri-Gondwanaland area.

From the analysis of the biostratigraphical correlation it results that the studied acritarch assemblage stands within the limit interval of Upper Cambrian and Lower Ordovician. This interval starts with *Cordylodus proavis* Biozone and *Acerocare* Biozone and ends with the last extension of the group of *Rhabdinipora flabelliformis* species, localized under the apparition level for the graptolites from *Adelograptus tenellus* Biozone (Martin, 1993).

The typical acritarch species for this interval, also present in our assemblage from the studied geological formations is *Acanthodiacrodium angustum*, which represents marker species for the base of Ordovician (Arenigian), where it disappears (Volkova, 1989), being present all along Tremadocian (Lower Ordovician).

This species is accompanied by some other species important for the biostratigraphical correlation, such as *Coryphidium bohemicum* (typical for Prague Basin), whereby Arenigian starts.

Thus, we can conclude that based on the acritarch assemblage, the studied acritarch geological formations belong to Lower Arenigian (the upper part of Lower Ordovician), and many of the acritarch species from the analyzed assemblage belong to Upper Cambrian-Arenigian, meaning Tremadocian (the lower part of Lower Ordovician).

These results are equivalent to those previously obtained by the chitinozoan study from the same geological formations.

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EXPLANATION OF PLATES

PLATE I

1. *Leiosphaeridia* sp. A (2 specimens)
2. *Acanthodiacrodium angustum* (Downie) Combaz
3. *Acanthodiacrodium angustum* (Downie) Combaz
4. *Arbusculidium* cf. *destombesii* Deunff
5. *Dactylofusa squama* (Deunff) Martin
6. *Dactylofusa velifera* Cocchio
7. *Lunulidia lunula* Eisenack
8. *Dactylofusa squama* (Deunff) Martin
9. *Lunulidia lunula* Eisenack
10. *Cymatiogalea* cf. *cuvillieri* (Deunff) Martin
11. *Baltisphaeridium setaceum* (Timofeev) Martin
12. *Baltisphaeridium aciculare* (Timofeev) Martin
13. *Acanthodiacrodium lanatum* (Timofeev) Martin
14. *Pirea orbicularis* Volkova
15. *Pirea cf. orbicularis* Volkova
16. *Pirea* sp.
17. *Dactylofusa* cf. *squama* (Deunff) Martin
18. *Poikilofusa squama* (Deunff) Martin
19. *Dactylofusa squama* (Deunff) Martin

All figures increased by 1000 X

PLATE II

1. *Orthosphaeridium extensum* Parsons & Anderson
2. *Leiofusa stoumonensis* Vanguestaine
3. *Veryhachium* cf. *dumontii* Vanguestaine
4. *Acanthodiacrodium angustum* (Downie) Combaz
5. *Leiosphaeridia* sp. A
6. *Cymatiosphaera deunffi* Jardiné et al.
7. *Ooidium* cf. *clavigerum* Parsons & Anderson
8. *Saharidia* cf. *fragilis* (Downie) Combaz
9. *Dactylofusa velifera* Cocchio
10. *Leiosphaeridia* sp. A
11. *Veryhachium dumontii* Vanguestaine
12. *Leiospharidia* sp. B (3 specimens)
13. *Cristallinium* cf. *cambriense* Slaviková
14. *Acanthodiacrodium golubii* Fensome et al.
15. *Vulcanisphaera* cf. *britannica* Rasul
16. *Coryphidium* aff. *bohemicum* Vavrdová
17. *Veryhachium dumontii* Vanguestaine
18. *Baltisphaeridium crinitum* Martin
19. *Buedingiisphaeridium tremadocum* Rasul
20. *Acanthosphaeridium angustum* (Downie) Combaz
21. *Lunulidia lunula* (Eisenack) Eisenack

All figures increased by 1000 X