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UPPER TRIASSIC PERITIDAL LIMESTONES FROM THE KONYAVA MOUNTAIN, SW BULGARIA

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Abstract

Four microfacies are distinguished in the section of Tran Formation exposed near Viden peak. The bioclastic wackestones at the base are defined as low-energy, shallow subtidal sediments. The laminated mudstones were deposited in the intertidal/supratidal zone of a tidal flat where fine-grained carbonate was mainly accumulated by tidal currents along with some in-situ microbially induced precipitation. The mudstones with root casts and the massive mudstones are interpreted as deposits in intertidal/supratidal ponds and supratidal marsh (palustrine) areas where alternating wetting and drying periods locally favoured desiccation and pedogenesis with vegetation development. The interbedding of laminites with non-laminated mudstones was likely controlled by a combination of autogenic and allogenic processes. The ambient waters did not reach hypersalinity for early dolomitization because the landward part of the restricted peritidal setting was influenced by freshwater input under semi-arid climatic conditions. Another hypothesis presumes that the sedimentation occurred in a coastal wetland with influence of both freshwater and seawater. However, the peritidal interpretation is preferred herein because it more adequately explains the general depositional environment. The carbonate succession indicates an upward-shallowing trend and was formed during the final regressive phase of Triassic platform development in Carnian–Norian times.

Key words: microfacies, laminites, tidal flat, palustrine, regressive, semi-arid, Carnian–Norian

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Introduction. Recently performed field studies in the Konyava Mountain showed the occurrence of laminated limestones in the Upper Triassic Tran Formation, which have not been described from other exposures of the unit. The present paper provides results from microfacies analysis of these rocks and the associated massive limestones. The aim is to interpret their depositional environment as two hypotheses are proposed and briefly discussed. Implications for the paleoclimatic conditions are suggested, and conclusions are made about the general depositional trend and the Late Triassic platform development.

Geological setting. Geographically, the study area is located in the eastern part of the Konyava Mountain (Kraishte region) in the vicinity of Viden peak (Fig. 1). According to the Alpine tectonic model proposed by ZAGORCHEV [1], it

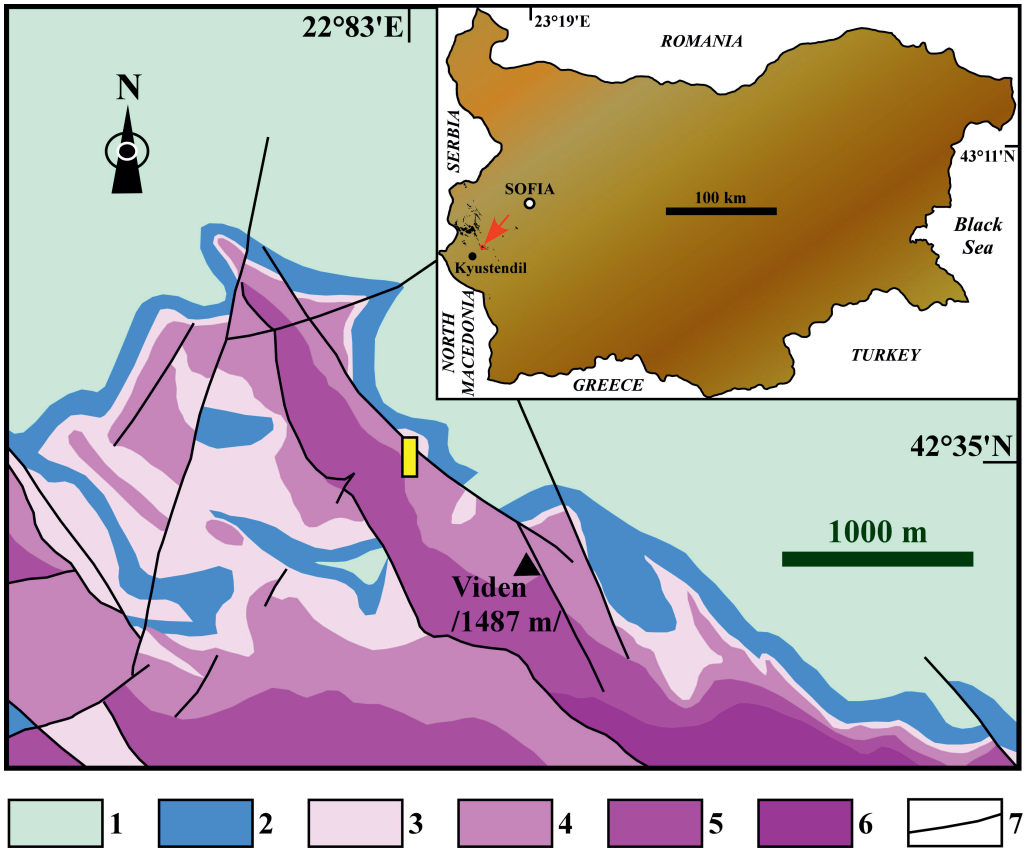


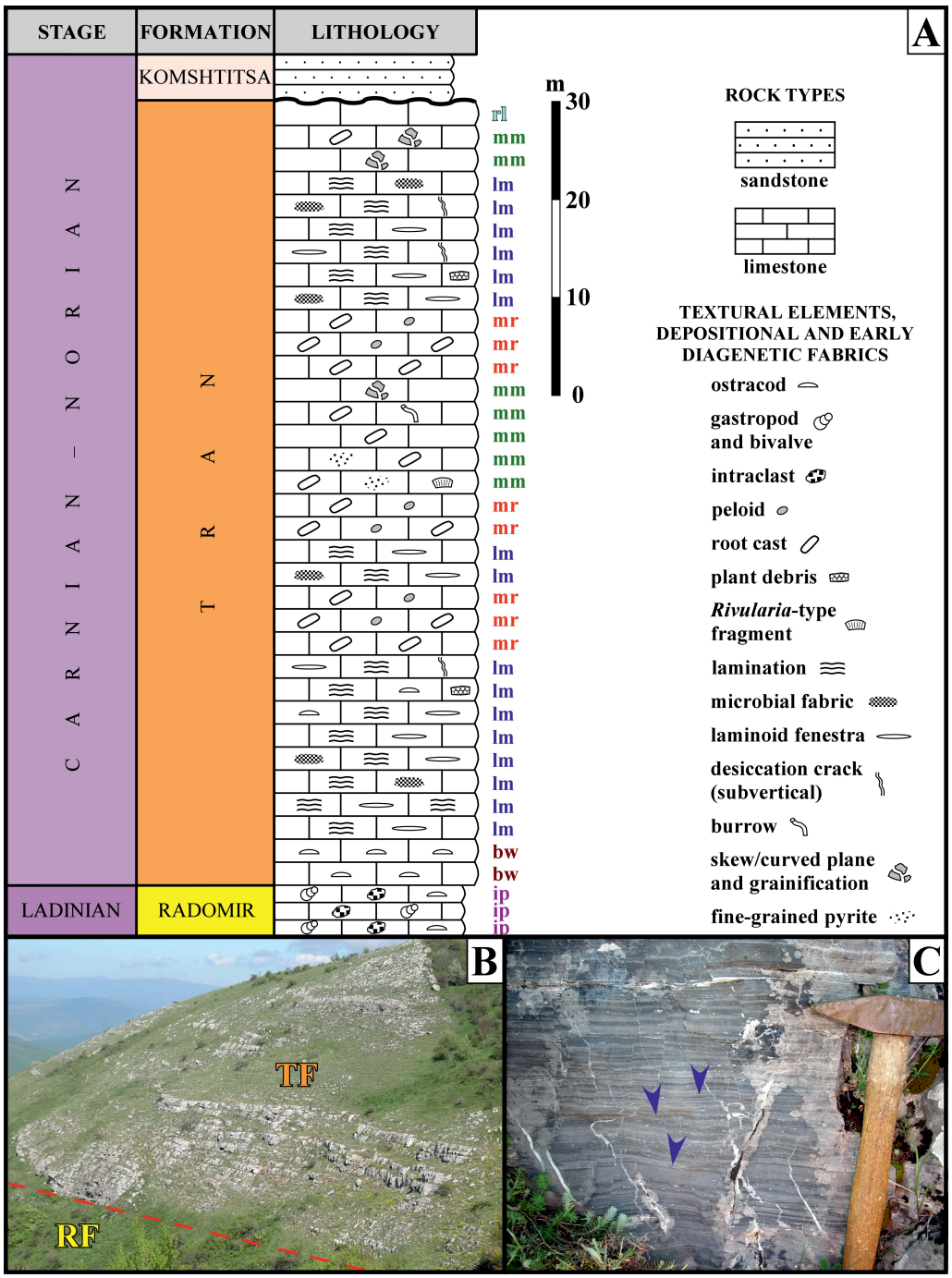
Fig. 1. Geological map of the area in the vicinity of Viden peak (from [3]) with location of the studied section of Tran Formation (yellow rectangle). Legend: 1 – Kostel Formation (Upper Jurassic–Lower Cretaceous), 2 – Lower to Upper Jurassic units, 3 – Komshtitsa Formation (Carnian–Norian), 4 – Tran Formation (Carnian–Norian), 5 – Radomir Formation (Anisian–Ladinian), 6 – Bosnek Formation (Anisian), 7 – fault. Inset map: The exposures of Tran Formation are shown as black patches and the study area is indicated by arrow

occurs in the Louzhnitsa-Trun unit of the Strouma superunit. The outcropping Triassic rocks belong to the autochthonous Balkanide (facies) type of Triassic. The Tran Formation [2] overlies with a short transition dark grey limestones of the Radomir Formation and is covered with an abrupt contact by red shales and sandstones of the Komshtitsa Formation (Upper Triassic) [3]. On the basis of conodont data from exposures south of Viden peak, BUDUROV and VAPTSAROVA [4] determined Anisian–Ladinian age of the rocks of Radomir Formation, while the presumed chronostratigraphic range of the Tran Formation was Carnian–Norian.

Material and methods. The studied stratigraphic section of Tran Formation is located at about 800 m northwest of the TV tower near Viden peak (Fig. 1). Field observations of the rock colours, bedding, lithology, sedimentary structures and textures were carried out. Thirty-four samples were collected from this unit and three additional samples were taken from the uppermost part of Radomir Formation (Fig. 2A). Standard thin-sections were prepared for examination by transmitted light microscopy. Microfacies types (MF) were distinguished by applying the routine methodology for microfacies analysis.

Field data. The succession of Tran Formation can be subdivided into two vertical intervals by general macroscopic characteristics (Fig. 2B). The lower part ($\sim$ 35 m thick) consists of grey and light grey, thin- to thick-bedded limestones having predominantly parallel lamination. The alternating dark- and light-coloured laminae are planar to wavy (also locally lenticular) and their thickness ranges from several millimeters to 3 cm (Fig. 2C). Scarce subvertical desiccation cracks and numerous microfaults of variable orientation are observed. The upper part ($\sim$ 45 m thick) includes light grey, grey and whitish-beige, medium- to thick-bedded limestones with massive structure and parallel lamination, which are brecciated and karstified immediately below the siliciclastic cover.

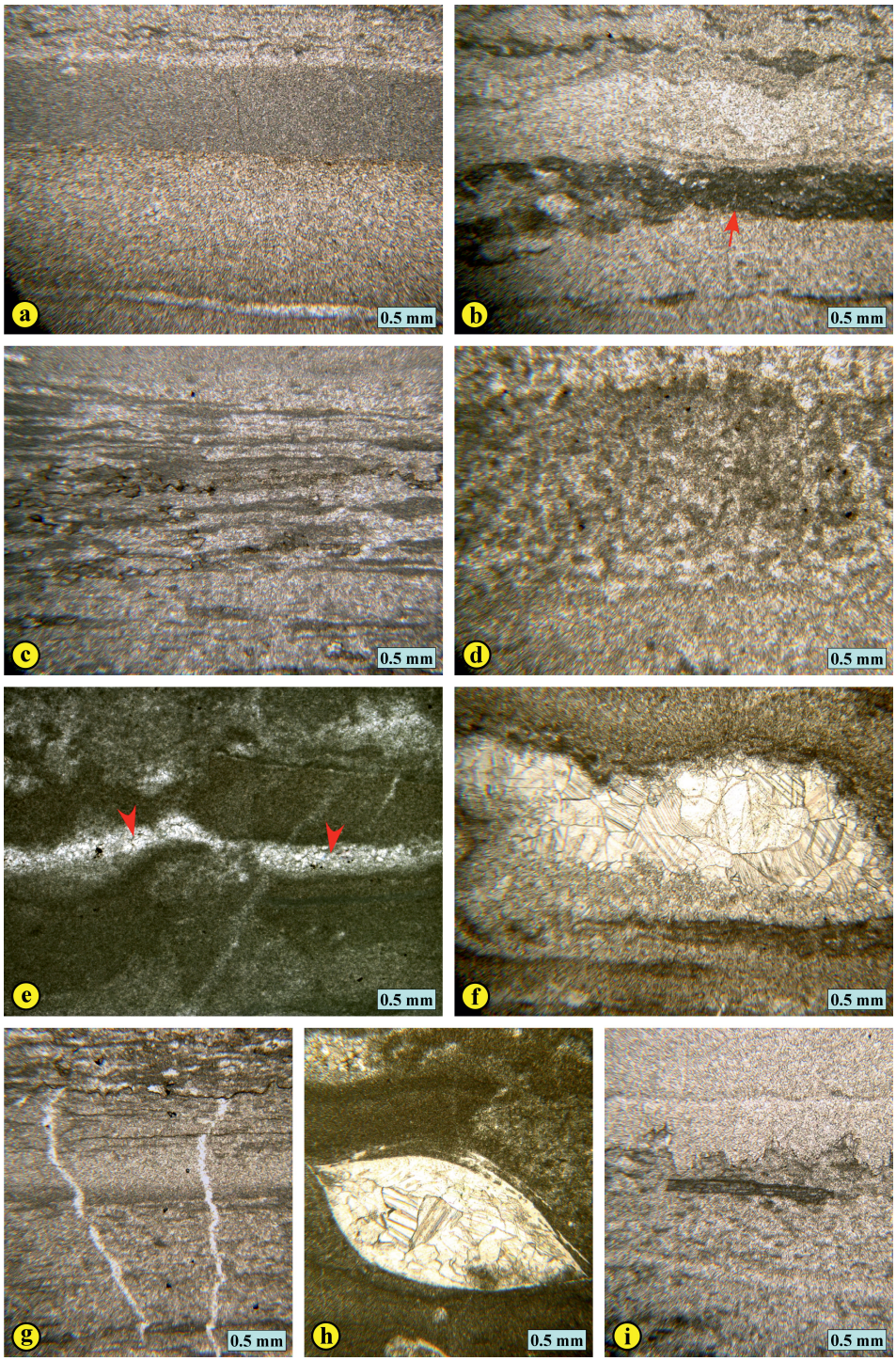
Microfacies types. Five MF were distinguished under the microscope. Intraclastic-bioclastic packstone occurs in the Radomir Formation and is characterized by skeletal grains (gastropods, bivalves, foraminifers, echinoids), intraclasts (bioclastic wackestone), scarce peloids and *Girvanella* oncoids. The basal beds of Tran Formation include bioclastic wackestone with mainly disarticulated ostracod valves. The lower part of the unit is dominated by laminated mudstone in which the interlaminar boundaries are locally disrupted by microscours or enhanced by stylolites. The discrete laminae consist of micrite, mixed micrite and microspar, or microspar that is commonly reddish stained by iron oxides (Fig. 3a). Thin dark-coloured laminae, that may be discontinuous and associated with plasticlasts (flat elongated intraclasts), are composed of clotted micrite with sparse microbial filaments (Fig. 3b, c). Elsewhere, peloids with well-defined margins or peloidal aggregates with diffuse boundaries are embedded in microsparitic matrix (Fig. 3d), forming peloid microspar fabric [5]. Fenestral pores varying from irregular to laminoid have sparry calcite infill (Fig. 3e), or geopetal structure with crystal silt (Fig. 3f). Other textural features comprise desiccation cracks up to


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ROCK TYPES
sandstone
limestone
TEXTURAL ELEMENTS, DEPOSITIONAL AND EARLY DIAGENETIC FABRICS
ostracod
gastropod and bivalve
intraclast
peloid
root cast
plant debris
Rivularia-type fragment
lamination
microbial fabric
laminoid fenestra
desiccation crack (subvertical)
burrow
skew/curved plane and grainification
fine-grained pyrite
B
TF
RF
C

2.2 mm high and 0.1 mm wide (Fig. 3g), ostracod valves and carapaces (Fig. 3h), scarce root traces and platy plant remains (Fig. 3i). Mudstone with root casts and massive mudstone occur mostly in the upper part of Tran Formation. In the former MF, root traces of various sizes (0.05–0.9 mm) have relative abundance of 25–40%. They are spar-filled and tubular in shape showing transverse, oblique and longitudinal sections (Fig. 4a, b). Subspherical, oval and irregular peloids (less than 0.1 mm in size) are present in the micritic matrix and their amount increases proportionally to the amount of root casts. The massive mudstones display one or more of the following characteristics: isolated burrows with microsparitic fill and peloids (Fig. 4c), cracking (skew and curved planes) with grainification (Fig. 4d), scattered fine-grained pyrite (Fig. 4e), scarce *Rivularia*-type fragments (Fig. 4f), plant debris and root casts. The latter are locally solution-enlarged, show tapering or branching, have dark micritic linings, relics of alveolar-septal fabric, and microsparitic or sparry infilling (Fig. 4g–j).

Interpretation and discussion. The packstones and wackestones are interpreted as subtidal deposits in a shallow lagoon with moderate- to low-energy conditions. The laminated mudstones show several characteristics (planar, wavy and lenticular lamination, mud-sized carbonate, desiccation cracks, laminoid fenestrae, laminar microbial fabrics, low diversity fauna) that suggest sedimentation in a muddy tidal flat (intertidal/supratidal zone). The origin of the fine-grained carbonate was mainly related to transport from the subtidal zone by tidal currents with subsequent settling-out from suspension. Additionally, the laminae with clotted micrite and peloid microspar fabric indicate in-situ microbially induced $CaCO_3$ precipitation [5]. The scarcity of microbial filaments implies that they did not undergo very early calcification and that carbonate precipitation occurred later during the bacterial degradation of organic matter [6]. The generally low-energy deposition on the tidal flat was episodically interrupted by weak storm waves resulting in microscours and disintegration of semi-consolidated laminae to form intraclasts (plasticlasts). The scarce ostracod shells reflect a restricted setting with unfavourable living conditions. Intermittent and short-lived subaerial exposure is inferred from the minor presence of desiccation cracks and laminoid fenestrae (some with vadose silt). The neomorphic microspar with iron oxide stain-

Fig. 2. A. Lithologic-stratigraphic log of the studied Triassic section with vertical distribution of the collected samples and distinguished MF. The chronostratigraphic framework is from Budurov and Vaptsarova [4]. Abbreviations: mm – massive mudstone, lm – laminated mudstone, mr – mudstone with root casts, bw – bioclastic wackestone, ip – intraclastic-bioclastic packstone. The top sample is from recrystallized limestone (rl) with obliterative diagenetic texture. B. Panoramic view of the section (RF – Radomir Formation, TF – Tran Formation, dashed line is boundary between the two units). The better exposed lower part of the Tran Formation is largely dominated by laminated limestones. C. Parallel lamination with alternating dark- and light-coloured, planar to wavy (locally lenticular – arrows) laminae

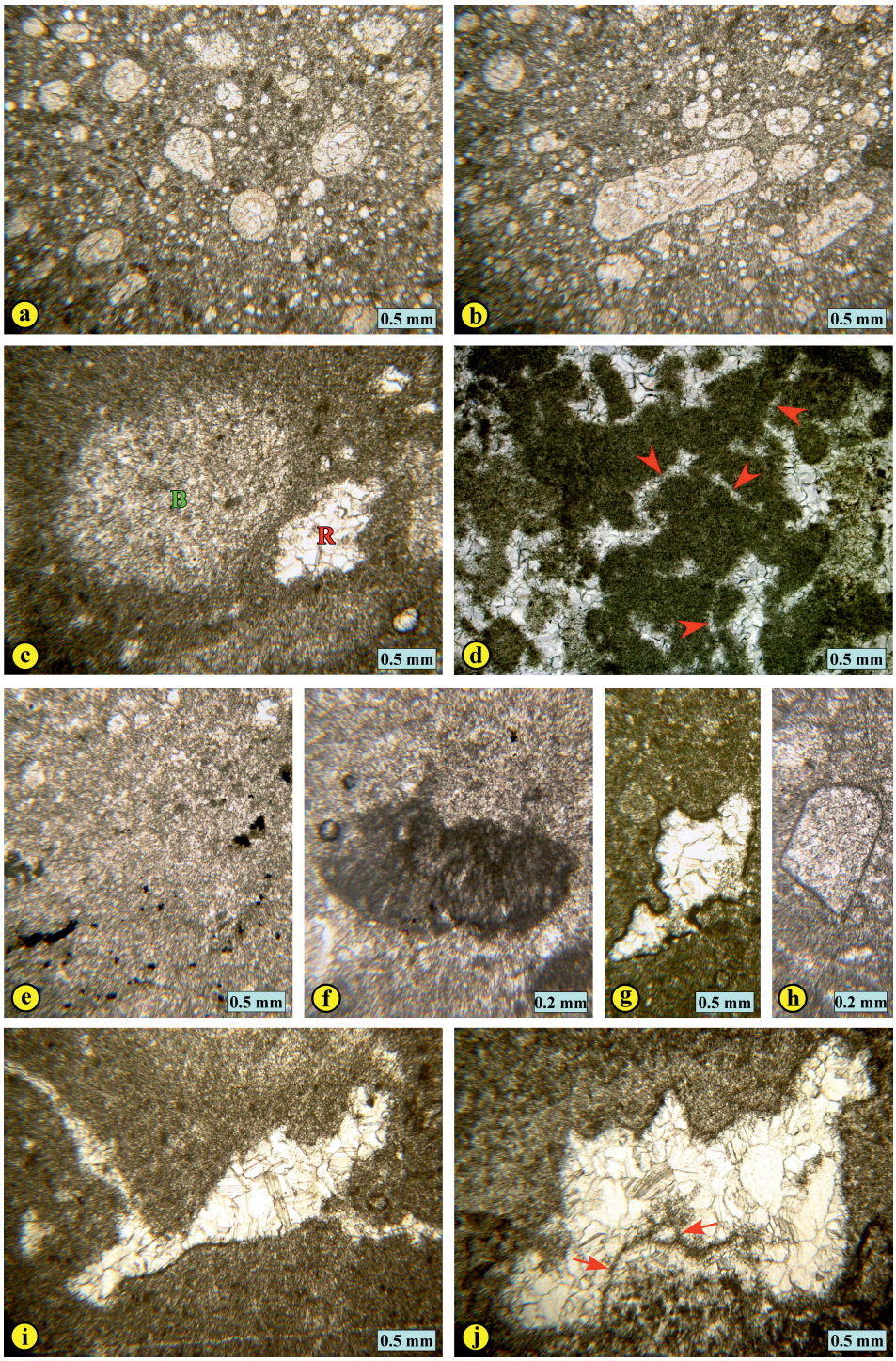

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ing may have likewise been formed through diagenetic change during exposure [7]. The mudstones with root casts and the massive mudstones can be interpreted as lime muds deposited in very shallow water bodies such as intertidal/supratidal ponds and marsh areas. Obliteration of laminated sediments by macrophyte root growth or animal bioturbation is implausible because relics of lamination are absent. The local occurrence of skew/curved planes with grainification and abundant rhizoliths (roots and root hairs) indicate sediment desiccation and soil development during more prolonged periods of exposure, i.e., formation of palustrine carbonates or pedogenic calcretes [7,8]. The precipitation of disseminated pyrite was probably related to hydromorphism due to marine water flooding [9]. The peloids represent products of root growth but some of them may also be calcified fecal pellets of burrowing organisms [10]. The lack of skeletal grains and the scarce burrow traces suggest stressful environmental conditions.

The presence of pedogenic calcretes or dolocretes in the upper part of shallowing-upward peritidal cycles is known from a number of Phanerozoic carbonate deposits [11]. By comparison, the studied Upper Triassic succession has no distinct cyclic pattern, and mudstones containing evidence for exposure and pedogenesis are interbedded with tidal-flat laminites. These mudstones can be interpreted as palustrine deposits in freshwater/brackish supratidal marshes that were subject to marine flooding during spring tides and storm events [7], while desiccation and vegetation developed during longer periods of low water level. The massive mudstones, which are devoid of features indicating exposure, are interpreted herein as subaqueous deposits in intertidal/supratidal ponds. It can be presumed that the vertical alternation of intertidal/supratidal laminites and marsh/pond deposits was controlled by some combination of autogenic (e.g., tidal-flat progradation) and allogenic (e.g., eustatic sea-level fluctuations) processes. A similar case was described from Devonian rocks in NW Canada where palustrine (marsh) limestones are interbedded with peritidal carbonates and locally intergrade into tidal-flat laminites and pond deposits [12].

The Upper Triassic limestones show similarities with some carbonate facies of the Lower Cretaceous Leza Formation from the Cameros Basin (N Spain). The general depositional system of this unit has been interpreted as a coastal wetland, i.e., a low-gradient area with influence of both freshwater and seawater, in which the water table was very close to the surface [13]. Small variations in

Fig. 3. Laminated mudstones: a – Discrete planar laminae consisting of micrite or microspar as the latter is reddish stained by iron oxides; b – Dark-coloured lamina (arrow) composed of clotted micrite with sparse microbial filaments; c – Thin dark-coloured laminae that are commonly discontinuous and associated with plasticlasts; d – Peloid microspar fabric; e – Spar-filled laminoid fenestra (arrows); f – Elongated fenestra with geopetal infilling (crystal silt and blocky calcite cement) surrounded by thin dark layer of clotted micrite; g – Subvertical desiccation cracks; h – Articulated ostracod shell; i – Platy plant fragment. All photomicrographs are in plane-polarized light


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the factors controlling sedimentation (climate, eustasy, tectonics) produced relevant changes in the water bodies (area, depth, water sources, salinity), which commonly resulted in sharp vertical transitions between contrasting facies [13]. Desiccation, anomalous salinity and salinity variations were stressful factors that predetermined low-diversity metazoan assemblages [13]. The Late Triassic depositional setting may have been such a low-gradient coastal area, prone to both flooding and desiccation, which is suggested by the evidence of very shallow water depth and tidal influence, interbedding of laminated with massive deposits, presence of ubiquitous features of exposure and edaphic alteration, and low-diversity biotic community. The laminites can be tentatively interpreted as deposits in tidally influenced areas of the coastal wetland, while the other two MF presumably comprise deposits in adjacent very shallow water bodies and palustrine areas where alternating wetting and drying periods locally favoured pedogenesis with vegetation development.

At this stage of the study, the classical peritidal interpretation is preferred because it more adequately explains the general depositional setting. The term 'coastal wetland' is very commonly used for modern environments in geomorphology and ecology, but it is very rarely used in the sedimentological studies of ancient carbonate and siliciclastic deposits [13]. Furthermore, the strata of Leza Formation demonstrate some significant differences when compared to the limestones of Tran Formation, e.g., associated various carbonate and siliciclastic facies, fossil evidence for marine, brackish and freshwater conditions, abundant and diverse microbialites, presence of marls, dolomite, gypsum/anhydrite, ooids and packstone to grainstone textures, general transgressive trend, and strong tectonic control on the sedimentation.

The lack of evaporite minerals and early formed dolomite in the studied mudstones implies that the carbonate deposition occurred under relatively humid climatic conditions [14]. However, the low-diversity skeletal fauna, the good preservation of laminated structures (including microbial laminae) and the particular pedogenic modification suggest a restricted environment with elevated salinity under semi-arid, probably seasonal climate [8, 12, 15]. The negligible amount of siliciclastics and absence of organic-rich facies in the carbonate strata of Tran Formation from the study area and adjacent regions in SW Bulgaria [2, 16] also

Fig. 4. Mudstones with root traces (a, b) and massive mudstones (c–j): a, b – Various sections of tubular, spar-filled root casts (the smaller ones are probably root hairs) associated with peloids; c – Spar-filled root cast (R) and tubular burrow (B) with microsparitic fill and scarce peloids; d – Development of mud cracking (skew and curved planes – arrows) ← and grainification; e – Scattered fine-grained pyrite (black); f – *Rivularia*-type fragment with fan-like fabric; g – Tapering root cast (probably solution-enlarged) with dark micritic lining; h – Root cast with microsparitic fill; i – Branching root cast; j – Irregular root cast with relics of alveolar-septal fabric (arrows). All photomicrographs are in plane-polarized light

contradicts the hypothesis of increased humidity. Moreover, the lithological and mineralogical proxies in Upper Triassic successions from other parts of the country indicate warm arid to semi-arid climate during most of the Carnian and Norian ages [17], and the same interpretation applies to coeval deposits from the Western Tethys realm [14,18]. A plausible explanation for the lack of early dolomitization is that the ambient tidal and groundwaters did not reach hypersalinity with high Mg/Ca ratio for dolomite formation [7,15,19], because the landward part of the peritidal setting was influenced by freshwater input. Such a conclusion is also supported by the limited presence of microbial fabrics, since it has been well demonstrated that microbial activity (most commonly in combination with high salinity) favours the penecontemporaneous dolomitization of modern and ancient peritidal sediments [20].

The limestones of Tran Formation were deposited during the final regressive phase (late highstand) of Triassic carbonate platform development in Carnian–Norian times [16] after a maximum deepening in the Ladinian [2]. The distinguished MF in the Middle–Upper Triassic succession from the Konyava Mountain clearly indicate an upward-shallowing trend, i.e., a temporal transition from subtidal to intertidal and supratidal deposition. This conclusion is in accordance with the performed facies analysis of other sections of the Tran Formation which has shown that the carbonate platform sedimentation occurred in shallow marine and marginal-marine environments (see [16], and references therein). For example, a progradational sequence with upward transition from lower and upper shoreface through foreshore (beach) to backshore deposits was described from the exposure nearby Bosnek village [16].

Conclusions. This pilot study presents new evidence for the occurrence of carbonate peritidal deposits in exposed Upper Triassic strata of western Bulgaria. An ongoing analysis of bulk rock isotopes (δ^{13}C, δ^{18}O) in the sampled lime mudstones is expected to better constrain the character of ambient waters, paleoclimatic conditions and origin of the fine-grained carbonate. Another future task is to trace the lateral distribution of laminated facies in other outcrops of the Tran Formation in the Konyava Mountain and elsewhere. This would help to elucidate the spatial and temporal relationships between the hitherto recognized various carbonate depositional paleoenvironments.

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