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DĂMUC SERIES OF HĂGHIMAŞ SYNCLINE FROM EAST CARPATHIANS, ROMANIA. NEW PETROGRAPHICAL AND PALYNOSTRATIGRAPHICAL DATA

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Abstract. Dămuc Series, described by Mureşan *et al.* (1974) from the southern extremity of Dămuc „Ridge", represents a monotonous succession of crystalline schists which include sericitous-muscovitic, weakly graphitic schists with biotite and garnets, representing the nucleus of an anticline with a western overfolding, covered on both flanks by Triassic dolomites, disposed on the top of the Formation with *Aptychus*. Our investigations are based on the study of the geological sections which crop out along Arşiţa Almaşului (Mâţului) Brook, left tributary of Dămuc Valley. Here, the crystalline schists are characterized by advanced schistosity and black colour, with a metallic aspect. From the microscopic analysis the presence a common quartzitic component with a marked schistosity was determined, which confers a granoblastic structure to the rocks, with all minerals (muscovite, biotite, sericite, chlorite and graphitic material) randomly dispersed. Iliescu and Mureşan (1972) made the first palynologically and palynostratigraphical observations on these deposits. These authors sketched the palynological assemblage in the rocks of Dămuc Series, Ordovician in age. Our study, abort all petrographic types, has separated two distinct palynological assemblages: acritarchs and chitinozoans. The acritarch assemblage includes palynomorphs specific for Tremadocian-Arenigian (Lower Ordovician). The chitinozoans (benthic faunistic microorganisms) assemblage developed during a more compressed stratigraphical interval, being dependent on quality and structure of the seabed, thickness of water layer, quality of nutrients, dynamics of marine streams etc. These microorganisms represent typical biozones, able to be correlated to the graptolites, trilobites, conodonts and acritarchs biozones. The chitinozoan assemblage is characteristic for Lower Arenigian-Upper Arenigian stratigraphical interval, and defines the age of the rocks from Dămuc Series. The initial deposition of these rocks took place during pre-Tremadocian-Upper Arenigian (Lower Ordovician), with arguments brought by the assemblages of acritarchs and chitinozoans synsedimentarily included. Subsequently, all these rocks were successively metamorphosed during the phases of Caledonian Orogenesis, starting with the Sardic one and continuing with the Taconic and probably Ardenian ones. The radiometric ages of 415 and 420 M.y. (Mureşan *et al.*, 1974), are equivalent to the last phase of Caledonian Orogenesis (Ardenian phase) at the limit between Upper Ordovician and Silurian. According to Balintoni (1997), the metamorphism which affected the Ordovician formations belongs to the Cadomian Orogeny, which proves the peri-Gondwana origin of the pre-Varistic terrains from Eastern Carpathians.

Keywords: Petrography; Palynostratigraphy; Dămuc Series; East Carpathians; Romania.

INTRODUCTION

The crystalline formations of Dămuc Series represent a peculiar feature among the metamorphic formations of the Eastern Carpathians; they include a monotonous succession with a quartz-rich content of sericitic-muscovitic, weakly graphitic schists with biotite and garnets. This mineralogical particularity of the crystalline rocks of Dămuc Series distinguishes them from both the mesometamorphites of Bretila-Rarău Group, uncomformably overthrusting them, and the epimetamorphites of Tulgheş Group, overthrusting both previously mentioned units.

The crystalline units of Dămuc Series are slightly spread, being best represented in the southern extremity of Dămuc "ridge", on Arşiţa Almaşului (Mâţului) Brook; here the stratotype section was defined (Figure 1), which we already studied. Structurally, here the crystalline of Dămuc Series occurs as an anticline westerly overturned, covered on both slopes by Triassic dolomites, which overlay the Formation with *Apychus*.

Firstly, our research brings important contributions to the mineralogical content of the petrographic types which form the crystalline formations of Dămuc Series. Secondly, the palynological and palynostratigraphical studies document – based on the rich acritarch and chitinozoan assemblages separated from the studied samples (Table 1) – the stratigraphical interval when the initial sedimentary rocks deposited (pre-Tremadocian–Upper Arenigian). Therefore, the age of the rocks from Dămuc Series is Lower Ordovician (Tremadocian – Arenigian).

Subsequently, the metamorphic process took place during the Caledonian Orogenesis, starting with the Saard Phase (Cambrian – Tremadocian), continuing with the Taconic Phase (Upper Ordovician) and probably ending with the Ardenian Phase (Upper Silurian).

This conclusion is based on the radiometric age of 415 and 420 M.y., established by Mureşan *et al.* (1974) on samples coming from Arşiţa Almaşului (Mâţului) Brook. As the radiometric data indicate the influence of the last metamorphic event, this exactly corresponds to the Ardenian Phase (Upper Silurian). However Silurian deposits are missing on Arşiţa Almaşului (Mâţului) Brook and thus they were probably eroded. Balintoni (1997) considers that the metamorphism which affected the Ordovician formations belongs to the Cadomian Orogeny, which affected all pre-Varistic terrains from the Eastern Carpathians, having a peri-Gondwana origin (Munteanu, Tatu, 2003). It seems to us that the assignment of the Caledonian Orogeny to the Lower Paleozoic metamorphism from the Eastern Carpathians (Balintoni, 1997) is improper because the Caledonian Orogeny is revealed only at the joints of the Avalonian terrains from Baltica and Laurentia and at the Laurentia-Baltica collision line. The succession of metamorphic phases and the dynamics of the regional metamorphism which affected the initial sediments determined the amalgamation of the petrographic and palynological constituents, as compared with their initial deposition characteristics.

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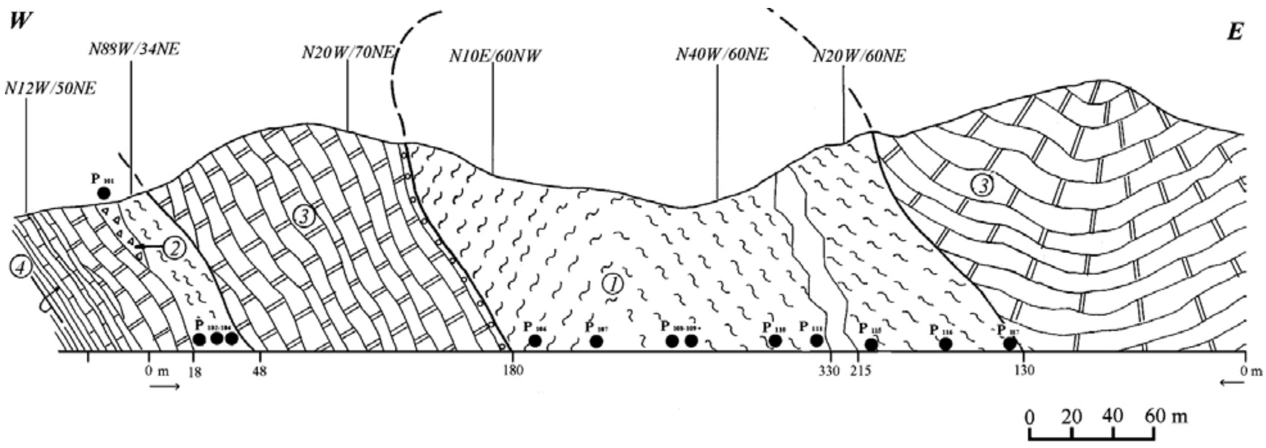

Fig. 1 - Geological cross-section in the crystalline unit of Dămuc Series, on Arşiţa Almaşului Brook. 1. Dămuc Series; 2. Hăghimaş Breccia (Permian); 3. Conglomerates, sandstones, dolomites (Triassic); 4. Formation with Aptychus (Upper Jurasic); 5 (●) Analyzed samples.

BRIEF GEOLOGICAL AND STRUCTURAL CHARACTERIZATION

Dămuc Series was described for the first time by Mureşan *et al.* (1974), being placed at the southern extremity of the crystalline spur of Dămuc (Dămuc "ridge"), which borders eastwards the northern half of the Mesozoic formations area of Hăghimaş Syncline. The crystalline of Dămuc Series consists of a monotonous succession of sericitous-muscovitic, weakly graphitic schists, with biotite and garnets. According to Mureşan *et al.* (1974), the petrographic characteristics of these crystalline schists differentiate them from both the mesometamorphites of Bretila-Rarău Group, which uncomformably cover them, and from the epimetamorphites of Tulgheş Group, which overthrust both the previously-mentioned units.

The authors also mentions that, besides the presence of micaschists, the Dămuc Series also shows finer crystallinity of the consisting minerals (muscovite, sericite, biotite). Additionally, the series evidenced two blastesis stages, sustained by the presence of a sericitous-quartzitic schistous, weakly graphitic mesostage, which subsequently was covered by muscovite, biotite and garnets. The second recrystallization phase is sustained by the transversal disposition of biotite and muscovite against the rock schistosity, as well as by the random disposition of the lamellas of the same minerals against the primary microfolds of the sericitous-quartzitic mesostage. According to Balintoni (1997), the minerals that are transversely disposed as compared to the main Varistic schistosity are not newly developed, but they represent relicts, being sectioned by the new foliation.

The investigated rocks were described on Arşiţa Almaşului Brook (see maps) or on Mâţului Brook (local name), where the stratotype section was defined.

The crystalline schists appear in the anticline buttonhole bordered by Triassic dolomites. Dămuc crystalline unit was also mentioned in the basin of Strungile Brook, in the upper basin of Lipichieşului Brook and in the northern slope of Ţepeşeni Valley. In these areas it also uncomformably overlays the mesometamorphites of Bretila-Rarău Group; together the two units overthrust Tulgheş Group, which represents the pre-Alpine Rarău Nappe. This tectonic situation results from the general overthrusting tectonic frame of Bretila terrains over the Rebra-Tulgheş depositional sequences, which explains the Paleozoic amalgamation phenomena of Gondwanaland terrains as well as those affecting the East-European Craton (Munteanu, Tatu, 2003).

Our field investigations took place in the stratotype geological section from Arşiţa Almaşului (Mâţului) Brook, left tributary of Dămuc Brook, upstream Huisurez locality, where the crystalline of Dămuc Series represents the core of an anticline westerly overturned, covered on both slopes by the Triassic dolomites which stand on the top of the Formation with *Aptychus* (Figure 1).

As it is shown in Figure 1, west from the anticline core, a longitudinal fault reveals the crystalline rocks of the same series, as a narrow strip; there a small strip from Hăghimaş Breccia, which normally is overlaid by the Triassic dolomites, is preserved.

In the studied geological section from Arşiţa Almaşului (Mâţului) Brook, the crystalline schists of this series are characterized by an advanced schistosity and a marked black colour, with metallic tint. The black metallic greasy colour of the rocks probably represents the effect of mineralization with iron sulphides polymorphs; these also cover the initially deposited palynomorphs, conferring them under the microscope an opaque or a bright-metallic lustre. This phenomenon, besides the thermal and dynamic metamorphism that affected the entire lithological assemblage, also determined changes in the initial general aspect and sizes of the palynomorphs (acritachs and chitinozoans), in comparison to the common ones in sedimentary deposits unaffected by metamorphism. The quartz enrichment determines brittleness contrasts at different levels between the rather though sequences (up to 1 m thick), and the plastic-schistous background of the whole series.

In the field, the lithological succession seems to be monotonous from petrographic point of view, and the microscopic analysis indeed indicates some common characteristics for this whole series, though there is a clear variation. Therefore, all the analyzed rock samples (12 samples) have a quartzitic background, with more or less pronounced schistosity, conferring a granular-blastic structure. The schistosity is often marked by the arrangement of muscovite, biotite, sericite and chlorite, and also by the disposition of the graphitic material. Given the granoblastic structure, minerals are randomly dispersed in the quartzitic matrix.

The microscopic study distinguished the following petrographic types: graphitic quartzitic-muscovitic schists with biotite (samples 102); quartzitic schists with biotite and garnets (sample 104); muscovitic-biotitic quartzitic schists with garnets (sample 107); quartzitic chloritic-graphitic schists (sample 106); quartzitic-sericitic-graphitic schists with biotite (samples 110, 114); quartzitic-sericitous schists with muscovite and garnets (sample 115); calcite-chloritic-graphitic quartzites (samples 109); quartzites with biotite and zoisite (sample 117); and feldspar-biotitic quartzites with sericite and garnets (sample 105) (Figure 1).

In the case of some varieties, the retromorphic character of chlorite after biotite is obvious.

As mentioned above, in these rocks the quartzitic mass is prevalent; in the schistous varieties the micaceous minerals alternate with stripes of graphitic material. Garnets are fissured and often included in micaceous minerals. Polysynthetically twinned plagioclase feldspars, as well as orthoclase were also indentified, the last ones being widely developed and presenting sericite inclusions.

PALYNOLOGICAL DATA AND PALYNOSTRATIGRAPHICAL CORRELATION

The acritarch and chitinozoan content represents an important argument for the characterization of the evolution of the included organic marine matter, as well as for the evolution of the environmental conditions during the deposition of the initial sediments of Dămuc Series.

From the beginning, we have to mention that both acritarchs and chitinozoans included in the initial sediments deposited in the marine basin have been, previously to their fossilization, morphologically modified due to dynamic sedimentation and then to metamorphism, which affected both the mineral and the organic fractions of the initial sediments. Therefore, at present, both acritarchs and chitinozoans present some specific originary morphological elements, but also some modified ones, especially concerning sizes and shapes. The changes are, mainly due to the rolling process, but also to the movements during sedimentation, and, secondly, due to dehydration, mineralization and again to the rolling process during the metamorphism.

Therefore, the temperature and pressure conditions from the ore, beside the dynamic phenomena during sedimentation and metamorphism phases are the main causes for the transformation suffered by the polymorphs included in the initial sediments.

In the initial marine basin, beside acritarchs and chitinozoans, other marine organisms such as conodonts, graptolites and trilobites lived, which are very good biostratigraphical markers. Unfortunately, in the metamorphosed sediments from the Eastern Carpathians, thus also in those from Dămuc Series, these faunistic organisms were not preserved mainly as result of dynamic metamorphism. In exchange, these faunas are present in similar platform sediments which were not disturbed by tectonics and metamorphism.

Acritarchs and chitinozoans are preserved in the metamorphic rocks due to their micrometric dimensions and also to the resistance of their external membrane and cellular walls at relatively higher temperatures and pressures during fossilization and, subsequently, metamorphism. In present, these acritarch and chitinozoan assemblages represent markers for biostratigraphical correlations with similar assemblages from the sedimentary environments unaffected by craton or platform metamorphism, where the above mentioned faunistic marine organisms were also preserved.

Therefore, regional biostratigraphical correlations between the microorganism assemblages from the metamorphosed geological environments with the similar ones from the non-metamorphosed sedimentary environments can be done, and accordingly between them and the marker-biozones of the faunas with conodonts, graptolites and trilobites.

ACRITARCH ASSEMBLAGES AND BIOSTRATIGRAPHICAL CORRELATION

The general assemblage resulted from the analysis of the 12 yielded samples from Dămuc Series includes an interference of genera and species typical for more subordinated assemblages, characteristic for the Middle Cambrian-Arenigian interval (Table 1).

Table 1 - Range chart showing stratigraphical distribution of acritarch and chitinozoan assemblages of Dămuc Series, Eastern Carpathians, Romania

Taxonomic units	Analyzed samples											Chronostratigraphy			
	107	108	109	111	106	116	117	104	105	102	101	Middle Cambrian	Upper Cambrian	Tremadocian	Arenigian
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Acritarchs														
Izhoria angulata GOLUB & VOLKOVA		X		X					X		X				
Cristallinium ovillense (CRAMER & Diez) Martin	X	X	X			X	X			X	X				
Leiosphaeridia sp.			X	X		X			X	X	X				
Cristallinium cambriense (SLAVIKOVA) VANGUESTAINE	X	X	X	X	X	X		X	X		X				
Lophodiacrodium valdaicum DEFLANDRE ET DEFLANDRE -					X				X		X				
Cymatiogalea sp. aff. *C. cuvillieri* (DEUNFF) DEUNFF								X		X	X				
Lunulidia lunula EISENACK		X						X	X		X				
Ovullum.cf.*O.saccatum*									X	X					

Ooidium rossicum TIMOFEEV		X						X			
Poikilofusa squama (DEUNFF) MARTIN	X	X	X		X		X	X	X		
Trachydiacrodium coarcuatum TIMOFEEV					X			X	X		
Micrhystridium sp.								X	X		
Timofeevia pentagonalis (VANGUESTAINE) VANG.		X						X			
Cymationgalea velifera (DAWNIE) MARTIN								X			
Buedingiisphaeridium tremadocum RASUL	X	X	X			X		X	X		
Leiofusa stoumonensis VANGUESTAINE								X	X		
Poikilofusa sp.	X							X			
Baltisphaeridium sp.								X			
Veryhachium sp.								X			
Eliasum llaniscum FOMBELLA	X							X			
Nellia magna VOLKOVA		X						X	X		
Vulcanisphaera sp.									X		
Pirea orbicularis VOLKOVA		X			X				X		
Trachysphaeridium annolovaense TIMOFEEV									X		
Navifusa navis (EISENACK) COMBAZ									X		
Cristallinium sp. *C. locale* VOLKOVA									X		
Volkovia sp.									X		
Cristallinium locale VOLKOVA		X			X				X		
Acanthodiacrodium timofeevi GOLUB ET VOLKOVA									X		
Trachydiacrodium signatum TIMOFEEV	X	X	X			X	X		X		
Dasydiacrodium palmatilobus TIMOFEEV									X		
Coryphidium bohemicum VAVRDOVA			X						X		
Acanthodiacrodium angustum (DOWNIE) COMBAZ	X	X	X	X	X	X			X		
Acanthodiacrodium lanatum (TIMOFEEV) MARTIN		X							X		
Saharidia fragilis (DOWNIE)	X	X			X				X		
Schizodiacrodium armatum VOLKOVA		X							X		
Dactylofusa velifera COCCHIO		X									
Veryhachium dumontii VANGUESTAINe	X	X	X	X	X	X	X				
Cristallinium baculatum VOLKOVA		X									
Cristallinium randomense MARTIN		X	X	X		X					
Dactylofusa squama (DEUNFF) MARTIN	X	X									
Dasydiacrodium cf. *caudatum* VANGUESTAINE		X									
Acanthdiacrodium golubii FENSOME ET ALL.		X									
Navifusa sp.		X									
Pirea sp.		X									
Timofeevia janischewskyi (TIMOFEEV) VOLKOVA		X									
Acanthodiacrodium simplex COMBAZ	X		X								
Baltisphaeridium longispinosum	X	X									

Retisphaeridium dichamerum Stapl., Jans. & Pocock	X		X			X	X								
Cymatiogalea trevisanii (Di Milia & Tongiorgi)			X			X									
Cymatiogalea cuvillieri (Deunff) Deunff			X			X									
Cristallinium dentatum (Vavrdova)			X			X	X								
Coryphidium elegans Vavrdova			X												
Polygonum martinae Mocz. & Crimes			X												
Polygonum dissimilare Volkova			X												
Acanthodiacrodium sp.		X	X	X											
Acrum aff. *cylindriferum* Downie				X											
Stelliferidium sp.				X											
Stelliferidium cf. *S. stelligerum* (Gorka) Deunff et all.				X											
Timofeevia phosphoritica Vanguestaine				X											
Timofeevia lancare (Cramer & Diez) Vang.						X									
Timofeevia aff. *T. phosphoritica* Vanguestaine						X									
	Chitinozoans														
Conochitina symmetrica Taugourd.& De Jekhowsky			X						X	X					
Lagenochitina combazi Finger										X					
Desmochitina bulla Taugourd. et De Jekhowsky		X	X	X					X	X					
Rhabdochitina sp.		X				X				X					
Lagenochitina sp.								X							
Lagenochitina cf. *L. combazi* Finger		X						X	X						
Rhabdochitina cf. *Rh. gallica* Taugourdeau			X	X				X							
Conochitina sp.								X							
Desmochitina sp.								X							
Conochitina cf. *C. symmetrica* Taugourd. et De Jekhowsky		X	X					X							
Fustichina grandicula Achab		X							X						
Lagenochitina esthonica Eisenack		X	X	X		X			X						
Lagenochitina spinatostoma Soufiane & Achab		X													
Conochitina raymondii Achab		X													
Rhabdochitina magna Eisenack		X		X		X									
Eremochitina tremadoca Taugourd. et De Jekhowsky		X													
Fustichitina sp. cf. *F. grandicula* Achab		X													
Conochitina decipiens Taugourd. et De Jekhowsky			X		X										
Lagenochitina destombesi Elaouad-Debbaj	X		X				X								
Lagenochitina brevicollis Taugourd. et De Jekhowsky	X		X	X											
Euconochitina brevis (Taugourd. et De Jekhowsky)			X												
Cyathochitina sp.			X												
Rhabdochitina sp. cf. *R. magna* Eisenack			X			X									
Rhabdochitina tubularis Umn.				X		X									

We have to mention here that acritarchs, as planktonic marine organisms, have evolved in relatively longer stratigraphical intervals, not being strictly limited and characteristic for short time periods. However, a few acritarchs are indeed characteristic for shorter time periods (Table 1). For example, from the total of 62 taxa determined in the analyzed samples, only 13 taxa (20.96 %) are characteristic for Upper Cambrian, 12 taxa (19.35 %) for Tremadocian and only 3 taxa (4.83%) for Arenigian.

Further, we can show that in total only 28 taxa (45.15 %) are specific for shorter stratigraphical intervals. The rest represent organisms with an extended stratigraphical character, which lived together with the characteristic ones in the marine planktonic core and they were deposited together in the initial sediments.

From the above presented statistics, it stands out that the main time or the peak of the sedimentation of the acritarch organisms took place between Upper Cambrian and Tremadocian.

The typical acritarch assemblage for Upper Cambrian includes the following taxa: *Lophodiacrodium valdaicum*, *Ooidium rossicum*, *Leiofusa stoumonensis*, *Baltisphaeridium* sp., *Veryhachium* sp., *Trachysphaeridium annolovaense*, *Navifusa navis*, *Acathodiacrodium timofeevi*, *Dasydiacrodium palmatilobum*, *Veryhachium dumontii*, *Dasydiacrodium caudatum*, *Nellia magna*, and *Vulcanisphaera* sp. (Table 1).

These taxa are associated with others which "originate" from the Middle Cambrian, but which developed and characterize better the Upper Cambrian. As examples, we can mention the following taxa: *Cristallinium cambieense*, *Ovulum* sp. *cf. O. saccatum*, *Micrhystridium* sp.,*Timofeevia pentagonalis*, *Elliasum llaniscum*, *Pirea orbicularis*, *Cristallinium locale*, *Cristalliunium* sp. *cf. C. locale*, *Volkovia* sp., *Timofeevia janischewskyi*, *Timofeevia phosphoritica*, and *T. lancare* (Table 1).

Many of these taxa were also encountered in the upper formation (Tg4) of Tulgheş Group from Bălan and Sândominic area, Eastern Carpathians (Olaru, 2005; 2008). The presence of numerous acritarch species in the assemblages from Newfoundland region (Random Island) in Canada (Parsons and Anderson, 2000) offered us the possibility to palynostratigraphically compare and correlate. In this region, 5 zones and subzones with trilobites, corresponding to the acritarch zones marked as RA4-RA10 were established for the Upper Cambrian–Lower Tremadocian interval.

Considering their content, our acritarch assemblages are comparable with the assemblages of the zones marked as RA4, RA6-RA9, equivalent to the trilobites zones with *Parabolina spinulosa* (RA4), *Peltura scarabeoides* (RA6, RA7), and *Acerocare* (RA8, RA9).

Beside the above mentioned acritarch assemblage, we have also to mention the assemblage that extends in the Tremadocian, with: *Izhoria angulata*, *Cristallinium ovillense*, *Cymatiogalea angulata* sp. *aff. C. cuvillieri*, *Trachydiacrodium coarcuatum*, *Buedingiisphaerdium tremadocum*, *Acanthodiacrodium lanatum*, *Schizodiacrodium armatum*, *Acanthodiacrodium angustum*, *Saharidia fragilis*, *Cristallinium randomense*, *Acanthodiacrodium golubii*, and *Stelliferidinium* sp. (Table 1). This latter acritarch assemblage is equivalent to the graptolite zone with *Rhabdinipora flabelliformis* (Lower Tremadocian). We could correlate this zone, which continues with the one with *Acerocare* (trilobite) corresponding to the Upper Cambrian–Tremadocian interval with the upper part of Moscow Syneclise and with the basal area of OT1 assemblage from Estonia (East-European Platform). There it represents a faunistic conodont correlation zone, i.e. the *Cordylodus andresi* zone. For this correlation level, from our assemblage we can mention the following acritarch species: *Poikilofusa squama*, *Ooidium rossicum*, *Saharidia fragilis*, *Acanthodiacrodium golubii*, *A. lanatum*, *Cristallinium cambriense*, *Cymatiogalea cuvillieri*, *C. velifera*, and *Izhoria angulata* (Table 1). In our case, the entire Tremadocian is represented by a characteristic assemblage including: *Acanthodiacrodium angustum*, *Buedingiisphaeridium tremadocum*, *Dactylofusa squama*, *D. velifera*, *Lunulidia lunula*, *Polygonum martinae*, *P. dissimilare*, and *Stelliferidium* sp. This assemblage corresponds both to the zone with *Acerocare* and to the one with *Rhabdinipora flabelliformis*, and also to the OT1 and OT2 assemblages from Estonia, which characterize the interval between *Cordylodus proavus* and *C. intermedius* (conodonts). Some acritarch species: *Coryphidium bohemicum*, *C. elegans* (specific for Prague Basin), *Acanthodiacrodium lanatum*, *A. angustum* (cosmopolite species), *Dactylofusa squama*, *Saharidia fragillis*, *Leiosphaeridia* sp., *Acanthodiacrodium golubii*, or *Baltisphaeridium longispinosum* (Table 1) extend beyond the Tremadocian, being also characteristic for the Arenigian. These species were mentioned in all the characteristic assemblages – OT1, OT2, OT3 in the Baltic Sea area in Estonia, as well as in typical assemblages such as UC4B and UC4B-1 from Moscow Syneclise. They correspond to the zone with *Rhabdinipora flabeliformis*, to the conodonts zones *Cordylodus lindstroemi* and *Cordylodus rotundatus – Cordylodus angulatus*, and also to the trilobites zone *Clonograptus – Didimograptus*.

If we analyze the Mediterranean area, there is also the possibility to make interesting correlations. For the Tremadocian of the central area of Sardinia, in Solanas Sandstone Formation, Albani *et al.* (1985) mention an interesting acritarch assemblage for the Cambrian–Ordovician interval, with the following characteristic species: *Acrum* sp. *aff. A. cylindriferum*, *Acanthodiacrodium angustum*, *Timofeevia lancare*, *T. phosphoritica*, *Buedingiisphaeridium tremadocum*, *Coryphidium elegans*, *C. bohemicum* (specific for Arenigian), *Leiosphaeridia* sp., *Micrhystridium* sp., *Volkovia* sp., *Dactylofusa velifera*, and *Stelliferidium stelligerum* (Table 1). Modern studies in the same Mediterranean area (Central Sardinia, Solana Sandstone Formation), Di Milia A. & Tongiorgi M. (1993) bring new completions with acritarch species that complete the Tremadocian assemblage: *Cymatiogalea cuvillieri*, *Cymatiogalea trevisanii* (sp. nov.), *Veryhachium dumontii*, *Dasydiacrodium caudatum*, *Leiofusa stoumonensis*, *Retisphaerdium dichamerum*, *Timofeevia phosphoritica* (Table 1). Finally, in an older study on Tremadocian from Hassi-Messaoud drilling in Sahara, Combaz (1967), one of the first researchers in the field, indicated a rich acritarch assemblage, from which we selected the following for the sake of correlation: *Saharidia fragilis*, *Acanthodiacrodium angustum*, *Acanthodiacrodium* sp., *Cymatiogalea cuvillieri*, and *Dactylofusa squama*. All these acritarch assemblages from Sardinia and Sahara (Mediterranean area) are also found in our assemblage from Dămuc Series (Table 1), being correlated with the stratigraphical interval Upper Cambrian–Tremadocian–Arenigian. The same conclusion also could be drawn for Newfoundland (Canada) and East-European Platform (the littoral area of the Baltic Sea and Moscow Syneclise) regions, where the palynostratigraphical correlation with the acritarch biozones also could be compared with the conodonts, graptolites and trilobites faunistic biozones.

CHITINOZOAN ASSEMBLAGES AND BIOSTRATIGRAPHICAL CORRELATION

Chitinozoans are microscopic marine organisms that form the zoobenthos. Their basic chitinous constitution and their rapid evolution in a short stratigraphical interval provide them with valuable characteristics for being index fossils. Therefore, they may be used as correlated biozones both with the conodonts, graptolites and trilobites faunistic biozones, and with the acritarch (vegetal microorganisms) ones. The chitinozoans especially characterize the Ordovician, the first species occurring at the limit between the Cambrian and the Ordovician. They are also present with characteristic species during the Devonian, but showing an evolutive decline.

The chitinozoan assemblage established based on study of the 12 samples from Dămuc Series includes 24 taxa with species coming from genera such as: *Conochitina*, *Lagenochitina*, *Desmochitina*, *Rhabdochitina*, *Fustichitina*, *Eremochitina*, *Euconochitina*, or *Cyathochitina*.

As in the case of acritarchs, the chitinozoan organisms were modified during sedimentation and metamorphism by: dehydration leading implicitly to significant sizes decrease; by pressure, resulting in flattening or fragmentation of the individuals; by dynamic action, leading to erosion and breaking by dragging and rolling - all factors that finally determined the reduction of the number of individuals and the fragmentation of the already existent ones. In spite of all these, large numbers of organisms were separated and analyzed, thus making them available for palynostratigraphical correlations. The chitinozoan assemblages offered numerous marker-species for determining the biozones in the areas of Laurentian Shield (Canada), Baltic Shield, East-European Platform, Bohemia, South-West Europe, Gondwanaland (Sahara) as well as in Australia, Siberian Platform and Sinian Shield. This large horizontal spreading during a short stratigraphical interval, with a rapid evolution, offers them an important value as specific marker-organisms. Statistically, the analyzed samples from Dămuc Series (excluding sample 101 – barren), the age repartition (%)of the 24 determined taxa is the following:

- Tremadocian and Lower Arenigian – 2 taxa – 8.33 %;
- Lower Arenigian – 9 taxa – 37.50 %;
- Arenigian – 12 taxa– 50 %;
- Upper Arenigian – one taxon – 4.16 %.

From the beginning, we considered that 50 % of the determined taxa characterize Arenigian in its whole; when adding specific taxa for the lower and the upper part of the Arenigian, the total percentage for this stage is 91.66 % (Table 1).

An important preliminary observation is the presence of species *Lagenochitina destombesi*, characteristic for the Tremadocian, and *Eremochitina tremadoca*, characteristic for the Tremadocian and the Lower Arenigian (Table 1).

- *Lagenochitina destombesi* is spread in the northern area of Gondwanaland, where it constitues a specific biozone equivalent to the graptolite zone *Rhabdinipora flabelliformis* (Paris, 1992). It was mentioned in the Ordovician chitinozoan fauna from Rügen Island (Samuelson, Vernier & Vecoli, 2000), also included before in our discussion on the acritarch assemblages. In Romania, this species has been also identified in other studied areas from the Eastern Carpathians (Olaru, 2005; Olaru, 2008; Olaru, Apostoae, 2004; Olaru, Apostoae, Apostoae, 2003-2004), such as the upper formation (Tg4) of the Tulgheş Group in Bălan-Sândominic area.

- *Eremochitina tremadoca* was mentioned as new species for Tremadocian in Hassi-Messaoud drilling (Combaz, 1967) from Sahara, being specific for the stratigraphical interval Tremadocian–Lower Arenigian.

- *Conochitina symmetrica* appears in many of the analyzed samples from Dămuc Series (Table 1). It is characteristic for the Lower Arenigian from Gondwanaland and the Laurentian Shield (Achab, 1980; 1986; Paris, 1992). It was firstly found in Klabava Formation (Prague Basin, Bohemia) by Paris and Mergl (1984), being equivalent to the graptolites biozones *Clonograptus* and *Tetragraptus approximatus*. In the same formation, an acritarch assemblage equivalent in age with "*messaoudensis trifidum*" was separated, which also includes species *Coryphidium bohemicum* (Lower Arenigian), separated by us in Dămuc Series and in the upper formation (Tg4) of Tulgheş Group, Eastern Carpathians (Olaru, Apostoae, Apostoae, 2003-2004; Olaru, Lazăr, 2005).

In the Baltic region *Conochitina symmetrica* is missing, but within this biozone equivalent species are present: *Lagenochitina esthonica* and *L. raymondii*, correlated with the conodont biozone *Prionodus elegans*, species which we have also separated in Dămuc Series and in the upper formation (Tg4) of the Tulgheş Group in Bălan-Sândominic area, Eastern Carpathians (Olaru, 2005, 2008; Olaru, Apostoae, 2003; Olaru, Apostoae, Apostoae, 2003-2004). From the Lower Arenigian we have separated more species, among which: *Fustichitina grandicula*, *Lagenochitina spinatostoma*, *Rhabdochitina magna*, and *Rh. tubularis* etc. (Table 1), which were previously separated in the Eastern Carpathians from the Tg4 Formation of Tulgheş Group, as well as in other typical areas such as: Quebec, Terra Nova (Canada), Sahara, Baltic, South-West Europe, Russia, Australia and China. In Northern Gondwanaland and in China the biozone with *Conochitina symmetrica* is equivalent to the zone of graptolite *Didimograptus deflectus*; in the Russian Platform it was mentioned for the Lower Ordovician (Umnova, 1967).

- *Desmochitina bulla* represents another species typical for the biostratigraphy of Lower Ordovician. This species characterizes Upper Arenigian (Table 1), at the limit with Llanvirnian. It was separated in Klabava Formation from Bohemia (Paris, Mergl, 1984) and it corresponds to the zone with *Didimograptus artus* graptolite. It was also mentioned as upper limit marker-species for Arenigian, in the lithological formations with normal succession in Gondwanaland and in the Baltic area (Paris, 1981, 1996); in Tadla Basin from Morocco, Sahara (Soufiane, Achab, 1993), and in other localities from the Baltic region, Bohemia and Russia (Achab, 1982, 1991).

We separated this species in the analyzed samples from Dămuc Series as well as in the upper formation (Tg4) of Tulgheş Group, Eastern Carpathians, in Bălan-Sândominic area (Olaru, 2005, 2008; Olaru, Apostoae, 2003; Olaru, Apostoae, Apostoae, 2003-2004).

Beside this marker-species for chitinozoan biozones characteristic for the lower and the upper limit of the Arenigian, the chitinozoan assemblage separated from Dămuc Series also includes other species which characterize the entire Arenigian, and which also were mentioned in other areas in Romania and worldwide: *Lagenochitina combazi* (Tg4 Eastern Carpathians; Australia, Quebec, Terra Nova), *Rhabdochitina gallica* (Montagne Noire, France), *Conochitina decipiens* (Tg4 Eastern Carpathians, Sahara, Quebec, Terra Nova), *Lagenochitina brevicollis* (Tg4 Eastern Carpathians; Montagne Noire, France), and *Euconochitina brevis* (Tg4 Eastern Carpathians; Montagne Noire, France). Also, other species such as: *Fustichitina* sp., *Rhabdochitina* sp., *Lagenochitina* sp., *Conochitina* sp., or *Desmochitina* sp. could be added, which accompany the other determined species and which complete the typical assemblage for Arenigian. Because of the presence of the two species typical for Tremadocian (*Lagenochitina destombesi* and *Eremochitina tremadoca*) enclosed to an Arenigian specific assemblage, where also marker-species for Lower Arenigian and Upper Arenigian stand out, we considered that they define the age of the sediments where they were deposited, i.e. Tremadocian-Arenigian.

CONCLUSIONS

- Dămuc Series from Arşiţa Almaşului (Mâţului) Brook is represented by crystalline schists, which are disposed as an anticline with western slopes, flanked by Triassic dolomites, with a clear display on the top of the Formation with *Aptychus*.

- The crystalline unit of Dămuc Series represents a monotonous succession of sericitous-muscovitic crystalline, weakly graphitic schists, with biotite and garnets.

- The petrographic and mineralogical characteristics of these schists differentiate them from both the mesometamorphites of Bretila-Rarău Group, and the epimetamorphites of Tulgheş Group, Eastern Carpathians.

- From structural point of view, the crystalline unit of Dămuc Series uncomformably stands on the top of the mesometamorphites of Bretila-Rarău Group; together the two formations are overthrusting the epimetamorphites of Tulgheş Group, within Rarău Nappe.

- The initial sedimentation of the rocks which form the crystalline of the Dămuc Series took place in the pre-Tremadocian and Upper Arenigian interval.

- The metamorphosis of the initial sediments took place in several stages, during the Caledonian Orogenesis, probably starting with the Saard phase, continuing with the Taconic phase (the most important and the most definitive) and ending with the Ardenian phase.

- The absolute ages established by K-Ar method show values of 415 and 420 M.y. (Mureşan *et al.*, 1974), corresponding to the Ardenian phase at the end of Silurian. However Silurian sediments were not preserved, probably being eroded.

- Palynologically and palynostratigraphically, the yielded and analyzed samples from Dămuc Series offered a rich acritarch and chitinozoan assemblage.

- The acritarch rich assemblage (planktonic organisms) recorded a sedimentation peak during the stratigraphical interval Upper Cambrian–Tremadocian (46.76 % of the organisms), and Tremadocian–Arenigian (a drop down to 30.62 % of the organisms).

- Considering the acritarch contribution, the palynostratigraphical age of the sediments is Tremadocian–Arenigian.

- The chitinozoan (benthic organisms) assemblage is poorer; most of the organisms (50 %) point to an Arenigian age.

- Chitinozoans offered marker-taxa for Tremadocian (*Lagenochitina destombesi*), for Lower Arenigian (*Conochitina symmetrica* and *C. esthonica*) and for Upper Arenigian (*Desmochitina bulla*).

- These taxa besides other ones represent biostratigraphical markers for biozones specific for the stratigraphical interval Tremadocian–Upper Arenigian; this can be correlated with the faunistic zones with conodonts, graptolites and trilobites, and with the equivalent acritarch biozones from different regions worldwide: Quebec, Terra Nova, Canada, Baltic Sea region, East-European Platform, Sahara, South-West Europe etc.

- The age of the chitinozoan assemblage is Tremadocian–Arenigian which correlates well to that given by the acritarch assemblage, both representing the age of the initial sediments of Dămuc Series.

- Based on the palynostratigraphical results, Dămuc Series can be correlated with the upper formation (Tg4) of Tulgheş Group, Eastern Carpathians and with the sedimentary regions, tectonically not affected, from the Laurentian Shield, Baltic Shield, East-European Platform, Gondwanaland and Sinian Shield.

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PLATES

PLATE I-

1. *Fustichitina* cf. *grandicula* ACHAB, sample no. 102, Arenigian
2. *Lagenochitina destombesi* ELAOUAD – DEBBAJ, sample no. 109, Lower Tremadocian–Upper Tremadocian
3. *Lagenochitina esthonica* EISENACK, sample no. 109, Lower Arenigian
4. *Lagenochitina* cf. *combazi* FINGER, sample no. 106, Arenigian
5. *Lagenochitina esthonica* EISENACK, sample no. 108, Lower Arenigian
6. *Lagenochitina* cf. *combazi* Finger, sample no. 105, Arenigian
7. *Desmochitina bulla* TAUGOURDEAU & DE JEKHOWSKI, sample no. 104, Upper Arenigian
8. *Lagenochitina destombesi* ELAOUAD – DEBBAJ, sample no. 106, Lower Tremadocian–Upper Tremadocian
9. *Conochitina symmetrica* TAUGOURDEAU & DE JEKHOWSKI, sample no. 105, Lower Arenigian
10. *Lagenochitina esthonica* EISENACK, sample no. 105, Lower Arenigian
11. *Conochitina decipiens* TAUGOURDEAU & DE JEKHOWSKI, sample no. 105, Lower Arenigian
12. *Conochitina raymondii* ACHAB, sample no. 109, Lower Arenigian
13. *Conochitina symmetrica* TAUGOURDEAU & DE JEKHOWSKI, sample no. 105, Lower Arenigian
14. *Conochitina decipiens* TAUGOURDEAU & DE JEKHOWSKI, sample no. 105, Lower Arenigian
15. *Conochitina decipiens* TAUGOURDEAU & DE JEKHOWSKI, sample no. 105, Lower Arenigian
16. *Conochitina symmetrica* TAUGOURDEAU & DE JEKHOWSKI, sample no. 109, Lower Arenigian
17. *Lagenochitina* cf. *combazi* FINGER, sample no. 108, Arenigian
18. *Lagenochitina esthonica* EISENACK, sample no. 108, Lower Arenigian
19. *Lagenochitina esthonica* EISENACK, sample no. 107, Lower Arenigian
20. *Lagenochitina decipiens* TAUGOURDEAU & DE JEKHOWSKI, sample no. 106, Arenigian
21. *Lagenochitina esthonica* EISENACK, sample no. 108, Lower Arenigian
22. *Rhabdochitina magna* EISENACK, sample no. 116, Lower Arenigian
23. *Conochitina symmetrica* TAUGOURDEAU & DE JEKHOWSKI, sample no. 109, Lower Arenigian

PLATE II

1. *Retisphaeridium dichamerum* STAPLIN, JANSONIUS & POCOCK, sample no. 117, Tremadocian.
2. *Stelliferidium* cf. *stelligerum* (GORKA) DEUNFF et al., sample no. 111, Upper Cambrian (*Peltura scarabeoides* Zone)–Tremadocian
3. *Pirea orbicularis* VOLKOVA, sample no. 105, Middle–Upper Cambrian
4. *Cristallinium cambriense* (SLAVIKOVA) VANGUESTAINE, sample no. 116, Upper Cambrian–Lower Tremadocian.
5. *Saharidia fragilis* (DOWNIE) COMBAZ, sample no. 102, Upper Cambrian (*Peltura* Zone to *Cordylodus proavus* Zone)–Tremadocian.
6. *Lophodiacrodium valdaicum* DEFLANDRE & DEFLANDRE – Rigaud, sample no. 101, Upper Cambrian, *Peltura* Zone.
7. *Cristallinium ovillense* (CRAMER & DIEZ) MARTIN, sample no. 107, Upper Cambrian–Tremadocian.
8. *Cristallinium randomense* (MARTIN) MARTIN, sample no. 105, Upper Cambrian–Tremadocian.
9. *Poikilofusa squama* MARTIN, sample no. 105, Tremadocian
10. *Cristallinium* cf. *cambriense* (SLAVIKOVA) VANGUESTAINE, sample no. 101, Upper Cambrian–Lower Tremadocian.
11. *Buedingiisphaeridium tremadocum* RASUL, sample no. 104, Upper Cambrian (*Peltura* Zone)–Tremadocian.
12. *Izhoria angulata* GOLUB & VOLKOVA, sample no. 111, Upper Cambrian (*Leptoplastus & Peltura* Zones to *Cordylodus proavus* Zone)–Lower Tremadocian.
13. *Trachydiacrodium coarcuatum* TIMOFEEV, sample no. 104, Upper Cambrian (*Peltura* Zone)-Lower Tremadocian.
14. *Acanthodiacrodium angustum* (DOWNIE) COMBAZ, sample no. 105, Upper Cambrian–Tremadocian.
15. *Cristallinium ovillense* (CRAMER & DIEZ) MARTIN, sample no. 101, Upper Cambrian (*Olenus – Parabolina* Zone)–Tremadocian.
16. *Vulcanisphaera* sp., sample no. 105, Upper Cambrian (*Peltura* Zone).
17. *Izhoria angulata* GOLUB & VOLKOVA, sample no. 105, Upper Cambrian (*Leptoplastus & Peltura* Zones to *Cordylodus proavus* Zone)–Lower Tremadocian.
18. *Acanthodiacrodium angustum* (DOWNIE) COMBAZ, sample no. 106, Upper Cambrian–Tremadocian.
19. *Leiofusa stoumonensis* VANGUESTAINE, sample no. 105, Upper Cambrian–Lower Tremadocian.
20. *Coryphidium* cf. *bohemicum* VAVRDOVA, sample no. 109, Arenigian.
21. *Leiofusa stoumonensis* VANGUESTAINE, sample no. 105, Upper Cambrian
22. *Trachydiacrodium signatum* TIMOFEEV, sample no. 109, Tremadocian.
23. *Veryhachium dumontii* VANGUESTAINE, sample no. 109, Upper Cambrian, (*Olenus – Parabolina spinulosa* Zone).
24. *Coryphidium elegans* VAVRDOVA, sample no. 109, Arenigian.
25. *Timofeevia* cf. *pentagonalis* (VANGUESTAINE) VANGUESTAINE, sample no. 108, Upper Cambrian–Lower Tremadocian.
26. *Poikilofusa* sp. cf. *Poikilofusa squama* (DEUNFF) MARTIN, sample no. 106, Tremadocian.

PLATE I

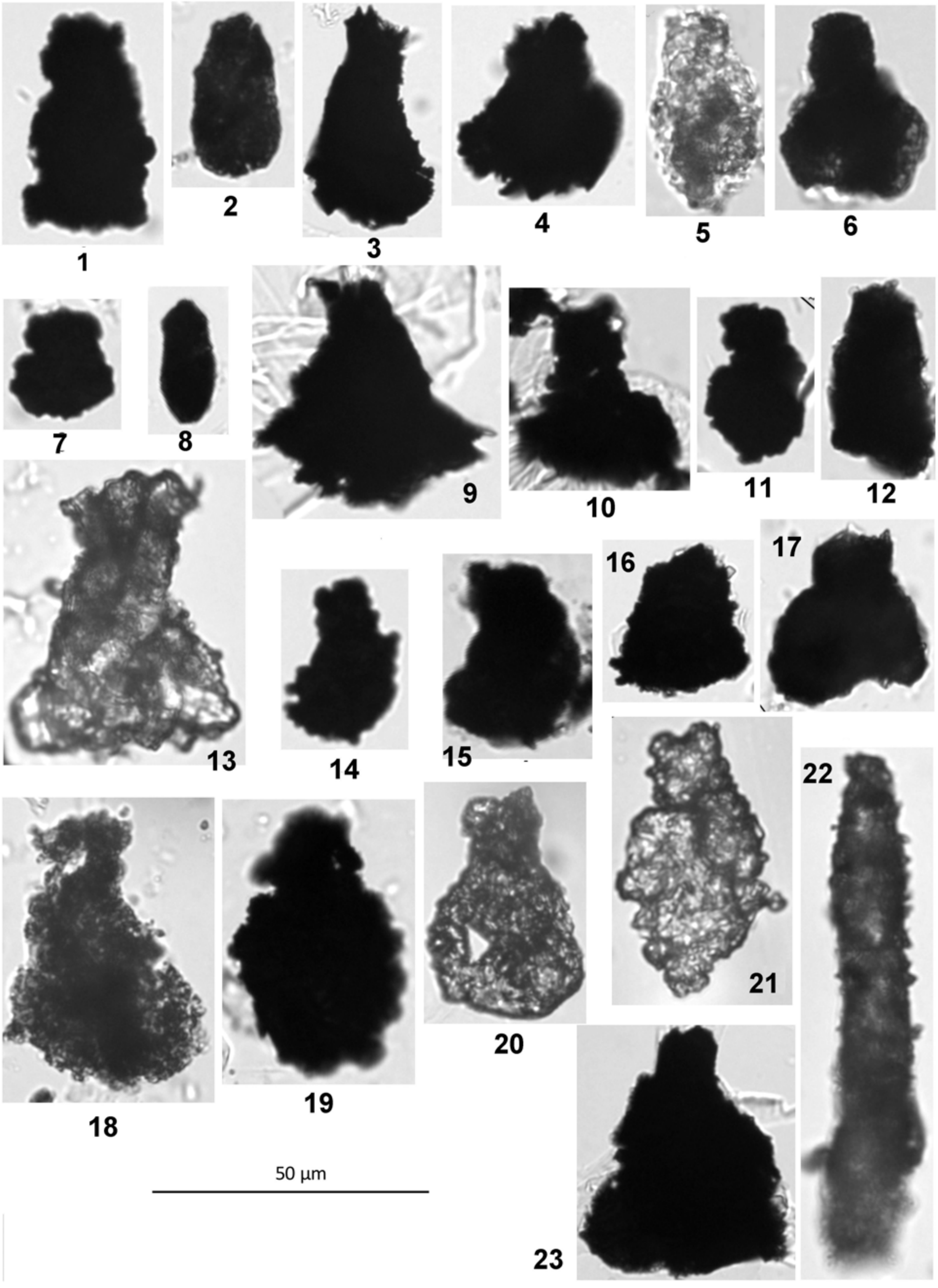

PLATE II