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TYPES OF LITHOLOGICAL SEQUENCES AND SUCCESSIONS IN THE TUFF AND GYPSUM SUBFORMATIONS OF LOW BADENIAN FROM PIATRA VERDE (SLĂNIC-TEIŞANI)

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Abstract: This paper presents the diagnosis and interpretion of the sulphatic-evaporitic facieses from the Southern side of Eastern Carpathians, Slănic syncline, in Badenian deposits at Piatra Verde. The succession of evaporitic facieses, with emphasis of different gravity flow stages, is followed by facies modelling and basin evolution interpretation by means of sequential stratigraphy analysis concept.

Keywords: the Southern side of Eastern Carpathians, Tarcău nappe, Badenian of Slănic molasse, sulphatic-evaporitic facieses modeling.

1. Introduction

The paper is part of a general study on the petrography and sedimentology of the Miocene sulphatic evaporites from southern part of the Eastern Carpathians. The study is concentrated on the determination of the facial characteristics (textural, structural, compositional) of the Cosmina Breccia from the Slănic Molasse of the Carpathian Foredeep, correlated with optical microscopy, petrography, X-ray diffraction, and palinological analysis. On the basis of identified sulphatic and siliciclastic facies, and of the associated interpretative facies, it was possible to separate environmental sequence with specific processes, which can be attributed to cycles of the different orders. Sedimentological interpretations are made on these successions, and the integration in the larger setting of the Carpathian Foredeep is attempted by facies modeling, and sequence stratigraphy analysis of the deposits from the basin.

2. Geological setting

Within Slănic and Drajna synclines, Slănic molasse (Ştefănescu and Mărunţeanu, 1980) contains (Grujinschi, 1972): a tuff and gypsum low subformation and a salt and sulphur upper subformation (low Badenian = upper Langhian) and breccia subformation and a grey lutitic subformation for „radiolarians shales" and „Spiratella marls" (upper Badenian = Kossovian) (Fig. 1, 2, 3). In this paper the tuff and gypsum low subformation of the low-Badenian (upper Langhian) is explained, respect-

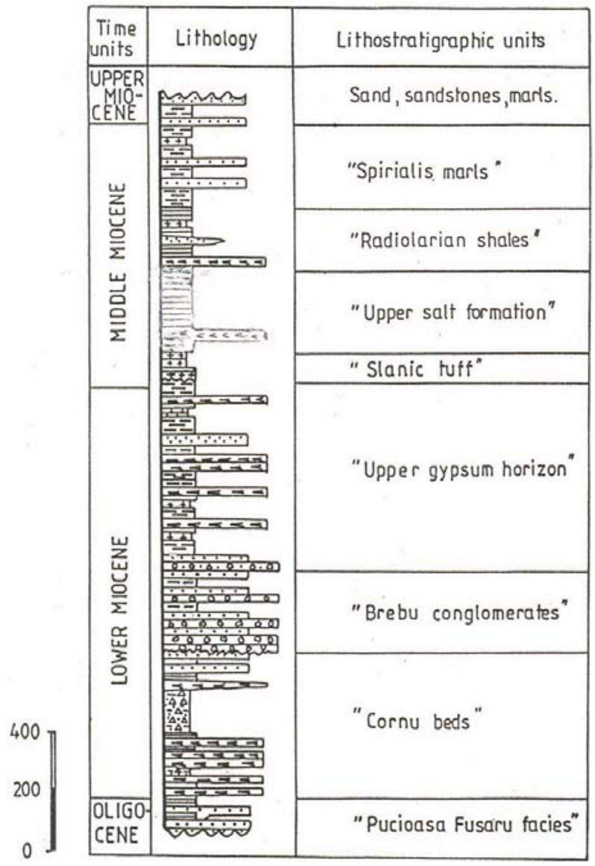


Fig. 1. The synthetic stratigraphic column of Neogene formations from Tarcău unit (Slănic/Drajna synclines).

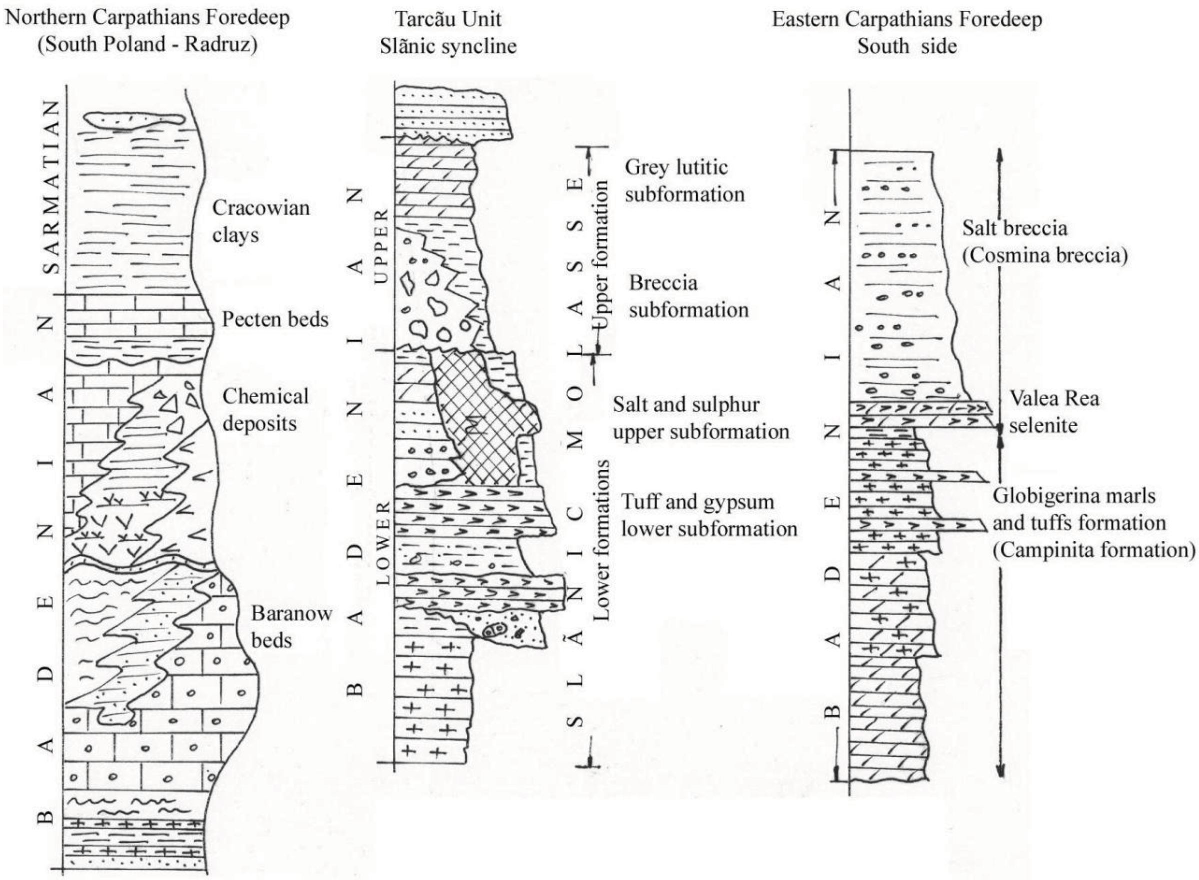


Fig. 2. Litostratigraphic columns in Northern Carpathians foredeep and the Southern sector of Eastern Carpathians.

tively, the breccia and gypsum that are above Slănic tuff. Breccia is discordantly disposed on the globigerina marls and tuff. It has a stratigraphic thickness and clastes frequency that are lower from the outer side to the inner side. The breccia matrix is marly-clayey and the clastes are reworked from subjacent formations: Răchitaşu type calcareous sandstones, grey marly-limestones, bituminous carbonatic laminites or bituminous shales, *Lithothamnium* limestones, sands, green volcanic tuff (Slănic tuff), globigerina marls. The limestones from the reef levels that are suprajacent to the tuffs have been eroded. In Piatra Verde outcrop, approximately 8 meters over Slănic tuff, breccia changes to the sulphatic evaporites (gypsum).

The gypsum appears as a 40-50 meters megasequence, divided into two piles of sulphatic lithons, separated from breccia, each lithons having obvious reworking features. The low sulphatic pile shows features of some kind of gravity flow stages with few breaks of algal/clastic rhythmic accumulation. The upper sulphatic pile contains algal/clastic rhythmites, followed by 20 meters of clastic debris (Fig. 4).

The sulphatic lithofacies of the tuff and gypsum subformation from Piatra Verde are referred to the top side of one typical megasequence quoted from the Northern Carpathians Foredeep from Poland, Ukraine, Bukovina (Fig. 5).

3. Methods

On Piatra Verde outcrop a few clastic gypsum lithofacies are described and interpreted in accordance with the geological literature (concerning the ancient occurrences or modern settings). These clastic gypsum lithofacies are supplied from some reworked sulphatic material, which was previous or contemporary to the resedimentation and was adjacent to the sedimentation area. Various lithofacies have been stated and they have been coded, defined and interpreted in figure 6 (disturbed facies in tuffaceous siltolutites = dLST, dolomitic carbonatic shales = l-D, laminitic clastic gypsum = c-la-g, banded clastic gypsum = c-b-g, gypsum slumps structures = sl-g, gypsum ball and pillow structures = b-p-g, gypsum debris-flow structures = DF-g, gypsum mud-flow structures = MF-g, gypsum Bouma type structures = TS-g, mud-flow structures = MF) (Fig. 4).

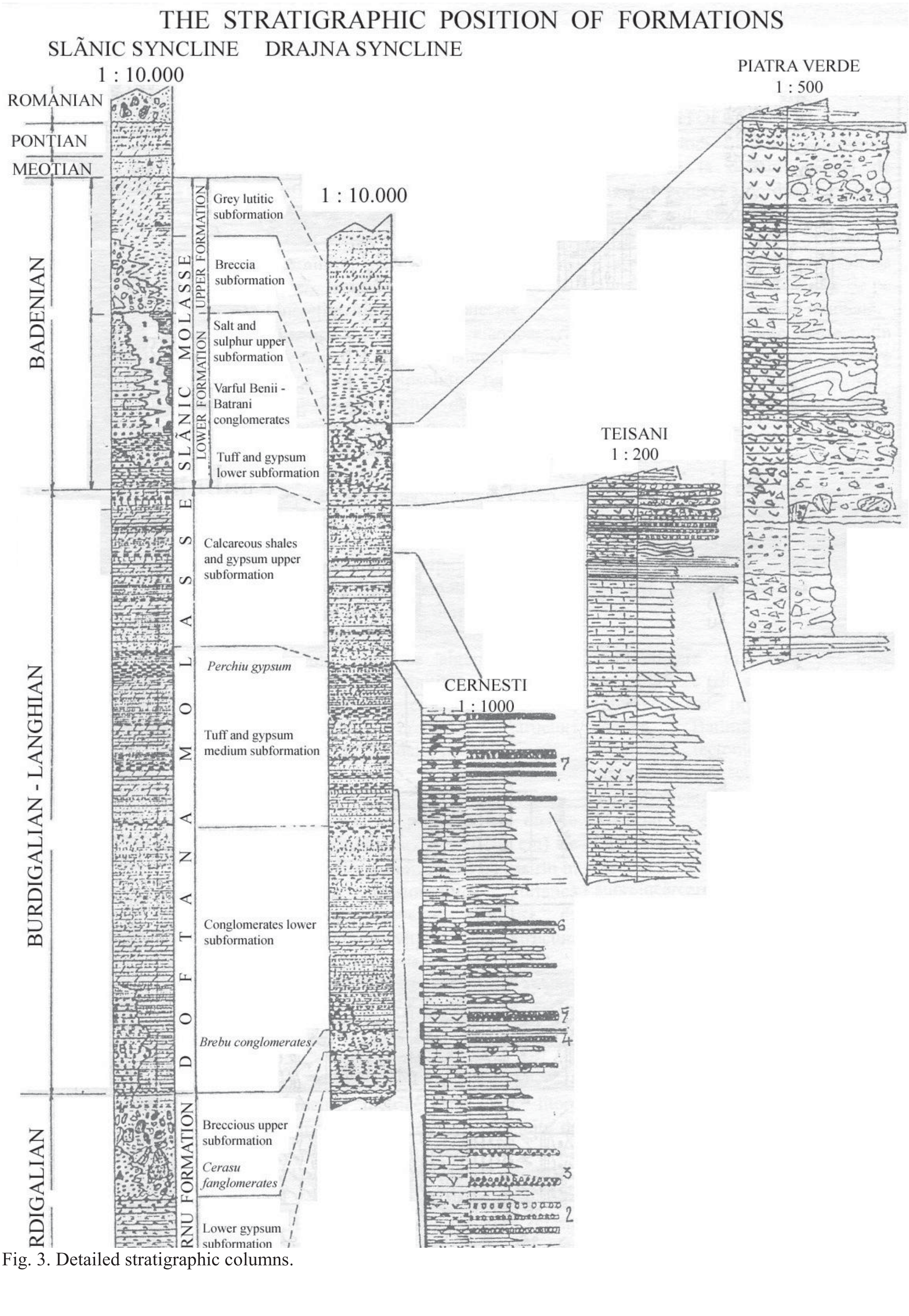


Fig. 3. Detailed stratigraphic columns.

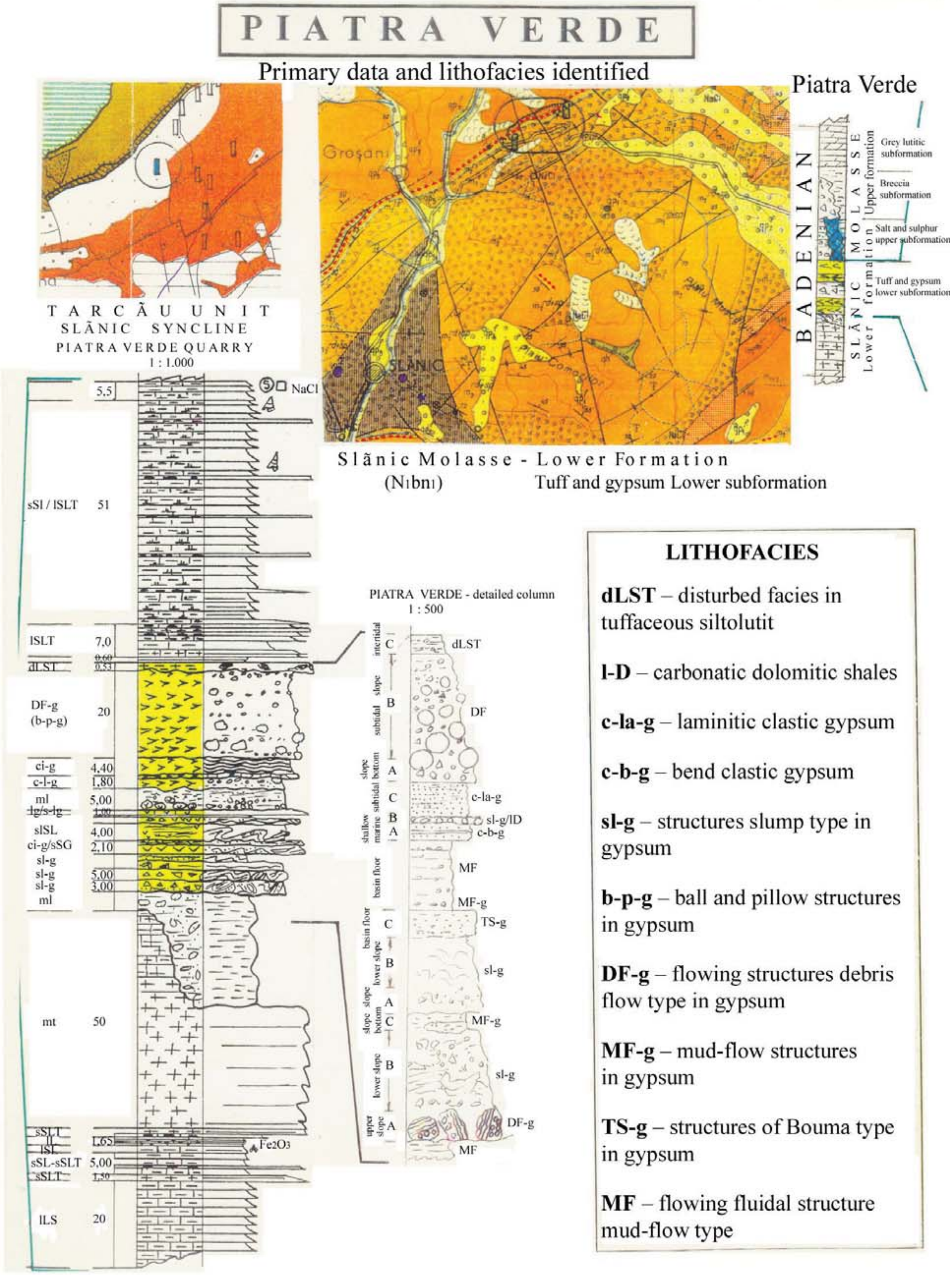


Fig. 4. Primary data and lithofacies identified in the column of Piatra Verde outcrops.

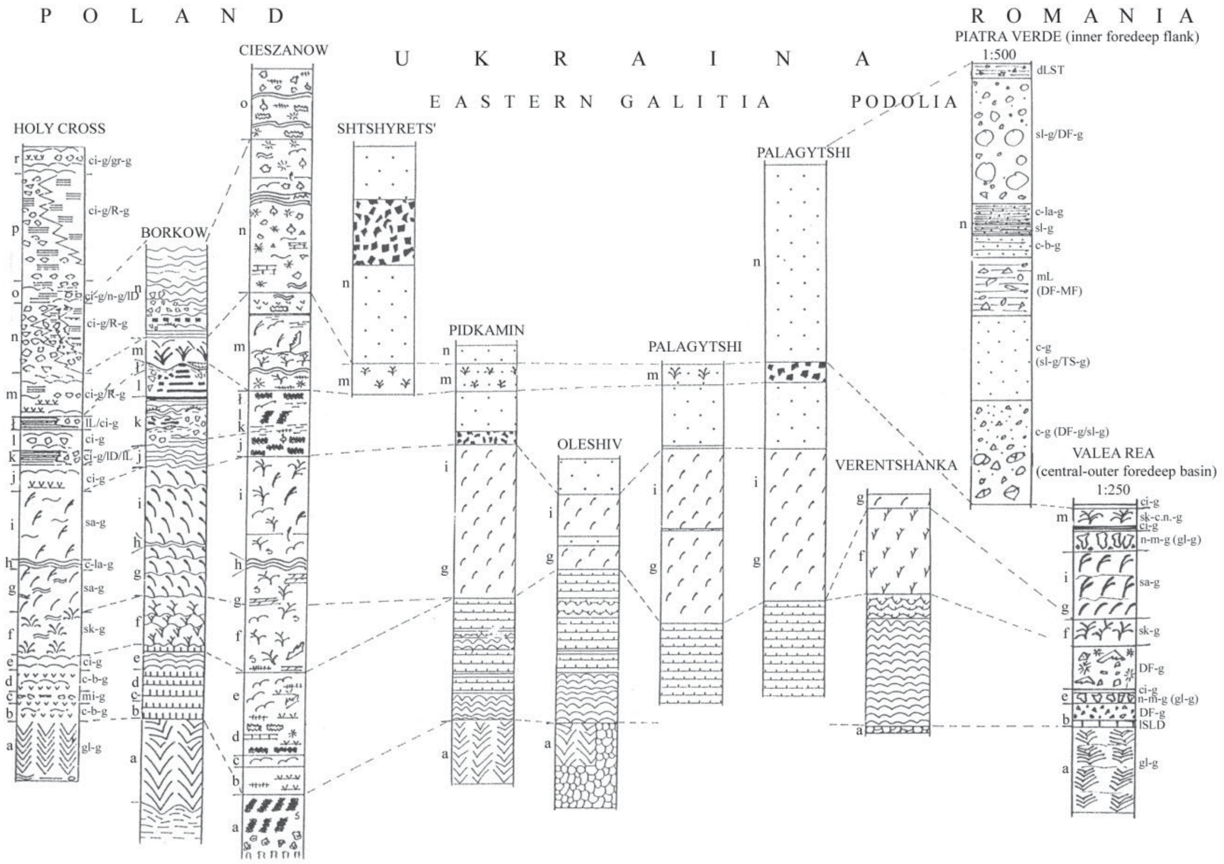


Fig. 5. Correlation of litostratigraphic units in sedimentological columns of Badenian gypsum in the Northern Carpathic foredeep (Poland, Eastern Galitia, Podolia) and the Southern part of Eastern Carpathians

4. Sedimentology and sequence stratigraphy

The lithofacies from Piatra Verde outcrop (Fig. 7) are incorporated ABC, ABC, etc., type parasequences of some deep settings. These parasequences are dominated by the clastic gypsum lithofacies that are supplied from the sedimentation of a previous or contemporary adjacent sulphatic material. The parasequences batimetry is ranged between: A = basin floor (of salinas = mud flow with scaterred alabastrin gypsum clastorudites, turbiditic gypsum); B = distal slope – proximal slope (debris flow or slumps); C = subtidal – intertidal mouth creek (banded clastic gypsum, laminitic clastic gypsum associated with flaser structures or disturbed facieses). Some parasequence show deepening upward trends.

At the beginning of the sulphatic accumulation, the basin paleography (Fig. 9) is marked by tectonic balances with uplift in Carpathian areas and the water transgression over foreland cliff, on the outer side, generalizing the lagunar system separated by islands or shoals barriers. The emerged areas ridges of Lera-Văleni-Buştenari or Homorâciu spurs are toward the inner side of the Carpathians and the pointed islands sills are toward the exterior side. The slopes are light, due to the fact that the morphology has been attenuated by the previous highstand deposits: tuff, siliciclastics, or *Lithothamnium* reefs limestones and by their erosion during the lowstand successive episode, contemporary to the evaporites. The evolution of the sulphatic sedimentation is different and, seldom is diacronic between the border areas (of foreland) and the inner areas (Carpathian areas). The parasequences correspond to a lowstand system tract of a cycle of III-rd or IV-th rank, which is characterized by a higher amplitude of the lower and medium terms to the superior term. The parasequences from Piatra Verde have got an agradational-stocking pattern for the lower pile and a backstepping stocking pattern for the upper pile (Fig. 8).

5. Discussion and conclusions

The megasequence from Piatra Verde is dominated by allohtonous gypsum. On the inner emergent ridges, sulphatic evaporites periodically flooded sabkha types are generated. Disturbed facieses

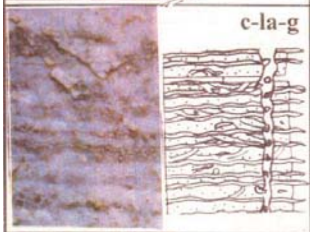
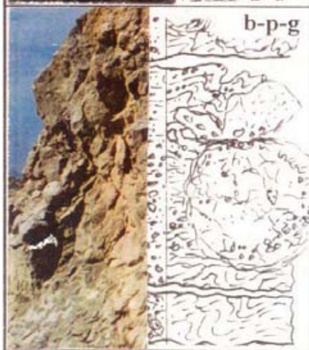
PIATRA VERDE CODES	DESCRIPTION	LITHOFACIES INTERPRETATION
dSLT 	Microruditic clastes of alabastrin gyspum in tuffaceous siltic marly-clays vaguely stratified 	Periodically flooded sabkha. The tuffaceous siltolutit from the start of the flooding influx conservates the products of the previous arid cycle: chips, sulphatic nodules, lithic pebbles, tuff enclaves
ID ci-g 	Gypsified/dolomitic/terrigene disturbed algal mats: wavy, crinkled, broken, thrust	Resedimentation on salinas slope of a algal mats material from the adjacent sabkha, periodically flooded
c-la-g 	Cyanobacteria laminae (<1 mm) disturbed by emersion and laminae (>1 cm) of recrystallized alabastrin gypsolutit with current flow or fold structures; parallel erosion/dissolution contacts; succession affected by fill fisures that separate creep trends piles	Accumulation in very shallow settings of weathering sabkha products (fine size) periodically flooded, or salinas in the last stage of clogging
c-b-g 	Cyanobacteria laminae (<1 mm) very disturbed and lithones (<1 dm) of sulphatic clastorudites (1-3 cm) = algal mats crusts; current flow structures, channel filling, flaser, which are diagenetically blurred	Accumulation in deeper settings (salinas) of aeolian/underwater weathering sabkha products (coarse size) periodically flooded
sl-g 	Algal/clastic sulphatic rhythmical alternations with the initial stratification a primarly disturbed (tectiform folds, small faults, thrusts, breccifications, convolute and fluidal structures	Mass rearranging of some accumulations of c-la-g or c-b-g type sabkha (in their turn c-la-g or c-b-g type of are sabkha weathering products). Increasing batimetry by tectonic and eustatic causes with seismic shock/storm/overloading mass flow prime
b-p-g 	Ellipsoidal or spheroidal concretions (meganodules 10-40 cm diameter size) of nodular mosaic or alabastrin gypsum in sulphatic clastoruditic matrix (c-b-g); there are frequent gravity flow structures and loss water fluidal structures 	Algal mats material (siliciclastic = sulphatic nodules) resedimentated and affected by overloading (ball & pillow structures). After, duet o erosion, transport, resedimentation by debris flow in an increasing basin slope batimetry (salinas/marine basin). The diagenetic growth of sulphate is large in meganodules in small in the clastoruditic matrix
DF-g 	Metric blocks made up of two lithons (gypsorudites c-b-g type and cianobacteria laminites ci-g types) in clastoruditic matrix 	Deposit of gravity flow on a short distance toward the slope bottom of a previous accumulation (c-b-a type followed by ci-g initially supplied by the adjacent sabkha
MF-g 	Clayly matrix with rare polimictic clastes or exclusively sulpahtic clastes (breccia aspect). Massive structure which is vaguely fluidal	Deposit of gravity flow at increasing batimetry towards the slope bottom

Fig. 6. Description and interpretation of lithofacies recorded at Piatra Verde outcrops.

clasts which are multiple reworked are accumulated on the margin of the basin (salinas, playa), under the form of laminitic clastic gypsum or banded clastic gypsum. The rapid accretion, but most of all the tectonic instability balance that takes place after the early stirical folding phase generates drastic erosion effects on the area margins and also batimetry increases into the basin, accompanied by lowstand wedge accumulation. The flows are primed by seismic or storm mechanical shock, and the entire range of gravity flows is recorded: from incipient stages or from lamina level

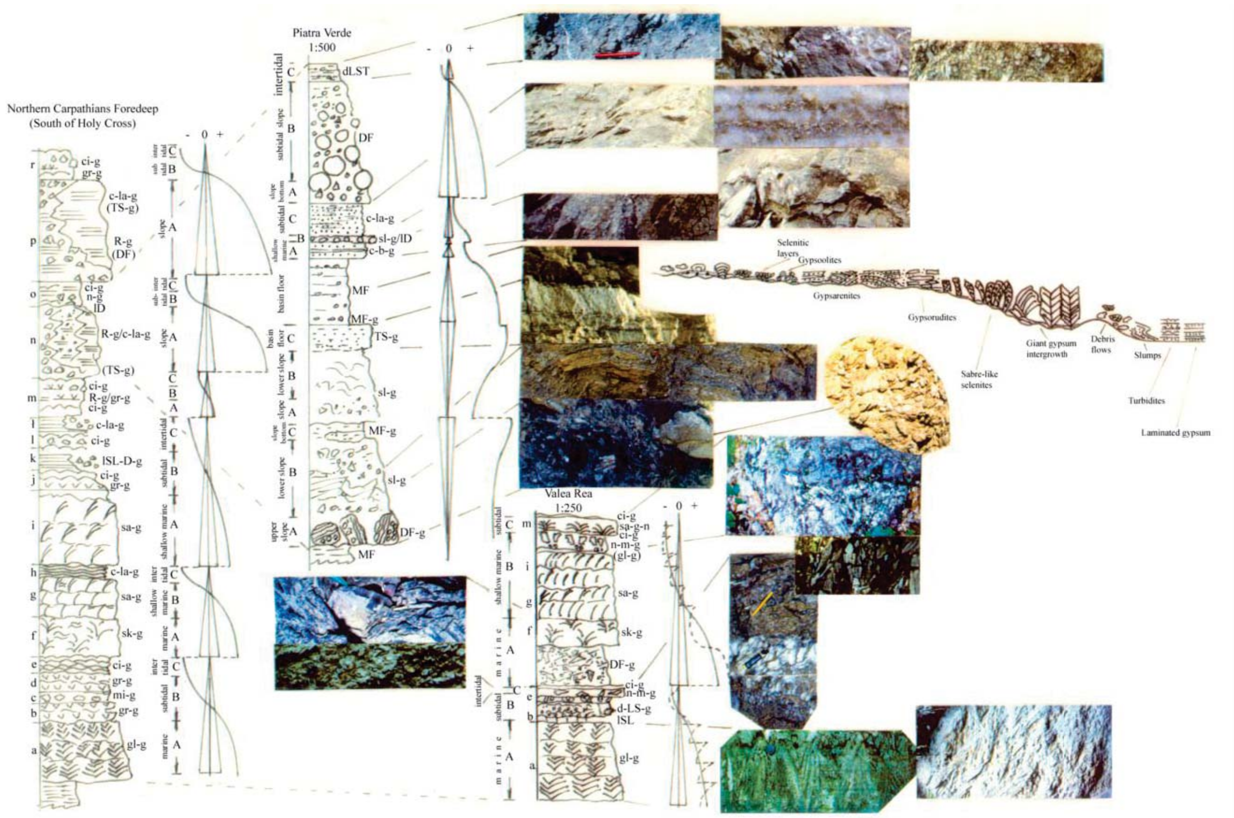


Fig. 7. Facies successions. Typical parasequences of the Badenian gypsum and the depositional correspondent of component lithofacies.

or lithon scale to deposits assemblage. Creep, slide, slump, debris flow, mud flow, turbidite stages are noticed. These stages are associated with flaser or load casts structures. The flow effects are emphasized by the horst/graben tectonics, which increases the subsidence in Slănic fallen sector. On

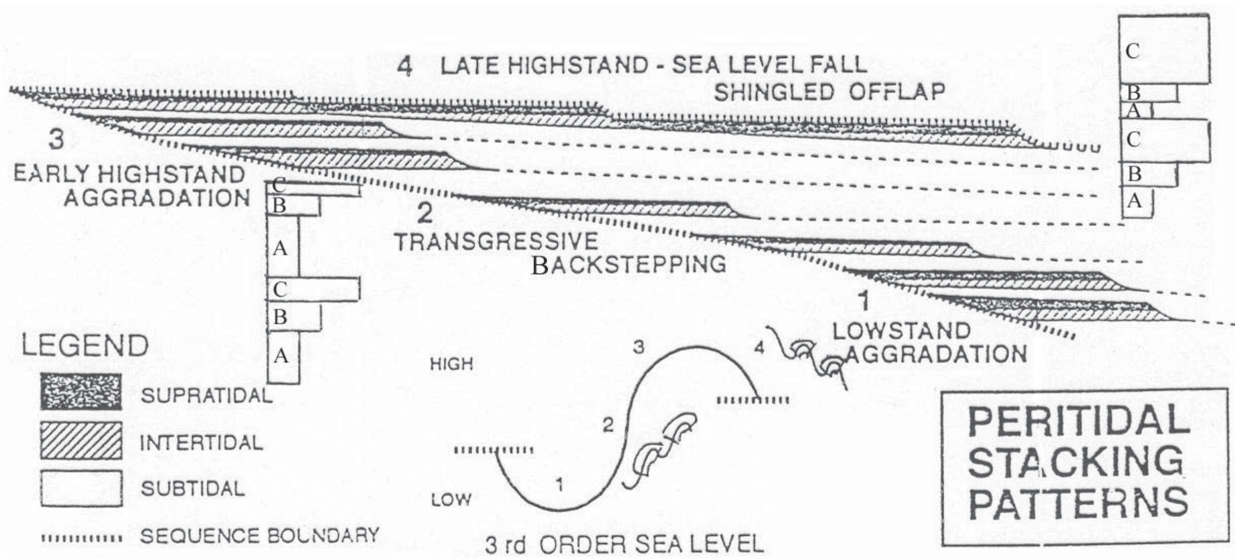


Fig. 8. Tilted shelf with a hypothetical stratigraphy of metric-decimetric peritidal parasequences between sequence limits. Each parasequence has been formed by progradation that took place in the opportunity window produced by short-time fluctuations of IV-th and V-th rank during a rise or a fall of long-time sea level of III-rd rank. The slow movement of III-rd rank of the seashore will dictate where tidal shelf areas will develop. The resultant between eustacy, sedimentation, subsidence will dictate the successive tidal flats stocking pattern: agradation, back stepping or shingled offlap (modified, according to Walker, 1992).

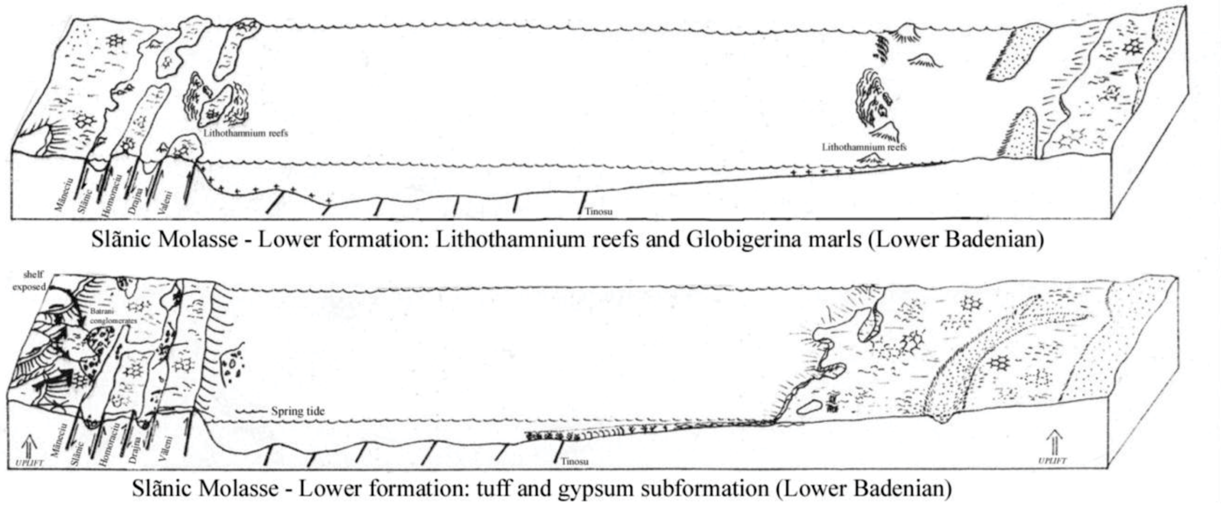


Fig. 9. Paleographic aspects of foredeep basin during low Badenian.

the top of the megasequence dissolution collapse breccia are recorded too. The megasequence has got two piles: a lower one, which is accumulated in the deep sea realm and another upper one which is accumulated in subtidal/intertidal realm. The source area can be found in Lera-Văleni-Buştenari emergent spur area. On the Northern Carpathian border, contemporary to the evaporitical flows the accumulations of some aluvial cone ruditic deposits are quoted: Bătrâni and Vârful Benii conglomerates (Grujinschi, 1972).

The megasequence from Piatra Verde only corresponds to the upper part of the typical column from Poland. The lack of the lower part of its correspondent from Poland is related to the non-sedimentation on the emergent areas, but most of all it is caused by a lowstand type drastical erosion, which is advanced lower than the evaporite level; e.g. the erosion could be advanced at the level of the *Lithothamnium* limestones marine sequence and even at the subjacent level of globigerina marls and tuffs formation.

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