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A SEQUENCE FROM LATE TRIASSIC SHALLOW WATER CARBONATES TO JURASSIC BASINAL RADIOLARITES: KAP KASTELLO/HYDRA AT THE WESTERN MARGIN OF THE PELAGONIAN PLATFORM

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ABSTRACT

In the northeastern part of Hydra island, a brecciated level (Breccia succession) of uppermost Triassic to Early Jurassic age (e.g. Baumgartner, 1985) is overlying lagoonal carbonates of Norian/Rhaetian age, which cover a Carnian prograding reef-complex. Petrographic as well as biostratigraphic investigations were carried out for the following reconstruction: **1.** At Kap Kastello, the changing from reef (Backreef) limestones to Loferites, corresponds to the Carnian/Norian boundary. **2.** The Rhaetian upper part of the Loferites is affected by fracture-tectonics, causing cement-filled fissures. **3.** Monomictic mass flows in the lower part of the Breccia succession change into polymictic breccias, including grey mudstone clasts. The upper part of this succession is dominated by red limestone clasts and red limestone matrix, followed by Liassic, partially brecciated red nodular limestones (Ammonitico Rosso). **4.** Middle/Late Jurassic radiolarites with intercalations of sandy grain flows and calcareous debris flows, indicate the final deepening of the hydriotic depositional environment. Volcanic clasts and chrome spinels occur in the grain flows, while the debris flows contain shallow water clasts of Middle Jurassic age.

KEY WORDS: Triassic/Jurassic transition - Late Triassic microfossils - Pelagonian platform - breccias - Hydra island

1. INTRODUCTION

A Middle to Late Triassic reef basin complex dominates the geology of Hydra island (Greece), consisting of deep water carbonates on the southern thrust sheet, while the northern part of the island is characterized by shallow water limestones (Fig.1). Schäfer & Senowbari-Daryan (1982) described a vertical as well as horizontal facies differentiation of this "Pantokrator limestone", caused by the progradation of the carbonate platform towards the south. We do not agree with the term "Pantokrator limestone", because of its facial development. The original Pantokrator limestone of Korfu island (Ionian unit) is typical for shallow water carbonates. In contrast, the hydriotic "Pantokrator limestone" contains deep water deposits, additionally. In 1994, Turnsek & Senowbari-Daryan investigated the reef limestones east of Hydra Chora and described Carnian/Lowermost Norian coral associations. Schäfer & Senowbari-Daryan (1983) studied the biota of the Norian/Rhaetian Loferites. Dragastan et al. (1997) described new Norian and Rhaetian taxa from the lagoonal facies of the Kap Kastello section. Massive tectonic activity, *associated with the formation of breccias at the Triassic/Jurassic boundary*, caused the rapid subsidence of the carbonate platform. Lithology and genesis of these breccias are discussed in Richter & Füchtbauer

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(1981), Füchtbauer & Richter (1983) and Richter (1994). In general, the transition from Late Triassic carbonate platforms to Jurassic radiolarites, represented by complex brecciated horizons, is not only typical for the western margin of the Pelagonian Zone, but widespread in the Tethyan realm.

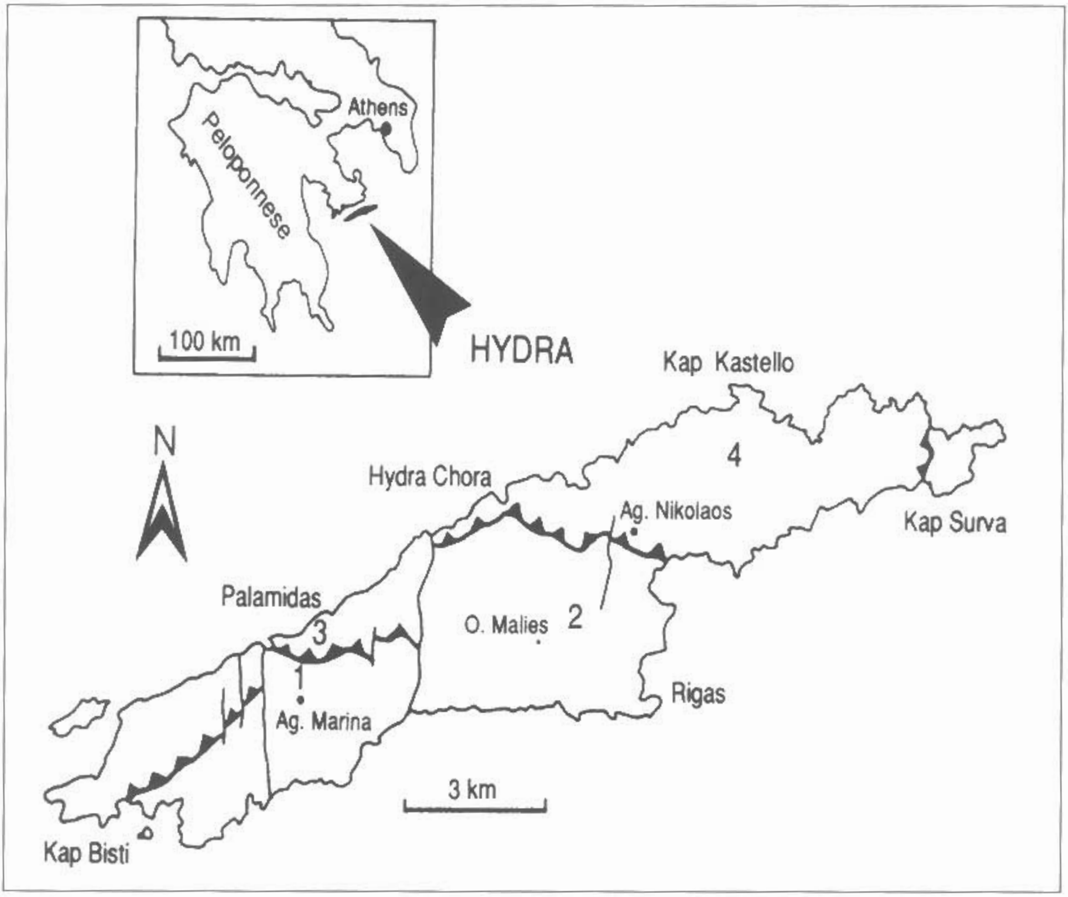


Fig. 1: Sketch map of Hydra island including the positions of the studied sections. Southern thrust sheet: 1 = Ag. Marina section; 2 = Malies section. Northern thrust sheet: 3 = section located between Palamidas and Hydra Chora; 4 = sections located between Hydra Chora and Kap Kastello.

2. GEOLOGICAL SETTING

The sedimentary series of Hydra island are located at the southwestern margin of the Pelagonian Platform in a transitional position to the Pindos zone (Jacobshagen, 1986). The Lower Permian to Late Jurassic successions, with a thickness of more than 1500m (Römermann, 1969), are divided in two EW-striking thrust sheets (northern and southern thrust sheet), dislocated at vertical faults (Fig.1). The hydriotic sequence documents the build up, fracture and subsidence of 3 carbonate platforms (Richter & Füchtbauer, 1981). Richter (1994) considered the multiphase subsidence with formation of internal breccias and mass flows to be associated with strike-slip faults, activated during the rifting phase of the Hellenids.

Permian shallow-marine deposits are overlain by Scythian gravity flows and deep water limestones of Lowermost Anisian age. Reef limestones demonstrate the formation of a Middle to Late Anisian carbonate platform (Eros Limestone).

Illyrian mass flows (reworked Eros Limestone), tuffites (Quartz keratophyric tuff) and ammonoidbearing red limestones (Hallstatt Limestone) demonstrate massive tectonic activity, that is comparable to the "Reifling event" of the Northern Calcareous Alps (Schlager & Schöllnberger, 1974). This event caused a strong facies differentiation with basinal deposits on the southern and shallow-water carbonates on the northern thrust sheet of Hydra (Fig.2). Based on conodont stratigraphy, Römermann (1968) and Dürkoop et al. (1986) suggest an Illyrian age of the Red Hallstatt Limestone, while Wendt (1973) and Angiolini et al. (1992) dated these sediments to be of Illyrian to Lowermost Ladinian age.

During the Late Triassic, deposition of laminated cherty limestones (Hornsteinplattenkalk) indicate deep-water sedimentation in the south (sections 1,2,3; Fig.2), while reef limestones document the growth of a carbonate platform on the northern thrust sheet. The transitional area of this reef-basin complex is represented by well bedded fore slope limestones containing gravity flows with shallow-water bioclasts. The progradation of the platform towards the southwest resulted in a horizontal as well as vertical facies zonation (Schäfer & Senowbari-Daryan, 1982).

Intercalations of red limestones in the foreslope- and in reef limestones of Carnian age (Dükoop et al., 1986) demonstrate that the progradation of the platform was interrupted by a temporary deepening of the southwestern platform-margin (sections 2,3,4; Fig.2). This tectonic event ("Reingraben event") caused the deposition of up to 70m thick filament-bearing limestones, covering reef limestones between Palamidas and Hydra Chora (section 3, Fig.2). Here, the deposition of reefal sediments reoccured not before Norian time, when the platform expansion reached this area again. In the Kap Kastello region, however, sedimentation of lagoonal carbonates took already place during this period (section 4, Fig.2). Backreef limestones are overlain by Norian/Rhaetian Loferites in the northeastern part of the island.At the Triassic/Jurassic transition the "Adnet event" caused a rapid subsidence of the carbonate platform, accompanied by internal breccias and mass flows (Breccia succession). Middle to Late Jurassic pelagic cherts (radiolarite), covering Liassic red limestones (Ammonitico Rosso), indicate the final deepening of the hydriotic depositional environment.

The Jurassic drifting of the Pindos ocean effected the development of a convergent plate margin. Subduction towards the northeast (Pelagonian platform) took place until Tertiary time, and the hydriotic succession became part of an accretionary wedge.

3. FACIES DEVELOPMENT OF THE KAP KASTELLO SECTION

REEF LIMESTONE

A lateral facies differentiation of discrete reefs and debris-rich interreef deposits is developed at the top of the coarsely bedded Carnian reef limestones (Fig.3). The dominance of algal rich sediments (especially encrusting cyanophyceans) as well as the overlying deposition of lagoonal carbonates, indicate patch reefs growing in a backreef area. High variety of species (Schäfer & Senowbari-Daryan, 1982) and primary pores, cemented by radiaxial calcite (containing homoaxial microdolomites) indicate a normal marine environment.

The biota of the uppermost reef limestones is composed of a coral assemblage with *Volzeia* and *Stuoresia* (Turnsek & Senowbari-Daryan, 1994) replaced by a sponge assemblage with *Pantokratoria fasciculata* (Flügel et al., 1988). The reef microfossil assemblage consists of benthonic biota and is controlled by coral or by sponge environments. It is composed of foraminifera (*Tignumparina zeissi* Senowbari-Daryan), dasycladaceans (*Oligoporella minutuloidea* Herak), cyanophyceans (*Rivularia lemaitre* Dragastan), and microproblematicae (*Microtubus, Paleomicrocodium*). The assemblages of coral or coralgal facies and spongalgal facies are of Late Carnian age. The thickness of the reef limestones is up to 1000m.

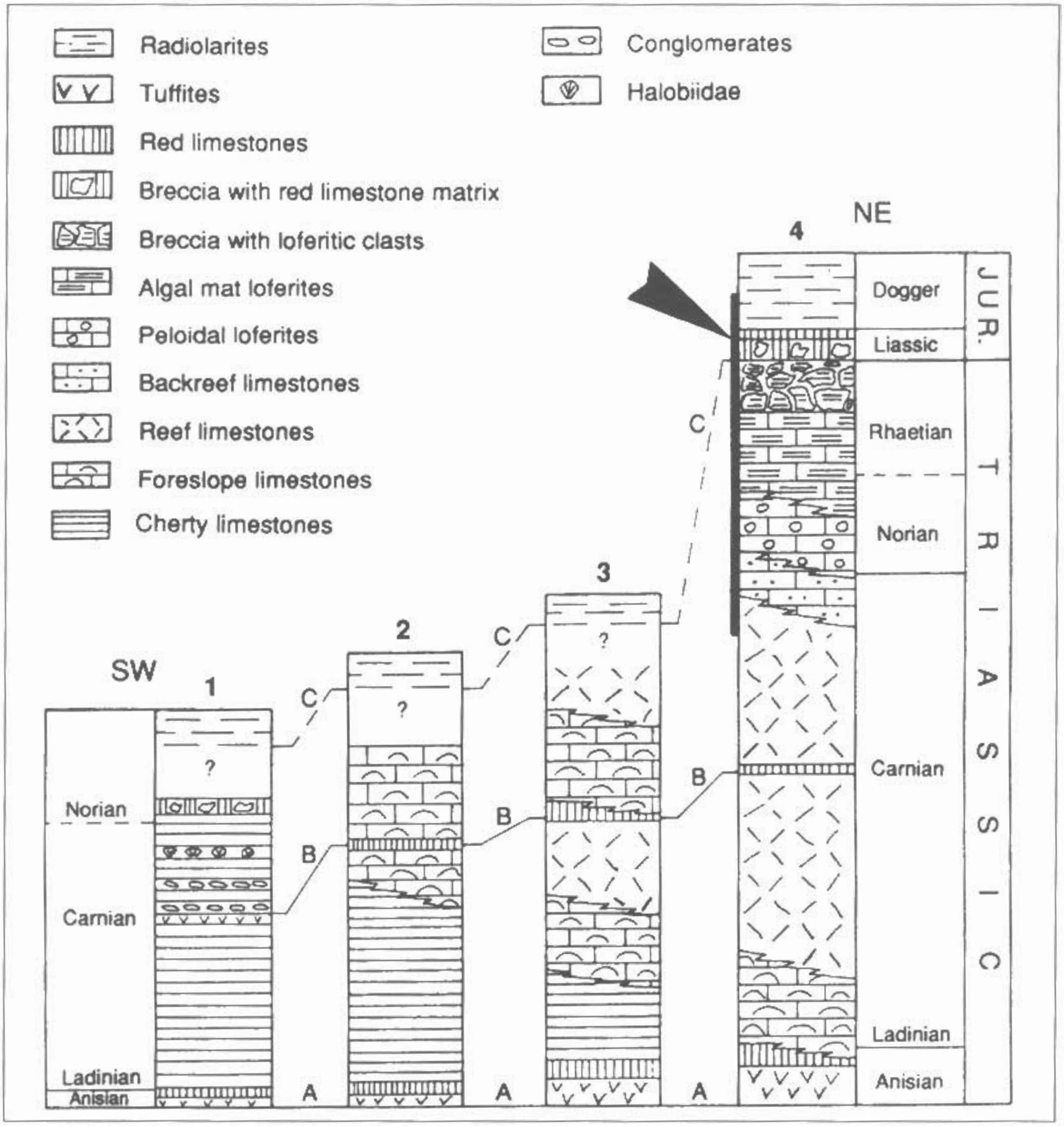


Fig. 2: Simplyfied sections (1-4) of Middle to Late Triassic rocks from Hydra island showing the lithofacial development of the reef-basin complex (from southwest to northeast). Tectonic events (A="Reifling event", B="Reingraben event", C= "Adnet event") are characterized by tuffites, breccias, and red limestones. The arrow points at the Kap Kastello section.

BACKREEF LIMESTONE

Late Triassic lagoonal sedimentation starts with deposition of 80m thick calcareous mudstone-facies (Fig.3). Ostracod-mudstones of a low energy environment represent the background sedimentation. Grainstone intercalations of high species-variety (algae, bivalves, echinoderms, sponges, corals etc.) as well as the occurrence of ooids, indicate the temporary existance of a higher energetic realm. Transported cortoid-like bioclasts, covered by micritic envelopes, demonstrate cyanobacterian participation in the lagoon. The upper part of the backreef facies is characterized by Zebra limestones, briefly mentioned by Schäfer & Senowbari-Daryan (1982), consisting of an alternation of thin bedded micritic limestones and horizontally bedded bipolar calcite cements. Development and composition of this microdolomite-bearing cements of radiaxiale habitate show the dominance of marine water during early diagenesis. Such phenomenons are suggested by Fischer (1964) as sheet cracks while Weller (1989) argues that they are a special stromatactis fabric. We suggest that these Zebra limestones result from a disaggregation of the partially compacted lagoonal sediment in the area of a Late Triassic/Early Jurassic strike-slip zone (Richter, 1994), due to the initial fracture-tectonics, that can be observed in the overlying Loferites. The genesis of the Late Carnian Backreef limestone at Kap Kastello can be compared to that of the Dachsteinkalk in the Northern Calcareous Alps (Piller,1976) and has its modern equivalent in the lagoonal pellet-mud facies of the Bahama Bank (Purdy, 1963).

The Late Carnian Backreef limestones are characterized by a microfossil assemblage consisting of cyanophyceans (*Ortonella myrae* Racz), dasycladaceans (*Oligoporella hydrae* Dragastan et al.), foraminifera (*Tignumparina zeissi* Senowbari-Daryan, *Diplotremina*), and several microproblematicae (*Aeolisaccus*, *Tubiphytes*, *Muranella sphaerica* Borza, *Palaeomicrocodium*, *Microtubus*).

LOFERITES

Norian/Rhaetian Loferites overly the Carnian Backreef limestone in the area of Kap Kastello. The 450m thick sub- to supratidal limestones are characterized by white to greyish partially dolomitized loferitic layers. The lower 170m are dominated by peloidal Loferites subsequently replaced by algal mat Loferites (Fig.3), formed by stromatolites. The succession consists of an alternation of loferitic layers and subtidal micritic limestones. It is comparable to the cyclic deposition in lagoonal carbonates of the Loferer Steinberge (Austria), described by Fischer (1964). Lofer-cyclothems are widespread in the western Tethys (Haas,1991) indicating a global control of cyclicity during the Late Triassic. Lagoonal carbonates of the Peloponnese have been investigated by Kalpakis & Lekkas (1982) and Vatris-Matarangas & Matarangas (1991).

The 20-60cm thick **loferitic layers** are the characteristic facies, composed of dolomicritic mats with embedded calcified fenestrae as well as irregular dolomitic peloids with dolomitic meniscus cements. Prism cracks, sheet cracks and syndepositional faults are typical features. Arenitic intercalations of algae, foraminifera, ostracods and ooids occur sporadically. Intraclast bearing layers at the top of the Loferite layers contain reworked dolomite clasts. Prism cracks indicate an intertidal realm of a carbonate tidal flat, that can be compared with section B of the Lofer-cyclothems sensu Fischer (1964).

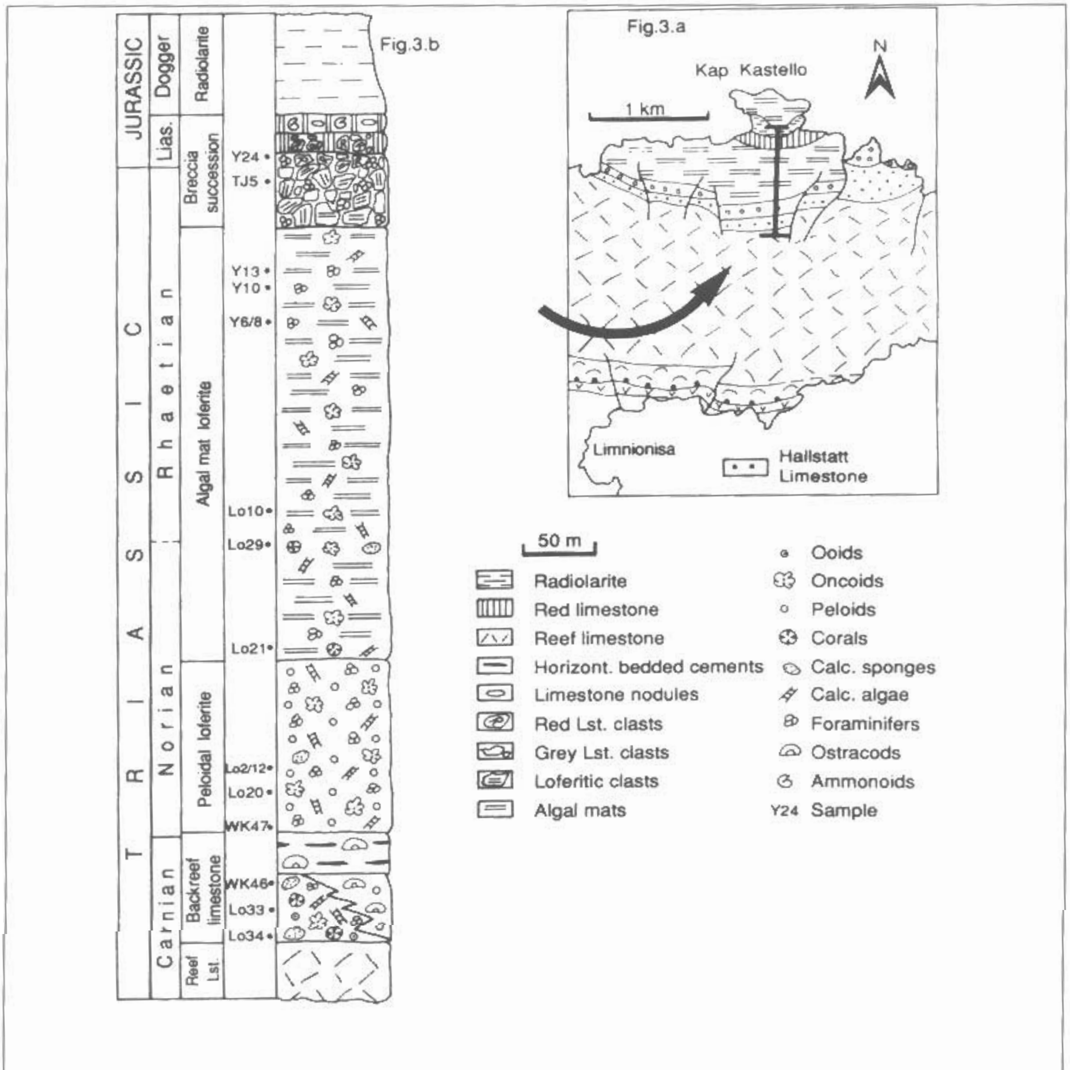
Subtidal **micritic limestones** are characterized by the occurrence of megalodontids. This deposition of a very low energy environment is mainly composed of ostracod limestones. Pack- to grainstones, containing biodetritus of foraminifera, algae, bivalves, corals, and sponges, show a transport of bioclasts deriving from adjacent patch reefs. The lagoonal character of this sediments is represented by a partially strong micritisation of the bioclasts. Pseudomenisci can be observed frequently. Such phenomenon is considered by Richter et al. (1992) from the Parnassus-Kiona unit to be caused by algal influence. Similar micritisations of components in modern grapestones of the Great Bahama Bank are interpreted by Purdy (1963) and Winland & Matthews (1974) as being affected by organic matter and/or blue-green algae. The megalodont- and detritus-bearing micritic limestones correspond to the section C (subtidal environment) of the Lofer-cyclothems (Fischer, 1964). Megalodont shells are replaced by radiaxial, microdolomite inclusions bearing calcite, representing marine cementation of Mg-calcite after aragonite solution.

Cyclic sedimentation of the hydriotic Loferite succession is mainly composed of BC-cycles sensu Fischer (1964). Complete Lofer-cyclothems are developed on the Argolis peninsula (Kuhfeld, 1989).

The distribution of Norian biota at Kap Kastello is limited to the peloidal Loferites and to the lower part of the algal mat Loferites. The Norian lagoonal microfossil community is represented by foraminifera (Aulotortidae, Glomospirellids, Ataxophragmiidae), green algae (Bryopsidales-Pseudoudoteaceae, Dasycladales), cyanophyceans (*Rivularia*, *Polytrichella*), red algae (*Parachaetes*, *Solenopora*), microproblematicae (*Tubiphytes*, *Aeolisaccus*) and microsponges (*Ladinella porata* Ott). Green algae such as *Pseudoudotea*, *Hydraea*, *Salpingoporella* and *Pseudogyroporella* occur very often in the Norian lagoon (Dragastan et al., 1997).

The Rhaetian tidal flat environment contains beside the coral *Retiophyllia*, a large range of microbiota such as foraminifera, algae and microproblematicae. Involutinids (*Aulotortus*), miliolids (*Agathammina*) and glomospirellids (*Glomospirella*) represent the foraminiferal assemblage. Dasyclads (*Griphoporella curvata* Gümbel, *Heteroporella zankli* Ott, *Macroporella retica* Zanin-Buri), halimedaceans (*Halimeda* sp., *Boueina* sp.), udoteaceans (*Pseudopenicillus aegaeicus* Dragastan et al.), cyanophyceans (*Rivularia lemaitre* Dragastan) and red algae (*Parachaetaetes, Solenopora, Permocalculus pelagonicus* Dragastan et al.) form the algal association. The uppermost part of the Rhaetian lagoonal succession is characterized by only a few species of Aulotortus, Glomospirella, Aeolisaccus, Salpingoporella, while the Thaumatoporellid-type A organism is very abundant. This restricted community indicates a very low energy environment at the end of the Triassic sequence.

Fig. 3. a: Geological map of the Kap Kastello area showing the location of the investigated section (Fig. 3.b.). Explanation see Fig. 2. **b:** Schematic columnar section of the Late Triassic/Jurassic facies evolution. Late Triassic shallow water limestones (Backreef limestone, Loferites) are overlain by Rhaetian/Liassic breccias (Breccia succession). Basinal deposits are represented by Middle/Late Jurassic Radiolarites.



BRECCIA SUCCESSION

An about 80m thick succession of internal breccias and mass flows is overlying the loferitic limestones in the Kap Kastello area. The uppermost part of the algal mat Loferites is affected by fracture-tectonics, forming internal breccias. Gradiational changes into mass flows are not uncommon. The geological situation of Kap Kastello is complicated by polyphase brecciation, that took place at the Triassic/Jurassic boundary.

The transition of the Loferites towards the Breccia succession is characterized by the first occurrence of red limestone matrix, embedded in fissures. A monomictic breccia represents the lowermost 30 meters of the Breccia succession (Fig.3), consisting of Loferite-clasts (dimension: cm^3-m^3) and micritic grey limestone matrix. The following 20 meters are characterized by a decrease of Loferite-clasts and clast size, whereas the matrix content as well as the content of grey mudstone clasts increases. Fifty meters upsection the first red limestone clasts can be observed (Fig.3). The lithological variety of clasts of this mass flow becomes more polymictic, while clast roundness increases. The upper part (from 50 up to 70 meters) of the succession is dominated by red limestone clasts and red limestone matrix, while the content of grey limestone clasts decreases. In the uppermost 12 meters of the section, the breccias are replaced by red nodular limestone (Ammonitico Rosso) containing ammonoids, filaments, radiolarians, ostracods and few foraminifera (Fig.3). Lithology and faunal composition point at a sill-facies of deep water environment (below photic zone), comparable to other Mediterrannean Jurassic nodular limestones, as described by Jenkyns (1974). The Ammonitico Rosso is syndepositional brecciated, whereas polymictic parts can be observed.

Late Triassic biota (*Rivularia lemaitre* Dragastan, *Triasina hantkeni* Majzon, *Aulotortus sinuosus* Weynschenk and *Agathammina austroalpina* Kristan-Tollmann) occurs only in the lower to middle part of the Breccia succession. Jurassic microfossils (*Involutina liassica* Jones, *I. silicea* Terquem, *I. lacunosa* Ruggieri & Giunta, *Siberina virgata* Fuchs) are found not before the occurrence of red limestone clasts (at 50 meters) in the section. The Early to Middle Jurassic foraminifer *I. lacunosa* is restricted to the Ammonitico Rosso, according to Römermann (1968), who determined a Middle to Late Liassic cephalopod fauna for this red limestone.

RADIOLARITE

Up to 100m thick radiolarites cover the Breccia succession at Kap Kastello (Fig.3). The background deposition of the radiolarites is formed by radiolarian ooze and variable amounts of clay and silt. In the thin bedded radiolarites, gravity flow intercalations occur frequently. The lower part of the succession is dominated by matrix poor sandy grain flows containing basaltic clasts, pyroxene and chrome spinel. Therefore, a source area of oceanic crust material is indicated during depositional time. Debris flows composed of radiolarite- and carbonate clasts occur in the upper part of the radiolarite sequence. The Jurassic radiolarite biota is represented by radiolarians (most Spummellaria) and few sponge spiculae (Middle to early Late Bajocian after Baumgartner et al., 1993, p.19). Baumgartner (1985) investigated similar radiolarites from the Argolis peninsula and assigned a Late Jurassic age (Oxfordian-Kimmeridgian). Clasts of shallow water limestones as constituents in the debris flows, contain the Bajocian-Bathonian foraminifer *Archaeosepta*.

4. PALEOGEOGRAPHIC INTERPRETATION

The development of the Breccia succession indicates the transition of a carbonate tidal flat (Loferites) to a deeper water environment (Ammonitico Rosso). The Triassic/Jurassic rifting phase caused a polybrecciation of the Kap Kastello area ("Adnet event" sensu Schlager & Schöllnberger, 1974). Reefs are not developed between the deposition of the Loferites and the Ammonitico Rosso. This lack in reef development may indicate a rapid initial subsidence around the Triassic/Jurassic boundary as indicated by a grey mudstone facies on top of the Loferites and an increase of grey mudstone-clasts in the central part of the Breccia horizon. During Jurassic time, we consider an oceanic crust source for radiolarite sedimentation, because of the occurrence of chrome spinel and basaltic clasts in contemporary grain flows. The presence of ophiolitic material documents MOR activity and formation of oceanic crust in the Pindos ocean during Jurassic time (Robertson et al., 1991). In context with a partial subduction of the Pindos basin towards the northeast (Pelagonian platform), obduction of oceanic crust in the accretionary wedge along the Central Hellenic sutur is our most favoured scenario.The main phase of subsidence in the hydriotic area took place during Middle to Late Jurassic time, as indicated by clasts of Late Bajocian/Bathonian shallow water limestones embedded in the radiolarite. This tectonic pulse is comparable to the "Ruhpolding event" of the Northern Calcareous Alps (Schlager & Schöllnberger, 1974).

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