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Ichnological analysis of stratigraphic discontinuities of external flysch deposits

Ph.D. Thesis Summary

Scientific advisor:
Prof. Dr. Mihai Brânzilă

Ph.D. student:
Anca-Maria Anistoroae

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Contents

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INTRODUCTION

Considered „ludus naturae" and ignored for a long time, trace fossils produced both by invertebrates and vertebrates are used nowadays in *biostratigraphy* (as ichnostratigraphical markers for paleogeographical reconstructions), *paleontology* (as proof of metazoans evolution and behavior at Precambrian/Cambrian boundary), *paleoecology* (as biotic and paleoenvironmental features), *sedimentology* (as indicators of depositional processes) and *sequence stratigraphy* (as support for identification of stratigraphical discontinuities).

Ichnological analysis is a tool for recognition of stratigraphic hiatuses (erosional or non-depositional), for caracterisation of depozitional systems and also for identification of sequence stratigraphical surfaces by recognition of substrate-controlled ichnofacies or by employing detailed vertical analysis of trace fossils and sedimentary facies successions.

The pursuit of this thesis is to initiate the organism-sediment relationship studies of Outer Carpathians external flysch deposits, following international trends regarding the use of both ichnological and sedimentological analysis.

The main objectives are:

- Applying sedimentary facies analysis on unstudied deposits;
- Applying, for the first time, ichnological analysis to establish the organism-sediment relationship and also the discontinuities from sedimentary records.

We have framed the Vrancea Nappe from Outer Carpathians external flysch due to its area of deposition in Moldavide Basin, which was close to paleoshoreline and therefore the sea level rises or falls were best recorded in the sedimentary successions as discontinuity surfaces or depositional trends. From the Cretaceous -Miocene formations of Vrancea Nappe we selected for sedimentary and ichnological analysis Piatra Uscată Formation, red and green clays member of Bisericani Formation and gray-greenish clays member of Bisericani Formation.

In the first chapter – Ichnology – An integrated and integrative science we approached the global and local history of ichnology, integrated „in" and integrative „with" paleontology, sedimentology and sequence stratigraphy.

The idea of using ichnological data in paleoenvironmental analysis was employed centuries ago (XVIth century) when Leonardo da Vinci demonstrated the marine origin of Apennine's sedimentary succession (Baucon, 2008). It was needed for another four centuries of ichnological development in order to become a real instrument for paleoenvironmental analysis.

In the '70 Osgood stated the fact that we don't have yet a complete history of ichnology and the only person fit to the task might have been Walter Häntzschel, who was passed away at that time (Osgood and Frey, 1975). In the same paper Osgood remembered an earlier article (1970) where he separated the ichnological studies in three, more or less theoretical, sections: (1) *The Age of Fucoids* (until 1881) – during this time many trace fossils were described as fossil marine algae - "fucoids"; (2) *The Period of Controversy* (1881-1920) – when the vegetable origin of "fucoids" was seriously questioned; (3) The Development of the Modern Approach (1920 – present) – initiated by the work of Richter, continued by Seilacher and having a spectacular development in the last few years.

References on Romanian trace fossils are found in several papers published prior or after 1900. The oldest ichnological paper was published after mid XIXth century by Capellini (1868) who identified "macigne schistoso con fucoidi e *Paleodictyon*" in the Eocene sediments from Moinești (near Starchiojd, Subcarpathian Bend Area).

After Brustur (1997), the evolution of paleoichnological studies in Romania may be divided into three stages: (1) *the stage of "fucoids"* (1910-1955) - the time when different ichnospecies of chondritides were cited in Cretaceous-Paleogene Outer Carpathians flysch deposits; (2) *the stage of vertebrate footprints* (1960-1970) – with references regarding vertebrates trace fossils from Miocene molasse deposits from Moldova and Vrancea area (Panin, 1961, 1965), when was generated the first classification scheme for vertebrates footprints and new ichnospecies and ichnogenera were described (Panin & Avram, 1962; Panin & Ștefănescu, 1968); (3) *the stage of paleoichnological study revival* (after 1980) – from which we select resting traces of Permian amphibians(Brustur, 1997), Mezozoic tetrapoda tracks (Popa, 2000), the first Jurassic vertebrate burrows in Europe (Popa & Kedzior, 2006), early Jurassic dinosaur footprints described for the first time in our country (Pieñkowski, 2009), late Cretaceous dinosaur footprints from Transylvania region (Vremir & Codrea, 2002) and reinterpretation of Mammalian footprint described in 1927 by Popescu-Voitești (Brustur, 2012).

Until present, from Romanian formations were identified 179 ichnospecies of Cretaceus, Paleogene, Miocene vertebrates and invertebrates. Over 100 of them are new forms for our country, 13 of them are new for science (Brustur, 1997, 2007).

When they are used in conjunction with primary sedimentary structures, trace fossils become useful for facies and separation of facies associations. When ichnological behavior aspects are integrated with sedimentological and stratigraphical analysis, the result is a strong instrument for recognition and genetic interpretation of sedimentary record discontinuities (Pemberton *et al*., 2007).

For paleoenvironmental interpretation, trace fossils have two advantages: 1 – they are found always *in situ*, undisturbed by waves or other currents; 2 – the presence/absence of an ichnospecie or ichnogenus is completely controlled by the environment and not related to the age of the deposits (Stearn & Carroll, 1989).

The second chapter – Paleoenvironmental aspects deals with the organism behavior described by feeding strategies, the position relative to the water-sediment interface and the degree of mobility.

There are five major trophic groups: suspension feeders, detritus feeders (known as surface deposit feeders), deposit feeders (known as miners), grazers and predators. To those mentioned were added others feeding strategies as: trapping, farming, photo- and chemosymbiosis, but also parasitism (Buatois &Mangano, 2011).

The position in relation to the substrate-water interface is connected to (Bromley, 1996): the degree of substrate consolidation, food availability and oxygen content. The degree of substrate consolidation controls the substrate consistency on or within benthic communities are living (fluid, soft, firm, hard).

Six main positions can be recognized: pelagic (living in the water column as either plankton or nekton), erect (benthic, extending into the water mass), epifaunal at surface (benthic, not extending significantly upwards), semi-infaunal (partly infaunal, partly exposed to the water column), shallow infaunal (living in the upper 5 cm of the surface) and deep infaunal (living below the upper 5 cm of the substrate). The 5 cm boundary reflects approximately a depth above which organisms are challenged by disturbance rather than maintaining contact with the sediment-water interface, but is highly variable due to hydrodynamic energy and the depth of redox surface (Bush *et al.*, 2007).

Regarding the degree of mobility were established six categories (Bambach et al, 2007; Buch & Novack-Gotshall, 2012): freely fast (unencumbered), freely slow (maintain intimate contact with substrate), facultative unattached (free-lying), facultative attached (moving only when is necessary), non-motile unattached and non-motile attached both categories incapable of self-propulsion.

In the third chapter – Paleoecological aspects were discussed ecological factors (oxygen content, salinity, substrate consistency, bottom waters hydrodynamic, sedimentary processes, source and type of organic matter) that controls the evolution of benthic communities (the producers of trace fossils) inducting stress that manifest by diminishing the diversity, abundance and sizes of organisms and obviously their traces.

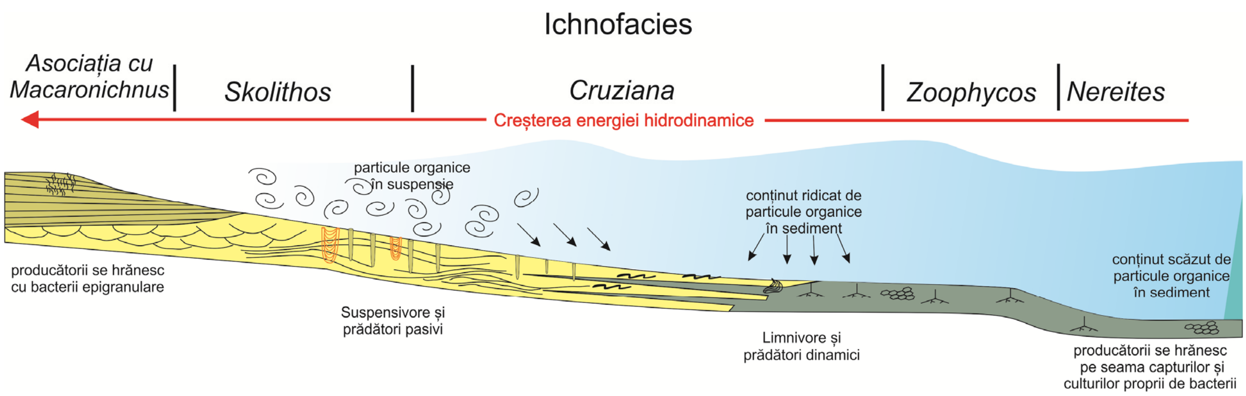

Fig. 1 Relatioship between trace-fossil associations, hydrodynamic energy and food supply (Buatois și Mangano, 2011)

The hydrodynamic energy controls the organisms behavior and their preservation potential. The ichnoassembleges changes when hydrodynamic energie modifies from low to high (fig. 1). Ichnofauna developed in low energy conditions is dominated by horizontal traces made by detritus feeders and dynamic predators. At higher depths, the producers are forced to develop sophisticated feeding strategies like trapping or microorganisms farming (Seilacher, 2007).

The type and consistency of substrate controls infaunal communities and their techniques of constructing galleries (Bromley, 1996). The vertical changes are due to fluid expulsion and progressive compaction of sediments and diagenesis. Depending on the degree of consolidation were separated substrates: fluid (soupy), soft , firm and hard (Ekdale *et al.*, 1984). Bromley *et al.* (1996) adds woody substrate.

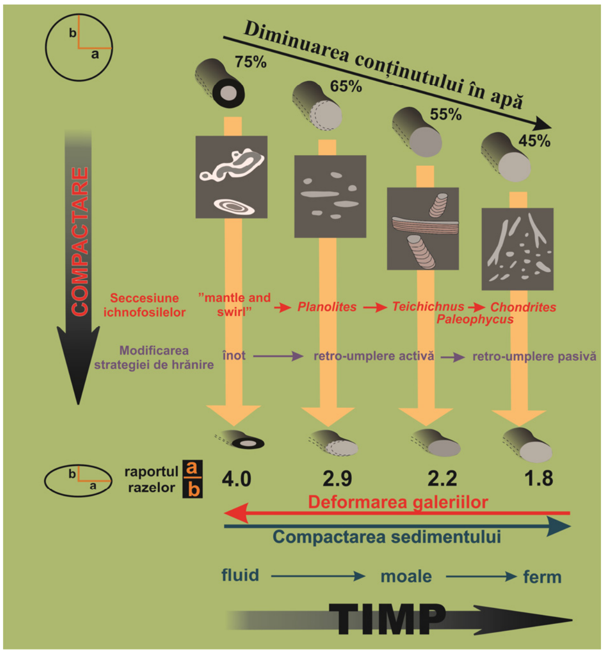

Fig. 2 Estimation of sediment water content at bioturbation time by establishing the degree of deformation using a:b ratio (Schieber, 2003)

Schieber (2003) expresses the quantity of water content in the sediment at the time of bioturbation.

The estimation was based on evaluation of trace fossils cross sections deformations, using a:b ratio (a – large radius; b – minor radius; fig. 2).Three fundamental processes interact to produce: accumulation of sediments, erosion and bioturbation. Each operates at independent rates and the balance between them imprints specificity for any deposit.

Where sedimentation rate exceeds the bioturbation are, primary sedimentary structures prevail. Otherwise, they will be ”deleted” and replaced by biogenic sedimentary structure (Bromley, 1996).

It is widely accepted that there is an abundance of dweling structures (domichnia) in shallow water, the feeding, locomotion and resting traces (fodinichnia, pasichnia, cubichnia) dominate at intermediate depths and the farming (agrichnia) and traping traces are specific to deeper waters (Seilacher, 1964, 2007; Ekdale *et al.*, 1984)

Chapter IV – Methods of analysis and interpretation include the instruments that we have employed to obtain the results.

Sedimentary facies analysis has already become a classic method which involves: indentifying sedimentary facies in terms of their processes; facies association separation by grouping genetically coherent sedimentary facies to identify depositional sub-domains; differentiation of facies associations successions in order to establish depositional trends (progradational/retrogradational), thus deciphering the history of a sedimentary basin fill.

Ichnological analysis seeks the following (Coe *et al.*, 2010): (1) the size distribution of trace fossils; (2) the geometries of ichnofossils; (3) associations with other trace fossils; (4) characteristics of the sedimentary deposits; (5) frequency and density; (6) presence/absence of burrow wall ornamentation/lining; (7) the infilling type compared with the sediment burrowed and any other clues that indicate if it was a passive (by gravity collapse) or active (backfilling by the organism) infill; (8) the positions of trace fossils relative to a reference deposit and (9) cross-cutting relations.

For the description of trace fossil we used simultaneously ethological (Ekdale *et al.*, 1984) and toponomical classifications (Martinsson, 1970 – fig. 3). We also added the evaluation of galleries/tubes deformation by calculating the cross section a:b ration in order to establish the substrat consistency when bioturbation occurred (Schieber, 2003 – fig. 2).

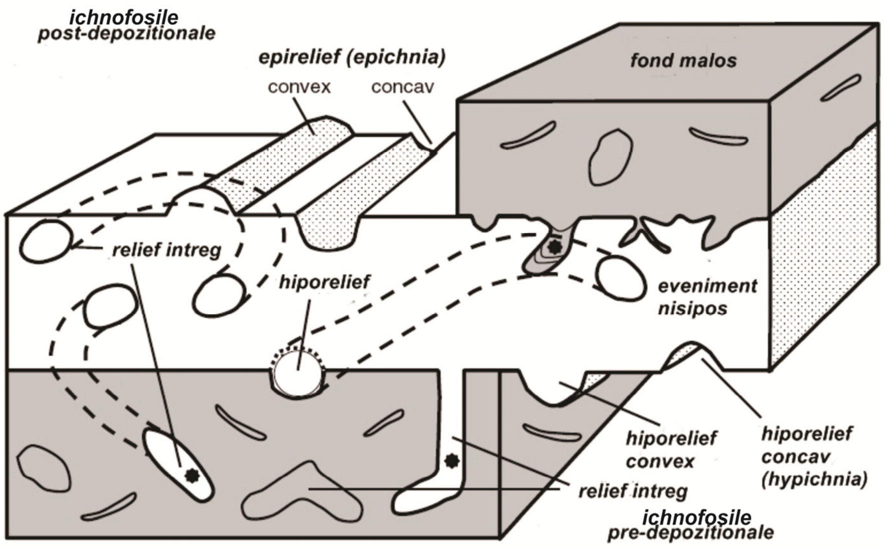

Fig. 3 Toponomical classification (după Ksiazkiewicz, 1977; Martinsson, 1970; Seilacher, 1964)

Chapter V - Bioturbated deposits of external flysch from Outer Carpathians were analyzed deposits belonging to: 1) the upper part of Piatra Uscată Formation (Paleogene), from an outcrop on the external flank of Runcu Syncline or internal flanck of Doamna Horaița Anticline, on Runcu Brook, tributary to Cuejdiu; 2) Green and red clays Member of Bisericani Formation, from an outcrop located on approximately 100 m upstream of where the Piatra Uscată Formation outcrops, on a left tributary to Runcu Brook; 3) Greenish-gray mudstone Member of Bisericani Formation from a wide outcrop opened in the southern part of Bistrița half-window, on Nechit Brook, downstream of the confluence with the Alunu Brook (fig. 4).

5.1. Piatra Uscată Formation – Runcu Brook

The Piatra Uscată Formation (40-50 m thick) outcrops in continuous sedimentation over the Izvor Formation with an opening of 15 m (46º59'41.82 "N / 26º16'22.84" E -GPS), but low accessibility permitted observations for about 10 m (fig. 5).

Using sedimentary facies analysis method we defined eight sedimentary facies: (1) µCs – *microconglomerate with green schists; (2)* S_m – *massive sandstone; (3)* S_g – *normal graded sandstone; (4)* S_{pp} – *sandstone with plane parallel lamination; (5)* S_{hcs} – *sandstone with hummocky cross lamination; (6)* S_{rcl} -

sandstone with ripple cross lamination; (7) Si_{pp} – Si_{op} *plan-parallel to wavy-parallel laminated blackish siltites; (8)Ml – greenish-gray laminated mudstones.*

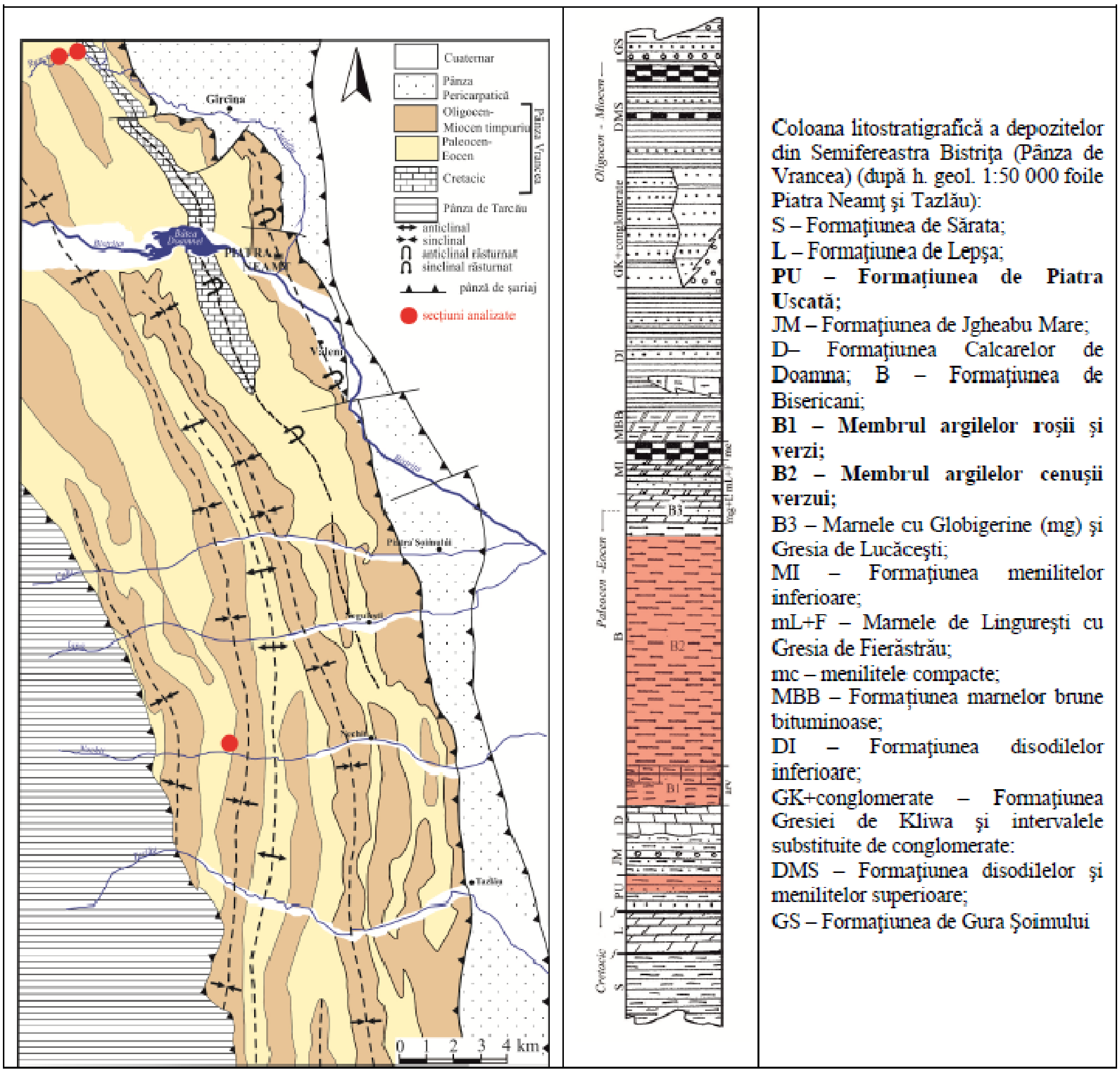

Fig. 4 Tectonic sketch of Bistriţa Half-Window with analyzed sections (red dots) (after Micu,1976; Grasu *et al.*, 1988)

Interpreted sedimentary facies indicates two major categories of sedimentary processes: on one hand gravity-type processes, on the other hand traction processes. The lower massif sanstone layer (S_m) was accumulated by mainly gravity processes. Some processes are somehow related with sedimentary depositional areas of shallow waters (oscillating currents), while others (gravity flows) cannot be linked to a specific area. In theory, gravity-type sedimentary processes are associated with more pronounced relief as underwater shelf edges or continental slopes (Shanmuham, 2006; Stow *et al.*, 1996; Walker, 1992; Posamentier and Walker 2006 among others), but also delta fronts.

Based on physical sedimentary structures described and interpreted, it is difficult to determine the depositional system, so we use ichnological analysis as support for discrimination.

Fig. 5 The Piatra Uscată Formationa outcrop, Runcu Syncline, Bistrița Half-window (with yellow is highlighted what we consider markers)

The sandstone layers are characterized on the bases, the tops or on both by hypichnial and epichnial ichnoformes, occasionally endichnial observed inside these deposits (fig. 6). All levels of mudstone, as well as some of the coarser ones, show trace fossils that can be classified by toponomical and ethological criteria.

Some of the trace fossils from analysed section were determined on genus level: *Chondrites* , *Planolites* , *Thalassinoides* , *Ophiomorpha* , *Bergaueria* and *Lockeia*. Others were determined with prudence due to the absence of some defining elements (Diplocraterion , Rhizocorallium , Cochlichnus , Treptichnus).

Trace fossils of Piatra Uscată Formation can be toponomicaly separated in: **hypichnia** associated with μC_s, S_g, S_m, S_{pp} and S_{rcl}; **epichnia** associated with S_{pp} and S_{rcl}; **endichnia/exichnia** found in Si_{pp}-Si_{op}, Ml, rarely in S_{rcl}. Epichnia and hypichnia trace fossils associated with coarser layers are larger in size and they have pronounced morphology, while those associated with mudstones are smaller and smother. Obviously, the situation may be the result of low preservation potential of delicate structures in coarse layers

Epichnia and hypichnia type structures associated with coarser layers have large and sharp morphology, while those associated with the finest materials are softer. Obviously, the situation may be the result of conservation potential of delicate structures on coarse bed surfaces, not their absence on/in sediments accumulated prior to bioturbation.

Ethologicaly, trace fossils belong to the groups **cubichnia** (resting trace), **fixichnia** (fastening / anchoring), **domichnia** (home structure), **fodinichnia** (feeding trace) **chemichnia**.

In relation to the event-beds, traces fossils studied in this section may be: **pre- depositional** or **post- depositional**. The structures build up in the background sediments were grouped in syn-depositional category, all though, some of them can be differentiated by different degrees of contemporaneousness with sedimentation (Table 1).

In Piatra Uscată Formation case the trace fossils were analyzed in relation to sedimentary deposits (fig. 6). Each ichnogenera described characterize wider or narrower fields of a sedimentary basin (Buatois and Mangano , 2011) , as follows :

1) *Chondrites* - marine conditions (possibly deficient in oxygen); fodinichnia (deposit feeders) - chemichnia; potential producer - marine worm polychaeta type;

2) *Planolites* - shallow marine sea (and continental); domichnia-fodinichnia (deposit feeders); potential producers - worms and worm-like animals;

3) *Thalassinoides* - shallow marine to deep sea (abyssal cones); fodinichnia traces (suspention feeders) and domichnia; possible producer - shellfish shrimp;

4) *Ophiomorpha* - marine to brackish shallow waters, shoreface abundant; domichnia lined with fecal pellets for consolidation; possible producers - prawns and other shellfish;

5) *Bergaueria* - shallow marine to deep marine waters; big fodinichnia domichnia (suspension feeders); sea anemones;

6) *Lockeia* - any aquatic environment; cubichnia; producers - bivalves;

7) *Diplocraterion* – from intertidal to the distal shelf; domichnia-fodinichnia (suspension feeders); possible producers - shrimps;

8) *Rhizocorallium* - shallow marine waters; domichnia and /or fodinichnia; potential producers - Anelide worms, crustaceans;

9) *Cochlichnus* - shallow marine (and continental) waters; repichnia; possible producers – Anelide worms, some larvae.

Trace fossils description shows that some ichnogenera from analyzed section may appear in different positions proximal-distal in a sedimentary basin.

From the description of trace fossils show that ichnogenera determined more or less safe in the analyzed section Formation dry stone may appear in different positions proximal - distal marine.

Among marine ichnofacies, proximal - distal distributed in succession *Cruziana* → *Skolithos* → *Zoophycos* → *Nereites*, it seems that the only solution is *Cruziana*. This ichnofacies is characterized by mostly horizontal, incline, and vertical traces, many of them are domichnia type of mobile animals. It is also characterized by the greatest diversity of forms, especially deposit feeders and, in addition, contain incumbent traces made at different depths with respect to water-sediment interface.

This last feature, determined by sedimentation rate fluctuations, is one that does not appear in other ichnofacies. In such overlaps, Ekdale (1990, 1996) and Ekdale and Bromley (1991) defined ichnoguilds reflecting three parameters: 1) the lastingness of structures (semi-permanent to permanent transient); 2) to exploit food resources (suspension and deposit feeders or chemichnia type); 3) the use of space (equivalent to the vertical position in the substrate).

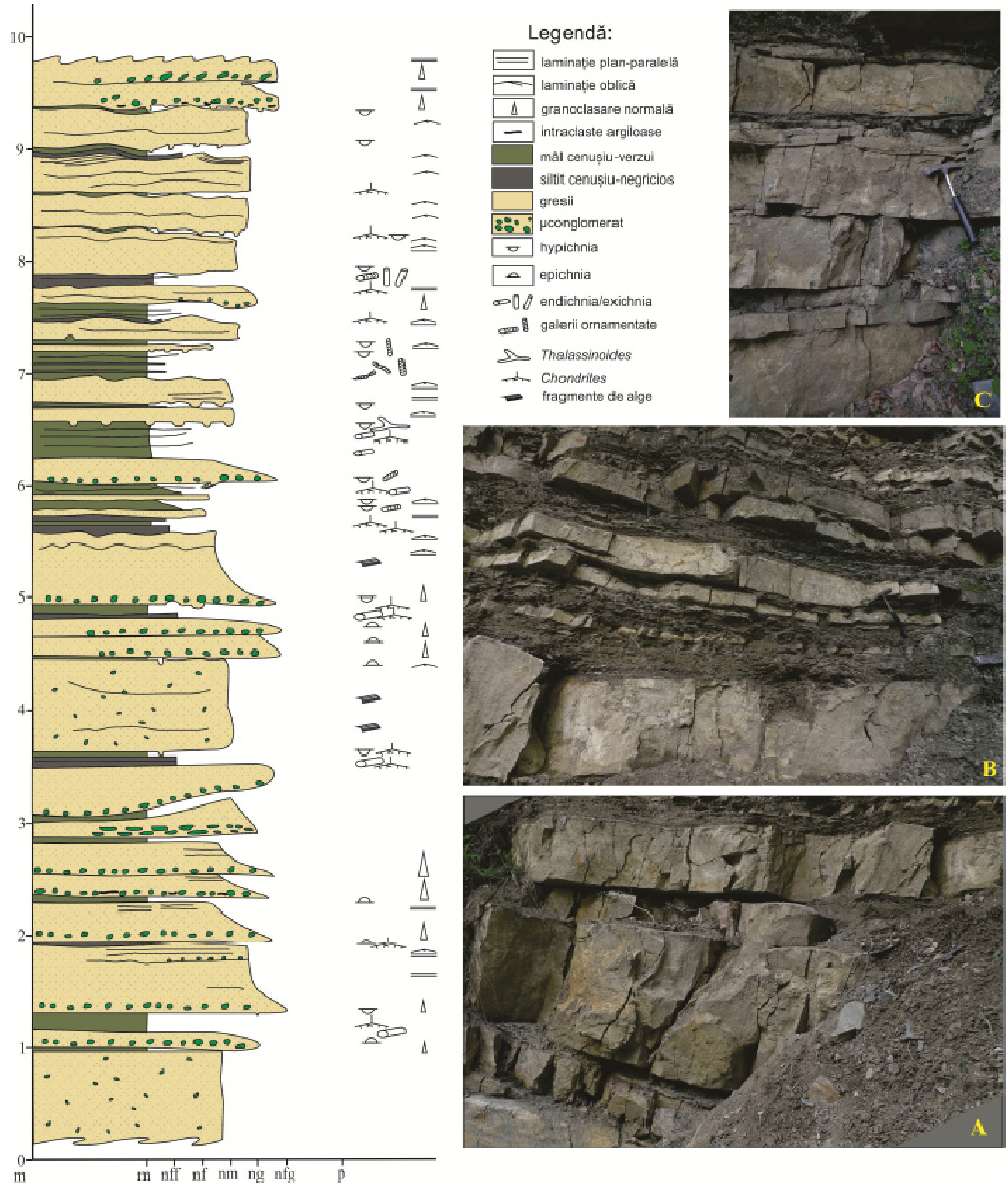

Fig. 6 Sedimentological column of the upper part of Piatra Uscată Formation, Runcu Brook, Bistrița half-window, Vrancea Nappe. A – sandstone beds in the outcrop base; B – heterolithic beds in the middle part of the section; C – sandstone beds in the uper part of the section.

A good exemple is the association of *Chondrites* and *Planolites* from silty beds. This association is apparent since they both belong to deferent ichnoguilds which exploit different conditions at different depths below the water-sediment interface. *Chondrites* is the latest and last trace fossil built in a sediment (fig. 7).

Reducing conditions are frequently installed in the sediments of marine environment due to degradation processes of organic matter by bacteria, which quickly diminishes the oxygen content from pore waters. In this way, the overlap of *Chondrites* and *Planolites* is justified, the later beening buried and removed from the surface oxidizing environment.

Planolites Ichnoguild
Structures build up by vagile organisms, deposit feeders on the surface, high oxigen content

Thalassinoides Ichnoguild
Permanent structures made by slouly moving animals, sub-surface deposit feeders, good oxigen content

Taenidium-Phycosiphon Ichnoguild
Structures made by vagile organisms, deeper deposit feeders

Chondrites-Zoophycos Ichnoguild
Non-vagile, deposit feeders and chemo-symbiosis, deepest burial

Fig. 7 Ichnoguilds and bioturbated levels (Buatois and Mangano, 2011): *Pl – Planolites*; *Th – Thalassinoides*; *Ta – Taenidium*; *Ph – Phycosiphon*; *Ch – Chondrites*; *Zo – Zoophycos*

Ichnological analysis allowed us to establish that the ichnogenera identified in Piatra Uscată Formation belongs to *Cruziana* ichnofacies.

The sedimentological analysis has established only that the accumulation was made by two categories of sedimentary processes, gravity, traction and traction with an oscillating component.

Integrating the results obtained by these two methods of study allows to eliminate the variation of depositional area of turbiditic systems, given that , although deposits suggests gravitational processes, and they are often considered characteristic for slope - base of slope, the trace fossils content don’t permit such an interpretation.

So even if depositional processes indicates turbiditic systems , they must be placed somewhere in the basin where the conditions for Cruziana Ichnofacies development are favorable, possibly a shelf characterized by episodic coarse sediments continental input.

The relationship between trace fossils toponomy in conjunction with their position in relation to the background sediment or the event-bed provides information regarding sedimentary record discontinuities, highlighted by two models: **endichnia - hypichnia** and **endichnia - non- hypichnia** (Table 1).

Tabelul 1 Relationship sedimentation-bioturbation in Piatra Uscată Formation – Runcu Brook

Cod	Facies sedimentar	Asociatii de faciesuri	Tip toponomic	Tip etologic	Relația sedimentare-bioturbare	Ichnogenuri	Ichnofacies
PU 17	**S_{pp} și μC_g**	**Asociația faciesurilor dominant grezoase (procese dominant tractive)**	hypichnia	fodinichnia domichnia cubichnia	pre-depoziționale	*Thallassinoides Ophiomorpha Lockeia*	**C R U Z I A N A**
	Ml				sin-depoziționale		
PU 16	**S_{rcl} și S_m**		epichnii convexe și concave	fodinichnia	post-depoziționale		
			hypichnii convex și concave		pre-depoziționale		
	Ml				sin-depoziționale		
PU 15	**SI_{pp}**		Endichnii	fodinichnia	sin-depozitionale	*Planolites*	
	8 seturi de S_{rcl} și S_{hcs}		endichniI	chemichnia	sin-depoziționale	*Chondrites*	
			hypichnii concave	fodinichnia	pre-depozionale	*Planolites*	
	Ml				sin-depoziționale		
PU 14	**S_m**		hypichnia concave	fodinichnia	pre-depoziționale		
	3 seturi de S_{rcl}				post-depozitional		
	S_m		hypichnia concave		pre-depoziționale		
	Ml	**Asociația faciesurilor grezo-pelitice (procese dominant tractive)**	endichnia orizontal-subverticale	domichnia fodinichnia	sin-depoziționale	*Planolites ?Diplocraterion*	
	S_{pp}		endichnia	chemichnia	post-depoziționale	*Chondrites*	
PU 13	**S_{rcl}**						
	3 seturi μC_{tcs}						
	SI_{pp} cu S_{pp}		endichnia	chemichnia	post-depoziționale	*Chondrites*	
	Ml		endichnia	chemichnia	sin-depoziționale	*µChondrites*	
PU 12	**SI_{rcl}**						
	3 seturi de S_{rcl}		hypcihnia convexe	fodinichnia	pre-depozitionale		
	Ml				sin-depoziținale		
	S_{rcl}		endichnie subverticală		post-depoziționale	*?Diplocraterion*	
			hypichnia concave		pre-depoziționale		
	Ml		exichnii vertical-subverticale	domichnia fodinichnia	post-depoziționale	*?Diplocraterion*	
			endichnii orizontale	fodinichnia	sin-depoziționale	*Planolites*	
PU 11	**S_{rcl}**						
	S_{pp}		hypichnii concave	fodinchnia	pre-depoziționale	*Planolites*	
	Ml				sin-depoziționale		
PU 10 Marker	**SI_{pp}**						
	3 seturi de S_{rcl} amalgamate		hypichnia concave	fodihnichnia domichnia fixichnia cubichnia	pre-depoziționale	*Planolites Thallassinoides Bergaueria Lockeia*	
	SI_{pp} (30 cm)		endichnia	fodinichnia chemichnia	sin+post-depoziționale	*Planolites Chondrites*	
			exichnia orizontale subcilindrice	fodincihnia	post-depoziționale	*Planolites*	
PU 9	**S_{pp}**						
	μC_{tcs} lenticular, apparent nestructurat		hypichnii concave	cubichnia domichnia fodinichnia	pre-depoziționale	*Lockeia Ophiomorpha Phycodes*	
	SI_{rcl} și S_{rcl}						
	Ml		exichnia		pre-depoziționale		

			orizontale				I C H N O F A C I E S U L
	SI_{pp}		endichnia	chemichnia	post-depoziționale	*Chondrites*	
	5 seturi de S_{rcl}		hypichnia concave		pre-depoziționale		
	SI_{pp}-Ml-SI_{pp} în plachete		endichnia exichnia	chemichnia fodinichnia	post-depoziționale	*Chondrites Treptichnus*	
	S_{pp}		endichnia		post-depoziționale		
	Ml-Si_{pp}		endichnia	chemichnia	post-depoziționale	*Chondrites*	
PU 8	**S_{rcl}**	**Asociația faciesurilor dominant grezoase - procese sedimentare dominant gravitaționale (curgeri hiperconcentrate la curenți turbiditici)**					
	S_m						
	μC		hypichnia concave și convexe		pre-depoziționale		
	Ml		endichnia	chemichnia	post-depoziționale	*Chondrites*	
	Si_{pp}		endichnia	chemichnia fodinichnia	post-depoziționale	*Chondrites Planolites* cu *glauconit*	
PU 7	**2 seturi μC_g la S_{pp}**		epichnia concave	fodinichnia domichnia	post-depoziționale	*Ophiomorpha ?Diplocraterion*	
	Ml		exichnia		post-depoziționale	*?Diplocraterion*	
PU 6	**? seturi amalgamate de S_m**		epichnia convexe	fodinichnia domichnia	post-depoziționale	*Planolites Thallassinoides*	
			hypichnia concave		pre-depoziționale		
	Ml		endichnia	chemichnia fodincihnia	sin+post-depoziționale	*Chodrites Planolites ?Cochlichnus*	
	S_{pp}		endichnia	chemichnia	post-depoziționale	*Chondrites*	
PU 5	**μCg la S_{pp}**						
	Ml		endichnia	fodinchnia	sin-depoziționale	*Planolites* cu *glauconit*	
PU 4	**3 seturi de S_g**						
	Ml						
PU 3	**S_{pp}**		epichnia convexe și concave	fodinichnia	post-depoziționale	*Planolites*	
	S_g						
	SI_{pp}		epichnia convexe și concave		post-depoziționale		
			endichnia	fodinichnia chemichnia	sin+post-depoziționale	*Planolites Chondrites*	
PU 2	**2 seturi de S_g la S_{pp}**		epichnia concave și convexe	fodinichnia	post-depoziționale	*Planolites*	
			hypichnia concave și convexe	fodinichnia	pre-depoziționale	*Planolites*	
	Ml		endichnia	fodinichnia chemichnia	sin+post-depoziționale	*Planolites Chondrites*	
PU 1	**μC_g la S_g**		epichnia concave și convexe	fodinichnia domichnia	post-depozițional	*Planolites ?Rhizocorallium*	
	Ml						
PU 0	**S_m**						

Legend: proven discotinuity surfaces (endichnia-hypichnia model – red marked); major discotinuity surfaces (abundant endichnia-hypichnia model – red marked); deducted discontinuity surfaces (endichnia-non-hypichnia model – blue marked); μCg – normal graded microconglomerate; μC_{tcs} – microconglomerate with cross stratification; S_m – massive sandstones; S_g – normal graded sandstones; S_{pp} – plan-parallel laminated sandstones; S_{hcs} – hummocky cross laminated sandstones; S_{rcl} – ripple cross laminated sandstones; Si_{pp}-Si_{po} – plan-parallel to wavy-parallel laminated blackish siltites; Ml – greenish-gray laminated mudstones.

5.2. Green and red shale member of Bisericani Formation

Member of red and green clays are basal unit Bisericani Formation and from petrographic point of view consists of greenish clays and sandstones with rare, glauconitic, lenticular microconglomeratic beds with green schists (Grasu *et al.*, 1988). In some synclines/anticlines, especially in the southern part of Bistrita half-window, they have a very good developement and the red-green color contrast is spectacular (Nechit Brook, Falcău Anticline - fig. 8). Runcu Brook outcrops reveal no such contrasts; these outcrops are relatively monotonous in color (fig. 9), greenish-gray, with variations to whitish-gray, yellowish-gray and rarely purplish-red thin beds.

On a right tributary of Runcu Brook, 46º59'39.01"N/26º16'6.90"E (GPS), also trobutary to Cuejdiu river, in Runcu Syncline, we skeched a 7 m high column (fig. 10) with a 4 m log on the left (fig. 10A) and another 3 m on the right (fig. 10B, C).

Using sedimentary facies analysis we identified 8 facies: 1) Cs – paraconglomerate with ruditic sandstones clasts; 2) Cl –breccia with gray limestone clasts; 3) S_{pp} – plan-parallel laminated sandstones; 4) S_{rcl} – ripple cross laminated sandstones; 5) S_{tcl} – trough cross lamination; 6) Si_{pp} – blackish plan-parallel siltite; 7) Si_{rcl} – blackish cross laminated siltite; 8) Ml - greenish-gray laminated mudstones – fissile mudstone.

Fig. 8 Green and red clays Member of Bisericani Fm., Nechit Brook, Falcău Anticline

Fig. 9 Green and red clays Member of Bisericani Fm, Runcu Brook, Runcu Syncline

Three fundamental processes were involved in the accumulation of green and red clays Member of Bisericani Formation that outcrops on Runcu Brook: gravitational processes such as debris flows (Cs and Cl); high energy traction currents responsible for accumulation of S_{pp}, Si_{pp}, low energy traction currents S_{rcl}, S_{tcl}, Si_{rcl} and pelagic/hemipelagic garvitational accumulation or traction currents (Ml).

The sedimentary record described with the above sedimentary facies, except coarser ones (in placed by gravitational processes), is characterized by heterolithic sandstones and mudstone accumulated throughout traction processes. Where sedimentary structures with plan-parallel lamination were preserved, high energy traction currents were employed; for sedimentary structures with cross lamination the same traction currents decelerated and permitted ripple cross lamination or stratification to develop.

S_{pp} and Si_{pp} sedimentary facies are are Bouma Sequence T_b subdivisions. S_{rcl} and Si_{rcl} are T_c subdivisions of the same Bouma Sequence. The mudstone sedimentation is attributed to the settling of suspended particules and reprezents T_e subdivision, which is the final term of a turbiditic sequence.

Based on the description and interpretation of physical sedimentary structures alone we can not specify the depositional environment. That is the reason why we added ichnological analysis. Sandstone levels are characterized by trace fossils of epichnia, hypichnia and exihnia types. Mudstone beds, some siltstones and sandstones are characterized by endichnia, rare exichnia. All identified and described sedimentary facies were genetically grouped in **the heterolithic facies association** of a turbiditic system.

Some trace fossils were identified at ichnogenera level: *Chondrites, Avetoichnus, Planolites, Lockeia, Thalassinoides* and *Rhizocorallium*.

Toponomicaly (after Martinsson, 1970), the described trace fossils are: dominant ***hypichnia*** and ***endichnia***, subordinate ***epichnia*** type.

Etologicaly, most representative are: ***chemichnia*** (*Chondrites*), ***fodinichnia*** (*Planolites*), ***domichnia-fodinichnia*** complex (*Thalassinoides*, *Rhizocorallium*) and ***agrichnia*** (*Avetoichnus*).

In green and red Member of Bisericani Formation case the trace fossils were analyzed in relation with the sedimentary deposits. Each ichnogenera described characterize wider or narrower fields af a sedimentary basin (Buatois and Mangano, 2011). *Chondrites, Planolites, Thalassinoides, Lockeia* and *Rhizocorallium* are ichnofossils found also in Piatra Uscată Formation. We recall and add:

1) *Chondrites* - marine conditions (deposit feeders) - chemichnia; potential producer - marine worm polychaeta type;

2) *Planolites* - shallow marine sea (and continental); deposit feeders; fodinichnia;

3) *Thalassinoides* - shallow marine to deep sea (abyssal cones); possible producers – crustacean (domichnia-fodinichnia);

4) *Lockeia* - any aquatic environment; cubichnia; producers - bivalves;

5) *Protovirgularia* – any aquatic environment; repichnia; producers – bivalves;

6) *Rhizocorallium* - shallow marine waters, rarely deep waters; domichnia and/or fodinichnia; potential producers - Anelide worms, crustaceans;

7) *Avetoichnus* – complexe feeding trace fossils in sediment depleted of organic matter, low energy sedimentary environment.

Except for the last ichnogenera mentioned, all the others are part of *Cruziana* Ichnofacies.

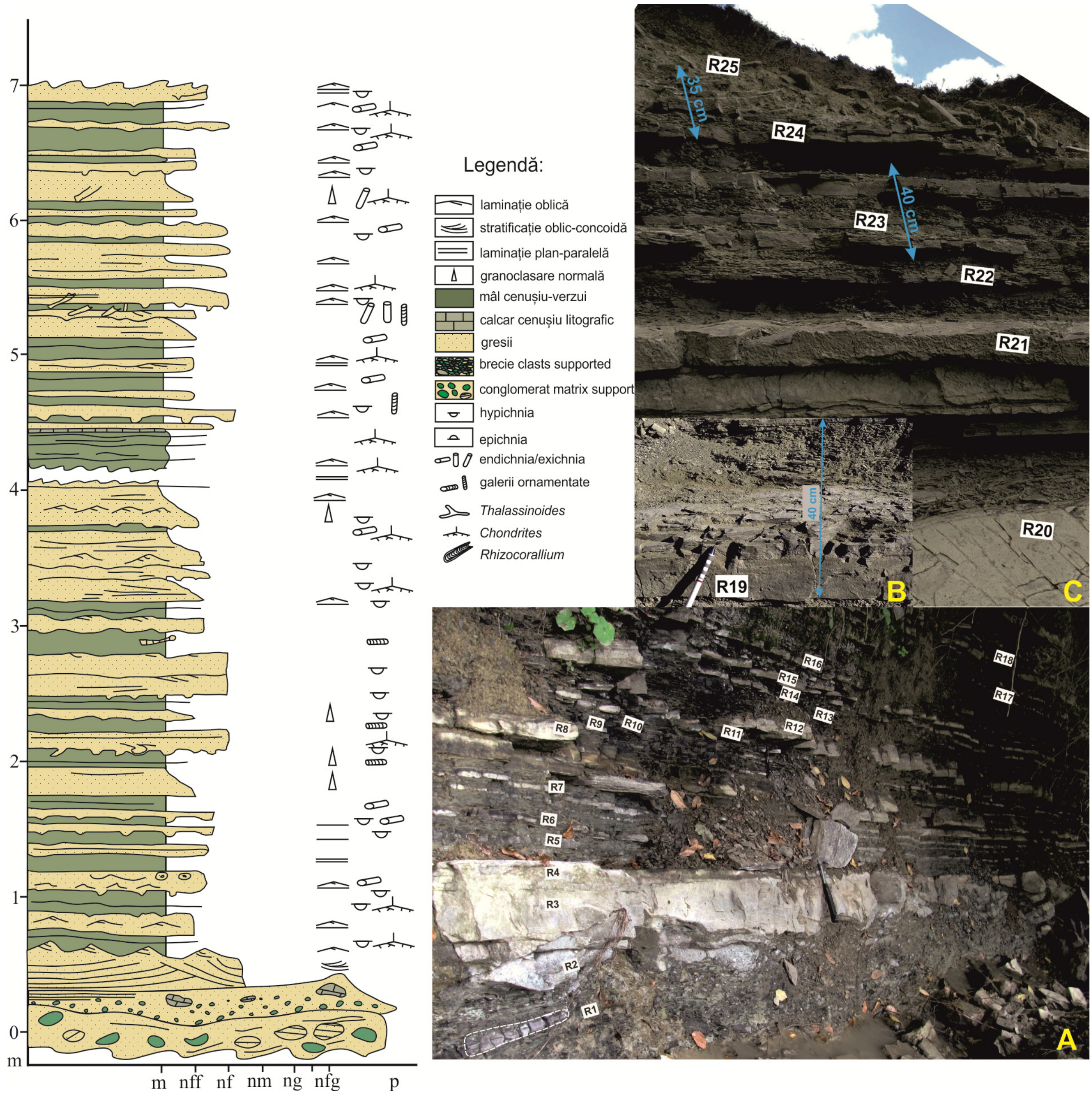

Fig. 10 Sedimentological column of green and red clays Member of Bisericani Formation, Runcu brook, Runcu Syncline

Throughout sedimentological analysis we determined that the accumulation of these deposits happen due to gravitational and traction processes. Overall, the distribution of this section trace fossils is somewhat uniform, this being in line with uniformity of sandstone:mudstone ratio.

As we can observe in Table 2, the trace fossils described in relation to event-beds are pre-depozition (hypichnia) or post-depozition (epichnia) phenomena. The interlaminated mudstones (background sediment) trace fossils are sin- and post-deposition phenomena, represented by *Planolites*, *Chondrites* and one level with *Avetoichnus*.

Based on sedimentological and ichnological analysis of the green and red clays Member of Bisericani Formation, we may say that the depositional system is characterized by turbidites that were accumulated in an environment favorable for *Cruziana* ichnofacies development.

Table 2 Relationship sedimentation-bioturbation in green and red clays Member of Bisericani Formation – Runcu Brook

Cod	Facies sedimentar	Asociații de faciesuri	Tip toponomic	Tip etologic	Relația sedimentare-bioturbare	Ichnogenuri	Ichnofacies
R25	Alternanță de S_{pp}	Asociația faciesurilor heterolitice	hypichnia concave	fodinichnia cubichnia	pre-depoziționale	*Planolites Lockeia*	CRUZIANA
	și Ml verzui-oliv		endichnia	chemichnia fodinichnia	sin-depoziționale	*Chondrites Planolites*	
	S_{pp} la SI_{pp} și SI_{rcl}		hypichnii concave	fodinichnia cubichnia	pre-depoziționale	*Planolites Lockeia*	
	Ml verzui-oliv		endichnia	fodinichnia	sin-depoziționale	*Planolites*	
R24	4 seturi de S_{pp} la SI		hypicnia concave endichnia	fodinichnia chemichnia	pre-depozitionale sin-depoziționale	*Planolites Chondrites*	
	SI_{pp} la Ml		endichnia	fodinichnia	sin-depoziționale	*Planolites*	
	Seturi de SI_{rcl}		hypichnii concave	fodinichnia cubichnia	pre-depozitionale	*Planolites Lockeia*	
R23	Alternanțe de S_{rcl}		epichnia	fodinichnia	post-depoziționale	*Planolites*	
			hypichnia concave	fodinichnia cubichnia	pre-depozitionale	*Planolites Lockeia*	
	și Ml verzui-oliv		endichnia	chemichnia	sin-depoziționale	*Chondrites*	
R22	S_{rcl}		epichnia endichnia endichnia	fodinichnia fodinichnia chimichnia	post-depoziționale sin-depoziționale sin-depoziționale	*Planolites Planolites Chondrites*	
R21	SI_{pp} la Ml verzui-oliv		endichnia	fodinichnia chimichnia	sin-depoziționale sin-depoziționale	*Planolites Chondrites*	
	S_{rcl} la SI		epichnia	domichnia	post-depoziționale	*Rhizocorallium*	
			hypichnia concave	fodinichnia	pre-depoziționale	*Planolites*	
	S_{pp} la SI		endichnii verticale	?domichnia	sin-depoziționale	*?Thalassinoides*	
	SI_{pp} la Ml		endichnia	chemichnia fodincihnia	sin-depoziționale	*Chondrites Planolites*	
R20	Ml la SI roșiatic		epichnia endichnia	fodinchnia chemichnia	post-depoziționale sin-depoziționale	*Planolites Chondrites*	
R19	SI_{pp} în plachete		epichnia endichnia	fodinchnia chemichnia	post-depoziționale sin-depoziționale	*Planolites Chondrites*	
	Ml verzui		endichnia	chemichnia	sin-depoziționale	*Chondrites*	
	S_{rcl}		epichnia convexe endichnia	fodincihnia fodinichnia	post-depoziționale sin-depoziționale	*Planolites*	
			hypichnia concave	cubichnia	pre-depoziționale	*Lockeia*	
R18	S_{rcl} la SI		endichnia endichnia	fodinichnia chemichnia	sin-depoziționale sin-depoziționale	*Planolites Chondrites*	
			hypichnia concave	cubichnia domichnia	pre-depoziționale	*Lockeia Thalassinoides*	
R17	S_{pp} la Ml cenușii		endichnia	chemichnia	sin-depoziționale	*Chondrites*	
			hypichnia concave	fodinichnia	pre-depoziționale	*Planolites*	
R16	Ml negricioase		enichnia	fodinichnia	post-depoziționale	*Planolites*	
R15	S_{rcl}		hypichnia	fodinchnia cubichnia chemichnia	pre-depoziționale	*Phycodes Planolites Lockeia Chondrites*	
R14	Ml negricioase						
	S_{pp} la S_{rcl}		hypichnia concave	cubichnia fodinichnia domichnia	pre-depoziționale	*Lockeia Planolites Thalassinoides*	
R13	Ml verzui						

	SI_{rcl}	Asociația faciesurilor heterolitice	hypichnia	fodinichnia	pre-depoziționale	*Planolites*	ICHNOFACIESUL
R12	S_{rcl}		endichnia	chemichnia fodinchnia	sin-depoziționale	*Chondrites Planolites*	
			hypichnia	fodinichnia domichnia	pre-depoziționale	*Planolites Thalassinoides*	
R11	Ml verzui						
	SI_{pp} negricioase		epichnia endichnia	fodinichnia chemichnia	post-depoziționale sin-depoziționale	*Planolites limon. Chondrites*	
R10	S_{pp}		endichnia	fodinichnia	sin-depoziționale	*Planolites*	
R8	3 seturi de S_{rcl}		endichnia hypichnia concave	fodinichnia cubichnia	sin-depoziționale pre-depoziționale	*Planolites Lockeia*	
	Ml verzui		endichnia	chemichnia	sin-depoziționala	*Chondrites*	
R7	Ml albicioasă		endichnia	agrichnia	sin-depozițional	*Avetoichnus*	
	S_{pp}						
	Ml negricioase						
R6	2 seturi de S_{rcl}		hypichnia concave	fodinichnia cubichnia domichnia	pre-depoziționale	*Planolites Lockeia Thalassinoides*	
R5	Ml verzui						
	S_{pp}		hypichnia concave	fodinichnia	pre-depoziționale	*Planolites*	
	Ml verzui						
	SI_{pp} la SI_{rcl}						
	Ml verzui						
	S_{pp}		hypichnia concave		pre-depoziționale	*Planolites*	
	Ml verzui						
R4	S_{rcl}						
R3	S_{tcs}						
R2	Cl						
R1	Cs						

Legend: proven discotinuity surfaces (endichnia-hypichnia model – red marked); deducted discontinuity surfaces (endichnia-non-hypichnia model – blue marked); Cs –microconglomerate with green schists clastes; C_l – breccia with gray limestone clastes; S_{pp} – plan-parallel laminated sandstones; S_{tcs} – through cross stratificated sandstones; S_{rcl} – ripple cross laminated sandstones; Si_{pp} – plan-parallel laminated siltites; Si_{rcl} – ripple cross laminated silstones; Ml –laminated mudstones.

5.3. Greenish-gray mudstone Member of Biserican Formation

On Nechi Brook, Falcău Anticline, 46º46'2.83"N/26º20'55.42"E (GPS), we skeched a sedimentological column of over 100m high from greenish-gray mudstrone Member of Biserican Formation (fig. 11).

Using sedimentary facies analysis we identified 7 facies: 1) µCgs – microconglomerate with green schist clasts; 2) M_{gs} – massive mudstone with green schists; 3) S_{pp} – sandstone with plane parallel lamination; 4) S_{rcl} – sandstone with ripple cross lamination; 5) Si_{rcl} – siltstone with ripple cross lamination; 6) Ml – laminated mudstones and 7) SL – sideritic lens – which are not primary sedimentary facies but early digenesis products. These sedimentary facies were genetically grouped in two facies associations: a heterolithic one (AF1) and a homogeneous mudstone-sandstone one (AF2).

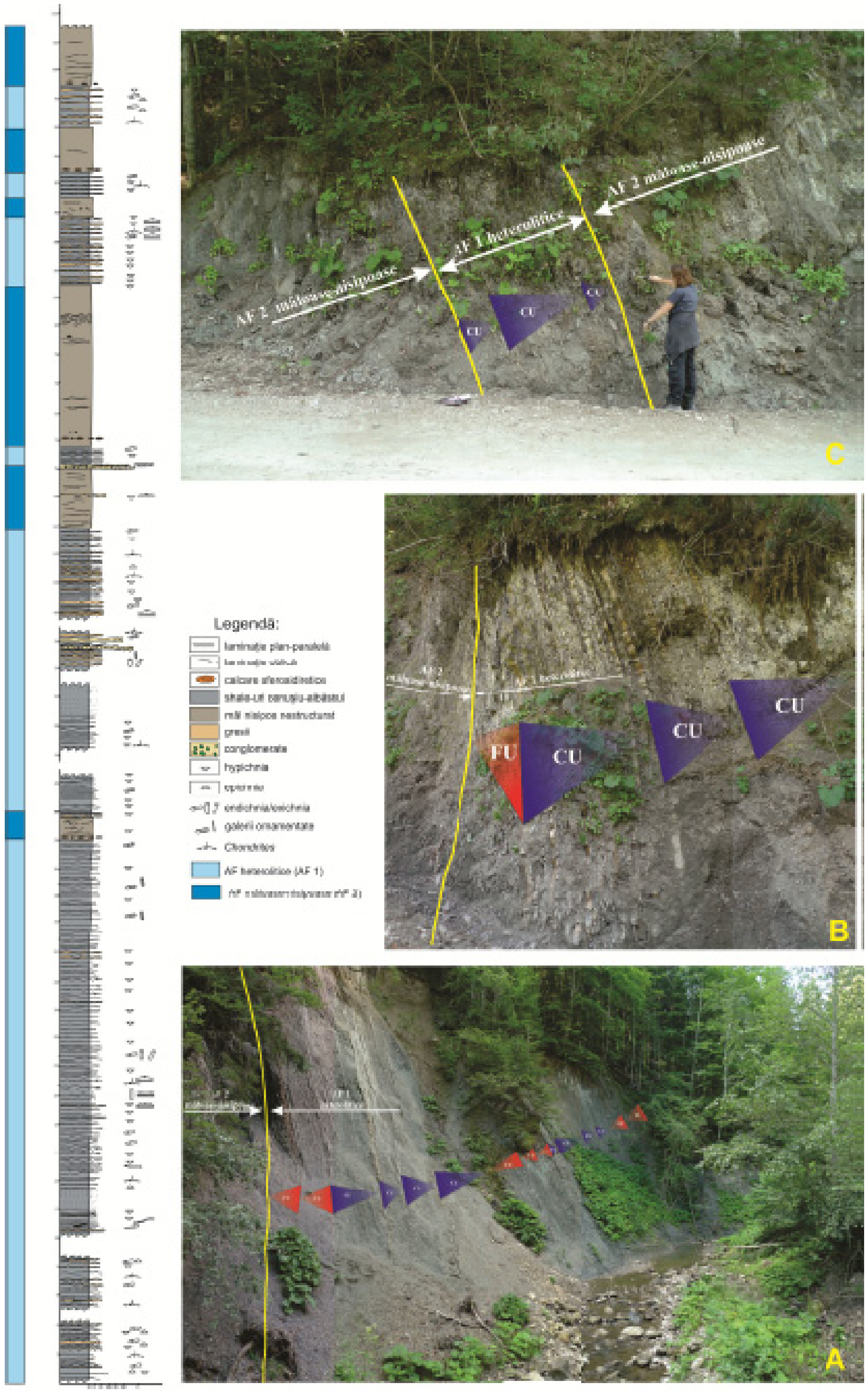

Fig. 11 Sedimentological column of greenish-gray mudstone Member of Bisericani Formation, Nechit brook, Falcău Anticline, Bistrița half-window, Vrancea Nappe

Some of the trace fossils from analysed section were determined on genus level: *Palaeophycus, Lockeia, Protovirgularia, Planolites, Thalassinoides, Chondrites* and *?Rhizocorallium*.

The majority of analyzed trace fossils of greenish-gray mudstone Member of Bisericani Formation are ***hypichnia*** type, but ***exichnia*** and ***endichnia*** are also important to be mentioned. Hypichnia type trace fossils are associated with coarser layers, usually event-beds, while rarely observed ***epichnia*** are found on top of the same layers.

Two ethological types are dominant: ***domichnia*** (dwelling traces) and ***fodinichnia*** (feeding traces), but some others are present such as ***repichnia*** (moving traces), ***cubichnia*** (restig traces) or ***chemichnia*** (feeding by chemical processing of deposit nutrients).

Throughout sedimentological analysis AF1 deposit indicates a depositional environment dominated by diverse processes of fine grains sediments accumulation where some episodic traction currents happened – **distal turbiditic/tempestitic system.** AF1 has large hypichnia type ichnoformes, made by opportunistic organisms that had a colonization window big enough to populate the exposed firm substrate.

The fine grains fresh deposits are fluid, the firm substrate is the result of burial associated with water excess expulsion. At the time of exposure the environment was characterized by good benthic oxygenation, high organic matter content and moderate to calm hydrodynamic energy which are the parameters for an ideal colonization window. This is the reason why the exichnia and endichnia type trace fossils are extremely large, with or without ornamentation and circle profile cross-sections.

AF2 is massive, apparently unstructured with rare cross lamination figures of traction currents. Cryprobioturbation may be the reason why the primary sedimentary structures are obliterated. This phenomena happens in shallow marine waters, on fluid or soft substrates. The presence of sideritic limestones is also a clue for a **depositional environment with shallow water** where high energy episodic coarser sedimentation alternates with low energy intervals.

Vertical succession of AF1 and AF2 is due to a significant change in the rate of sedimentation, a natural consequence of sediment supply rate changes. We observed that the carpathic coarser sediment source diminishes upwards in the analysed log.

We stated before that the described trace fossils belongs to *Cruziana* ichnofacies, which develops in a proximal zone of a marine sedimentary basin (Seilacher, 1964, 2007).

All of the above are solid arguments for the accumulation of greenish-gray mudstone Member of Bisericani Formation in a **distal, shallow waters turbiditic/tempestitic system**.

In Chapter VI – Ichnofossils – stratigraphic discontinuities we discussed how we can distinguish stratigraphic discontinuities trough vertical succession analysis of trace fossils assemblies.

In analysed logs we establish some repetitive models (table 1, 2, 3):

1. endichnia-hypichnia model – proven discontinuity surface;
2. endichnia –hypichnia abundant model – proven major discontinuity surface;
3. endichnia-non-hypichnia model – deducted discontinuity surface.

For each outcrop we demonstrated that what may have accumulated must have been much more then what has been record. For this statement we employed the simplest scenario: homogeneous sediment accumulation, continuous burial with porosity changes and one erosion event.

Table 3 Relationship sedimentation-bioturbation in greenish-gray mudstone Member of Bisericani Formation – Nechit Brook

Cod	Facies sedimentar	Asociații de faciesuri	Tip toponomic	Tip etologic	Relația sedimentare-bioturbare	Ichnogenuri	Ichnofacies
BMM 12	M_m (+4 m)	AF mâloase-nisipoase	exichnia	fodinichnia	post-depozițional	*Planolites*	CRUZIANA
			endichnia	fodinichnia	sin-depozițională	*Criptobioturbare*	
BMM 11	alternanțe de S_{rcl}	AF heterolitice	hypichnia mari oriz.	fodincihnia domichnia	pre-depoziționale	*Planolites Thalassinoides*	
	și Ml		exichnii orizontal-verticale	fodincihnia	sin-depozițional	*Planolites*	
	M_m (2 m)	AF mâloase-nisipoase	endichnia	fodinichnia	sin-depozițională	*Criptobioturbare*	
BMM 10	alternanță deS_{rcl}	AF heterolitice	hypichnia mari oriz.	fodincihnia domichnia	pre-depoziționale	*Thalassinoides*	
	Ml		exichnii orizontale	fodincihnia	post-depozițional	*Planolites*	
	M_m (1m)	AF mâloase-nisipoase	endichnia	fodinichnia	sin-depozițional	*Criptobioturbare*	
	Alternanțe de S_{rcl}	AF heterolitice	epichnii convexe	domichnia fodinichnia	post-depoziționale	*Thalassinoides*	
			hypichnii concave	domichnia fodinichnia	pre-depoziționale	*Thalassinoides*	
	și Ml		endichnii/ exichnii abundente	fodinichnia chemichnia	sin+post-depoziționale	*Planolites Chondrites*	
BMM 9	M_m (13,2 m) și SL	AF mâloase-nisipoase	endichnia	fodinichnia	sin-depozițional	*Criptobioturbare*	
BMM 8	Alternanțe de S_{rcl}	AF heterolitice	hypichnii concave	domichnia fodinichnia	pre-depoziționale	*Thalassinoides*	
	Ml		exichnii	fodinichnia	post-depozițional	*Planolites*	
	și SI_{rcl}		exichnii	fodinichnia	post-depozițional	*Planolites*	
	μC la S_{rcl}		hypichnii mari concave	domichnia fodinichnia	pre-depoziționale	*Thalassinoides*	
	Ml		exichnii ornamentate	domichnia	post-depoziționale	*Planolites Thalassinoides*	
	μC						
	M_m (1,6 m)	AF mâloase-nisipoase	endichnia	fodinichnia	sin-depozițional	*Criptobioturbare*	
	6 seturi de S_{rcl}	AF heterolitice	hypichnii mici concave	fodinichnia	post-depoziționale	*Planolites Lockeia*	
	M_m (2,2 m) și SL	AF mâloase-nisipoase	endichnia	fodinichnia	sin-depozițional	*Criptobioturbare*	
BMM 7	Alternanțe de S_{rcl}	Asociația faciesurilor heterolitice	epichnii convexe	fodinichnia	post-depoziționale	*Planolites Thalassinoides*	
			hypichnii concave	fodinichnia	pre-depoziționale	*Planolites Thalassinoides*	
	și Ml		exichnii	fodinichnia	post-depoziționale	*Planolites*	
	μC Marker		hypichnii mari concave	fodinichnia domichnia	post-depoziționale	*Planolites Thalassinoides*	
	alternanță de Ml		exichnii orizontal-	fodinichnia domichnia	post-depoziționale	*Planolites Thalassinoides*	

	Ml		exichnii suborizontale	fodinichnia domichnia	post-depoziționale	*Planolites* *Thalassinoides*	ICHNOFACIESUL
BMM 6	alternanță de S_{rcl}		hypichnii concave	fodinichnia domichnia repichnia cubichnia		*Planolites* *Thalassinoides* *Protovirgularia* *Lockeia*	
	și Ml		exichnii	fodinichnia	post-depoziționale	*Planolites*	
BMM 5	M_m (1,5 m) și SL	**AF mâloase-nisipoase**	endichnia	fodinichnia	sin-depoziționale	*Criptobioturbare*	
BMM 4 (8 m)	Alternanță de S_{pp} la S_{rcl}	Asociația faciesurilor heterolitice	endichnii	fodinichnia	post-depoziționale	*Planolites*	
			hypichnii concave	domichnia repichnia cubichnia domichnia	pre-depoziționale	*Paleophycus* *Protovirgularia* *Lockeia* *Thalassinoides*	
	și Ml		exichnii suborizontal-subverticale	fodinichnia	post-depoziționale	*Planolites* *Thalassinoides*	
BMM 3	alternanță de S_{rcl}		hypichnii concave	domichnia repichnia	pre-depoziționale	*Thalassinoides* *Protovirgularia* *Treptichnus*	
	și Ml		exichnii suborizontal-subverticale	fodinichnia domichnia	post-depoziționale	*Planolites* *Thalassinoides*	
BMM 2	alternanță de S_{rcl}		hypichnii concave	domichnia repichnia	pre-depoziționale	*Thalassinoides* *Protovirgularia* *Planolites*	
	și Ml		exichnii suborizontale	fodinichnia	post-depoziționale	*Planolites*	
BMM 1	alternanță de S_{rcl}		epichnii concave și convexe	domichnia domichnia	post-depoziționale	*Thalassinoides* *?Rhizocorallium*	
			hypichnii concave	domichnia fodincihnia	pre-depoziționale	*Thalassinoides* *Planolites*	
	și Ml		exichnii suborizontal-subverticale	fodinichnia	post-depoziționale	*Planolites*	
			endichnii	chemichnia	post-depoziționale	*Chondrites*	

Legend: proven discotinuity surfaces (endichnia-hypichnia model – red marked); major discotinuity surfaces (abundant endichnia-hypichnia model – red marked); deducted discontinuity surfaces (endichnia-non-hypichnia model – blue marked); µC –microconglomerate with green schist clasts; S_{pp} – plan-parallel laminated sandstones; S_{rcl} – ripple cross laminated sandstones; Si_{rcl}– riple cross laminated siltstones; Ml –laminated mudstones; M_m – massive mudstone; SL – sideritic limestones

Based on this scenario we estimate that from the Piatra Uscată Formation are "lacking" at least 150 m, from the red and green clays Member of Bisericani Formation over 700 m and from the greenish-gray mudstone Member of Bisericani Formation over 3000 m !!

It is hard to say how long the accumulation and erosion of these absent logs lasted, but it must have been a considerable interval, assuming that they were exclusively mudstone. In this context, it should be pointed out that ichnological analysis can highlight gaps materializing different time intervals, estimated by other methods.

CONCLUSIONS

All studied outcrops are characterized by alternations of deposits accumulated in low energy conditions and deposits accumulated due to event processes (such as debris flows, turbiditic currents or storm waves). In strata accumulated in calm conditions were recognized ichnoassemblies reflecting abundant populations of high diversity producers, that generated nearly all main ethological type trace fossils (fodinichnia, domichnia, repichnia, cubichnia, chemichnia).

For Piatra Uscată Formation were described some ichnogenera: *Chondrites, Planolites, Thalassinoides, Ophiomorpha, Bergaueria, Lockeia, Diplocraterion, Rhizocorallium, Cochlichnus* and *Treptichnus*. Toponomicaly, they are hypichnia, epichnia, rare endichnia/exihnia type. Ethologicaly, the described trace fossils are: *chemichnia*, *fodinichnia* and *domichnia*.

For red and green clays Member of Bisericani Formation were described: *Chondrites, Avetoichnus, Planolites, Lockeia, Thalassinoides* and *Rhizocorallium*. Most of them are *hypichnia* and *endichnia* type, rare *epichnia* (from toponomical point of view, Martinsson's terminology, 1970). Ethologicaly, they are chemichnia, fodinichnia, domichnia and agrichnia.

Greenish-gray mudstone Member of Bisericani Formation has the highest content of trace fossils. Among them some ichnogenera were described: *Palaeophycus, Lockeia, Protovirgularia, Planolites, Thalassinoides, Chondrites* and *?Rhizocorallium*. Most of them are preserved on the lower surface of the event-beds, as *hypichnia* type, subordinate *exichnia* and *endichnia* type. The hypichnia forms were already built up in the background sediment when the event sedimentation happens. So *hypichnia* were actually *endichnia* background sediment type. In this fine grains sediment we observed a high density of *endichnia* type trace fossils that show no contrast between galleries fillings and surrounding sediment lithology and also *exichnia* type ones with obvious contrast.

For each outcrop on which sedimentary facies and ichnological analysis was applied we have built summary tables with sedimentary facies, associated ichnogenera and their toponomical and ethological attributes and especially their placement relative to the event-beds (tables 1, 2, 3).

By tracking syn-depositional (*endichnia* type), post-depositional (*exichnia* and *epichnia* type) and pre-depositional (*hypichnia* type) trace fossils successions we identified discontinuity surfaces in sedimentary records. Some of them are proven using endichnia-hypichnia model, other are deducted trough endichnia-non-hypichnia model.

In this context were indentified over 25 discontinuity surfaces in Piatra Uscată Formation (aprox. 10 m logging), 16 surfaces in red and green clays Member of Bisericani Formation (aprox. 7 m logging) and over 30 surfaces in greenish-gray mudstone Member of Bisericani Formation (over 100 m analyzed log).

The method applied by us allows a qualitative assessment of discontinuities in the sedimentary records. So it should be point out that ichnological analysis is a very good tool to emphasize discontinuities form apparently continues deposits, embodying different time intervals, estimated by other methods not involved in this paper.

If we discuss the ratio between the thickness of the sediment recorded and potentially recorded, we can draw one conclusion: *what is preserved is only a small part of what happened in the sedimentary basin in analyzed points.*

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