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CORELLATION OF LATE TRIASSIC AND EARLY JURASSIC LOFER-TYPE CARBONATES FROM THE PELOPONNESUS PENINSULA, GREECE

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Abstract

Correlation of the Late Triassic carbonate successions, formed at the passive Pelagonian margin (SE of Dhidymi Mt.) with the Early-Middle Liassic successions of the Gavrovo-Tripolitza zone (SE of Leonidion), in eastern and central Peloponnesus respectively, is attempted. Detailed microfacies analysis revealed that the studied carbonate formations were deposited in analogous restricted inner-platform environments (lagoon-peritidal domain) and are composed of meter-scale, shallowing-upward, mostly incomplete peritidal cycles. The top of the supratidal and/ or shallow subtidal deposits are often affected by meteoric diagenesis tracing sea-level lowering and periodic emersions episodes. The well-developed pedogenic features observed in the Early Jurassic platform carbonates indicate long-lasting subaerial exposure intervals and semi-arid to arid climate. Instead, the Late Triassic strata preserve vadose diagenetic indices which point to shorter exposure events, weaker meteoric alteration and slightly wetter climatic conditions. The detected sedimentological features suggest the occurrence of wide lagoonal-peritidal depositional systems during Late Triassic and Early Jurassic, eastern and western of the Pindos basin, respectively. The basic facies pattern and the meter-scale cyclicity show many analogies with the Lofer cycles of the Alpine Triassic, supporting that in the Hellenides the Dachstein-type platform systems evolved till Early-Middle Liassic (Gavrovo-Tripolitza zone).

Key words: *peritidal facies, Lofer cycles, subaerial exposure, Peloponnessus, Greece.*

1. Introduction

Lofer cyclothems—i.e., distinct meter-sized lagoonal-peritidal cycles, were first recognized and described in the Norian-Rhaetian Dachstein Limestone (Austria) by Sander (1936). According to Fischer (1964) the typical Lofer cyclothems is a deepening-up, asymmetric sequence and each cycle is composed of : (i) a disconformity at the base (d); (ii) a basal argillaceous member/ "palaeosol" (member A); (iii) an intertidal laminated carbonate member (member B: loferites); and (iv) a subtidal massive fossiliferous carbonate member (member C). Subsequent studies modified as symmetric the ideal basic stacking pattern of Lofer cyclothems (Haas, 1982, 1991) or reinterpreted them as regressive, shallowing-upward cycles (e.g. Goldhammer et al., 1990). Dachstein-type platform carbonates have been also recognized in different areas along the Late Triassic Tethys (e.g. Eastern Alps, Southern Alps, Dinarides, Hellenides) and they are well-studied by several authors (e.g. Fis-

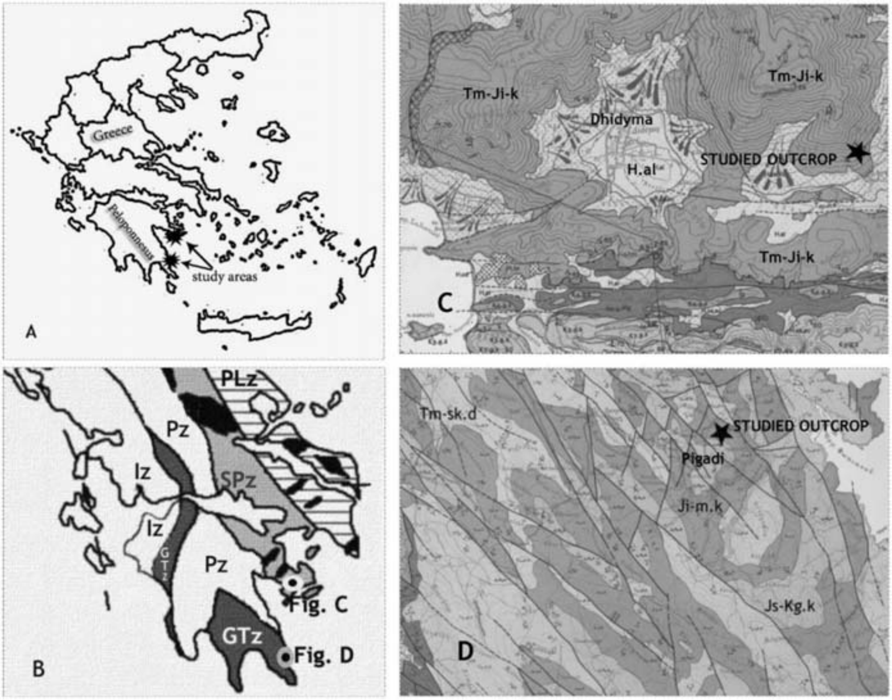


Fig. 1: (A) Geographical location of the studied areas (✷). (B) Map of the central-southern Greece showing the studied areas (⊙) and their setting within the geotectonic zone framework of the Hellenides. (C) Dhidymi section; geological map showing the study area and its location (★). "Spetses-Spetsopoula Sheet" 1:50.000 (Gaitanakis et al., 2007). (D) Fokianos section; geological map showing the study area and its location (★). "Leonidion Sheet" 1:50.000 (Dimadis et al., 1978). Key: GTz=Gavrovo-Tripolitza zone; PLz=Pelagonian zone; SPz=Subpelagonian zone; Pz=Pindos zone; Iz=Ionian zone; Tm-Ji-k=M. Triassic-Lias; H.al=Alluvial deposits; Tm.sk.d=M.-U. Triassic; Ji-m.k=E.-M. Jurassic; Js-Kg.k=Upper Jurassic-L. Cretaceous.

cher, 1964; Haas, 1994, 2004; Haas and Balog, 1995; Enos and Samankassou, 1998; Pomoni-Papaioannou et al., 1986, Pomoni-Papaioannou, 2008). However, Lofer cycles have been observed in platform strata of different age from that of the Dachstein Limestone (Dozet, 1993). Autocyclic (e.g. Satterley, 1996), tectonic (e.g. Satterley, 1996; Bosence et al., 2009) or allocyclic (e.g. Fischer, 1964; Haas, 2004) mechanisms have been proposed to explain the formation of the Lofer cycles.

This paper aims to report the sedimentological and diagenetical features of the analyzed Late Triassic (Dhidymi succession, "Pantokrator facies"-Pelagonian carbonate platform, Argolis peninsula) and Early Jurassic (Pigadi-Fokianos succession, Gavrovo-Tripolitza zone, SE of Leonidion) shallow-water platform carbonates and to compare the loferitic facies detected.

2. Geological setting

The Pantokrator facies-Pelagonian carbonate platform: The investigated Late Triassic shallow-water carbonate sediments (Fig. 1, 2) cropping out in the area of Argolis peninsula are part of the Late Triassic–Early Jurassic extensive and thick neritic carbonate series ("Pantokrator facies") that formed at the passive Pelagonian continental margin.

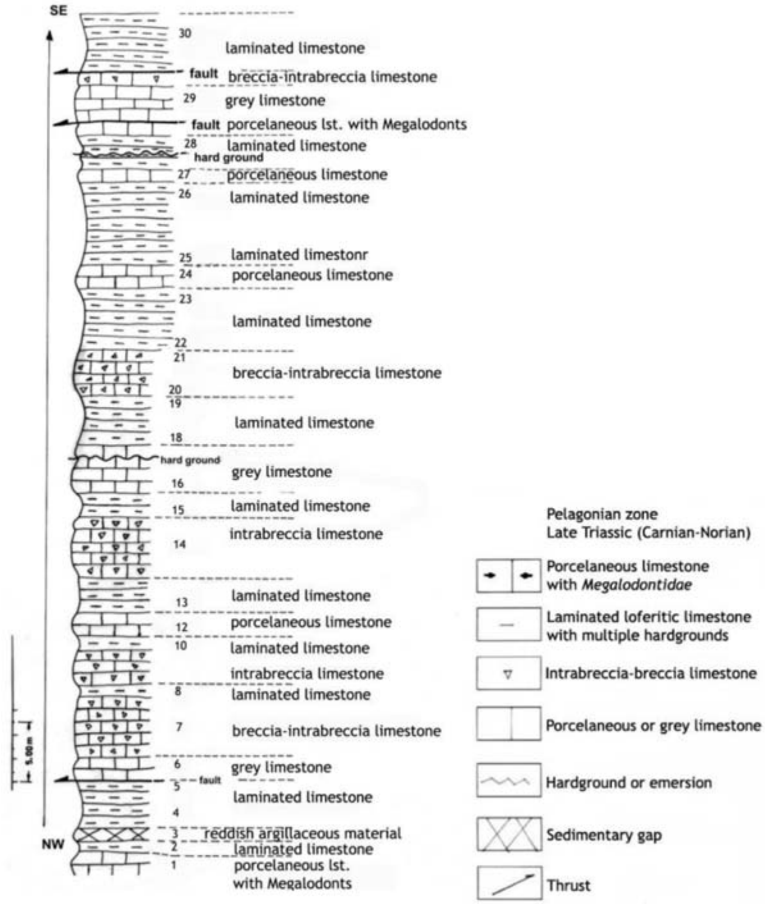
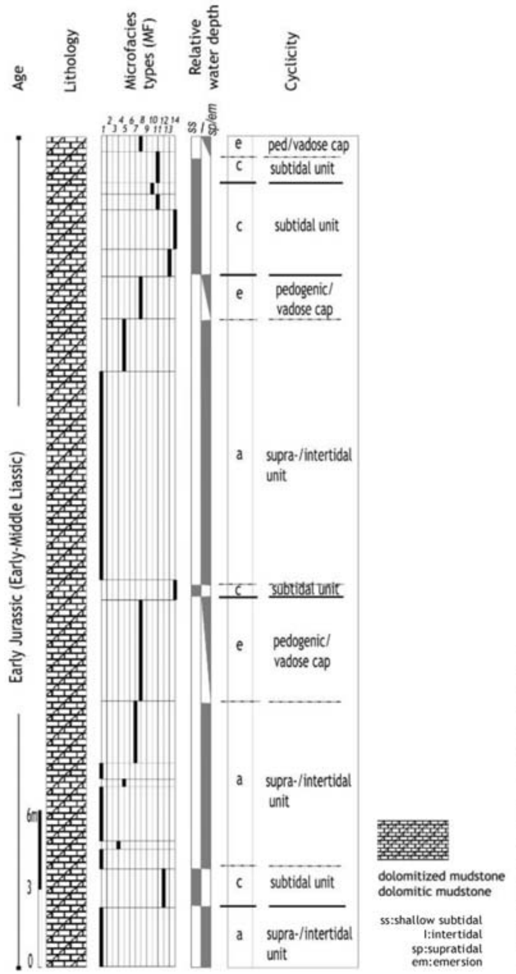


Fig. 2: Dhidymi section.

The Argolis peninsula belongs to the Pelagonian-Subpelagonian domain of the Hellenide nappe and its geological structure have been studied in detail by several authors (e.g. Bachmann and Risch, 1979; Vrielynck, 1981-1982; Baumgartner, 1985; Photiades, 1986; Gaitanakis and Photiades, 1991, 1993; Photiades and Skourtsis-Coroneou, 1994; Bortolotti et al., 2003; Gaitanakis et al., 2007). The Pantokrator carbonate formation covers a great part of the Argolis Peninsula. The Dhidymi Mt. is also built up of these facies (Gaitanakis et al., 2007). The Late Triassic to Liassic shallow-water facies are dominant in the Iria area and in the Dhidymi Mt. region of SW Argolis (Schäfer and Senowbari-Daryan, 1982; Vartis-Matarangas and Matarangas, 1991). In the Dhidymi area, Late Triassic Lofer cycles have been studied by Pomoni-Papaioannou and Photiades (2007) and Pomoni-Papaioannou (2008).

The Gavrovo-Tripolitza zone (GTz): The studied stratigraphic section (Fig. 1, 3) of Early Jurassic age is exposed SE of Leonidion town. It forms part of the thick neritic Triassic-Jurassic carbonate platform succession that appear along the eastern coasts of Peloponnesus and geologically are included in the GTz of the Hellenide nappe. The Gavrovo-Tripolitza platform developed early — in the Late Triassic-Liassic and persisted throughout the rest of the Mesozoic — within the passive continental margin of the Southern Tethys. The GTz consists of thick neritic carbonate successions



Microfacies types	*MF*
pedogenic crust/palaeosol	8
dolomitic mudstone + saddle dolomite	1
fenestral dolomicrite	2
peloidal dolomitized mudstone	3
microbrecciated dolomitized mudstone	4
dolomitized mudstone	5
recrystallized carbonates	6
vadolitic carbonates	7
fenestral binstones	9
intraformational breccia	10
peloidal packstone/grainstone	11
bioclasts bearing peloidal mudstone	12
aggregate grain grainstone	13
foram-green algae packstone/grainstone or rare boundstone	14

Fig. 3: Fokianos section.

ranging in age from Late Triassic to Late Eocene (Thiebault 1973; Fleury 1980; Zambetakis-Lekkas and Alexopoulos 2007). The Late Palaeozoic-Triassic volcano-sedimentary sequence of "Tyros Beds" (Ktenas, 1924) underlain the GTz in Peloponnesus and considered to be its original basement (Thiebault, 1982). Shallow-water facies of cyclic pattern are observed in the Late Triassic and Liassic deposits of GTz (Kalpakis and Lekkas, 1982; Pomoni-Papaioannou et al., 2005; Kati et al., 2007; Pomoni-Papaioannou and Kostopoulou, 2008).

3. Results of sedimentological analysis

3.1 Carbonate microfacies and depositional environments

Dhidymi section — The investigated Dhidymi section (5.5 Km E of Dhidyma) is approximately 70m in thickness and shows a succession of Late Triassic neritic carbonates that are part of the thick Late Triassic–Early Jurassic "Pantokrator carbonate facies" formed at the passive Pelagonian con-

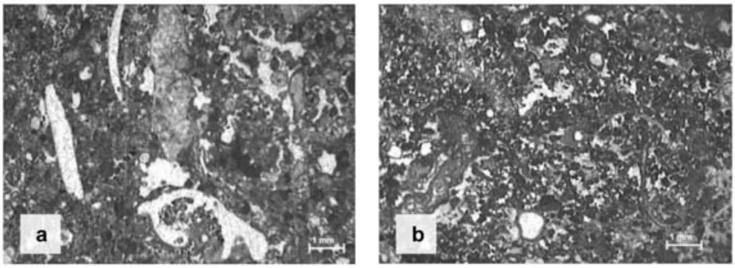


Fig. 4: Shallow subtidal/lagoonal environment - a. Packstone with fragments of megalodonts, benthic forams and calcareous algae (Dhidymi). b. Foram-green algae pack/grainstone with dasycladacean algae, thaumatoporellids and small benthic foraminifers (Fokianos).

tinental margin. The following sedimentological features characterize the carbonate sediments exposed in the Dhidymi section:

Subtidal facies — The shallow subtidal/back-reef lagoon facies (Fig. 4a) are composed of prevailing wackestones, packstones and packstones/grainstones with an abundant and diverse marine fauna (Megalodontids, Aulotortinae, Dacycladaceans). The non-skeletal material is mainly represented by peloids.

Inter-supratidal facies — The inter-supratidal facies generally consist of laminated dolomitic and fenestral dolomitic mudstones. They are characterized by well-developed laminations, probably of microbial origin, small fenestrae with geopetal filling and a variety of desiccation structures (Fig. 5a). Bird's eyes and desiccation cracks indicate a tidal/supratidal setting.

Subaerial exposure-related facies — The Late Triassic neritic carbonates contain emergence-related diagenetic features (e.g. glaebules, laminar dolocrete crusts, filled small-sized palaeokarstic cavities, geopetal filling) (Fig. 6a, b), which reflect emersion events of limited duration and weak subsequent early meteoric modification under a slightly wetter climate regime (Esteban and Klappa, 1983; Wright and Tucker, 1991; Jimenez de Cisneros et al., 1993).

Fokianos section — The studied Fokianos section (13 Km SE of Leonidion) is ca. 30m thick and shows a succession of Early-Middle Liassic neritic carbonate sediments that forms part of the Triassic-Jurassic thick platform carbonates which crop out along the eastern coasts of Peloponnesus and geotectonically belongs to the Gavrovo-Tripolitza zone. The carbonate sediments exposed in the Fokianos section are characterized by the following sedimentological features:

Subtidal facies — The subtidal facies (Fig. 4b) are mostly composed of fossiliferous packstones/grainstones. The most important biogenic components are Dacycladaceans (*Palaeodasycladus mediterraneus)* and Thaumatoporellids. A few shell-fragments of molluscan debris (megalodonts, gastropods) and not abundant small benthic foraminifera (Valvulinidae, Ammodiscidae, Textulariidae*)* are also found. Peloids, aggregate grains, cortoids and small intraclasts are included in the observed non-skeletal particles.

Inter-supratidal facies — The peritidal sediments (Fig. 5b) comprise mainly unfossiliferous dolomitized mudstones and rare fenestral bindstones. Neomorphism commonly has affected the original texture (supratidal settings). The occurrence of saddle dolomite crystals, interpreted as pseudomorphs after evaporite minerals, imply hypersaline conditions. The presence of authigenic idiomorphic quartz crystals and the faunal absence suggest elevated salinities, as well (Flügel, 1982).

Subaerial exposure-related facies — The well-developed diagenetic in origin facies preserved in these Early Jurasssic peritidal strata are mainly represented by laminated, fenestral and massive ley-

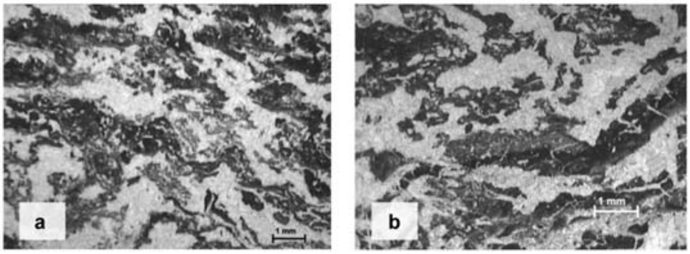


Fig. 5: Inter/supratidal environment – a. Fenestral laminated mudstone desiccated and fragmented (Dhidymi). b. Fenestral laminated mudstone desiccated and fragmented (Fokianos).

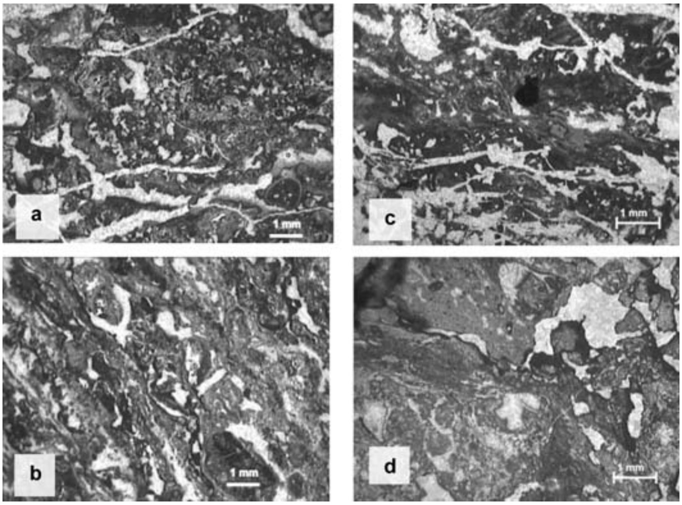


Fig. 6: Vadose environment, subaerial exposure – a. Laminar dolocrete with spar-filled interconnecting elongated cavities (Dhidymi). b. Glaebules. Spar-filled voids and cracks (Dhidymi). c. Microlaminated black micritic layers of pedogenic origin. Spar-filled interconnecting elongated cavities (Fokianos). d. Glaebules. Spar-filled voids and cracks (Fokianos).

ers which display several diagenetic textures (e.g. microlaminated black micritic layers, root structures, glaebules, circum-granular cracking) (Fig. 6c, d) that considered to be indicative of former plant-roots and of intense meteoric influence. They testify long-lasting emersion episodes and provide indices of pedogenesis and palaeosol formation under semi-arid to arid climate (Esteban and Klappa, 1983; Wright and Tucker, 1991; Jimenez de Cisneros et al., 1993).

In summary, the recognized facies associations of both selected outcrop sections include shallow subtidal-lagoonal and inter-supratidal facies. The depositional environment corresponds to the inner restricted platform–tidal flat system (Fig. 7). Several subaerial exposure-related evidencies pointing to emersion events and related to climate are preserved in both successions.

3.2 Microfacies correlation

By the comparison of the subtidal facies, a differentiation consisting primarily in the skeletal con-

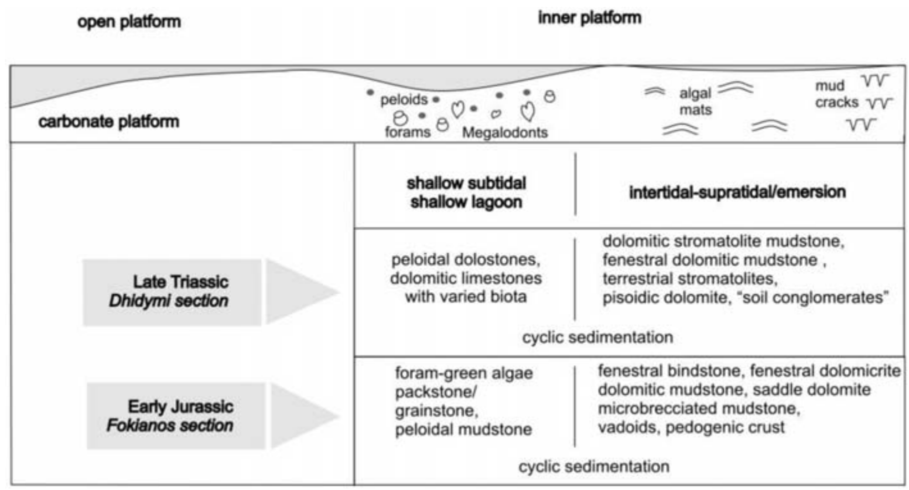


Fig. 7: Depositional settings of the Dhidymi and Fokianos sections.

tribution has been dedected. Late Triassic deposits are characterized by a rather good and rich amount of macro- and microfossil skeletal grains, reflecting a warm, lagoonal and productive environment with low water energy. Regarding to the Early Jurasssic facies, the biogenic contribution is less abundant and suggestive of more restricted and protected very shallow water conditions (transitional from a restricted lagoonal to a tidal-flat domain).

In both analyzed areas, a relative abundance of the inter-supratidal facies in respect to the subtidal ones, is noticed. However, the prevalence of supratidal deposits is more pronounced in the Early Jurasssic carbonate succession.

Early palaeoexposure surfaces and pedogenetic levels (palaeosols) are detected in both carbonate successions. The well-developed pedogenic features observed in the Early Jurassic platform carbonates indicate long-lasting subaerial exposure intervals and semi-arid to arid climate. Instead, the Late Triassic strata preserve vadose diagenetic indices which point to shorter exposure events, weaker meteoric alteration and slightly wetter climatic conditions (Pomoni-Papaioannou, 2009).

3.3 Vertical facies distribution and Lofer-type development

Considering the vertical evolution of various microfacies types/ facies associations defined, their arrangement reflects: (i) a general regressive trend from shallow subtidal-lagoonal to tidal-flat and subaerial exposure conditions and (ii) a general development of small-scaled peritidal cycles with a similar shallowing-upward trend.

The investigated platform carbonate successions, in both localities, consist of lagoonal-peritidal cycles. The basic facies pattern and the meter-scale cyclicity detected show close similarity with the Alpine Dachstein Lofer cycles. The indentified cyclothems are mostly incomplete, show a general regressive upward-shallowing trend and their topmost parts always preserve subaerial exposure evidences. Moreover, pedogenetic features suggesting sea-level lowering and periodic emersions episodes (Strasser, 1991) often overprint subtidal deposits. The subtidal carbonate facies with varied marine biota (e.g. Megalodont dolostones, foram-green algae grainstones) correspond to Member C of the typical Dachstein Lofer cycle. The recognized tidal-flat facies (e.g. loferites with fenestral structure) and the diagenetic-pedogenetic in origin layers (e.g. loferitic breccias, laminar dolocretes) correspond to the Member B and Member A of the classic Lofer cycle, respectively. However, the affected by intense diagenesis studied Early Jurassic peritidal carbonate platform cycles differs from the real Dachstein Lofer cyclothems showing a general regressive shallowing-upward asymmetric pattern. Instead, in the Dhidymi area, some of the cycles appear to be symmetric and the subtidal facies mark a clear deepening–upward trend. The commonly developed on tops of the peritidal cycles and/or directly superimposed upon the subtidal deposits pedogenic surfaces, support an allocyclic/eustatic control on their formation (Strasser, 1991; Haas et al., 2007, 2009). However, the contribution of autocyclic processes cannot be excluded.

The recognized sedimentological features suggest the occurrence of vast, Dachstein-type carbonate platform depositional systems, during the Late Triassic and Early Jurassic, eastern and western of the Pindos basin, respectively. Furthermore, the detected Early-Middle Liassic Lofer cycles support that in the Hellenides the Dachstein-type platform systems evolved till Early-Middle Liassic (GTz), under similar conditions. Additionally, the Liassic cyclic peritidal sediments of the Gavrovo-Tripolitza zone are comparable with similar coeval peritidal cycles distinguisted in the western peri-Mediterranean area (e.g. Bosence et al., 2000) denoting the development of analogous carbonate platform depositional systems within the western Tethys, during the Early Jurassic times.

4. Concluding remarks

Sedimentological analysis of the Late Triassic carbonates formed at the passive Pelagonian margin (Dhidymi) and of the Early-Middle Liassic successions of the Gavrovo-Tripolitza zone (SE of Leonidion) reveals:

- The recognized facies of both selected outcrop sections can be organized into three major groups/associations; shallow subtidal-lagoonal, peritidal (inter/supratidal) and subaerial exposure/pedogenic deposits.
- The deposition of the studied carbonate formations in analogous warm, quiet, very shallow marine environment (restricted, protected lagoon-tidal-flat settings) suggesting the occurrence of extensive, lagoonal-peritidal environments, during the Late Triassic and Early Jurassic, eastern and western of the Pindos basin, respectively.
- Sediments were repeatedly subaerially exposed and affected by meteoric diagenesis. They were completely or partially dolomitized. Well-developed subaerial exposure/emersion surfaces that dislpay strong evidence of early vadose diagenesis and terrestrial conditions have been observed.
- The pedogenic features detected in the Early Jurassic platform carbonates indicate long-lasting subaerial exposure intervals and semi-arid to arid climate. Instead, the Late Triassic strata preserve vadose diagenetic indices, which reveal shorter emersion episodes, minor meteoric influence and less arid climatic conditions.
- The vertical distribution of the defined microfacies associations and of the subaerial exposure related features show a characteristic repetitive pattern and organization in small-scaled cycles/units. The basic facies pattern and the meter-scale cyclicity, detected in both examinated localities, resemble closely the Alpine Dachstein Lofer cycles, supporting that in the Hellenides the Dachstein-type platform systems evolved till Early-Middle Liassic (Gavrovo-Tripolitza zone).

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