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CALCAREOUS KLIPPE FROM METALIFERI MOUNTAINS (BRAD – GALDA AREA): MICROFACIES, MICROFOSSILS AND PALEOENVIRONMENT RECONSTRUCTIONS

~PhD Thesis Summary~

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INTRODUCTION

In the Metaliferi Mountains limestones occur frequently as isolated blocks within the Cretaceous wildflisch. They appear as calcarous klippes of variable sizes in the Mesozoic deposits.

The study of calcarous klippe from Metaliferi Mountains (Brad-Galda area) represents the subject of this Phd thesis. The topics chosen represents a novelty in an area where geological studies of sedimentary deposits were limited. Calcarous klippe from South Apuseni Mountains have not been studied in terms of microfacies and micropaleontology.

The present study aims to contribute to the knowledge of microfacies, biostratigraphy and paleoenvironmental reconstruction of these calcareous klippe.

Cap.1. Geological and geographical features

Metaliferi Mountains represents the structural unit of South Apuseni Mountains, extending from the Aries valley to the north and Mures valley to the south (Bleahu & M.Lupu, 1963, Ianovici et al., 1969) (Fig. 1).

From geological point of view this structural unit is characterized by the presence of four morphologically different complexes: mesozoic ophiolites, jurassic and cretaceous limestones, cretaceous flysch and neogene eruptive.

The tectonic units from the western basin are assigned to the Western Transilvanide, term used by Săndulescu (1984) and Balintoni (1994).

Transilvanide are subduction nappes (Săndulescu, 1984), composed of magmatic rocks and mesozoic sedimentary rocks. According to the tectogenesis that affected them (Balintoni, 1994, 1997), Western Transilvanide are divided into Transilvanide Austrice and Transilvanide Laramice.

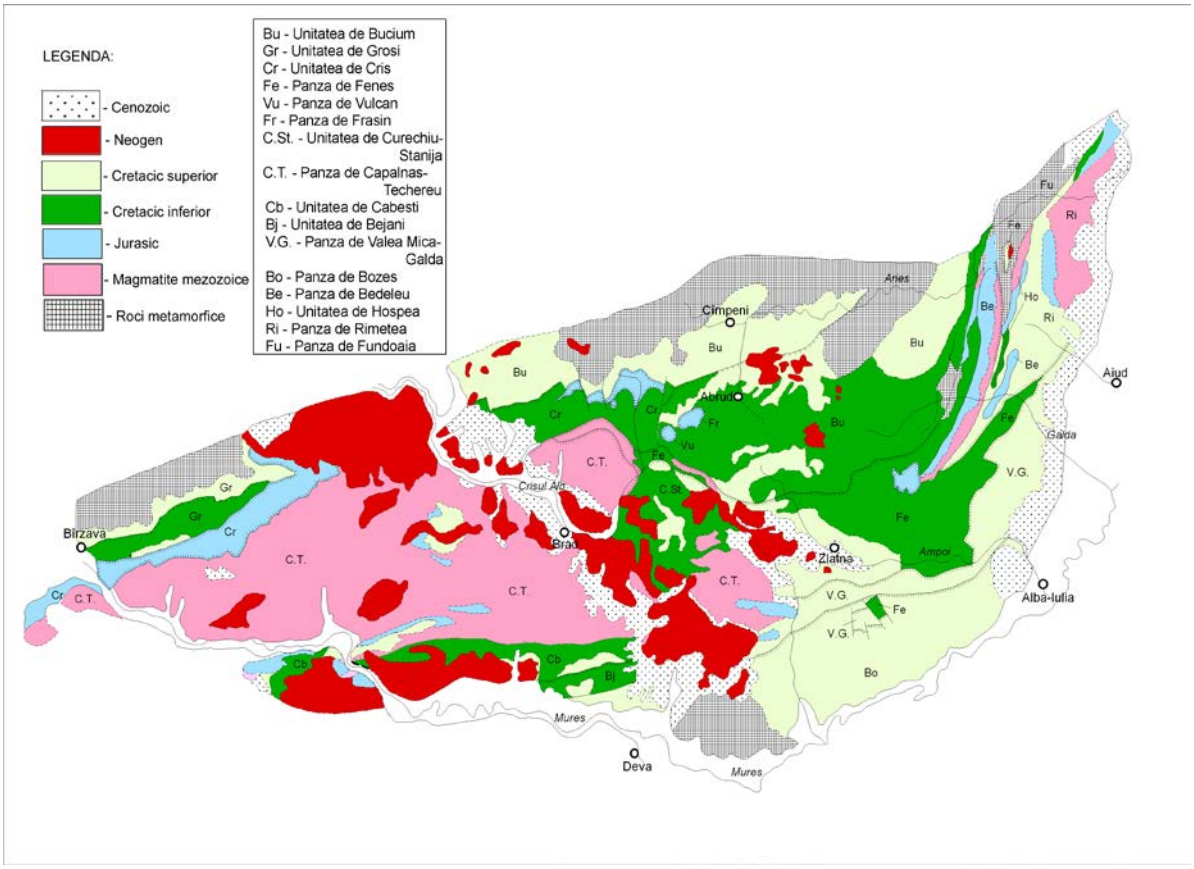

Fig. 1. Structural map of South Apuseni Mountains (from Cioflică et al.,1981, modified).

Bleahu & Lupu (1963) were the first who noted the existence of three structural units differentiated by the subbasement nature and by tectonic and facies features.

Following the investigation of S. Bordea (1971, 1972) and M. Lupu (1972) South Apuseni structure became better known and made it possible to distinguish several structural-facies units.

The main authors who have developed tectonic schemes in Southern Apuseni Mountain are: M. Lupu (1976), Bleahu et al. (1981), M. Lupu (1983), S. Bordea (1992), Balintoni (1996, 1997, 2001, 2003) (Fig. 2).

Lupu (în Ianovici et al., 1976)	Bleahu et al., 1981	M. Lupu, 1983	Săndulescu, 1984	Bordea, 1992	Balintoni, 1997, 2003
Unitatea de Bucium: • Calcare micritice • Stratele de Căbeşti • Stratele de Valea Dosului • Stratele de Ponor • Stratele de Pârâul Izvorului *Unitatea de Trascău:* • Stratele cu Aptychus • Calcarele de tip Stramberk • Seria detritică barremian-albiană *Unitatea de Drocea-Criş:* • Seria de Groşi • Formaţiunea de Crişul Alb • Flişul calcaros • Flişul grezos • Formaţiunea de Wildflisch (Formaţiunea de V. Morgaşului) *Unitatea de Feneş:* • Stratele de Feneş inferioare • Stratele de Feneş superioare • Stratele de Meteş (Formaţiunea de Wildflisch) *Unitatea de Căpâlnaş- Techereu:* • Stratele de Curechiu • Complexul calcaros cenuşiu stratificat • Seria vărgată • Stratele de Pârâul Izvorului *Pânza de Bedeleu:* • Formaţiunea mixtă • Calcarele de tip Stramberk	*Unitatea de Bucium:* • Formaţiunea de Valea Povernei • Formaţiunea de Ponor • Formaţiunea de Pârâul Izvorului *Unitatea de Groşi:* • Formaţiunea de Wildflisch inferioară • „Formaţiunea" senoniană *Pânza de Criş:* • „Formaţiunea" argilos micritică • „Formaţiunea" flişului nisipos-şistos • Formaţiunea de Valea Morgaşului *Pânza de Feneş:* • Formaţiunea de Feneş • Formaţiunea de Valea Dosului • Formaţiunea de Meteş • Formaţiunea de Valea lui Paul *Pânza de Frasin:* • Formaţiunea de Frasin *Pânza de Vulcan* *Pânza de Curechiu-Stanıja:* • Formaţiunea de Curechiu • „Formaţiunea" marno-calcaroasă • „Formaţiunea" vărgată • Formaţiunea de Pârâul Izvorului *Pânza de Căpâlnaş-Techereu:* • Formaţiunea de Fornădia *Unitatea de Căbeşti:* • Formaţiunea de Căbeşti • Formaţiunea de Dumeşti • Formaţiunea de Fornădia *Unitatea de Bejan:* • Formaţiunea de Bejan • Formaţiunea de Dumeşti *Pânza de Valea Mică-Galda* *Pânza de Bozeş:* • Formaţiunea de Bobâlna • Formaţiunea de Geoagiu • Formaţiunea de Bozeş *Sist. Pânzelor de Bedeleu:* • Unitatea de Hospea • Pânza de Fundoaia • Pânza de Bedeleu • Pânza de Rimetea (Formaţiunea de Râmeţi)	*Sistemul Pânzelor de Criş:* ➢ *Unitatea de Bucium* (caracter autohton) ➢ *Unitatea de Groşi* ➢ *Pânza de Criş* ➢ *Pânza de Feneş* ➢ *Petecul de acoperire Frasin* ➢ *Pânza de Vulcan* ➢ *Unitatea de Curechiu-Stănija* ➢ *Unitatea de Căpâlnaş-Techereu* ➢ *Unitatea de Căbeşti* ➢ *Unitatea de Bejani* ➢ *Pânza de Valea Mică-Galda* • *Pânza de Bozeş* *Sistemul pânzelor de Bedeleu:* ➢ *Unitatea de Hospea* ➢ *Pânza de Fundoaia* ➢ *Pânza de Bedeleu* ➢ *Pânza de Rimetea*	în Vest: ➢ *Pânza de Groşi* ➢ *Pânza de Criş* ➢ *Pânza de Techereu-Drocea* ➢ *Pânza de Căbeşti* • Stratele de Fornădia ➢ *Pânza de Bejani* • Stratele de Deva în Est: ➢ *Pânza de Feneş* ➢ *Pânza de Curechiu-Stănija* ➢ *Pânza de Trascău (Bedeleu)* ➢ *Pânza de Fundoaia* ➢ *Pânza de Bozeş*	➢ *Pânza de Bucium* • Formaţiunea de Ciuruleasa • Formaţiunea de Valea Povernei • Formaţiunea de Soharu • Formaţiunea de Pârâul Izvorului • Conglomeratele de Negrileasa ➢ *Pânza de Criş* • Formaţiunea de Crişul Alb • Formaţiunea de Valea Morgaşului ➢ *Pânza de Feneş-Blăjeni* • Formaţiunea de Feneş • Formaţiunea de Valea Dosului ➢ *Pânza de Frasin* ➢ *Pânza de Curechiu* ➢ *Pânza de Vulcan*	Transilvanide Austrice: ➢ *Pânza de Izvoarele* ➢ *Pânza de Valea Muntelui* ➢ *Pânza de Feneş:* • Formaţiunea de Feneş • Formaţiunea de Valea Dosului • Formaţiunea de Meteş ➢ *Pânza de Colţul Trascăului* ➢ *Pânza de Bedeleu* ➢ *Unitatea de Ardeu* ➢ *Pânza de Căbeşti:* • Formaţiunea de Căbeşti • Formaţiunea de Dumeşti ➢ *Pânza de Căpâlnaş-Techereu* ➢ *Unitatea de Bejan* Transilvanide Laramice: ➢ *Unitatea de Groşi* ➢ *Pânza de Criş:* • Formaţiunea argilos micritică • Formaţiunea flişului calcaros • Formaţiunea de Ciurulasa • Formaţiunea de Crişul Alb ➢ *Pânza de Vulcan* ➢ *Pânza de Frasin:* • Formaţiunea de Frasin ➢ *Pânza Munţilor Metaliferi:* • Pânze austrice: Feneş, Colţul Trascăului, Bedeleu • Formaţiunea de Valea lui Paul • Senonian detritic • Stratele de Râmeţ ➢ *Pânza de Mureş:* • Unităţi austrice: Curechiu-Stănija, Căpâlnaş-Techereu, Ardeu, Căbeşti • Cuvertura postaustrică: Stratele de Fornădia Stratele de Bobâlna Stratele de Geoagiu **N.B.** Balintoni (2003) include Pânza de Bozes în Pânzele Suragetice (Carpatii Meridionali)

Fig.2 Schemes proposed by various authors for the classification of western Transilvanides.

1.2. The Upper Jurassic and Lower Cretaceous carbonate deposits from Metaliferi Mountains

Jurassic sedimentation within Metaliferi Mountains started in the same time with the magmatic rocks occurrence. This is proved by the occurrence of some grainstones, limestones, marly shales and radiolarian jasp interlayers within the ophiolites (Ianovici et al., 1976).

The age of these interlayered sedimentary rocks was determine by the jasps from Râbicioare, where Dumitrică (in S. Bordea, 1972) identified a radiolarian association characteristic for Middle Jurassic. Another evidence is represented by the mediojurassic spores reworked within the Albian flish deposits from Ampoi Valley (Antonescu, 1973 in Ianovici et al., 1976). In the same wildflish deposits Herbich (1877, in Ianovici et al., 1976) have found oolithic limestones of Callovian age, proven by an ammonite association (Philloceras kudernatschi Hauer, Philloceras tortisulcatum d'Orbigny, Lytoceras adelaides Kuderatsch.)

Eocretacic formations occupy a large part of South Apuseni Mountains. Eocretacic sedimentary areas from of South Apuseni Mountains, develop differently from the Neojurasic ones and are also affected by different stages of diastrofism during the Cretaceous.

1.3 Evolution of ideas regarding the calcareous klippe from South Apuseni Mountains

The first description of calcareous klippes from Apuseni Mountains was provided by Hauer & Stache (1863, in Savu & Haidu, 1984); the author considers that the age of these deposits is Jurassic judging by the typical Stramberg like fauna. Later on Herbich (1866, 1867, in Savu & Haidu, 1984) assigned them a Tithonian age.

In that period of time most authors sustained that these klippe are coming from the basement overfolding movements. Pavai-Vajna (1915, in Savu & Haidu, 1984) and Vadasz (1917, in Savu & Haidu, 1984) described them as overthrust scales. Ilie (1930, in Savu & Haidu, 1984) considered that the main slope of Trascau Montains represented a nappe that was destroyed by erosion, the only proof of its existence being the reworked olistoliths.

Savu & Haidu (1984) considered klippe only the large limestone blocks located on the ridges while the smaller ones situated on hillsides or in valleys were considered olistolites (blocks that could be derrived from Bedeleu ridge or from bigger klippe.

In the studied area the limestones are well defined, confined by steep walls, without lateral continuity under the flish deposits that contains them. They have variable shapes and sizes ranging from several cubic meters (on Ampoi Valley) to kilometer long ridges (e.g Trascău- Ciumerna-Bedeleu ridge). Due to their solitary nature, their contrasting aspect comparing with the surroundings, they were named klippe, in order to emphasize the fact that they are allochtonous when compared with their substrate. It should be mentioned that these blocks used to be completely included into the wildflish deposits that contains them today.

Cap. 2. Methodology

The study of calcareous klippe from Metaliferi Mountains (Brad-Galda area) required a detailed research that involved several steps.

In an initial phase it was necessary to consult the existing papers related on the South Apuseni deposits from the library of the Faculty of Biology-Geology and those provided by the the scientific coordinator. Simultaneously we conducted several campaigns in the field, during which we have identified and sampled a number of 34 limestone klippe. During sampling a number of about 1000 samples were collected.

All the samples were processed in the laboratory by specific methods, resulting more than 1000 thin sections and polished slabs.

Next step was to analyze and describe the thin sections for the facies interpretations and microfossils identification in order to establish the depositional settings and the age of these deposits.

Cap.3. The calcareous Klippe from Valea Mică-Galda Nappe (between Galda and Cetea valleys)

Valea Mică-Galda Nappe (Lupu et al., 1979 Bleahu et al., 1981) develops in the eastern part of the Southern Apuseni Mountains. This Nappe has a monoformaţional nature and consists exclusively of Valea Mica Formation (Bordea

& board, 1982), which, based on the micropaleontological associations encountered, has been assigned to Senonian Campanian. The formation consists of a series of wildflisch type deposits occupying the right flamk of the Ampoiului valley, Văii Mici basin, and the springs area in the Cibului valley.

There are seven klippe belonging to this Nappe that we have studied. They ar located on Cetea Valley (Pietrele Cetii) and on Galda Valley (Gălzii Gorges and Galda de Sus).

3.1. PIETRELE CETII (CETII GORGES)

Three calcareous blocks have been sampled from these klippe, they are noted PC1, PC2 şi PC3, and have heights of over 60m.

Following the microfacies study the following microfacies types have been identified: coraligene boundstones with problematic microorganisms: wackestone–bindstone with *Bacinella* and ostreids, bioclastic lithoclastic rudstone-graistone/grainstone, bioclastic intraclastic rudstone/grainstone with oncoids, wackestone-packstone/mudstone with restrictive type fauna, coraligen-microbial boundstone with sponges. The microfacie types identified within the three olistoliths are indicative for an outer platform (PC1, PC2) and slope environment (PC3). Within PC1 and PC2 the bioclastic shoals containing frequent reef derived elements are the main constituents followed by microbial-coraligen bioconstructions; subordinate there are sediments belonging to a restricted subtidal area of a pretected platform. The carbonate breccia deposits from PC3 contains clasts eroded from a platform margin; they are probably the result of re-deposition on the slope controlled by gravitational processes.

The micropaleontologic association identified within the Pietrele Cetii is characteristic for Upper Tithonian–Berriasian

3.2. GĂLZII GORGES (POIENII GORGES)

Gălzii Gorges are located in the eastern part of Trascău Mountins on Galda Valley.

Following the microfaciesal study six microfacies types have been identified: fenestral laminitic mudstone; bioclastic mudstone/wackestone; peloidal bioclastic packstone-grainstone; bioclastic grainstone; coraligen microbial boundstone;

microbial bindstone. The deposition of these microfacies types took palce in the high energy areas of of the platform margin (bioconstructed and bioacumulated deposits) and in areas with low hidrdynamics from th eplatform interior (lagoon, tidal ponds, supratidal zone)

The micropaleontological association identified is characteristic for Berriasian–Valanginian interval.

3.3. CALCAREOUS KLIPPE FROM GALDA DE SUS

Calcareous Klippe from Galda de Sus are located in the eastern pat of Trascău Mountins on Galda Valley. The samples collected belong to three calcareous blocks. Several microfacies types belonging to subtidal, intertidal, and supratidal environments have been identified. Within these zones lagoon, tidal bar, pond and swamp sub-environments were identified.

The determined age of these deposits is Berriasian-Valanginian.

Cap. 4. Calcareous Klippe from Feneș Nappe (Ampoi Valley)

Feneş Nappe contains three formations (after Bleahu et al., 1981): Feneş Formaion, Valea Dosului Formation, Meteş Formation şi Valea lui Paul Formation. Nineteen olistoliths belonging to this Nappe were sampled, they crop out on Ampoi Valley and its tributary streams.

4.1. AMPOIŢEI GORGES

The limestones are cropping out on Ampoiţei Gorges and belong to the Upper Fenes Frmation.

Following the microfaciesal study two microfacies types have been identified: coraligen-microbial boundstones with sponges and intraclastic bioclastic rudstone-grainstone containing extraclasts. They are characteristic for the upper and lower slope. The micropaleontological association identified here is indicative for Upper Jurassic – Early Cretaceous.

4.2. PIETRELE AMPOIŢEI

Pietrele Ampoiţei are located on the southern border of Trascău Mountains on the left flank of Ampoi Valley. They belong to Meteş Formation and are

represented by three calcareous blocks with heights between 15 şi 44 meters. They were named PA1 and PA2.

The olistoliths are composed of carbonate breccia containing clasts with sizes varying from boulders to gravels, having variable degrees of roundness. The sorting is very poor and the clasts heve random orientation.

Following the microfacies analysis on the limestone breccia clasts I separated the following microfacies types: coraligen–microbial boundstone with red algae, bindstone with biogenic crusts, lithoclastic rudstone–grainstone, and bioclastic grainstone–packstone.

Following this analysis we can affirm that the limestone clasts comprising the breccia forming the two studied olistoliths derived from the marginal zone of a carbonate platform (coraligen–microbial boundstone) and also from the upper and middle part of the slope (rudstone and bindstone).

The micropaleontological association comprising algae and foraminifera is tipical for the Upper Tithonian – Berriasian in the tethyan area.

4.3. CALCAREOUS KLIPPE FROM FIERULUI VALLEY

It is located North from Pietrele Ampoiţei, on Fierului Valley. The limestones from this block are mainly composed of a bioconstruted/bioaccumulated micritic-peloidal sediment, with irregular thrombolitic structure (clotted fabric).

The presence of microbial limestones associated with sponges, of stromatactis type structures in these deposits are characteristic for a microbial mud mound (*microbial mud-mound*, James & Bourque, 1992; Bosence & Bridges, 1995) formed in relatively deep waters with low hidrodynamics, located probably on the upper slope.

The age of this Klippe can only be assumed to be Upper Jurassic – ?Lower Cretaceous.

4.4. PIATRA BOULUI

Piatra Boului is located on a ridge between Ampoiţei (to the north) and Ampoiului (to the south). It belongs to Meteş Formation.

Following the microfaciesal study two microfacies types have been identified: coral boundstone with bigenic crusts and lithoclastic bioclastic rudstone/grainstone. These mictofacies are characteristic for an outer platform environmnt. The

micropaleontological association identified here is sugesting an Upper jurassic age foe this klippe.

4.5. PIATRA CORBULUI

Piatra Corbului is located in Tăuţi village, on the left side of Ampoi Valley. Piatra Corbului blongs to Meteş Formation. It is made of breccia composed of limestone clasts and other extraclasts bound together into carbonate cement. The extraclasts are represented by basic volcanic rocks (andesite and basalts)

Following the microfaciesal study of the limestone clasts, several microfacies types have been identifie: coral-microbial boundstone, *Neoteutloporella socialis* boundstones, bindstone with biogenic crusts, bioclastic grainstone, peloidal bioclastic wackestone/packstone, wackestone with *Salpingoporella annulata* and grainstone-rudstone lithoclastic bioclastic. The microfacies types identified within the Piata Corbului are characteristic for peitidal, platform margin, and slope environments

Based on the fossil association encountered into the limestone clasts, an Upper Tithonian – Berriasian age is assigned for the time of their initial formation.

4.6. PIATRA VARULUI

Piatra Varului is located on the right side of Ampoi Valley and is also part of the Meteş Formation. The microfaciesal study of the olistolith revealed two microfacies types: coral-microbial boundstone and peloidal bioclastic grainstone. They formed on external areas of a carbonate platform. All these deposits were affected were highly affected by the burial diagenesis that led to important textural and fabric alteration.

The age of these deposits is uncertain, it can be assumed that they are Upper Jurassic – ?Lower cretaceous.

4.7. CALCAREOUS KLIPPE FROM MACIULUI HILL (METEŞ)

There were four olistoliths sampled in this area (M1, M2, M3, M4); they belong to the Meteş Formation.

Following the microfaciesal study of the four olistoliths the following microfacies types have been identified: reef bioconstructions, bioclastic lithoclastic

rudstone/grainstone and rudstone/floatstone lithoclastic-bioclastic. They are characteristic for two depositional systems: platform margin (M1) with reef bioconstructions and bioclastic shoals, and slope deposits (olistolitele M2, M3, M4) with microbial bindstones with sponges and gravity flows. An Upper Jurassic age have been assigned for these deposits based on the identified micropaleontological association .

4.8. CALCAREOUS KLIPPE FROM POIANA AMPOIULUI (METEŞ)

Calcareous Klippe localized in Poiana Ampoiului Village belong to the Meteş Formation.

The white limestone blocks are made out of carbonate breccia containing carbonate an volcanic clasts The limestone clasts contain different microfacies types: coral-microbial boundstone and laminated peloidal bioclastic packstone. Formation of the breccia is the result of re-deposition on the slope during gravity flow events. The identified characteristics of the breccia clasts and the presence of a granular carbonatic matrix justifies the assignment of these deposits to debritic cohesive flows.

The fossil association encountere both in the matrix and in the the breccia clasts points to an Upper Jurassic age for the formation of these deposits.

4.9. PIETRELE BULBUCI

Pietrele Bulbuci are located on a small peak situated on the left side of Ampoi Valley just few kilometers East of Zlatna. The calcareous klippes belong to Valea lui Paul Formation (Bleahu & Dimian, 1967) included in Feneş Nappe (Lupu M., 1975).

The studied limestone klippes exhibit clasts-supported, poorly sorted limestone breccia consisting of angular and rounded clasts of different sizes. The microscopic study of the clasts reveals the polimictic character of the breccia, the limestone pebbles containing four facies associations: coral-microbial boundstone, bindstone (algal microbial crusts), lithoclastic-bioclastic rudstone and bioclastic-intraclastic packstone/grainstone. The interpretation of microfacies types shows that the pebbles were eroded from a bioconstructed (coral-microbial boundstones and bindstones) or bioacumulated platform margin (bioclastic shoals) and from the

upper slope (rudstones and possibly some of the bindstones).This eroded and reworked material was transported by gravity flow processes and deposited somewhere on the upper slope.

The age of the limestone pebbles that forms the klippes is Late Tithonian-Berriasian.

4.10. LIMESTONES FROM VALEA MICĂ

These limestone blocks are represented by three blocks belonging to the Valea lui Paul Formation. The microfacies associations separated here are: boundstones with corals, sponges algae and microbes, rudstone/grainstone lithoclastic bioclastic, and grainstone bioclastic extraclastic. They are characteristic for two depositional systems: platform margin (bioconstructions) and upper slope deposits (gravity flows). În urma studiului microfaciesal au putut fi cunoscute asociaţii de faciesuri caracteristice zonelor de margine de platformă (bioconstrucţii) şi pantă superioară (curgeri gravitaţionale).

The limestone olistoliths from Valea Mică contain a microfossil association indicating an Upper Jurassic age.

Cap. 5. Vulcan Klippe

Vulcan Klippe is represented by a massive mountain ridge (1263m) located at the confluence between Crișului Alb and Arieșului streams.

The sedimentologic and micropaleontologic study encountered in the north-eastern part of this klippe allowed me to identify three facies types that belong to an external zone of a carbonate platform. The deposits are represented by reef bioconstructions, bioclastic shoals, and back reef grainy deposits.

The age of these deposits is based on foraminifera and algae association is Upper Oxfordian and Middle Tithonian.

Cap. 6. Calcareous Klippe from Pânza de Criș (Brad-Tomnatec area)

Criş Nappe is made of three formations: micritic-argilous “Formation” the sandy – shale “Formation” and Valea Morgaşului Formation. The later one is

containing all the olistoliths fron this area. Six calcareous Klippe from this Nappe were the subject of my analysis.

6.1. CALCAREOUS KLIPPE FROM MORGAŞULUI VALEY

Two calcareous klippe noted VMO1 and VMO2 located on the Morgaş Valley north from Ribiţa village were studied. The microfaciesal study of the VMO1 klippe revealed the existence of internal facies (protected facies, beach deposits, and open marine deposits), shallow subtidal deposits (intraclastic bioclastic grainstone or rudstone), and deep water dposits. The microfaciesal study of the VMO2 klippe indicated the existence of a carbonate ramp. The main difference when compared with VMO1 is that from a certain point on, the sedimentation character in the VMO2 changed and the platform changed from a ramp type morphology to a rimmed platform morphology (Fig. 3).

The identified micropaleontological association from VMO1 is typical for Tithonian - ?Berriasian while the one from VMO2 can be assigned to Kimmeridgian-Tithonian.

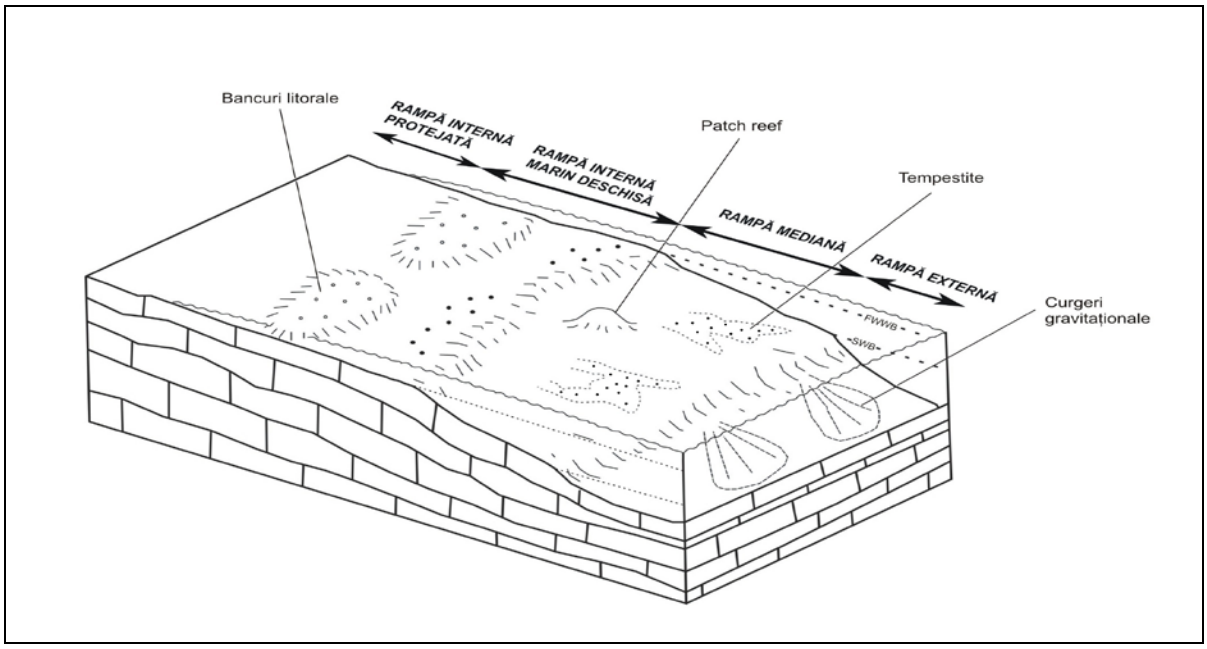

Fig.3 Paleoenvironment distribution on the carbonate platform VMO1 - schematic reconstruction.

6.2. PIATRA STRÂMBU

The grey limestones forming Piatra Strâmbu crop out on the north-west of Cris Village. The sedimentologic and micropaleontologic study allowed the recognition of two depositional environments: platform margin coral – microbial boundstone and peloidal bioclastic packstone-grainstone) and carbonate slope (rudstone/floatstone bioclastic intraclastic, graded grainstone-packstone and oolitic grainstone).

An Upper Tithonian – Berriasian was determined for the age of formation of these deposits.

6.3. KLIPPA BULZIŞORUL

The limestone block representing the Bulzișorul klippe is located in the NW of Cris Village. It is made of a fine grainstone sediment composed of bioclasts, intraclasts and extraclasts. These deposits may represent platform margin sediments formed under high energy conditions or gravitational flows on the slope. The determined age is Upper Jurassic.

6.4. CALCAROUS OLISTOLITH FROM CRIŞ VILLAGE

The microfacies study on the samples from this olistolithe revealed a composition dominated by reefal facies with coral microbial boundstones. They were deposited on a platform margin.

These limestones contain a flora and fauna that is specific for the Upper Jurassic.

6.5. GROHOT HILL

Grohot massive is situated in the northern part of Brad area.

Based on the microfossil association determined from these deposits we separated three units: Unit A (Upper Jurasic), Unit B (Berriasian–Valanginian), şi Unit C (Upper Barremian–Lower Apţian).

Unitatea A contains two microfacie types: boundstones with corals and biogenic crusts and peloidal bioclastic grainstone/packstone representing upper slope deposits and peri-reef environment.

From the lithostratigraphic point of view Unit B is represented by: platform margin deposits (coraligen microbial boundstone, bioclastic intraclastic grainstone, and bioclastic grainstone) and lacustrine deposits.

In unit C we have identified beach deposits, channel deposits, lagoonal deposits and slpe deposits.

Cap.7. Conclusions

Upper Jurassic was a period of intense development of coral reefs along the edge of Tethys (during a HST period). It also meant a period of prolific development of sponge and stromatoporoids reefs and of microbial carbonates in various depositional environments (Leinfelder & Schmid, 2000; Sclagintweith & Gawlick, 2008; Olivier et al., 2010).

The studied limestone Klippe from Brad-Galda area in Southern Apuseni Mountains represents large limestone blocks detached from the carbonate platforms developed in Upper Jurassic-Lower Cretaceous period in the northern part of Tethys, and embedded in Cretaceous wildflisch formations. Wildflish sedimentation began in the Upper Aptian and continued during the Lower Albian, sometimes even to lower Cenomanian (Bleahu & Dimian, 1967). Differential erosion has exposed limestone massifs that appear well individualized as singular projections, bounded by steep walls.

The limestone olistholits (klippe) from Brad-Galda area (Southern Apuseni Mountains) belong to four big tectonic units (from west to east): ***Valea Mică-Galda Nappe*** , ***Feneş Nappe***, ***Criş Nappe*** şi ***Vulcan Nappe***.

Valea Mică-Galda Nappe. Limestone Klippe studied within this Nappe are seven and are located on Cetea Valley (Pietrele Cetii) and Galda Valley (Gălzii Gorges and Galda de Sus). Olistolits are composed predominantly of carbonate breccias, bioclastic calcarenite and calcirudite beds with "reef" elements. Following the microfacies analysis deposits characteristic for inner platform environments (Cheile Gălzii, Galda de Sus) external platform (Pietrele Cetii, Gălzii Gorge) and slope (Pietrele Cetii) have been identified.

The micropaleontological associations encountered in the analyzed klippe from Valea Mică-Galda shows a Upper Tithonian - Berriasian age for the limestone that make up Pietrele Cetii and an Berriasian-Valanginian age for those from Gălzii Gorge and Galda de Sus.

Nineteen olistoliths have been sampled and anlysed from **Feneş Nappe,** in outcrops lovated on the Ampoi river valley and its effluents. After the microfaciesal study, deposits belonging to inner platform (Piatra Corbului) outer platform (Pietrele Ampoiței, Piatra Boului, Piatra Corbului, Piatra Varului, Dealul Maciului, Piatra Bulbuci and Valea Mică) and slope (Ampoiței Gorge, Pietrele Ampoiței, Fierului Valley, Piatra Corbului, Dealul Maciului, Poiana Ampoiului, Pietrele Bulbuci and Valea Mică) were encountered.

Based on a micropaleontological association of algae and foraminifera we can state that the limestones from Feneș Nappe have an Upper Jurassic age, sometimes extending into Lower Cretaceous.

There were seven studied limestone klippe from ***Criș Nappe;*** they demonstrate the existence of rimmed carbonate patforms (Piatra Stâmbu, Bulzișor Klippe, Olistolite from Criș, Dealul Grohot) and of those with ramp morphology (Valea Morgașului Klippe).

The micropaleontologic study of these deposits from Criș Nappe identified deposits of Tithonian – Berriasian age, except the deposits from Grohot Hill who's age is extending from Upper Jurassic to Upper Barremian – Lower Aptian.

Vulcan Klippe is a mountain range of considerable size made of carbonate sediments belonging to an external area of a carbonate platform. They were identified as reef bioconstructions, bioclastic shoals, and backreef deposits. The age of Vulcan Klippe is Upper Oxfordian – Middle Tithonian.

Selective bibliography

ANTONESCU, E. (1973) Asociaţii palinologice caracteristice unor formaţiuni cretacice din Munţii Metaliferi. *Dări de Seamă ale Institutului de Geologie* 59/3:115-169.

ANTONESCU, E. (1974) Date palinostratigrafice asupra depozitelor cretacice din regiunea Galda de Sus - Poiana Aiudului (Munţii Metaliferi). *Dări de Seamă ale Şedinţelor* 60/4: 25-49.

ARNAUD-VANNEAU A. & ARNAUD, H. (1990) Hauterivian to Lower Aptian carbonate shelf sedimentation and sequence stratigraphy in the Jura and northern Subalpine chains (southeastern France and Swiss Jura). *Special Publication int. Ass. Sediment.* 9: 203-233.

BALINTONI, I. (1994) Structure of Apuseni Mountains. *ALKAPA II, Field Guide Book, Romanian Journal of Tectonics and Regional Geology* 75, Supliment 2: 51-58.

BALINTONI, I. (1996) Transilvanide vestice, comentarii structurale. *Studia Universitats Babeș-Bolyai (Geologia)* 41/1: 95-99.

BALINTONI, I. (1997) Geotectonica terenurilor metamorfice din România. *Cluj-Napoca, Editura Carpatica*, 176 p..

BASSOULLET, J.-P. (1997b) Algue Dasycladales - Distribution des principales especes. In: Groupe Français d'Étude du Jurassique (1997). – Biostratigraphie du Jurassique ouest-européen et méditerranéen: zonations parallèles et distribution des invertébrés et microfossiles. Cariou E. & Hantzpergue P. (coord.). *Bull. Cent. Rech. Explor-Prod. Elf-Aquitaine* 17: 339-342.

BLEAHU, M (1976) Poziția structurală a Munților Apuseni în cadrul sistemului alpino-carpato-dinaric (în vol. Munții Apuseni). *Editura Academiei.*

BLEAHU, M. & LUPU, M. (1963) Dinamica scoarței terestre. *Editura științifică și Pedagogică,* București.

BORDEA, S. (1971) Date stratigrafice și tectonice noi în zona Blăjeni-Buceș Vulcan (Munții Metaliferi). *Dări de Seama ale Şedinţelor* 57: 17-26.

Cetea-Pleşa din zona Galda-Râmeţi. *Dări de Seama ale Şedinţelor* 54/1: 223-237.

BORDEA, S., BORDEA, J. & PURICEL, R. (1970) Contribuții la cunoașterea depozitelor cretacice din zona Curechiu – Munții Metaliferi. *Dări de Seamă ale Institutului Geologic Geofizic, București* 55 (1967-1968): 38-48.

BRANDNER, R., FLÜGEL, E., & SENOWBARI-DARIAN, B. (1991) Microfacies of carbonate slope boulders: indicator of the source area (Middle Triassic: Mahlknecht Cliff, Western Dolomites). *Facies* 25: 279-296.

BRUNI, R., BUCUR, I.I. & PREAT, A. (2007) Uppermost Jurasic-Lower Cretaceous carbonate deposits from Fara San Martino (Maiell, Italy): biostratigraphic remarks. *Studia Universitatis Babeș-Bolyai, Geologia* 52 (2): 45-54.

BUCUR, I.I. (1993) Les représentants du genre *Protopeneroplis* Weynschenk dans les dépôts du Cretace inferieur de la zone de Resita-Moldova Noua (Carpathes Meridionales, Roumanie). *Revue de Micropaleonologie*, 36: 213–223.

BUCUR, I.I. (1997b) Representatives of the genus *Protopeneroplis* (Foraminiferida) in the Jurassic and Cretaceous deposits in Romania.

Comparisons with other regions of the Tethyan area. *Acta Palaeontologica Romaniae* 1: 65-71.

BUCUR, I.I. (1999) Stratigraphic significance of some skeletal algae (Dasycladales, Caulerpales) of the Phanerozoic. *Palaeopelagos Special Publication* 2: 53-104.

BUCUR, I.I. & SASARAN, E. (2005b) Micropaleontological assemblages from the Upper Jurassic-Lower Cretaceous deposits of Trascău Mountains and their biostratigraphic significance. *Acta Palaeontologica Romaniae* 5: 27-38.

BUCUR, I.I., SĂSĂRAN, E., BALICA, C., BELEŞ, D., BRUCHENTAL, C., CHENDEŞ, C., CHENDEŞ, O., HOSU, A., LAZAR, D. F., LĂPĂDAT, A., MARIAN, A. V., MIRCESCU, C., TURI, V. & UNGUREANU, R. (2010b) Mesozoic carbonate deposits from some areas of the Romanian Carpathians. Case studies. Ed. *Presa Universitară Clujeană*, 203 p..

BURNE, R.V., BAUD, J & deDECKER, (1980) Saline lake charophytes and their geological significance. *Journal of Sedimentary Petrology* 50: 281-293.

BURNE, R.V. & MOORE, L.S. (1987) Microbialites: Organosedimentary deposits of benthic microbial communities. *Palaios* 2: 241-254.

CAMOIN, G.E. (1995) Nature and Origin of Late Cretaceous Mud-Mounds, North Africa. In: Monty C.L.V., Bosence D.W.J., Bridges P.H., Pratt B.R. (eds.) Carbonate mud-mounds: their origin and evolution. *Spec. Publ. Int. Assoc. Sediment.* 23: 385-400.

CATINCUŢ, C. & MICHETIUC, M. (2010) Microfacies and microfossils of the Upper Tithonian-Berriasian limestone in the Pietrele Bulbuci klippes (South Apuseni Mountains, Romania). *1st International Geosciences Student Conference, Bucharest, 22-24 April 2010.*

CATINCUŢ, C., MICHETIUC, M. & BUCUR, I.I. (2010) Reconstituirea unei margini de şelf Jurasic superior-Cretacic inferior pe baza klippelor calcaroase din Cheile Cetii (Cetea, judeţul Alba). *Sesiunea Ştiinţifică Anuală "Ion Popescu Voiteşti",* Program şi Abstracte, Eds.: Filipescu, S.

CIOFLICĂ, G., SAVU, H., NICOLAE, I., LUPU, M. & VLAD, S. (1981) Alpine ophiolitic complexes in South Carpathians and South Apuseni Mountains. *Carpato-Balkan Geological Association, XII Congress,* 18, 77 p..

DELECAT, S. & REITNER, J. (2005) Sponge communities from the Lower

DRAGASTAN, O., CIBOTARU, T. & BRUSTUR, T. (1987) *Neoteutloporella socialis* (PRATURLON), algue „recifale" du domaine Tethysien, *Revue de Paleobiologie* 6/1: 143-149.

DRAVIS, J. (1979) Rapid and widespread generation of recent oolitic hardgrounds on a high energy Bahamian platform. Eleuthera Bank, Bahamas. *Journal of Sedimentary Petrology* 49: 195-208.

EBLI, O. & SCHLAGINTWEIT, F (1998) On some biostratigraphically important microfossils (benthic foraminifera, dasycladales) from subsurface Late Jurassic–Early Cretaceous shallow water limestones of S-Germany. *Mitt Bayer Staatssamml Palaeont. Hist. Geol.* 38:9-23.

ELIÁŠOVÁ, H. (1981a) Some binding microorganisms of the Stramberk reef limestones (Tithonian, Czechoslovakia). *Věstnik Ústředniho ústavu geologickėho* 56/1: 27-32.

ELIÁŠOVÁ, H. (1981b) The Tithonian Reef of Stramberk Limestone (Czechoslovakia, West Carpathians). *Časopis pro mineralogii a geologii* 26: 113-124.

ELIOT, G.F. (1963) Problematicum microfossils from the Cretaceous and Palaeocen from the Middle East. Palaeontology 6 (part. 2): 293-300.
FLÜGEL, E. (1982) Microfacies analysis of limestone. Springer, 633 p..
FLÜGEL, E. (2004) Microfacies of carbonate rocks. Analysis, interpretation and aplication. Springer, 976 p..
FLÜGEL, E., DI STEFANO, P. & SENOWBARI-DARYAN, B. (1991) Microfacies and Depositional Structure of Allochthonous Carbonate Base-of-Slope Deposits: The Late Permian Pietra di Salomone Megablock, Sosio Valley (Western Sicily). *Facies* 25: 147-186.
GHERMAN, I. (1943) Cercetări geologice în colţul de SV al Depresiunii Transilvaniei (între Valea Stremţului şi Valea Ampoiului). *Revista Muzeului Mineralogic-Geologic al Universităţii din Cluj* 7/1-2: 1-110.
GHIȚULESCU, T.P. & SOCOLESCU, M. (1941) Étude géologique et minière des Monts Métalifères. *An. Inst. Géol. Roum.* 21: 181- 464.
GRANIER, B., DELOFFRE, R. (1993) Inventaire critique des algues dasycladaleans du Jurassique et du Crétacé. II° partie : les algues dasycladaleans du Jurassique et du Crétacé. *Revue de Paleobiologie* 12: 19-65.
IANOVICI, V., GIUȘCĂ, D., GHIȚULESCU, T.P., BORCOȘ, M., LUPU, M., BLEAHU, M. & SAVU, H. (1969) Evoluția geologică a Munților Metaliferi. *Editura Academiei R.S.R., București*, 742p..
ILIE, M. (1953) Structura geologică a depresiunii Abrud. *An. Comitetului Geologic* 25: 37-117.
INSALACO, E. (1996) Upper Jurassic microsolenid biostromes of northern and central Europe: facies and depositional environment. *Palaeogeography, Palaeoclimatology, Palaeoecology* 121: 169- 194.
INSALACO, E. (1999) Facies and palaeoecology of Upper Jurassic (Middle Oxfordian) coral reefs in England. *Facies* 40: 81-100.
INSALACO, E., HALLAM, A. & ROSEN, B. (1997) Oxfordian (Upper Jurassic) coral reefs in Western Europe: reef types and conceptual depositional model. *Sedimentology* 44: 707-734.
JENKINS, H. C. (1972) Pelagic "oolites" from the Tethyan Jurassic. *Journal of Geology* 80: 21-33. Abs.
KAŹMIERCZAK, J., COLEMAN, M.L., GRUSZCYSKI, M. & KEMPE, S. (1996) Cyanobacterial key to the genesis of micritic and peloidal limestones in ancient seas. *Acta Palaeontologica Polonica* 41/4: 319-338.
KEUPP, H., JENISCH, A., HERMANN, R., NEUWEILER, F. & REITNER, J. (1993) Microbial carbonate crusts - a key to the environmental analysis of fossil spongiolites? *Facies* 29: 41-54.
KOBLUK, D.R. & RISK, M.J. (1977a) Micritisation and carbonate- grain binding by endolithic algae. *AAPG Bull*. 61: 1069-1082.
KRAJEWSKI, M. & OLSZEWSKA, B. (2006) New data about microfacies and stratigraphy of the Late Jurassic Aj-Petri carbonate buildup (SW Crimea Mountains, S Ukraine). *Neues Jahrbuch für Geologie und Paläontologie Monatschefte* 5: 298-312.
LEINFELDER, R.R. (1992) A modern-type Kimmeridgian reef (Ota Limestone, Portugal): implications for Jurassic Reef Models. *Facies* 26: 11-34.
LEINFELDER, R.R., SCHLAGINTWEIT, F., WENER, W., EBLI, O., NOSE, M., SCHMID, D.U. & HUGHES, G.W. (2005) Significance of stromatoporoids

in Jurassic reefs and carbonate platforms - concepts and implications. *Facies* 51: 287-325.

LUPU, D. & LUPU, M. (1982) Noi elemente biostratigrafice privind depozitele eocretacice din Culoarul Mureșului din regiunea Devei (Munții Metaliferi). *St. Cerc. Geol. Geog. Geogr (Geologie), Academia R:S: România,* București 27: 98-105.

LUPU, M. (1964) Asupra vârstei stratelor cu Aptychus din masivul Trascău. *Dări de Seamă ale Institutului de Geologie și Geofizică,* București 50/2 (1962-1963): 247-250.

LUPU, M. (1965) Prezența microfaciesului cu Lombardia și Glochaete în Masivul Trascău. *Dări de Seamă ale Institutului de Geologie și Geofizică,* București 51/2 (1963-1964): 23-24.

LUPU, M. (1983) The Mesosoic history of the South Apuseni Mountains. *An. Inst. Geol., Geofiz., București (Lucr. Congr. XII Asoc. Geol. Carp.-Balc.)* 60: 115-124.

MANTEA, G. & TOMESCU, C. (1986) Geological structure of the Central area of the Metaliferi Mountains Balșa-Ardeu-Cib zone. *Dări de seamă ale ședințelor Institutului de Geologie și Geofizică* 70-71/5: 129-148.

MELIM, L.A. & SCHOOLE, P.A. (1995) The forereef facies of the Permian Capitain Formation: The roll of sediment supply versus sea-level changes. *Journal of Sedimentary Research* B65/1: 107-118.

MEYERS, J.M. (1987) Marine vadose beachrock cementation by cryptocrystalline magnesian calcite - Maui, Hawaii. *Journal of Sedimentary Petrology* 57: 558-570.

REID, P. (1987) Nonskeletal peloidal precipitates in Upper Triasic reefs, Yukon territory (Canada). *Journal of Sedimentary Petrology* 57/5: 893-900.

REID, R.P. & MACINTYRE, I.G. (2000) Microboring versus recrystalization: further insight into the micritization process. *Journal of Sedimentary Research* 70/1: 24-28.

REITNER, J. (1986) A comparative study of the diagenesis in diapir-influenced reef atolls and a fault block reef platform in the late Albian of the Vasco-Cantabrian Basin (Northern Spain). In: Schroeder, J.H. & Purser, B.H.(eds.), *Reef diagenesis.* Springer, p. 186-209.

REITNER, J. (1993) Modem Cryptic Microbialite/Metazoan Facies from Lizard Island (Great Barrier Reef, Australia) - Formation and Concepts. *Facies* 29: 3-40.

REITNER, J. & NEUWEILER, F. (1995) Mud mounds: recognising a polygenetic spectrum of fine-grained carbonate buildups. *Facies* 32: 1-70.

RIDING, R. (1991) Classification of microbial carbonates. In: R. Riding (ed.), *Calcareous algae and stromatolites*. Springer-Verlag, Berlin, p. 21-51.

RIDING, R. (2000) Microbial carbonates: the geological record of calcified bacterial-algal mats and biofilms. *Sedimentology* 47 (Suppl.1): 179-214.

RIDING, R. (2002) Structure and composition of organic reefs and carbonate mud mounds: concepts and categories. Earth-Science Reviews 58: 163-231.

RODINE, J. D. & JOHNSON, A. M. (1976) The ability of debris, heavily freighted with coarse clastic materials, to flow on gentle slopes. *Sedimentology* 23: 213-234.

RUBERTI, D. (1993) Late Cretaceous carbonate shelf-to slope facies in the central-western Matese (Central Apennines, Italy). *Geornale di Geologia*, ser.3 v. 52/2: 117-129.

SAVU, A. & HAIDU, I. (1984) Asupra genezei și evoluției klippelor de calcar din Munții Trascău. Studia Universitatis Babeș-Bolyai (Geologie-Geografie), Cluj-Napoca 29: 30-36.

SĂNDULESCU, M. (1984) Geotectonica României. *Editura tehnica,* București; 335 p..

SĂSĂRAN, E. (2000) Microfacies, microfossils and sedimentary evolution of the Sănduleşti limestone Formation in Cheile Turzii (Apuseni Mountains, Romania). *Acta Palaeontologica Romaniae* 2: 453-462.

SĂSĂRAN, E. (2001) Upper Jurassic-Lower Cretaceous carbonate rocks from Trascău Mountains. *Algae and carbonate platforms in western part of Romania: field trip quide book 4th regional meeting of IFAD,* Cluj-Napoca, Romania: 31-41.

SHEN, J-W & WEBB, G. (2005) Metazoan-microbial framework fabrics in a Mississippian (Carboniferous) coral-sponge-microbial reef, Monto, Queensland, Australia. *Sedimentary Geology* 178: 113-133.

SHINN, E. A. (1983) Tidal flat. In: Scholle A.P., Bebour D.G. & Moore C.H. (eds.): *Carbonate depositional environments. AAPG Memoir* 33: 171-210.

TUCKER, E. (1990) Shallow-marine diagenesis. In. TUCKER, E. & WRIGHT, V.P. (eds.): *Carbonate Sedimentology*. *Blackwell Scientific Publications*: 318-336.

WRIGHT, V.P., TAYLOR, K.G. & BECK V.H. (2000) The paleohydrology of Lower Cretaceous Seasonal Wetlands, Isle of Wight, Southern England, *Journal of Sedimentary Research* 70/3: 619-632.