doi: 10.13133/2280-6148/17835 *Journal of Mediterranean Earth Sciences 14 (2022), 95-130*

JMES **Journal of Mediterranean Earth Sciences**

Stepwise tectono-sedimentary evolution of Meso-Cenozoic Pre-Apulian carbonate units of the Ionian Islands (External Hellenides, Greece)

Giovanni Accordi *, Federico Carbone

Istituto di Geologia Ambientale e Geoingegneria - CNR, Dipartimento di Scienze della Terra,
SAPIENZA Università di Roma, P.le A. Moro, 5 - 00185 Roma, Italy
**Corresponding author: giovanni.accordi@igag.cnr.it*

ABSTRACT - The tectono-sedimentary evolution of Meso-Cenozoic Pre-Apulian carbonate successions of the Ionian Islands has been investigated through a comparison of the outcropping sedimentary sequences. These sequences are the remnants of originally wide shallow water depositional units belonging to different Cretaceous-Paleogene sedimentary systems developed in a crustal segment positioned between the Apulian Carbonate Platform (ACP) and the Ionian Basin (IB). The evolutionary trends of the facies sequences highlight the existence of at least two depositional systems, one, including western Cephalonia and Zakynthos islands, linked to the ACP domain, and the other, including eastern Cephalonia and Lefkada islands, related to the IB domain. The evolution of these two systems, affected during the Mesozoic and Cenozoic by different phases of geotectonic deformation and sinking times, is strongly influenced by the hypothetical presence of a deep wide pelagic trough separating the two depositional systems, probably linked to the IB.

Down-faulting with backstepping of marginal areas, often accompanied by periods of emergences of blocks, caused repeated sediment mobilization by mass flows. Detrital carbonates dispersed and accumulated along the sloping seafloor, proximal to newly formed basin areas, not necessarily directly connected eastward with the basin areas of the IB. For a long time, the western unit, of which the Lixouri Peninsula and Zakynthos island were part, acted as a subsiding flat-topped rimmed carbonate platform. In Late Cretaceous times, this unit underwent a progressive marginal down-faulting that led to the development of a Paleocene ramp system with variable geometries related to the evolutionary trend of the eastern margin of the ACP. The eastern unit, including the part of Cephalonia east of the Enos thrust and part of Lefkada island, shows, at least since the Early Cretaceous, close relationships with the pelagic sedimentation of the IB. A depositional carbonate ramp system along the western margin of this deep water environment is recorded since the Berriasian, proven by the presence of resedimented shelf-derived fine calcidebrites interbedded with pelagic lime mudstone. The changes undergone by the depositional systems are related to the progressive disappearance of Mesozoic Neo-Tethys large infra-oceanic carbonate platforms mainly due to the series of tectono-sedimentary phases. These phases in time led to the demise of shallow water sedimentation on large areas, to the storage in deep water of rudist-bearing detrital carbonate transported by mass-flow, and finally to the spread of fine pelagic sedimentation throughout former shallow water areas. Therefore, only the Upper Cretaceous portion of the stratigraphic record of the Pre-Apulian zone related to the ACP domain can be attributed to a typical isolated flat-topped rimmed carbonate platform model.

Keywords: facies; biostratigraphy; Mesozoic-Cenozoic; Pre-Apulian platform; Ionian Islands; Greece.

Submitted: 7 September 2022-Accepted: 2 December 2022

1. INTRODUCTION

This paper aims to provide an account of the sedimentary evolution, during Early Cretaceous-early Miocene, of the shallow-water carbonate units located in a crustal segment affected now as in the past by strong tectonic movements linked to the syn- and post-collisional phases of the Alpine orogeny (Mantovani et al., 1997; Robertson and Shallo, 2000; Garfunkel, 2004; Stampfli and Kozur, 2006; Stampfli and Hochard, 2009; Argnani, 2013; Bega, 2013; Hosseinpour et al., 2016; Handy et al., 2019; Kilias, 2021).

The area investigated in this paper (Fig. 1) includes the islands southeast of the Cephalonia Transform Fault (CTF). This important tectonic line breaks the morpho-structural settings of the ACP, marking a sharp transition to the Hellenic Arc. The importance of this fault is evidenced by structural trends both inshore and offshore

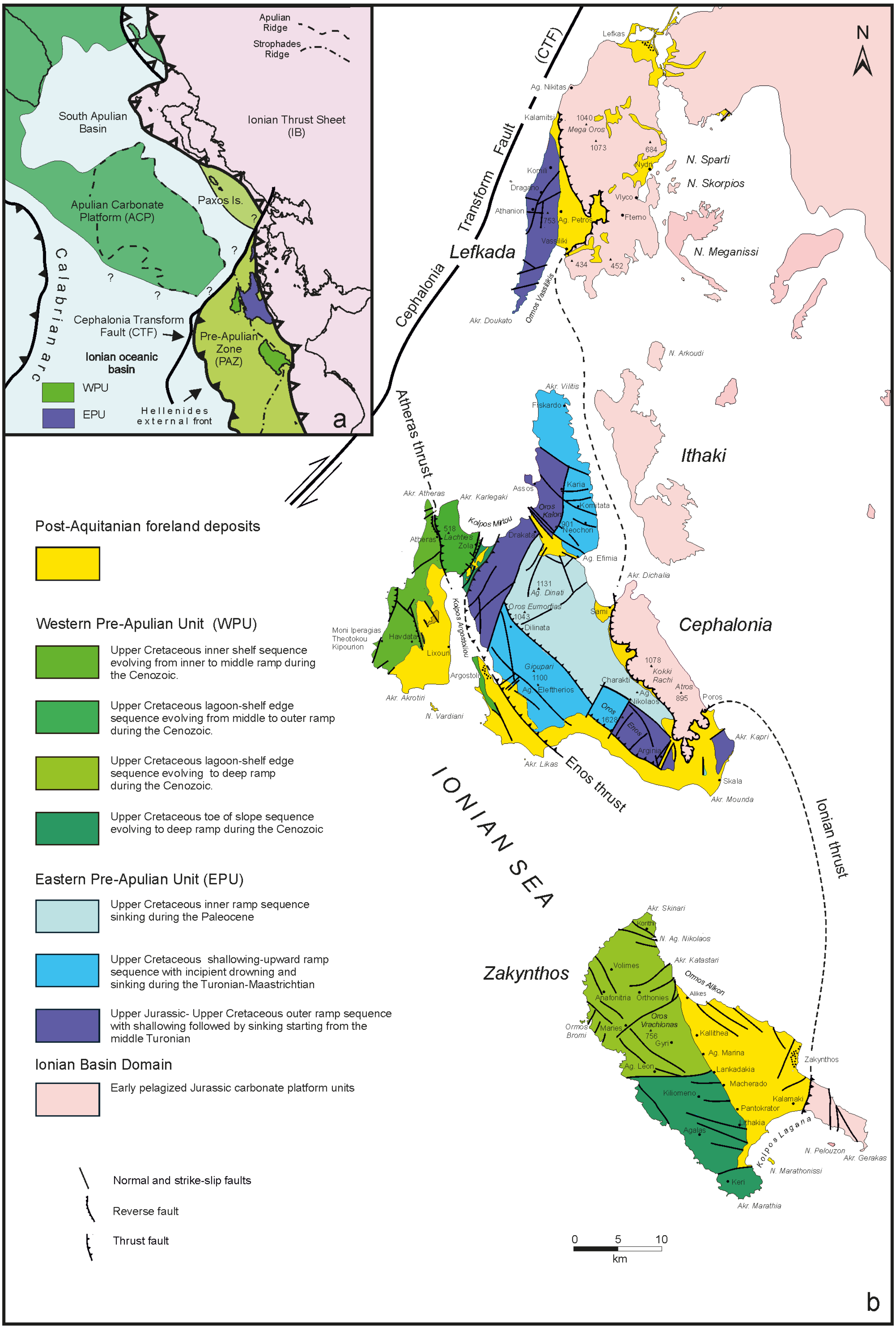


Fig. 1 - Map of the study area. a) Scheme of the tectono-sedimentary setting (modified from Del Ben et al., 2015; Carayon et al., 2017); b) schematic geological map of the main depositional sequences belonging to WPU and EPU sedimentary units tectonically juxtaposed (redrawn and modified from Accordi and Carbone, 1992).

and has been underlined by various authors (Morelli et al.,1975; Biju Duval et al., 1977; Auroux et al., 1984; Finetti and Del Ben, 1986; Louvari et al., 1999; Kokinou et al., 2005; Özbakır et al., 2020; Bourli et al., 2022).

The Pre-Apulian Zone (PAZ), reported in the literature as the logical eastern continuation of the ACP towards IB (Auboin, 1957, 1959; Auboin and Dercourt, 1962; Auboin et al., 1976; Le Pichon et al., 2002; Zelilidis et al., 2015), and considered in the past as little deformed, shows a complex tectonic setting (Brooks et al., 1988; Underhill, 1989). This crustal segment was affected only belatedly by the west-verging translation of the Hellenides-Dinarides orogenic fold-and-thrust belt which followed the geotectonic evolution of the eastern margin of the Adria microplate (Giese and Reutter, 1978; Kilias et al., 2002; Nicolai and Gambini, 2007; Karakitsios and Rigakis, 2007; Del Ben et al., 2010; Handy et al., 2019; Kilias, 2021). The western movement of the Hellenides and Dinarides thrust sheets, as opposed to that of the Apennine belt (Roeder, 1980; Catalano et al., 2001; Butler, 2009), is related to the development, drowning, and final shortening of the African passive continental margin, which occurred as a result of the opening during the early Mesozoic and subsequent closure during the late Mesozoic-Cenozoic of the Mediterranean Tethys (Gonzalez-Bonorino, 1996; Picha, 2002; Meulenkamp and Sissingh, 2003; van Hinsbergen and Schmid, 2012; Papanikolaou, 2013; Hosseinpour et al., 2016).

In the past, the PAZ has been interpreted as a vast segment of a margin-escarpment of a carbonate platform partially covered by the Ionian Thrust (Sami-Kalamitsi thrust, British Petroleum Co. Ltd., 1971; Jenkins, 1972). According to this hypothesis, the stratigraphic record of Zakynthos is believed to be closely related to the Apulian zone (IFP-IGRS, 1966). In contrast, other authors find great differences between the carbonate sequences of Zakynthos and Cephalonia and that of Paxos. Indeed, some authors (Bizon, l967, Bernoulli and Renz, 1970) introduce a subdivision of two subzones, one including Zakynthos and Cephalonia islands, the other Paxos island.

The structural and paleomagnetic data assign a stable tectonic behavior only to the Adriatic segment northwest of CTF. At the same time, southeast the current settings of the Hellenic Arc, of which Lefkada, Cephalonia, and Zakynthos are part, were conditioned by counterclockwise rotational movements since the Cretaceous (Mantovani et al.,1990; Kahle et al., 1995; Hirn et al., 1996; Clement et al., 2000; Kondopoulou 2000; Kokinou and Vafidis, 2003; Rosenbaum et al., 2004; van Hinsbergen et al., 2006, 2014; Carayon et al., 2017; Marton et al., 2017). Furthermore, other recent seismic stratigraphic data, (Carayon et al., 2017), revealed the existence of two submerged carbonate units, the "Apulian Ridge" and the "Strophades Ridge" positioned respectively north and south of the CTF (Fig. 1a). The first one, identified as a Mesozoic detached rimmed platform, is not significantly affected by the deformation typical of the External Hellenides thrust and fold belt; conversely, the second is strongly tectonized and represents part of a Mesozoic shallow-water carbonate unit.

The present work is based on the review of biostratigraphic and sedimentological data collected over the years on the carbonate units forming the Pre-Apulian zone of the Ionian Islands. These data, part of which in the past gave rise to specific publications (Accordi et al., 1987; Accordi and Carbone, 1992; Accordi et al., 1998; Pignatti et al., 2008; Di Carlo et al., 2010; Accordi et al., 2014), were analyzed and integrated by other unpublished data, in order to define a stepwise reconstruction of the sedimentary model relatable to the Mesozoic-Cenozoic geodynamic evolution of the studied area. Most of the data already used in previously published papers mainly concerned the biostratigraphy and facies analysis of the western unit, including part of Cephalonia and Zalynthos islands. In contrast, for the remaining part of Cephalonia and for Lefkada the collected data are mostly unpublished.

The stratigraphic and facies analysis carried out on the carbonate successions belonging to the Pre-Apulian zone of the Ionian Islands allowed us to highlight the tectono-sedimentary events that contributed to the setup and evolution of at least two carbonate depositional systems related to different carbonate platform models (Accordi et al., 2014). These depositional systems assumed flat-topped rimmed shelf and ramp geometries over time (Ahr, 1973; Kendall and Schlager, 1981; Read, 1982; Burchette and Wright, 1992; Wright and Burchette, 1998; Pomar, 2001; Bosence, 2005; Pomar and Kendall, 2007; Burgess et al., 2011; Williams et al., 2011; Pomar et al., 2017). These systems evolved in different ways, due to the interaction between tectonics and global sea-level variations. The difference in crustal behavior between a Western Pre-Apulian Unit (WPU), including Zakynthos island, and an Eastern Pre-Apulian Unit (EPU), including Lefkada island, is highlighted both by an initial difference in the evolution of depositional models and by the divergent trend of progressive drowning of shallow water areas. Particularly, the abundance of allodapic limestone intercalations characterizing the stratigraphic records, largely formed by shelf-derived skeletal debris and carbonate lithoclasts, fits well with complicated geotectonic relationships between the margins of the Apulian Carbonate Platform (ACP) and Ionian Basin (IB) during Mesozoic-Cenozoic period within the more general framework of the Adriatic domain evolution (Bosellini et al., 1999a; Graziano, 1999; Vlahović et al., 2005; Eberli et al., 2019; Le Goff et al., 2019).

2. GEOLOGICAL SETTING

The remnants of previous shallow-water carbonate units displaced between the ACP and the IB during the Cretaceous, are now juxtaposed to form the pre-Apulian zone of islands south of the CTF, as the corresponding sedimentary succession is partially hidden by the overthrusted strongly tectonized rock stack of the western margin of the IB (Fig. 1b).

The structural relationship between the Ionian thrust sheet and Pre-Apulian succession is well exposed in Cephalonia, whereas is less clear in Lefkada and Zakynthos. The most common setting shows an overthrust of Upper Triassic-Lower Jurassic shallow-water limestone of the Pantokrator Fm. on Miocene marly deposits belonging to the Pre-Apulian domain (British Petroleum Co. Ltd., 1971).

The stratigraphic record of the Ionian zone includes heterogeneous rocks deposited starting from the Late Liassic during crustal extensional phases that affected the region located between the Gavrovo carbonate platform to the east, and ACP to the west (Gonzalez-Bonorino, 1996).

From the Late Jurassic to the early Senonian, pelagic sedimentation, made of well-bedded mudstones, wackestones, and marls with jaspers and chert beds (Vigla Limestone Fm.), occurs.

The whole Senonian succession, especially along the western side of the basin, is characterized by allodapic limestone intercalations rich in rudist remains. Likewise, from the Paleocene up to the Priabonian, the sequence of fine pelagic limestone shows calcidebrite intercalations rich in reworked larger foraminiferal assemblages. The carbonate sedimentation ends with the arrival, at the Eocene-Oligocene boundary, of the Ionian flysch (Karakitsios and Rigakis, 2007; Karakitsios, 2013; Bourli et al., 2019).

At present, the tectonic pattern of the Ionian Islands seems to have been determined by west-verging movements, although paleomagnetic data indicate a clockwise rotation after the setting up of thrusts (Kissel et al., 1985; Kissel and Laj, 1988; Deurmeijer et al., 1999, 2000; van Hinsbergen et al., 2006). According to Underhill (1989), the folding and overthrusting events in the PAZ of the Ionian Islands occurred after the Early Pliocene setup of the Ionian thrust sheet.

Some authors report that the geotectonic evolution of the PAZ is highlighted by the tectonic approach of sedimentary sequences belonging to a Mesozoic to Cenozoic carbonate ramp, transitional between the shallow-water Apulian Platform to the west and the deeper-water Ionian Basin to the east. The relationships between these two zones were controlled during the Mesozoic by normal faults, reactivated in the Eocene-Miocene as thrust faults, and finally during the Plio-Quaternary as normal faults (Getsos et al., 2007; Zelilidis et al., 2015; Bourli et al., 2022).

Other authors (Accordi and Carbone, 1992; Accordi et al., 1998; Di Carlo et al., 2010; Accordi et al., 2014) report that the sequences of the PAZ of the Ionian Islands testify to the existence of two depositional systems with different tectono-sedimentary evolution.

In Lefkada island, the carbonate rock outcrops belonging to the PAZ are limited to the westernmost part of the island, including the Akros Doukato peninsula (Fig. 1b). The structural setting is made of a faulted anticline fold, N-S oriented, consisting mainly of Upper Cretaceous limestone. Several faults have down-faulted the western limb of the fold, creating a typical craggy seacliff where the lower part of the stratigraphic sequence crops out. Conversely, the eastern limb of the fold consists of the top of a depositional sequence characterized by Cenozoic marly limestone and marl with reworked larger foraminifera-bearing intercalations decreasing upwards. On the island of Lefkada, the tectonic relationship between the PAZ rocks and the Ionian thrust sheet, known as the "Sami-Kalamitsi thrust" (British Petroleum Co. Ltd., 1971), reflects the general geotectonic framework of the region, showing the overlap of the Pantocrator Limestone on the PAZ Miocene marls.

In Cephalonia island, the compressional tectonics displayed by the Pre-Apulian zone is evidenced by a dense fault network (Fig. 1b) where greater importance is given to inverse and thrust faults and subordinately strike-slip faults that, according to Underhill (1989), caused a significant crustal shortening, with the consequent obliteration of a large part of the original Hellenic foreland area. Among the numerous folds and thrusts characterizing the island, notable is the Enos thrust, located on the western side of the Enos range, separating the EPU from the WPU. This thrust, considered by British Petroleum Co. Ltd. (1971) as a normal fault with an about 1500 m dip-slip displacement, is reported by Underhill (1989) as a thrust fault that overlaps the Cretaceous limestone on both Miocene marls and Pliocene-Pleistocene deposits. The region east of this fault is affected by a series of reverse faults and back-thrusts interrupting the structural continuity of carbonate succession, whereas in the west a prominent overthrust (the Atheras thrust) subdivides the Lixouri Peninsula into two sectors that show different stratigraphic features. This part of the island is affected by an apparent minor shortening marked by a series of north-south trending folds associated with some very recent overthrusts (Accordi et al., 1998; Accordi et al., 2014),

In Zakynthos island, the PAZ carbonate succession is arranged as an NW-SE oriented anticline fold, affected by extensional tectonics after folding. Many normal faults roughly parallel to the anticline axis characterize the west coast of the island, while reverse faults, generally NW-SE oriented, produce obliteration or repetition of parts of the stratigraphic succession (Fig. 1b). The oldest rocks, Turonian-Maastrichtian in age, mainly occupy the western part of the island, while middle Eocene-Oligocene deposits overlie the Cretaceous rocks on the eastern flank of the fold. Also in this case a tectonic juxtaposition of originally not contiguous crustal segments is evidenced by the abrupt changes in the facies sequences from north to south crossing the island (Di Carlo et al., 2010; Accordi et al., 2014).

3. MATERIALS AND METHODS

The study of rock outcrops, carried out on many field sections located in the different sectors of Ionian islands, concerned the recognition of the sedimentary features of facies sequences discriminating the different depositional systems of sedimentary environments from shallow to deep water. The analysis of the skeletal and non-skeletal granular components was performed on thin sections and has been essential in defining the chronostratigraphic and environmental meaning of fossil communities. Globotruncanid- and globorotaliid-bearing layers were helpful in defining the stratigraphic record of middle-outer ramp facies sequences and particularly the timing of individual allodapic carbonate deposits. Similarly, the identification of benthic foraminiferal assemblages and rudist and nerineid communities was crucial for the definition of the sedimentary environment and age of Cretaceous shallow-water facies sequences, whereas the identification of the larger foraminiferal assemblages was helpful for the Cenozoic stratigraphy and especially for the definition of the evolutionary trend of the WPU. Furthermore, for the definition of the stratigraphic characters of the depositional system of the EPU, we utilized original unpublished chronostratigraphic data obtained from the thin section analysis of samples from some field sections.

The recognition of syn-depositional reworking features of the shelf-derived calciclastic debris also allowed us to speculate on the predominant role played by tectonics, as compared to global sea-level variations, on the evolutionary trend of the two hypothesized depositional systems, as documented in different areas of the Adria domain (Festa et al., 2010; Rubert et al., 2012; Bourli et al., 2019, 2022).

The results are summarized in a schematic facies map (Fig. 1) and in a series of synthetic logs related to the two tectono-sedimentary units characterizing the islands (Figs. 2, 3). Furthermore, a set of interpretative profiles, highlighting the relationships established over time between the WPU and the EPU, were performed (Fig. 17). The data obtained are summarized both in stratigraphic panels (Figs. 18, 19) and in a synthetic paleogeographic model (Fig. 20). Finally, we compared our results with data reported in the literature on the Cretaceous-Paleogene evolutionary history of the western margin of the ACP and the Hellenic foreland.

4. RESULTS

4.1. STRATIGRAPHIC FRAMEWORK

The extensive facies analysis performed on the Pre-Apulian carbonate rocks cropping out on the islands, integrated by literature data (Accordi et al., 1987; Accordi and Carbone, 1992; Accordi et al., 1998; Pignatti et al., 2008; Di Carlo et al., 2010; Zoumpoulis et al., 2010; Accordi et al., 2014; British Petroleum Co. Ltd., 1971; de Mulder, 1975; Civitelli et al., 1987; Steuber et al., 2006; Kati and Scholle, 2008; Mikellidou et al., 2018), allowed us to trace a framework of the early Cretaceous-early Miocene geotectonic evolution of this part of the Adria microplate. The tectono-sedimentary pattern of the investigated crustal segment of PAZ, placed between the ACP and the IB, is characterized by different carbonate facies sequences variously distributed and juxtaposed by tectonics. These are attributable to at least two carbonate tectono-sedimentary units, belonging to a much larger area of the Hellenic foreland. Each of them underwent a different evolutionary trend with changes in geometry in time, mainly due to periodic uplifts and progressive drowning of peripheral portions. A common sedimentary character that influenced the geotectonic evolution of the two units is the periodical production of large amounts of detrital carbonate originating in shallow areas and transported towards the basin through various types of gravity flows, whose depositional characters are widely reported in the literature (Reijmer et al., 2015; Stow and Smillie, 2020).

4.1.1. EPU - Eastern Pre-Apulian and Lefkada sedimentary records

In Cephalonia, the EPU includes two smaller sectors, separated by tectonic lines (Fig. 5): one, limited to the east by the Ionian thrust (Ag. Dynati-Gioupari), is represented by peritidal-shallow subtidal facies sequences typical of the inner-middle ramp environment (Fig. 2, log d), the other comprising both Lefkada Island (Fig. 2, log b) and the central part of Cephalonia (Fig. 2, logs a, c), shows facies sequences ranging from inner-middle ramp to outer ramp-proximal basin. These depositional environments are characterized by changes in the fossil assemblages related to environmental evolution affecting in time the carbonate ramp (Tab. 1).

4.1.1.1. Outer ramp-proximal basin facies sequence

The oldest part crops out in western Lefkada along the Athanion seacliff, where a stack about 1000 m thick of crumbly macrocrystalline grey dolostone, affected by gully erosion, is well exposed (Fig. 2, log b). The Tithonian layers with ammonite and aptich remains recorded by Bornovas (1964) probably originate from the bottom of this sequence. Upsection we found thin laminated dolostones, marls, and marly limestones (Fig. 6 a,b), without evidence of organic structures, and a few thin mudstone beds, positioned at the top of the dolomitic interval, with well-preserved calpionellid remains (*Calpionella alpina*, *Calpionellopsis simplex*, *Tintinnopsella longa*, and *Stomiosphaera moluccana*), suggesting a Berriasian-Barremian age. Upsection, an Aptian-Albian well-bedded pelagic lime mudstone sequence follows, containing stacks of dark marls correlatable with the anoxic events (black shales) that occurred in this timespan in many areas of the Mediterranean Tethys (Jenkins, 1999; Danelian et al., 2004; Erba, 2004; Karakitsios et al., 2004; Jenkins 2010; Graziano, 2013). In Cephalonia, along the Enos range (Fig. 2 log a), a stack of barren dolostone, showing in the highest part calcareous beds of Berriasian age, crops out. The sequence continues with well-bedded pelagic mudstone, containing dark chert nodules and the first thin

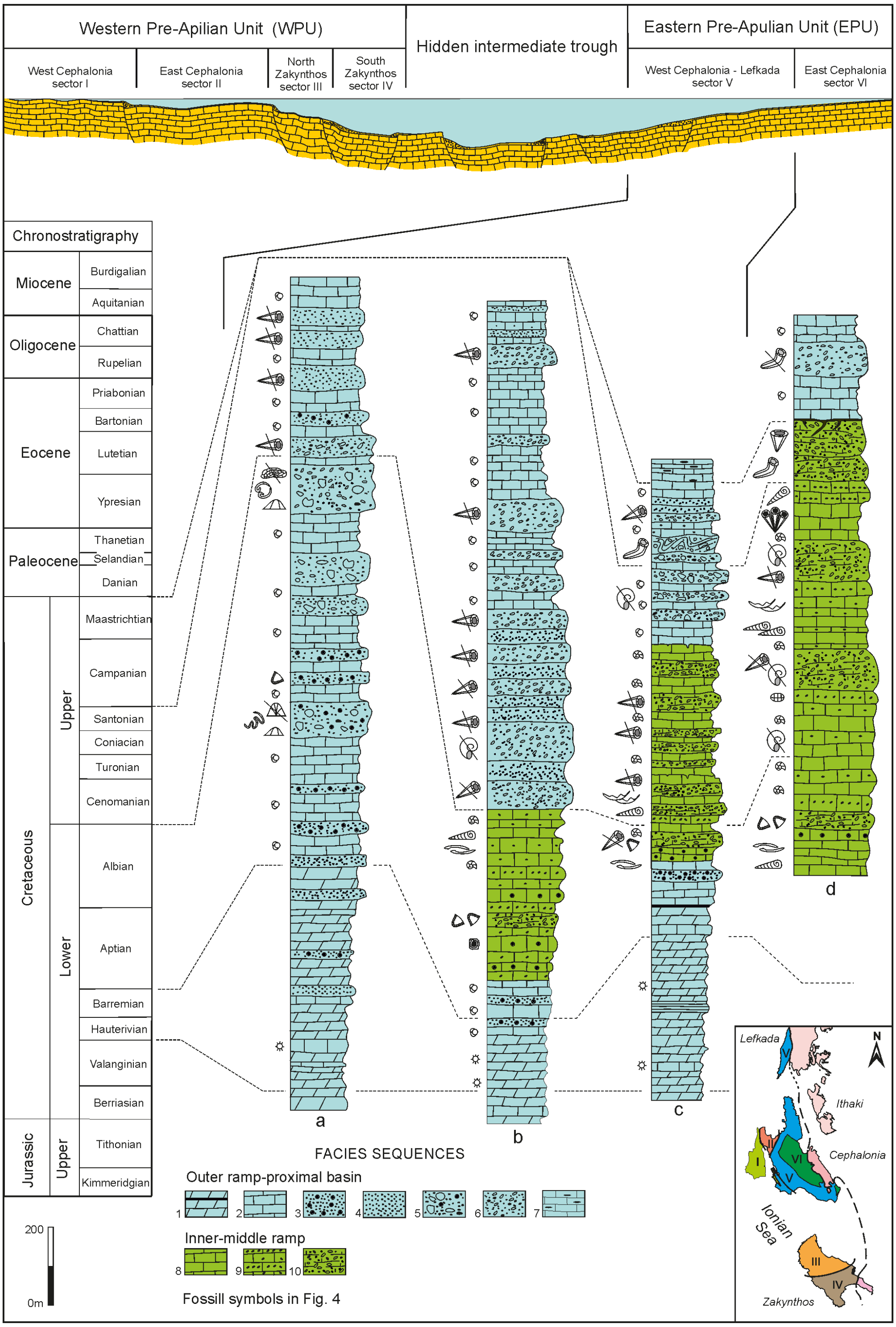


Fig. 2 - Synthesized stratigraphic logs of the sedimentary carbonate successions characterising the depositional framework of Eastern Pre-Apulian Unit (EPU) related to a schematic cross-section interpretative of the spatial relationship of depositional systems. West Pre-Apulian sector. a) Southern Enos outer ramp-proximal basin hemipelagic-pelagic sequence of allodapic limestone; b) Athani-Akr. Doukato (Lefkada) upward shoaling middle-outer ramp evolving to sinking ramp carbonate sequence; c) North Enos - Kalon upward shoaling middle-outer ramp evolving to sinking outer ramp sequence. East Pre-Apulian sector. d) Ag. Dynati-Gioupari inner-middle ramp sequence belatedly sinking. Facies sequence lithology. Outer ramp-proximal basin. 1) Dolostone with intercalations of dark marl and clayey marl; 2) Well-bedded pelagic lime mudstone with thin beds of ooidal and fine skeletal debris; 3) Gravity-driven ooidal packstone-grainstone; 4) Gravity-driven fine skeletal calcidebrites; 5) Gravity-driven conglomerate embedded in a matrix of coarse skeletal debris; 6) Gravity-driven densely packed rudist-bearing grainstone-rudstone; 7) Well-bedded marly mudstone with chert nodules. Inner-middle ramp. 8) Well-bedded peritidal foraminiferal mudstone; 9) Foraminiferal shallow subtidal skeletal wackestone-packstone; 10) Densely packed skeletal grainstone.

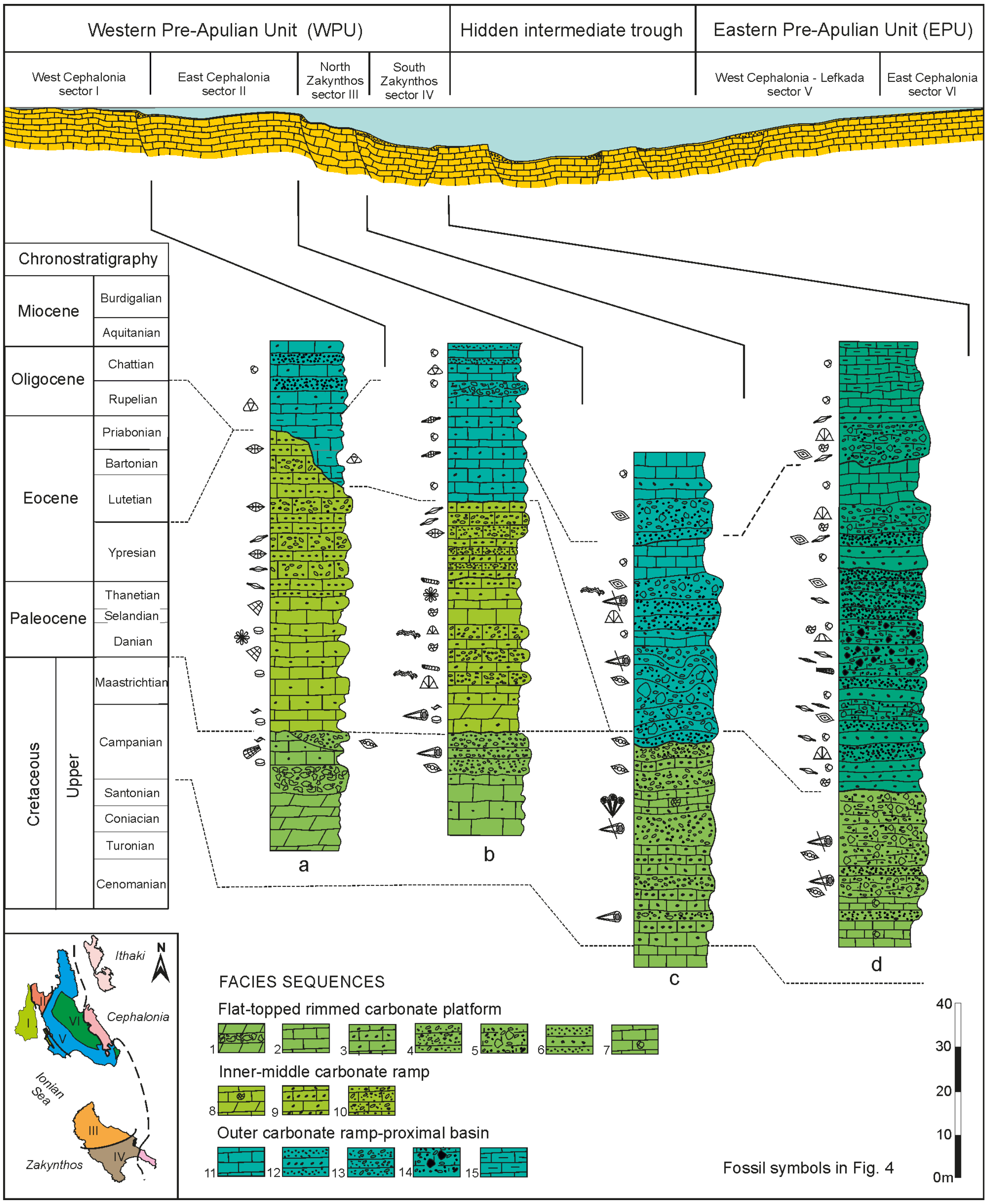


Fig. 3 - Synthesized composite stratigraphic logs of the sedimentary carbonate successions characterizing the depositional framework of Western Pre-Apulian Unit (WPU) related to a schematic cross-section interpretative of the spatial relationship of depositional systems. West Lixouri sector. a) Havdata-Akros Atheras sheltered rimmed shelf facies sequence evolving to inner-middle ramp incomplete facies sequence. East Lixouri sector. b) Atheras-Zola inner to outer rimmed shelf facies sequence evolving to outer ramp sequence. North Zakynthos sector. c) Korithi-Lankadakia inner to outer rimmed shelf facies sequence evolving to outer ramp incomplete sequence. South Zakynthos sector: d) Kiliomeno-Keri steep outer slope of rimmed shelf facies sequence evolving to deep-ramp proximal basin carbonate sequence (redrawn and modified from Accordi et al., 1998; 2014). Facies sequence lithology: Flat-topped carbonate platform. 1) Layered tidal flat dolostone with channelized breccias; 2) Layered shelf lagoon rudist-bearing mudstone-wackestone; 3) Layered shelf lagoon foraminiferal wackestone-packstone; 4) Shelf edge rudist-bearing skeletal grainstone-rudstone; 5) Outer slope gravity-driven densely packed conglomerate embedded in a skeletal detrital matrix; 6) Outer slope layered, gravity-driven, well packed skeletal packstone-grainstone. Inner-middle carbonate ramp. 7) Toe of slope pelagic Globotruncana-bearing mudstone; 8) Layered sheltered tidal flat dolostone-mudstone; 9) Layered peritidal-shallow subtidal foraminiferal wackestone-packstone; 10) Sandy shoal larger foraminiferal packstone-grainstone. Outer carbonate ramp-proximal basin. 11) Layered pelagic mudstone; 12) Layered wackestone-packstone with reworked larger foraminifera; 13) Layered gravity-driven larger foraminiferal skeletal packstone-grainstone; 14) Gravity-driven densely packed conglomerate embedded in a skeletal detrital matrix; 15) Open marine layered marl, clayey marl and marly mudstone with foraminiferal grainstone intercalations.

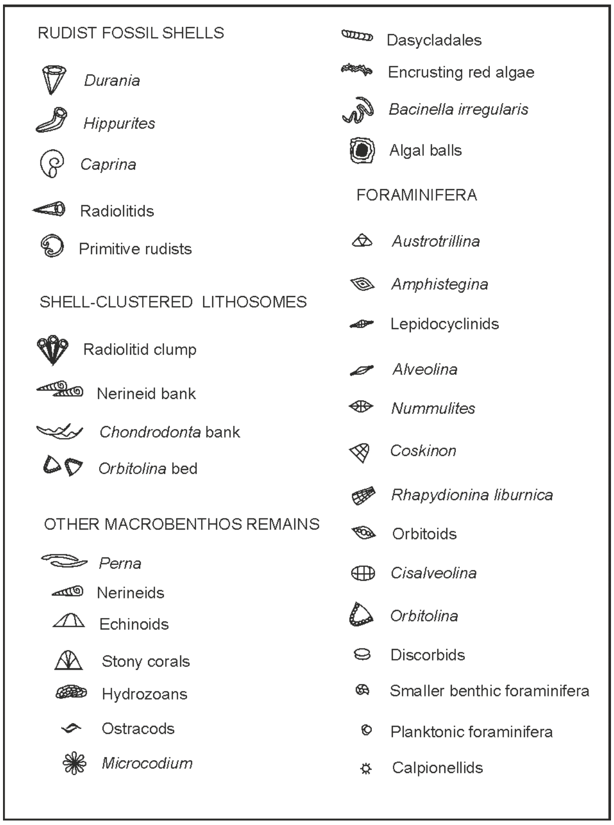


Fig. 4 - Legend of fossil symbols related to the facies of stratigraphic logs of Eastern Pre-Apulian Unit (EPU) and Western Pre-Apulian Unit (WPU).

intercalations of fine skeletal debris and small ooids (Fig. 5c). The same sedimentary trend is found in the north of the island, where strongly recrystallized dolostone largely crops out along the western side of the Oros Kalon. The late Aptian-Albian timespan is represented by a sequence of hemipelagic-pelagic limestone showing upwards a progressive increase in calcidebrite and calciturbidite layers, made up of shelf-derived skeletal remains and limestone lithoclasts. In places, as in the southern part of the Enos range, the sequence displays lens-shaped accumulations of chaotic breccia (Fig. 5d) containing coarse skeletal remains of open shallow marine biota, made up of gastropod, bivalve (primitive rudists and *Perna*), and chetetid hydrozoan fragments (Fig. 5 e,f,g). Local concentrations of exotic limestone boulders and pebble-sized lithoclasts are also present. In some outcrops, this lithic material is loose in a muddy matrix, testifying to a clear relationship with channelized high-density mass flow. Significant, in some well-sorted coarse-grained beds, is the presence of reworked abundant *Orbitolina* tests, whereas in some muddy layers radiolarians and sponge spicules occur, along with diverse assemblages of planktonic foraminifera (*Ticinella roberti*, *Biticinella breggensis*, *Pseudothalmanninella subticinensis*, *P. ticinensis*, *Praeglobotruncana stephani*) mostly indicating an Albian age.

The Cenomanian is scarcely documented by poorly preserved planktonic foraminifera due to an increase in the supply of calciclastic material mainly made of densely

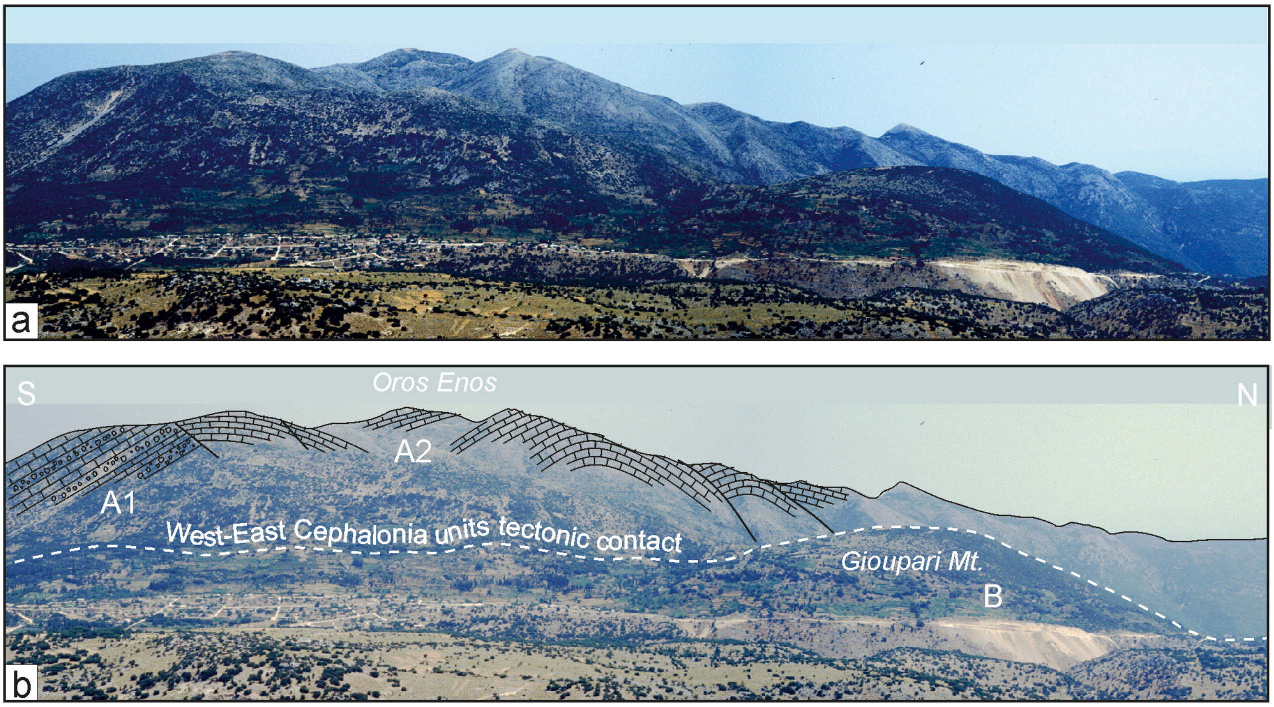
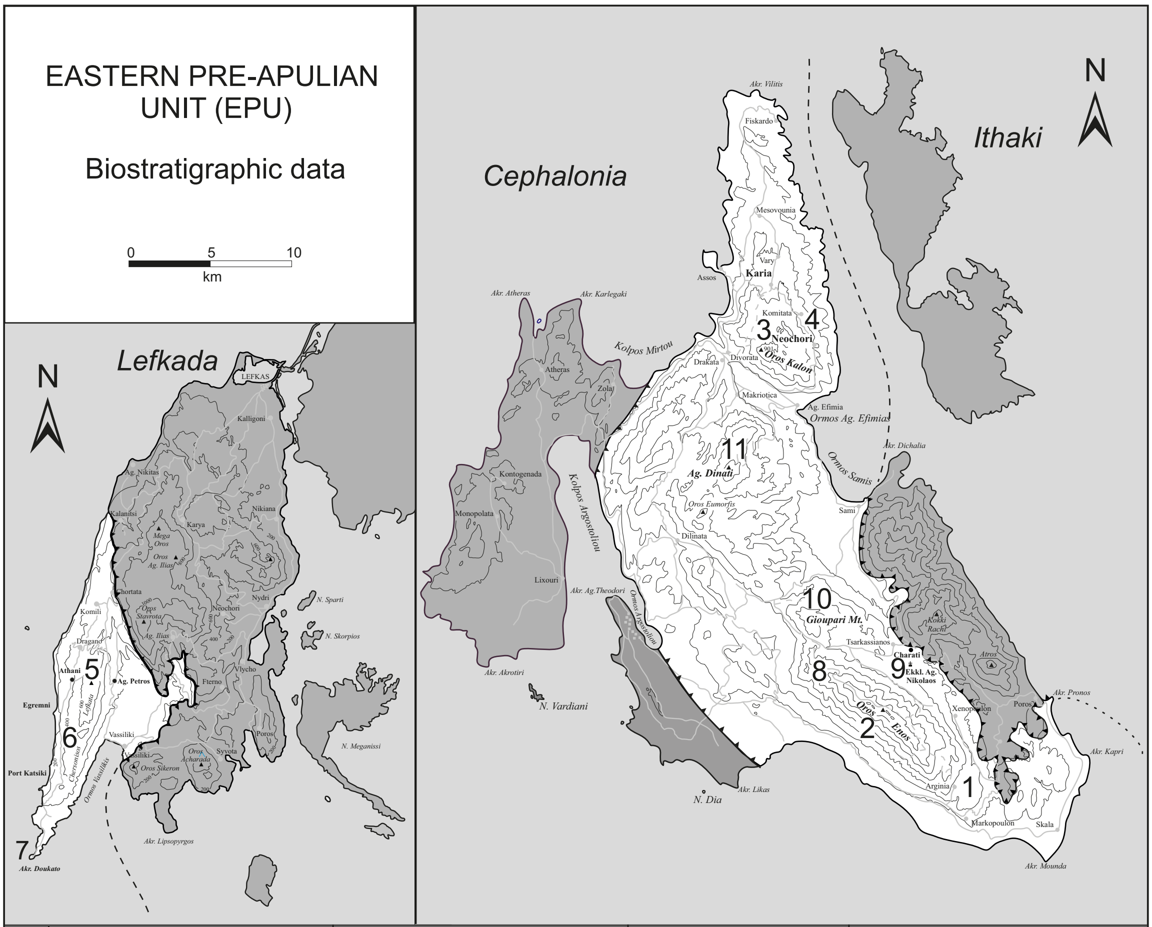


Fig. 5 - Eastern Pre-Apulian Unit (EPU). a) Panorama of the eastern side of the Enos Oros range; b) outline of the structural setting of the area showing in the background the lineament of carbonate outcrops of the East Cephalonia sector marked by the south-north transition from outer ramp pelagic deposit rich in calciturbidite and calcidebrite intercalations (A1) to outer-middle ramp carbonate sequence (A2). In the foreground, limited by faults, the outcrops of the inner-middle ramp carbonate rocks of the East Cephalonia sector (B).

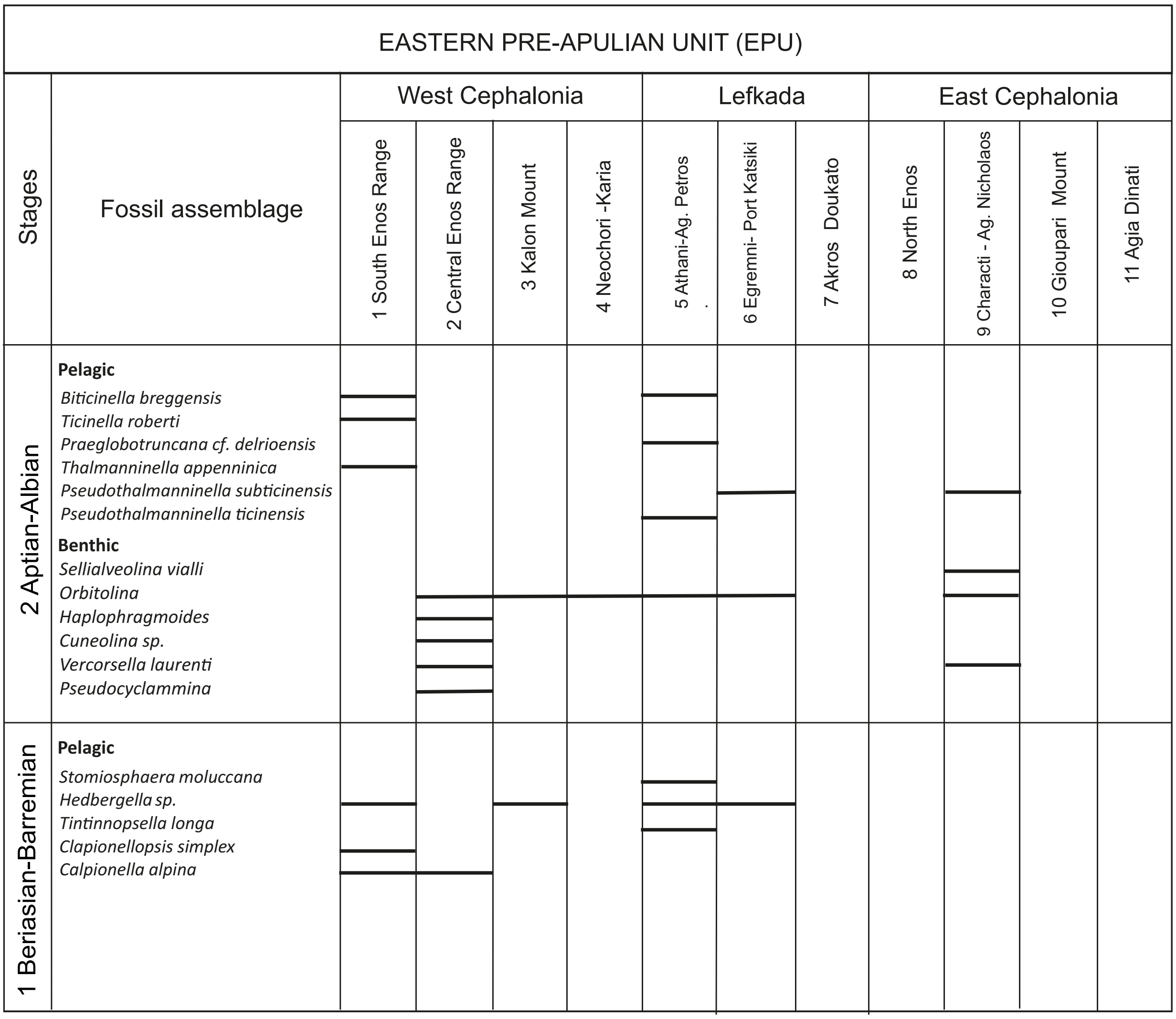


Stages	Fossil assemblage	West Cephalonia				Lefkada			East Cephalonia			
		1 South Enos Range	2 Central Enos Range	3 Kalon Mount	4 Neochori -Karia	5 Athani-Ag. Petros	6 Egremni- Port Katsiki	7 Akros Doukato	8 North Enos	9 Characti - Ag. Nicholaos	10 Gioupari Mount	11 Agia Dinati
5 Paleocene-early Miocene	**Pelagic** *Turborotalia cerroazulensis* *Turborotalia pomeroli* *Pseudoglobigerinella bolivariana* *Subbotina yeguaensis* *Orbulinoides bekmanni* *Morozovella aragonensis* *Morozovelloides cf. crassatus* *Acarinina bullbrooki* *Globanomalina pseudomenardii* *Morozovella angulata* *Morozovella velascoensis* *Globorotalia abundocamerata* *Igorina pusilla* *Globanomalina ehrenbergi* *Praemurica inconstans* *Subbotina triloculinoides* *Parasubbotina pseudobulloides* *Hantkenina*											

Tab. 1 - Significative chronostratigraphic data of microfossil assemblages related to evolutionary stages desumed from the analysis of some significative field sections of East Pre-Apulian Unit (EPU). In the table are listed only the indigenous microfossils. The absence of the benthic biota in stages 1 and 5 clarifies the evolution of the carbonate ramp, characterized at the bottom and at the top by pelagic facies sequences.

EASTERN PRE-APULIAN UNIT (EPU)												
		West Cephalonia				Lefkada			East Cephalonia			
Stages	Fossil assemblage	1 South Enos Range	2 Central Enos Range	3 Kalon Mount	4 Neochori -Karia	5 Athani-Ag. Petros	6 Egremni- Port Katsiki	7 Akros Doukato	8 North Enos	9 Characti - Ag. Nicholaos	10 Gioupari Mount	11 Agia Dinati
4 Late Turonian-Maastrichtian	**Pelagic**											
	Contusotruncana contusa							—		—		
	Globotruncanita cf. conica				—			—				
	Trinitella scotti					—		—				
	Gansserina gansseri					—						
	Globotruncanella pschadae				—			—				
	Kuglerina rotundata					—						
	Globotruncanita stuarti			—	—	—	—	—		—		
	Globotruncana falsostuarti					—						
	Globotruncana ventricosa			—				—				
	Globotruncanita stuartiformis					—		—				
	Rugoglobigerina rugosa			—		—		—				
	Globotruncana tricarinata					—						
	Globotruncana arca		—			—	—	—		—		
	Globotruncana bulloides					—	—	—				
	Contusotruncana fornicata		—		—	—	—	—		—		
	Globotruncana lapparenti		—		—	—						
	Globotruncana angusticarinata					—				—		
	Marginotruncana pseudolinneiana						—					
	Marginotruncana coronata		—	—	—	—	—	—				
	Marginotruncana renzi					—						
	Dicarinella imbricata			—						—		
	Helvetoglobotruncana helvetica			—		—						
	Stomiosphaera sphaerica									—		
	Benthic											
	Sirtina orbitoidiformis									—		
	Sivasella monolateralis						—					
	Scandonea samnitica									—		
	Scandonea mediterranea			—								
	Dicyclina schlumbergeri				—	—					—	
	Orbitoides cf. media						—					
	Siderolites calcitrapoides						—					
	Raadshoovenia sp.			—			—					
3 Cenomanian-early Turonian	**Pelagic**											
	Sigalitruncana sigali			—								
	Marginotruncana schneegansi					—						
	Dicarinella imbricata					—						
	Helvetoglobotruncana helvetica			—		—	—					
	Whiteinella sp.			—								
	Preglobotruncana turbinata			—								
	Praeglobotruncana stephani					—						
	Thalmanninella greenhornensis					—						
	Thalmanninella reicheli				—							
	Thalmanninella appenninica			—	—	—						
	Hedbergella washitensis					—						
	Praeglobotruncana cf. delrioensis			—								
	Benthic											
	Chrysalidinagradata						—					
	Cisalveolinafallax					—	—					
	Cisalveolinafraasi									—		
	Cuneolina parva		—		—		—			—	—	—
	Biconcava bentori				—							
	Nummoloculina heimi		—			—					—	—
	Archaealveolina reicheli					—						
	Nezzazatasimplex		—				—				—	
	Murgeina apula					—						
	Aeolisaccus		—							—		—
	Pseudorhapydioninadubia				—	—	—					
	Rotorbinella									—		
	Stensioina									—		

Tab. 1 - ...Continued



Tab. 1 - ...Continued

packed rudist debris, including *Caprina* remains. This abundance of shelf-derived carbonate probably coincides with a relative sea-level fall accompanied by a great production and dispersion of skeletal debris of flourishing rudist communities. Starting from the late Cenomanian, the sedimentary trend shows a rapid deepening of the depositional interface with a restoration of deep ramp sedimentation made of globotruncanid-bearing pelagic mudstone with interbedded, shelf-derived, well-sorted carbonate skeletal debris layers. This deepening trend continues during the Paleocene-Oligocene with a gradual decrease of calciclastic supply inside a sequence of globorotaliid-bearing pelagic mudstone.

4.1.1.2. Middle-Outer ramp facies sequence

Both in Lefkada and Cephalonia (Fig. 2, logs b and c respectively), the sedimentation in transitional areas from shallow to deep water environments is very variable from place to place because of frequent changes in the ratio between autochthonous and gravity-driven deposits. A shoaling-upward trend is recorded in the depositional succession until the early Cenomanian when a relative sea-level rise caused the progressive demise of shallow water sedimentation. Already during the late Aptian, peritidal and shallow-subtidal facies related to the presence of a gently dipping or nearly flat bottom geometry were established. In some outcrops, these facies are repeatedly interlayered with hemipelagic lime mudstone and fine grainstone made up of shallow water-origin skeletal debris and small ooidal grains (Fig. 7 a,b). The latter are also found scattered within muddy layers or concentrated in densely packed beds.

Among the facies rooted in shallow ramp environments, mudstones and wackestones prevail, rich in dasycladalean algae and benthic foraminiferal assemblages. They are normally interbedded with skeletal and ooidal packstone-grainstone layers and locally associated with banks crammed with nerineid (*Aptyxiella libanotica*, *Neoptyxis praefleuriaui*, *Diozoptyxis coquandi*) and ostreid shells.

The maximum thickness (about 1100 m) crops out in Cephalonia in the central part of the Enos range, where the top of the Albian sequence is marked by *Orbitolina*

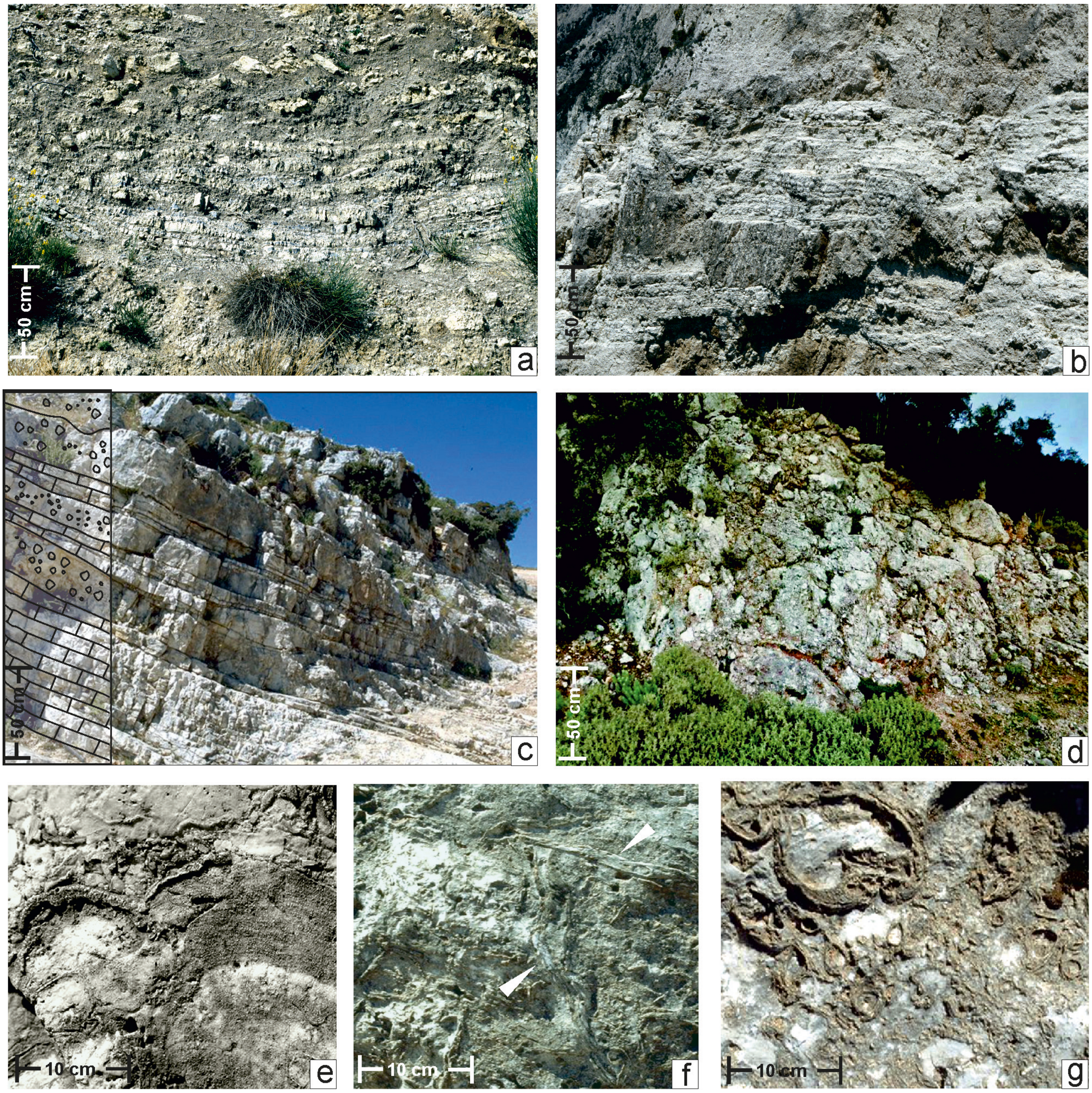


Fig. 6 - West sector of the Eastern Pre-Apulian Unit (EPU). Field photos of some outer ramp sedimentary features cropping out in south Cephalonia and Lefkada. a) Rhythmic sequence of marly, marly limestone, and dark clay marl, BerriasianHauterivian- Barremian, Athani seacliff; b) Thin layered dolostone characterizing the lower part of Athani seacliff, Berriasian-Barremian; c) Layered pelagic mudstone interbedded with skeletal and ooidal-bearing calcidebrite layers, graphically highlighted, Aptian-Albian, Arginia road; d) Chaotic polymictic breccia made of lithoclasts and skeletal debris embedded in shelf-derived material channelized inside the pelagic sequence, Arginia road; e), f), g) Details of some fossil remains from the previous conglomerate episode; e) hydrozoans; f) Perna shells (arrows); g) primitive rudist.

packstone and grainstone layers also containing other benthic foraminifera and *Bacinella irregularis*.

The transition to the Cenomanian is characterized by the spread of rudist-bearing facies. Radiolitids form densely packed shell accumulations (Fig. 7c), in rare cases still in growth position (Fig. 7d). These bivalve shells occur both in mudstone-wackestone layers and more frequently biodetrital deposits. Skeletal debris forms both thick intercalations within the shallow water muddy facies sequence, and well-packed, deeper-water, calcidebrite high-density flow deposits. In shallow water areas, coarse skeletal material forms densely packed thick layers of rudist debris (Fig. 7 e,f) interbedded with foraminiferal mudstone and wackestone layers characterized by a diverse benthic foraminiferal assemblage (*Cisalveolina fraasi, Pseudorhapydionina dubia, Pseudolituonella reicheli*). Locally, thick layers crowded with nerineid shells (Fig. 8a) (*Plesioptygmatis nobilis* and *P. schiosensis*), often

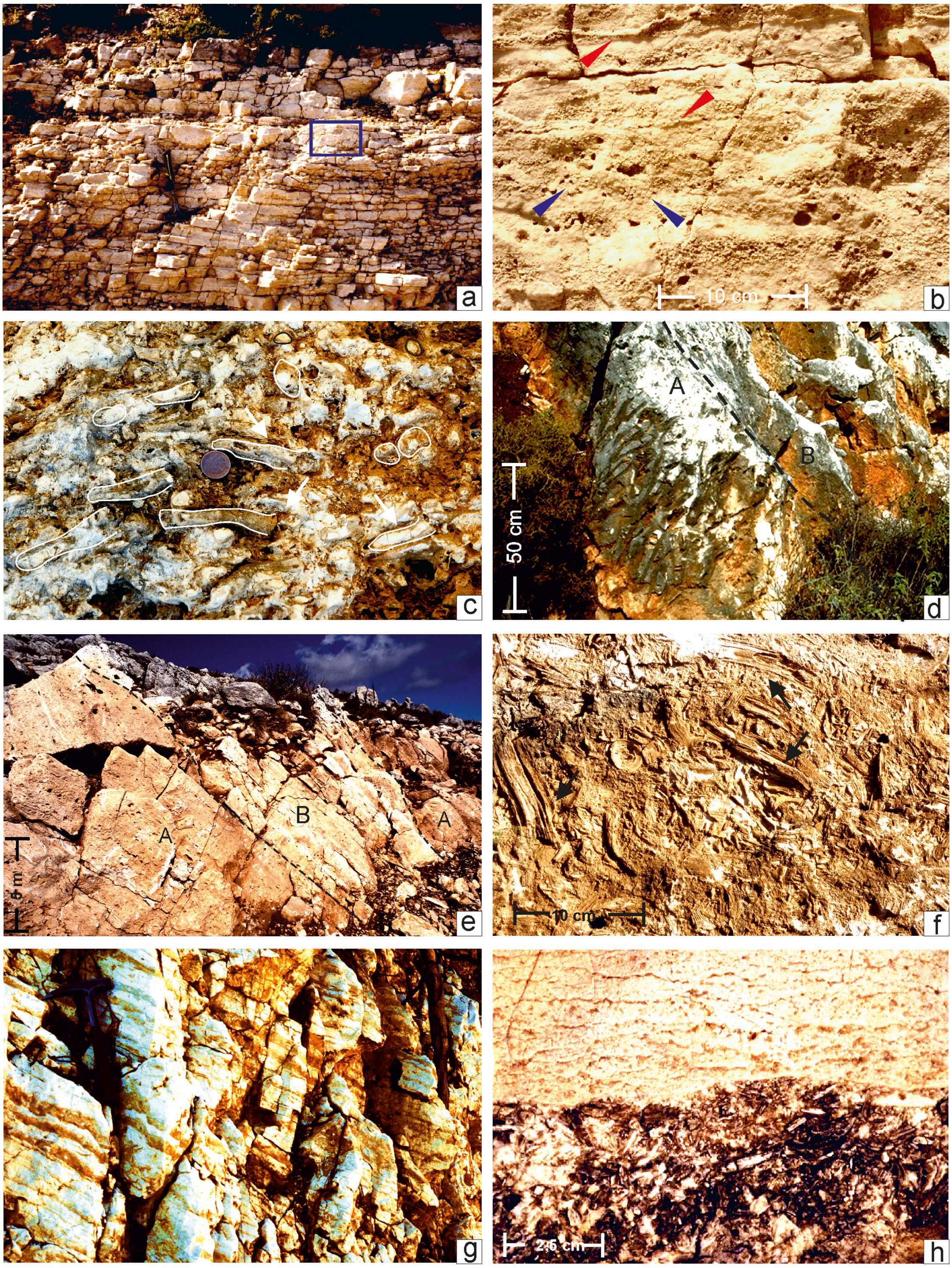


Fig. 7 - West sector of the Eastern Pre-Apulian Unit (EPU). Field photos of the middle ramp carbonate sedimentary facies cropping out in Cephalonia. a) Well-bedded granular limestone, Aptian-Albian, Enos Oros; b) Detail of the previous outcrop (blue frame) showing a packstone rich in ooids (blue arrows) and with a fenestral fabric (red arrows) attributable to a very shallow open marine bottom with medium-low water energy; c) Close-up view of a densely packed post-mortem accumulation of Radiolitid shells (marked by the white line) forming local mounds, Cenomanian, Neochori-Karya road; d) Thick muddy layer showing a radiolitid clump with shells still in growth position (A) covered by a shallow water fine skeletal grainstone (B), Cenomanian, Neochori-Karya road; e) Facies sequence of thick skeletal layers indicating open marine shoals richly colonized by radiolitid shells (A) interbedded with quiet muddy lagoon deposits (B), Cenomanian, Neochori-Karia road; f) Close up view of the typical texture of densely packed skeletal debris intercalations mainly made of rudist fragments; g) Close-up view of a rhythmic sequence of pelagic mudstone beds alternating with thin beds of well-sorted skeletal grainstone related to Turonian incipient drowning of the middle ramp shallow water areas, Turonian, Enos Oros road h) Detail of an intertidal deposit texture showing the sharp transition from a probable unsorted skeletal storm deposit (A) to a quiet muddy sediment characterized by a planar fenestral fabric (B).

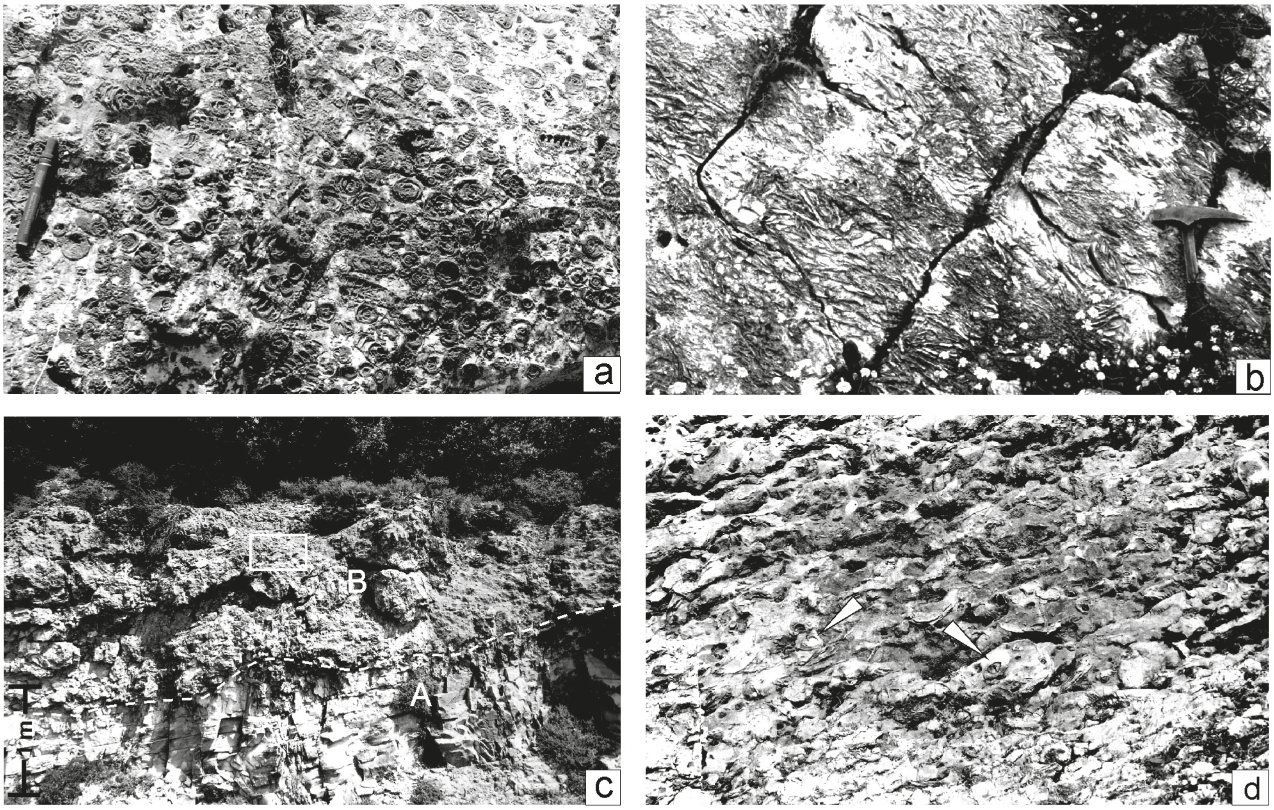


Fig. 8 - East sector of the Eastern Pre-Apulian Unit (EPU). Field photos of shell-dominated inner ramp sedimentary facies cropping out in Cephalonia. a) Close-up view of a Cenomanian thick layer crowded of *Plesioptygmatis nobilis* indicating an open marine lagoon bottom, Gioupari road; b) Close-up view of a Cenomanian tick bank of piled up *Chondrodonta joannae* shells typical of an open marine lagoon bottom, Sami-Enos pass road; c) General view of a road cut showing well-bedded Cenomanian lagoonal mudstone layers (A) topped by a chaotic muddy sediment accumulation, rich in radiolitid shells, due to gravity mass flow (B), Sami-Enos Pass road; d) Detail of the previous outcrop (white frame) showing a typical floatstone texture made of abundant whole radiolitid shells (white arrows) and other bivalve remains scattered in fine lime sediment.

associated with ostreid shells, and banks with radiolitids in growth position confirm the remarkable diversification of the shallow water depositional environment during this time. Intercalations of coarse-grained skeletal material, frequently exceeding the rudstone size, showing highly variable sorting and rounding, and often containing abundant radiolitid remains and scattered *Caprina* and *Ichtyosarcolites* shells, are also found.

At the end of the Cenomanian or during the early Turonian, the appearance of thin intercalations of *Globotruncana*-bearing lime mudstone together with skeletal debris layers is indicative of incipient flooding of the shallow water areas of the ramp that precedes their complete drowning (Fig. 7g).

In Lefkada, the stratigraphic record shows clear similarities with the previous one, with a thinner Cenomanian facies sequence, linked to the presence of peritidal and shallow-subtidal environments (Fig. 7h) than in Cephalonia (Fig. 2b). Also in this case, the depositional sequence shows a clear shoaling-upward trend with at the bottom small ooidal mudstones, and skeletal *Orbitolina* wackestone-grainstone layers, still of late Albian age, followed by thick layers of coarse skeletal grainstone and rudstone with sporadic intercalations of thin pelagic lime mudstone containing *Rotalipora*. The abundant skeletal debris, mostly made of poorly sorted radiolitid shell fragments, forms thick grain-supported deposits, locally interbedded with mudstone and wackestone layers characterized by remains of *Caprina*, acteonid, and nerineid shells. A well-diversified benthic foraminiferal assemblage (*Nezzazata*, *Aeolisaccus*, *Cuneolina parva, Cisalveolina fraasi,* and miliolids) is also present, especially in the mud-supported sediments.

At the end of the Cenomanian, the phase of maximum flooding of the ramp is documented by the increase inside the shallow water facies sequence of *Globotruncana*-bearing hemipelagic mudstone and sand-to-gravel-size calciclasitc layers often containing carbonate boulders.

The Turonian-Maastrichtian record is documented by a diverse globotruncanid assemblage (*Marginotruncana coronata, M. renzi, Globotruncana lapparenti, G. tricarinata, Globotruncanita stuarti*, *Contusotruncana fornicata*) and rudist shell remains (*Durania apula*, *Hippurites heritschi*, *H. colliciatus*, *Sabinia*, and *Sauvagesia*), often associated with reworked benthic foraminifera.

During the late Campanian-Maastrichtian interval, high tectonic instability generates various types of gravity flows with a conspicuous accumulation of detrital carbonate on the outer ramp. For instance, at Akros Doukato conspicuous chaotically arranged deposits made of shelf-derived bioclasts and scattered large limestone blocks (Fig. 9) are characterized by a well-diversified rudist assemblage with *Hippurites colliciatus*, *H. heritschi, H. lapeirousei, Rajka spinosa* (Fig. 9d)*, Pseudopolyconites ovalis apuliensis*, *Radiolitella maestrichtiana* (Fig. 9e) *Lapeirouseia*, *Sabinia*, *Joufia reticulata*, and *Mitrocaprina bulgarica*. Similar accumulations of carbonate debris are located in the easternmost sector of Cephalonia where they cover the Upper Cretaceous inner ramp facies sequence (Fig. 10). Normally, this sedimentary deposit precedes the Paleocene-Oligocene stack of planktonic foraminifera-bearing pelagic mudstone, containing decreasing calciclastic intercalations upwards with reworked *Discocyclina, Nummulites*, and *Alveolina* tests.

4.1.1.3. Inner-middle ramp facies sequence

The aggradational Albian-lower Campanian sedimentary succession, typical of sheltered peritidal and shallow-subtidal lagoon environments, confined in the easternmost sector of Cephalonia (Fig. 2, log d), is mainly represented by mud-supported inter-supratidal tidal flat facies (Fig. 11), alternating with shallow subtidal granular deposits. The whole sedimentary sequence, about 900 m thick, shows at the base well-bedded dolostone and lime mudstone with subordinate intercalations of foraminiferal packstones and grainstones characterized by a peloidal and intraclast granular fraction.

Open lagoon bottom conditions with good water exchange are evidenced by the appearance of thick layers crowded with *Chondrodonta joannae* (Fig. 8b) or made of densely packed radiolitid shells often related to a "post mortem" channel-fill (Fig. 8 c,d). Episodes linked to higher water energy are highlighted, especially during Cenomanian, by the appearance of skeletal grainstone and rudstone layers containing sporadic *Caprina* shell remains, often associated with a well-diversified benthic foraminiferal assemblage (*Orbitolina*, *Sellialveolina viallii*, *Cuneolina parva, Nummoloculina heimi*, *Cisalveolina fraasi, Pseudolituonella reicheli*). Typical of this period is the presence, also in the inner ramp areas, of muddy facies rich in nerineid shells (Fig. 8a) associated with radiolitids, ostreids or small shells of gastropods and radiolitids (Fig. 11 a,b).

The succession continues upward until possibly the early Campanian with the prevalence of foraminiferal mud-supported facies. Locally sheltered intertidal conditions are evidenced by laminated mudstone with fenestral fabric (Fig. 11c), or fine-grained wackestone characterized not only by *Cuneolina, Aeolisaccus*, and miliolid assemblages but also by columnar stromatolites (Fig. 11d). This lagoon sequence is normally topped by muddy layers with *Distefanella douvillei,* and *Biradiolites martelli,* followed by sand and gravel-sized skeletal deposits forming a chaotically arranged accumulation, which often contain whole rudist shells (*Durania apula, Hippurites heritschi, H. colliciatus*) and at places hermatypic coral fragments.

After a hiatus of uncertain amplitude, the Cenozoic stratigraphic record is represented by planktonic foraminifera-bearing pelagic lime mudstone, initially characterized by the presence of skeletal debris intercalations still containing shelf-derived biogenic material such as larger foraminifera and bivalve fragments associated with limestone clasts. Upwardly, these grain-supported deposits gradually disappear, while chert beds and nodules become consistent.

4.1.2. WPU - Western Cephalonia and Zakynthos sedimentary records

The crustal sector which includes the Lixouri Peninsula and the Zakynthos island is characterized by an Upper Cretaceous stratigraphic record related to a depositional system of a flat-topped, rimmed shelf, assuming a ramp setting during the Cenozoic. Sedimentation keeps pace with relative sea-level variations at least until the late Campanian, when synsedimentary differential vertical tectonics brings clear changes in the facies pattern with the appearance of marginal facies also in the innermost areas of the shelf. In the Lixouri Peninsula, at the beginning of the Paleocene, a change in the depositional model appears with the setup of a distally steepened carbonate ramp geometry. In the stratigraphic record, this change is marked by an initial hiatus comprising at least the whole Danian, followed by progressive areal diversification of the depositional system (Fig. 3 logs a,b).

Conversely, in Zakynthos, above the Upper Cretaceous inner shelf layers, a more extensive stratigraphic gap occurs, including the entire Paleocene-lower Eocene interval, followed by the onset of a persistent outer ramp environment gravity flow-fed (Fig. 3 logs c,d).

4.1.2.1. Flat-topped rimmed shelf facies sequence

In the Lixouri Peninsula, the Upper Cretaceous facies sequence shows notable differences among the outcrop areas. West of Atheras thrust, the lower part of the sequence is made of layered recrystallized dolostone (Fig. 3, log a) forming the cliff of the west coast (Fig. 12a). A sedimentary environment of a sheltered tidal flat is highlighted by a laminated dolomitic facies sequence (Fig. 12b) with episodes of channelized breccia containing algal chips derived from extensive contemporary rock dismantling (Accordi et al., 1998). The sparse low-diversity assemblages mostly consist of poorly preserved and leached tests of benthic foraminifera and ostracods. Rarely preserved calcareous layers containing *Accordiella*, *Rotalispira scarsellai*, *Stensioeina surrentina* and *Scandonea samnitica* suggest a Coniacian-Santonian age.

In the northwestern part of the peninsula, above the dolostone, layered lime mudstones and wackestones with *Rhapydionina liburnica* and *Fleuryana adriatica*, ascribable to the Maastrichtian (De Castro et al., 1994) crop out. Locally, the *Rhapydionina* layers are topped by

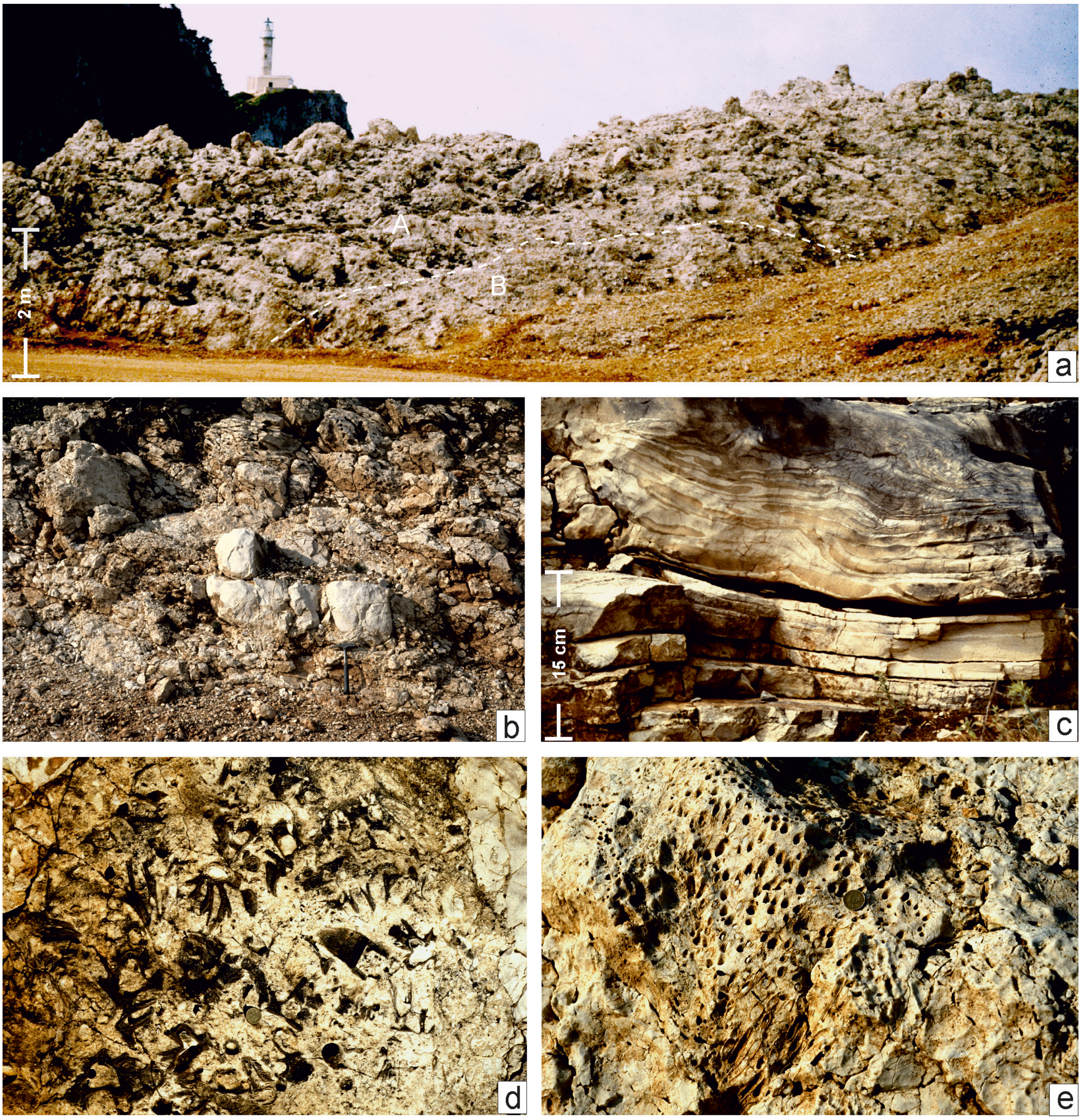


Fig. 9 - West sector of the Eastern Pre-Apulian Unit (EPU). Field photos of Late Campanian-Maastrichtian outer ramp sedimentary facies cropping out in Lefkada. a) Panorama of a gravity mass flow accumulation made of a mixture of skeletal debris, boulders, and blocks of limestone embedded in a finer matrix made of pelagic lime mud and calcisiltite (A) resting on fine slumped layers (B), Akr. Doukato; b) Closer view of the previous mélange (A) showing large lime mudstone blocks embedded in a chaotic accumulation (A); c) Close-up view of the base of the mélange (B) showing layers with both thin parallel and wavy lamination resulting from slump working; d) *Rajka spinosa* shell remains; e) *Radiolitella maastrichtiana* clump from some limestone boulders embedded into the mélange.

a few meters of skeletal grainstone made of a granular fraction containing *Orbitoides cf. apiculatus* tests scattered into debris made of rudist, echinoid, and coral remains.

East of Atheras thrust the facies sequence differs sharply from the previous one; in this area, most of the exposed rock is represented by Santonian-lower Campanian well-bedded mudstones and wackestones (Fig. 3 log b, Fig. 13a) characterized by *Dicyclina schlumbergeri*, *Thaumatoporella*, and radiolitid shell remains (Fig. 13b). These inner shelf deposits are topped by upper Campanian-Maastrichtian coarse packstone, and grainstone layers rich in remains of an open marine biota made of a foraminiferal assemblage (*Hellenocyclina, Lepidorbitoides*, *Orbitoides*, *Pseudomphalocyclus*, *Praesiderolites*, *Siderolites*, *Simplorbites*, *Goupillaudina*, *Omphalocyclus*, *Pseudocuvillierina*) and rudists (*Durania arnaudi*, *Rajka spinosa*, *Lapeirousia*, *Plagioptychus*, and *Sabinia*) (Fig. 13c). The maximum deepening of sedimentary interface

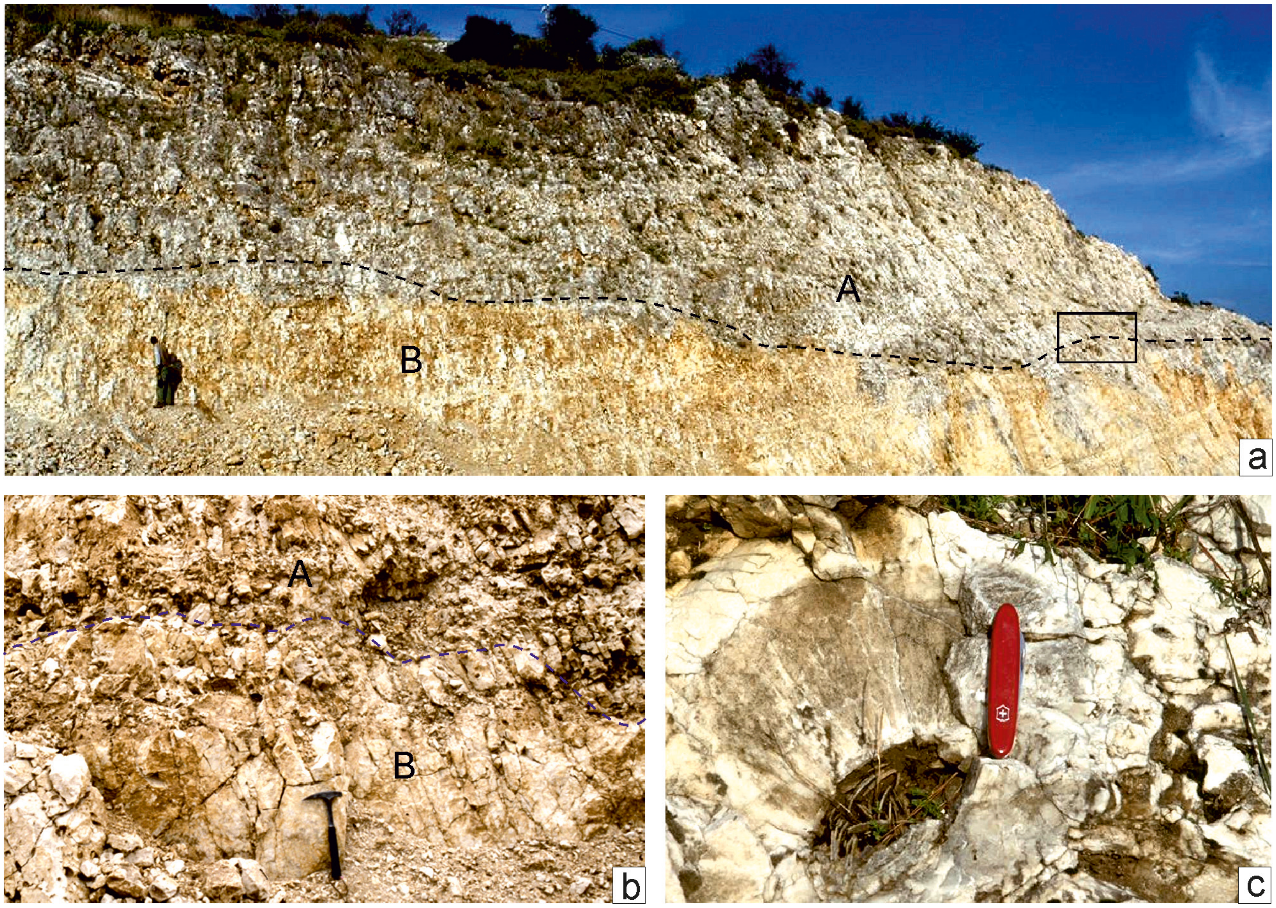


Fig. 10 - East sector of the Eastern Pre-Apulian Unit (EPU). Field photos of the Upper Campanian-Maastrichtian middle-outer ramp sedimentary facies cropping out in Cephalonia. a) General view of a road cut wall showing a big chaotic calciclastic debris accumulation related to a gravity mass flow (A) on the top of the peritidal facies sequence (B), Sami-Poros road; b) Close-up view of the previous outcrop (frame) showing the irregular erosional contact separating the chaotic accumulation of calciclastic deposit with scattered large rudist shells (A) from the well-sorted basal sandy deposit (B); c) Detail of a specimen of *Durania apula*, very frequent in the calciclastic debris accumulation (A).

probably was reached at the end of Maastrichtian, when the deposition of densely packed skeletal grainstones and rudstones mainly made of rudist debris took place.

Also in the northern sector of Zakynthos, outcrops of an Upper Cretaceous muddy facies sequence rich in radiolitid shells (Fig. 14a), rarely still in growth position (Fig. 14b), document quiet shallow water lagoon environments (Fig. 3 log c), whereas laminated dolomitic or barren lime mudstone layers are related to sheltered intertidal bottoms. As in the Lixouri Peninsula, in this part of the island the Maastrichtian is marked by a clear facies change due to the appearance of coarse skeletal grainstone layers mainly made of rudist debris, also containing orbitoids and hydrozoan remains (Fig. 14c). In some outcrops, the presence of layers with *Biradiolites angulosissimus* and *Rajka spinosa*, assumes a chronostratigraphic significance, as in other cases packstones with *Hippurites socialis* clumps (Fig. 14b). On the contrary, in the southern part of Zakynthos (Fig. 3 log d), the Turonian-lower Campanian is mainly identified by the presence of allodapic skeletal calcidebrites episodes, interbedded with globotruncanid-bearing (*Contusotruncana fornicata* and *Globotruncana linneiana*) microbioclastic mudstone layers.

4.1.2.2. Outer ramp-proximal basin facies sequence

In the Zakynthos island, the Cenozoic part of the stratigraphic record is represented by an incomplete succession of pelagic mudstone containing several calciclastic episodes related to gravity flows. These are often represented by chaotically arranged conglomerate deposits, which contain carbonate lithoclasts, coming from the dismantling of neritic and pelagic rocks incorporated in a skeletal matrix (Fig. 15).

In the northern part of the island (Fig 3 log c), time-transgressive Lutetian-Priabonian conglomerate episodes contain lithoclasts mainly coming from the underlying Campanian-Maastrichtian shelf carbonate layers. Upwardly, the sequence continues with repeated conglomerate episodes, among which the most substantial, Rupelian-Aquitanian in age, often rests on Lutetian-Priabonian pelagic mudstone layers. Peculiar in these conglomerates is the presence of the Rupelian lithoclasts coming from the erosion of *Operculina* and

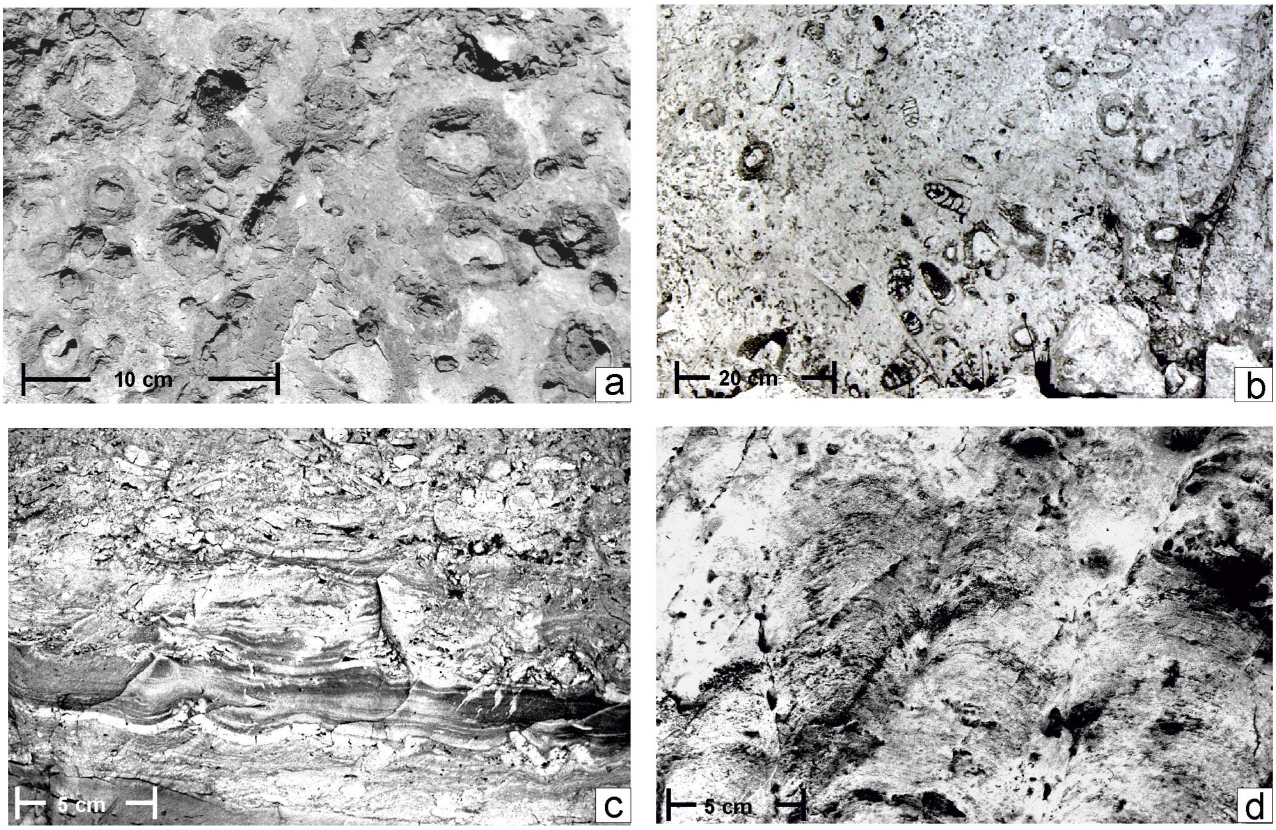


Fig. 11 - East sector of the Eastern Pre-Apulian Unit (EPU). Field close-up photos of sheltered inner ramp sedimentary facies cropping out in Cephalonia. a) Detail of isoriented radiolitid shells embedded in Cenomanian muddy sediment of quiet lagoon, Sami-Enos pass road b) Typical Cenomanian deposit of quiet shallow subtidal lagoon characterized by small radiolitid and gastropod assemblage, Sami-Enos pass road; c) Mud flat deposit showing typical texture related to evaporitic pumping, Gioupari road; d) Columnar stromatolite related to an Upper Cretaceous quiet lime muddy lagoon environment, Gioupari road.

Amphistegina shallow water sandy deposits. Likewise in some conglomerate accumulations, the presence of pebbles with reworked *Amphistegina* and *Heterillina* tests, associated with planktonic foraminifera, suggests an erosion of rocks originally sedimented in deeper water environments.

Moving from north to south of the island, the stratigraphic record shows changes in the age and composition of conglomerate episodes. In some areas, the Cretaceous limestone is directly topped by micro-bioclastic mudstone related to tails of low-density calciturbidite, which in turn is covered by middle Eocene *Hantkenina* well-bedded pelagites.

In the southernmost part of the island (Fig. 3 log d), hiatuses and abrupt changes in thickness accompany conglomerate episodes containing mainly upper Eocene and Oligocene lithoclasts. The whole stratigraphic record includes Lutetian-Rupelian pelagic mudstone with intercalations of fine detrital carbonate characterized by *Nummulites meneghini* layers, followed by Chattian-Burdigalian micro-bioclastic mudstone. Still, in some outcrops, this upper part of the sequence directly covers Lutetian-Priabonian conglomerates linked to submarine channelized deposits (Fig. 16).

In the Lixouri Peninsula, a facies sequence about 10 m thick, partially comparable to that of Zakynthos, crops out only in a limited area east of Zola village, partially hidden by Miocene and Plio-Pleistocene sedimentary cover. This facies shows Upper Cretaceous *Thaumatoporella* mud-supported layers directly covered by Bartonian *Nummulites* and *Discocyclina* wackestone-packstone layers containing planktonic foraminifera, with intercalations of coarse grainstone rich in imperforate foraminifera. In this case, the lack of Paleocene and Priabonian-Oligocene deposits resembles the sedimentary trend of the Zakynthos island (Accordi et al., 2014).

4.1.2.3. Middle-outer ramp facies sequence

The Cenozoic stratigraphic record of the Lixouri Peninsula related to the region east of the Atheras thrust (Fig. 3 log b) shows, above the Cretaceous inner shelf limestone, Danian?-Thanetian muddy layers still related to typical sheltered lagoon environments. These are followed upsection by wackestone and packstone showing a progressive enrichment in coral, hydrozoan, and corallinacean algae (*Polystrata alba*) remains, associated with a diverse benthic foraminiferal assemblage (*Stomatorbina*, *Globoflarina*, *Glomalveolina*, *Miscellanea*,

Fig. 12 - West sector of the Western Pre-Apulian Unit (WPU). Field photos of the sedimentary sequences cropping out in Lixouri peninsula. a) General view of the well-bedded dolomitic succession forming the steep seacliff of the southwestern coastline; b) Close up photo of thin layered Upper Cretaceous dolostone (A), widely brecciated by tectonics (B), cropping out at the base of the Thanetian-Lower Ypresian peritidal carbonate facies, Moni Iperagias Theotokou Kipourion road; c) General view of Thanetian middle ramp facies sequence graphically highlighted, characterized by the morphological prominence of an *Alveolina-Nummulite*s bank (B), overhanging the *Coskinon* layers (A), Havdata road; d) Close up view of the sharp facies change between well-bedded Thanetian *Coskinon* peritidal wackestone-packstone facies (A) and Lower Ypresian chaotically arranged sandy shoal packstone-grainstone rich in *Alveolina* and *Nummulites* tests (B) exposed in a quarry near Havdata; e) Sedimentary sequence showing at the bottom white calcarenite with nodular marl intercalations (A), followed by yellowish to red clayey marl (B), and skeletal calcarenite rich in *Austrotrillina asmariensis* tests (C) Chattian-Aquitanian, Havdata surroundings; f) Detail of the previous outcrop (frame) showing the sharp transition between the red clayey marl bed (B) and the *Austrotrillina asmariensis* calcarenite (C).

Soriella, and *Dictyoconus*). Particularly, the presence of *Globoflarina sphaeroidea* and *Glomalveolina primaeva* respectively assumes a remarkable chronostratigraphic value, indicating the late Selandian and early Thanetian.

During the Thanetian-early Ypresian time, a shift of the sedimentation towards more open marine environments is highlighted by the development of a diversified facies pattern made of fine skeletal wackestone and packstone

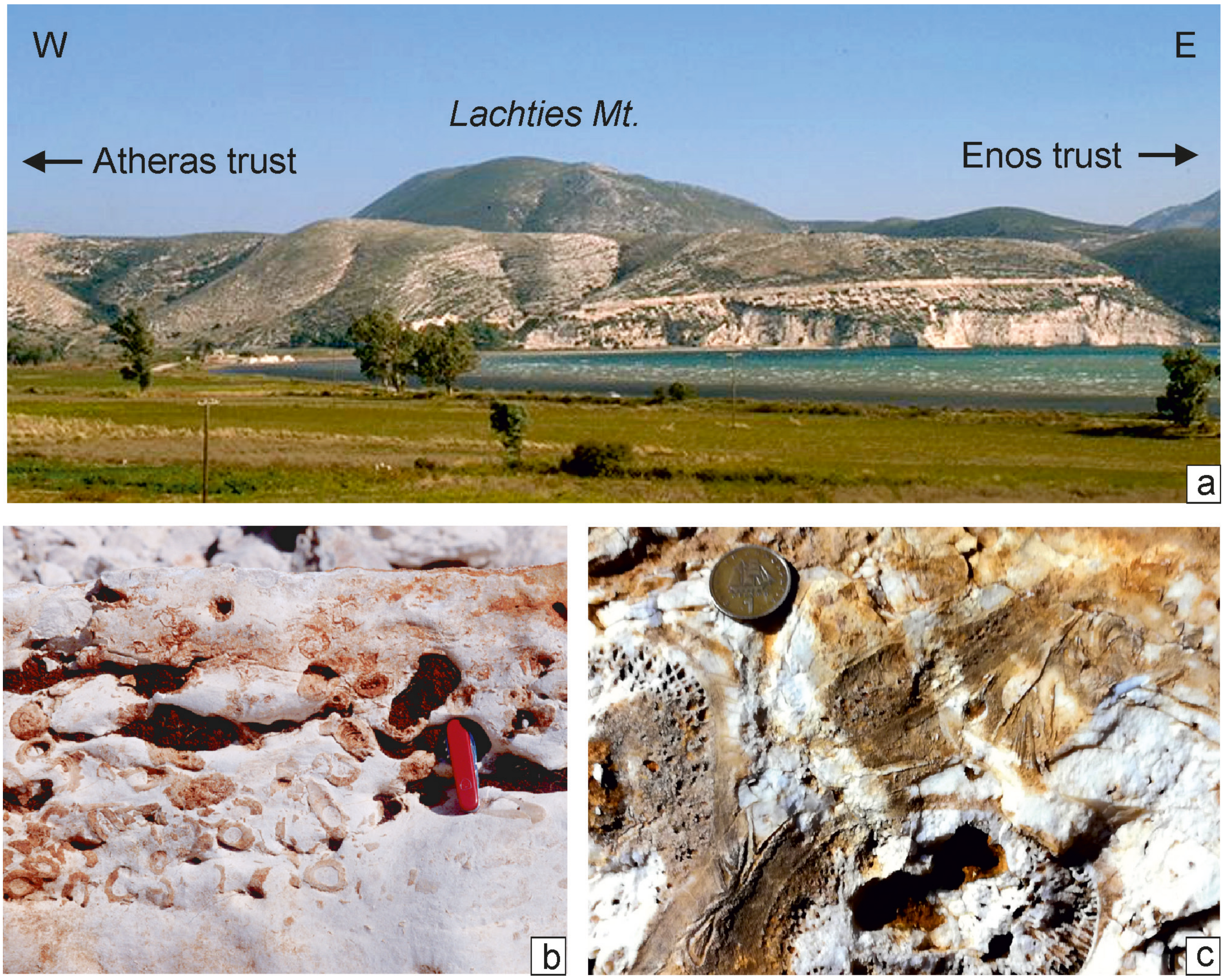


Fig. 13 - East sector of the Western Pre-Apulian Unit (WPU). a) General view of the Upper Cretaceous layered sedimentary sequence of inner platform W-E folded and bordered by Atheras and Enos thrusts, southern side of Lachties Mt.; b) Detail of the typical muddy facies of shallow subtidal shelf lagoon with reworked small radiolitid shell nests characterizing the previous sequence; c) *Sabinia* remains in the uppermost part of the sequence cropping out along the Zola-Lixouri road.

containing planktonic foraminifera (*Acarinina*, *Morozovella*, and *Planorotalites*). At the top, the appearance of *Alveolina* and *Nummulites* grain-supported layers testifies to an upward shallowing sedimentary trend with a consequent outwards migration of sandy shoals. The stratigraphic record is interrupted by a substantial sedimentary gap linked to a prolonged emersion period producing the dismantling of emerging rocks. The resume of sedimentation during Bartonian is marked by the appearance of calciclastic deposits containing shelf-derived sand and gravel-sized skeletal debris and lithoclasts. The reworked fossil assemblage, mainly made of larger foraminifera (*Nummulites*, *Discocyclina*, *Orbitoclypeus*, *Asterocyclina*, *Alveolina*, *Asterigerina Sphaerogypsina*, *Fabiania*, *Gyroidinella*, *Orbitolites*, *Gypsina*, *Chapmanina*, *Heterostegina*, *Borelis*, and *Pellatispira*), associated with *Hantkenina*, *Turborotalia* and *Globigerina* tests, is indicative of a hemipelagic environment of the outer ramp. This type of sedimentation lasts for the entire Aquitanian with micro-detrital and peloidal packstone and floatstone layers, always characterized by a well-diversified larger foraminiferal assemblage (*Spiroclypeus, Nephrolepidina*, *Eulepidina*, *Cycloclypeus*, *Miogypsinoides*, *Miogypsina*, *Amphistegina*, *Neorotalia*, *Austrotrillina*, *Peneroplis*, *Planorbulina*, *Praearchaias*, *Pfendericonus*, *Operculina*, and *Heterostegina*), enriched towards the top with planktonic foraminifera (*Globorotalia, Globigerina*, and *Catapsydrax*). An Aquitanian age is testified by the basal beds containing *Globigerinoides trilobus*, *Globorotalia kugleri*, and *Globigerina binaiensis,* whereas the first siliciclastic turbidite layers, containing glauconite and characterized by *Globorotalia obesa*, *G. peripheroronda*, *Globoquadrina dehiscens*, and *Orbulina suturalis*, suggest an early Serravallian age.

4.1.2.4. Inner-middle ramp facies sequence

In the Lixouri Peninsula, west of Atheras thrust, the K/T boundary shows limestone layers affected by

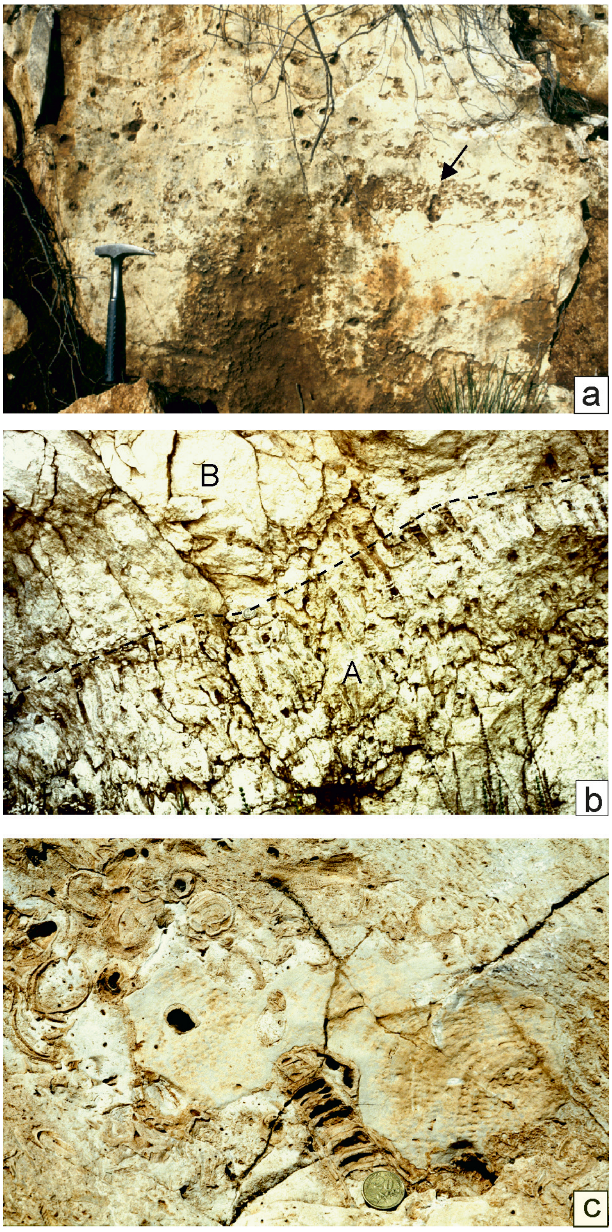


Fig. 14 - North Zakynthos sector of the Western Pre-Apulian Unit (WPU). Field photos of the Upper Cretaceous sedimentary sequences. a) Thick mudstone layer containing clouds of reworked small radiolitid shells (arrow) typical of quiet subtidal bottoms of lagoon, Maries-Exo Chora road; b) Close up view of *Hippurites socialis* bafflestone characterizing shelf lagoon colonized bottoms, Anafonitria road; c) Peri-reef coarse skeletal deposit made of unsorted large fragments of a flourishing fossil assemblage, among which large hydrozoan fragments, hippuritid shells and other mollusk remains are recognizable, Campanian-Maastrichtian, Korithi road.

secondary dolomitization and intense tectonization. This probably hides a stratigraphic hiatus of uncertain amplitude comprising at least the Danian. The Cenozoic sedimentary sequence (Fig 3 log a) continues with discorbid and ostracod mud-supported facies, interbedded with packstone containing poorly diversified benthic foraminiferal assemblages. The latter, and especially the protelphidiids, associated with dasycladaceans (*Microsporangiella*, *Oroseina*, *Broeckella*, *Orioporella*) and other calcareous algae (*Neomeris* and *Cymopolia*) are indicative of a Thanetian age. Above a series of grain-supported layers rich in colony coral, hydrozoan, bryozoan, and algae remains, together with a taxonomically well-diversified foraminiferal assemblage testify the establishment of an open lagoon environment. This is also supported by the presence of muddy intercalations rich in encrusting coralline algae (*Polystrata alba*), associated with benthic foraminifera (nubeculariids, miliolids, textulariids), dasycladalean algae, and mollusk fragments.

In the southernmost part of this sector, the stratigraphic record shows variously extended stratigraphic hiatuses (Accordi et al., 1998); typical of this sector is Upper Cretaceous dolostone (Fig. 12 a,b) covered by a Thanetian-Ypresian facies sequence made of well-bedded *Coskinon* wackestone-packstone layers followed up by a considerable thickness of chaotic arranged banks of *Alveolina* and *Nummulites* packstone (Fig. 12 c,d). The facies pattern lateral changes, even over a short distance, both in the grain-mud ratio and the fossil assemblage can be mainly attributable to variations in the sea floor morphology of the ramp. Particularly, the appearance of grain-supported deposits characterized by larger foraminiferal assemblages, taxonomically well-diversified and primarily consisting of alveolinid and nummulitid tests, are indicative of well-developed sandy shoals with a flourishing benthic community positioned in the middle ramp areas.

In the western sector of the Lixouri Peninsula (Fig. 3 log a), a large stratigraphic gap generally separates the Paleocene-lower Eocene succession from the Chattian-Aquitanian one, but in some places, this hiatus extends to the Maastrichtian, often separated by a basal conglomerate. This Oligocene resumption of the sedimentation corresponds to a clear change in the geometry of the carbonate ramp, indeed the top of the sedimentary sequence is characterized by about 10 m of reddish and yellowish clayey marl (Fig. 12 e,f), with rare benthic foraminifera interbedded with a nodular limestone covered by *Austrotrillina* packstone layers also containing coralline algae, bivalve, and echinoid remains. In the lower part of this sequence, *Valvulina*, *Clavulina*, *Melonis*, and *Bolivinella* prevail, while in the middle part *Spiroclypeus*, *Miogypsinoides*, *Nephrolepidina*, *Eulepidina*, *Amphistegina*, and *Neorotalia* tests are present. Finally, *Austrotrillina*, *Miogypsinoides*, *Nephrolepidina*, *Amphistegina*, *Gypsina*, *Sorites*, *Rotalia*, *Borelis*, *Peneroplis*, *Planorbulina*, and *Praearchaias* associated with globigerinids, globorotaliids, and *Cassigerinella* planktonic foraminifera are found in the upper part. Finally, the sedimentary sequence is topped by lower Miocene fine yellowish calcarenite containing planktonic foraminifera (*Globigerina binaiensis*, *G. venezuelana*, *Globorotalia siakensis*, and *Globoquadrina dehiscens*).

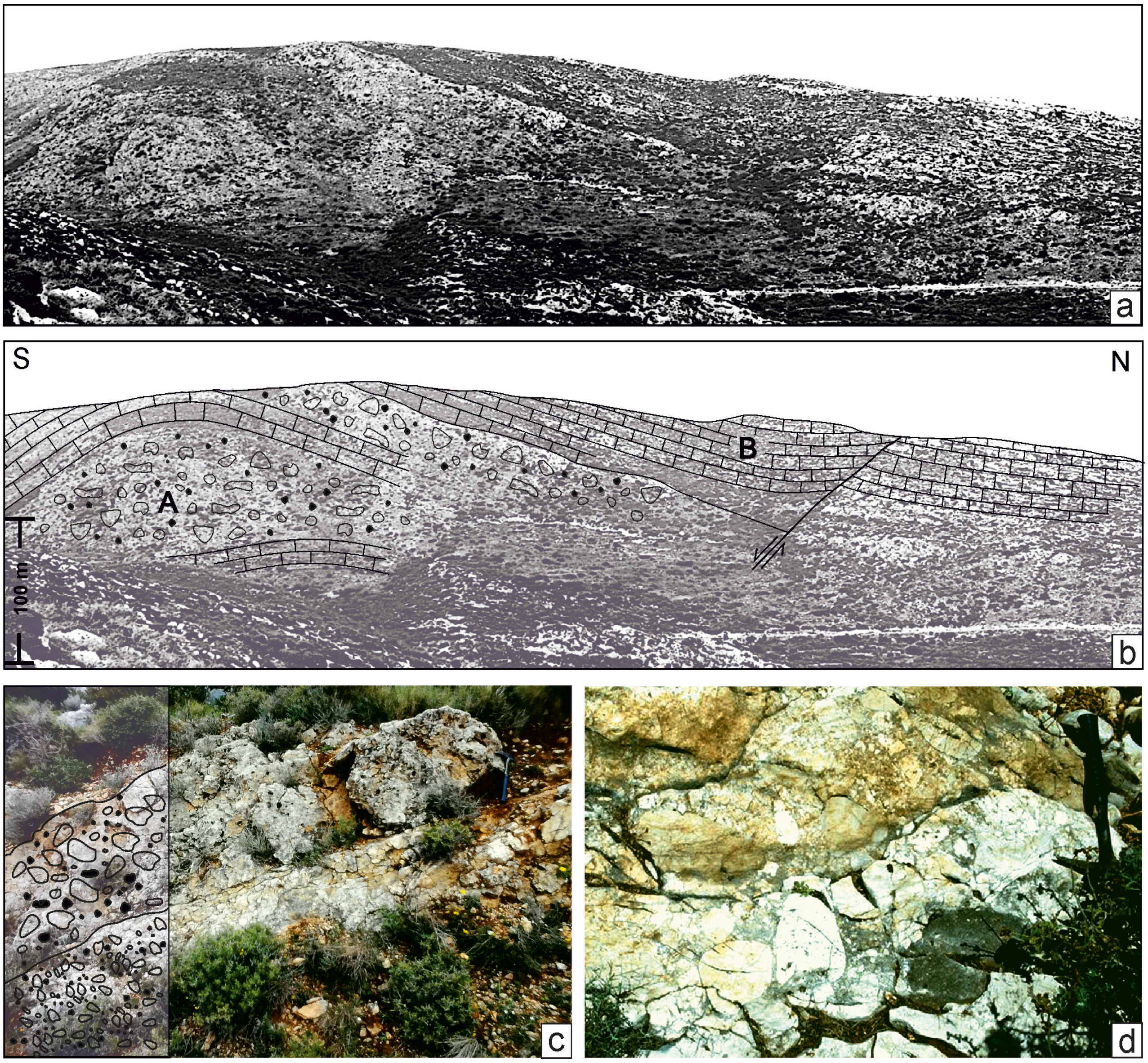


Fig. 15 - South Zakynthos sector of the Western Pre-Apulian Unit (WPU). a) S-N general view of the eastern side of the relief overlooking Lankadakia village; b) Structural setting of the area graphically highlighted showing the outcrop of a huge Lutetian-Aquitanian conglomerate body containing unsorted lithoclasts and shelf-derived boulders (A), packed in a layered toe of slope limestone made of pelagic mudstone interbedded with fine-grained skeletal beds due to grain flows (B); c) Field photo of a conglomerate body, graphically highlighted, characterized by thick layers with lithoclasts of different size, Lutetian-Rupelian, Kiliomeno-Macherado road; d) Detail of the top layer of the previous conglomerate highlighting densely packed lithoclasts with different textural characters due to dismantling of different calcareous rocks.

4.2. EVOLUTIONARY STAGES

The tectono-sedimentary evolution of the Meso-Cenozoic shallow-water carbonate units of the PAZ south of CTF, of which the Ionian islands are part (Fig. 1a), can be summarized through a series of stages (Fig. 17). A sedimentary model of a low-angle carbonate ramp applies to the EPU. This, already identifiable since the Early Cretaceous, shows during the Barremian-early Cenomanian a shoaling-upward sedimentary trend, followed, in the late Cenomanian, by a progressive drowning, mainly controlled by tectonics. Conversely, an initially detached carbonate flat-topped rimmed platform model can be attributed to the Upper Cretaceous portion of WPU, while a model of carbonate ramp is applicable starting from the Paleocene when a primary control on sedimentation is exerted by tectonics.

4.2.1. Lower Cretaceous
Stage 1 - Berriasian-Barremian

EPU - Shelf-derived fine carbonate-fed pelagic basin

A sequence of thin-layered marly limestone and

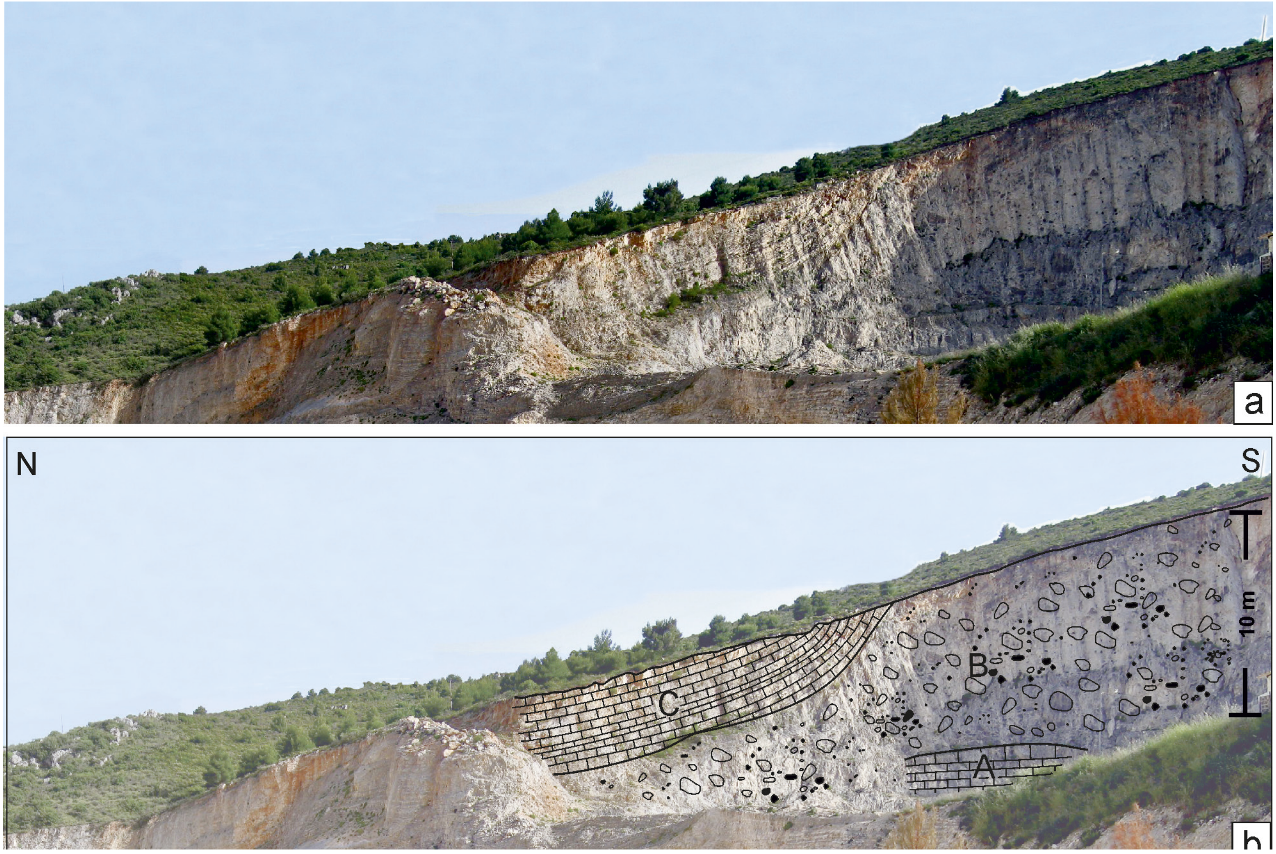


Fig. 16 - South Zakynthos sector of Western Pre-Apulian Unit (WPU). a) Panorama of outer ramp sedimentary sequence cropping out in the quarry west of Lithakia; b) Graphically highlighted structural setting of the outcrop showing Upper Cretaceous skeletal limestone (A) overlapped by a very thick Bartonian-Priabonian calciclastic body (B), followed by a layered pelagic mudstone-wackestone sequence (C). The irregular B-C parting line indicates a probable erosional or non-depositional gap presence.

dolostone (Fig. 6 a,b) and calpionellid marly limestone crops out at the base of the succession both in Cephalonia and Lefkada, testifying initial basin sedimentation. Upwardly, a generalized change in sedimentation takes place with the deposition of a mudstone similar to that of Vigla Limestone Fm., characterizing the sedimentation along the western margin of the IB. The facies stack contains thin distal calciturbidites and probable contourites, made up of small ooids and fine bioclastic debris (Fig. 6c), which suggest a proximal basin environment fed by shallow shelf areas. Periodically, starved basin conditions are furthermore evidenced by the occurrence of black marl beds inside the calpionellid lime mudstone. The evolutionary sedimentation trend probably reflects a progressive relative sea-level lowering, which triggers the mobilization and dispersion of large amounts of fine detrital carbonate along a gently sloping ramp. At the top of the sequence, an increase of fine granular layers is certainly related to distal turbidites, while more consistent intercalations of calcidebrite episodes related to high-density flows are probably triggered by periods of relative sea-level lowering.

WPU - No outcrop

Stage 2 - Aptian-Albian

EPU - Detrital carbonate-fed gently dipping ramp

From late Barremian or early Aptian, a sharp areal diversification of facies pattern testifies to the establishment of a well-developed carbonate ramp depositional system. The previous deposits of pelagic mudstone with radiolarians and sponge spicules are replaced by a new assemblage of planktonic foraminifera. At the same time, a further increase of skeletal and ooidal granular deposits distributed both in shallow and deep water environments occurs (Fig. 7 a,b). The presence inside a pelagic sequence of thin blankets of well-sorted grainstone, formed by fine skeletal debris and small ooids, fits with the presence of a wide and gently dipping ramp fed by remobilized sediments coming from the shallower water areas.

Conversely, the appearance of intercalations of thick chaotically arranged channelized breccia bodies (Fig. 6d), containing shelf-derived carbonate lithoclasts or coarse calcidebrite thick layers with different sorting and packing, suggests changes in the ramp geometry, as in the dynamics

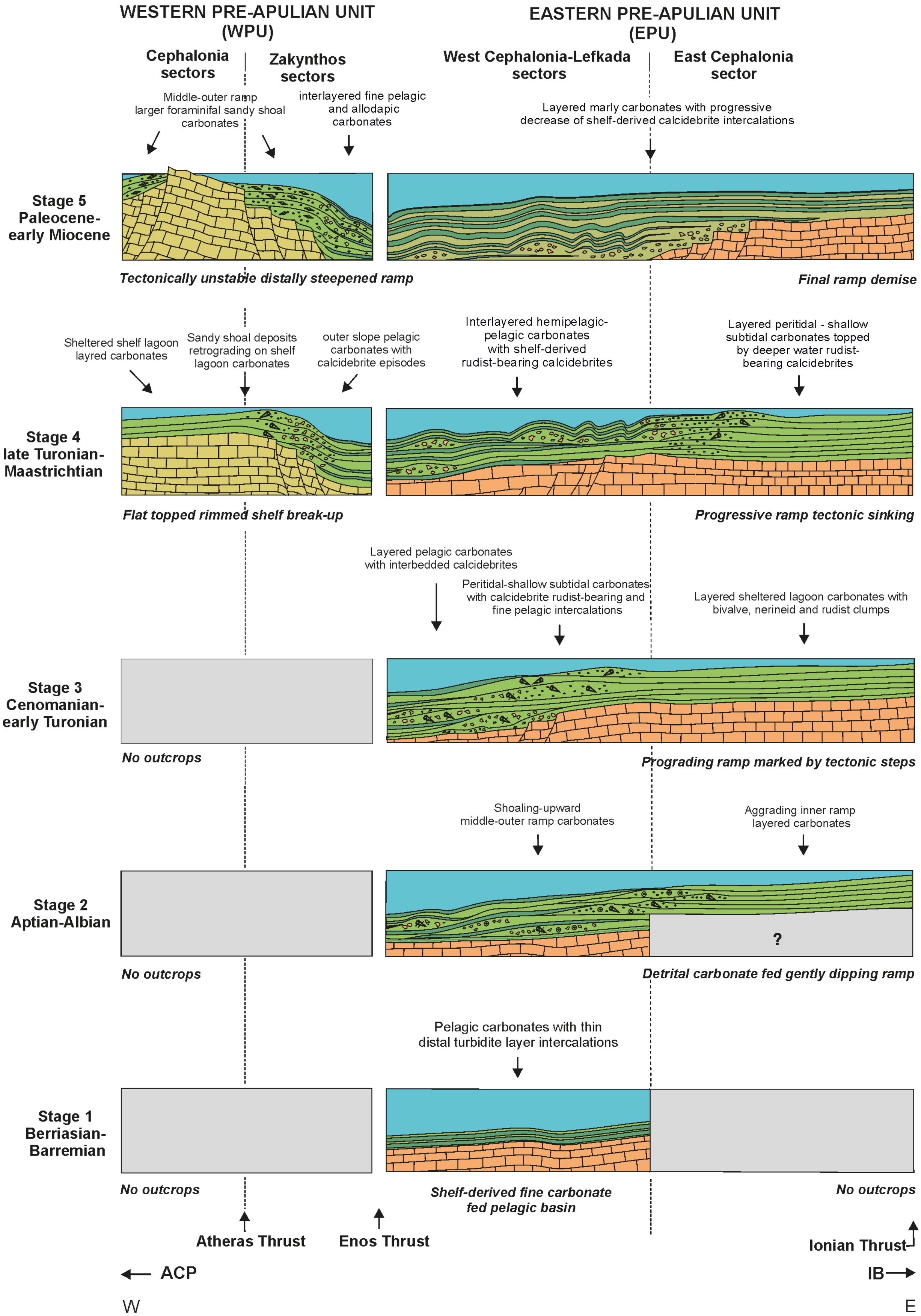


Fig. 17 - Interpretative cross-sections highlighting the relationships over time between the western (WPU) and eastern (EPU) Pre-Apulian units. The evolutionary trend of the tectono-sedimentary framework is summarized in five stages representative of the changes over time of the main facies patterns.

of transport and dispersion of sediment due to periodic relative sea-level fluctuations. The shoaling upward trend of sedimentation is evidenced by a widening of the shallow water ramp areas, characterized by the development of the *Aptyxiella libanotica* community on quiet lagoon bottoms. The cyclical presence of sandy blankets made of well-sorted ooids and algal balls characterized by both sheet cracks and thin laminations testifies to very shallow flat or gently dipping bottoms affected by weak tractive currents (Fig. 7b). The simultaneous deposition in outer ramp sedimentary sequences of channelized bodies of unsorted shelf-derived calcidebrites, often containing large limestone clasts, suggests periods of more marked sea level falls, possibly linked to tectonics. This caused subaerial exposure of some ramp areas and a consequent increase in erosion and mobilization processes.

WPU - No outcrop

4.2.2 Upper Cretaceous
Stage 3 - Cenomanian-early Turonian

EPU – Prograding ramp marked by tectonic steps

At the beginning of the Cenomanian, an increase in differential movements between shallow and deep water ramp areas causes sharp changes in the depositional model: the shallow peritidal environments are distinguishable by several muddy facies, sometimes characterized by algal stromatolites, sheet cracks, and oligotypic fauna. Similarly, local accumulations of densely packed radiolitid shells (Fig. 7c) indicate shallow channel morphologies. Locally, rich communities of *Chondrodonta joannae* (Fig. 8b) and oyster shells are always linked to sheltered muddy bottoms while sandy deposits with *Cisalveolina fraasi*, locally enriched with *Plesioptygmatis nobilis* (Fig. 8a) or radiolitid shells, sometimes still in growth position (Fig. 7d), are indicative of diversified shallow subtidal open lagoon bottoms. In addition, local accumulations of coarse poorly sorted skeletal debris, often containing *Caprina* remains, can be related to the presence of sandy shoals located offshore, where marine water circulation is good and a rudist-coralline algae community flourishes. The setup of highly biotic productive marginal conditions is corroborated by abundant rudist debris (Fig. 7e) stored in internal and external areas of the ramp. In the deeper external belt, the presence of numerous well-packed calciclastic episodes, inside the hemipelagic-pelagic depositional sequences, are correlatable to gravity flows that originated during periods of tectonic instability causing up and down movements of different parts of the ramp.

Particularly, during the late Cenomanian-Turonian, the occurrence of incipient drowning periods is highlighted, in the middle ramp areas, by thin layers of hemipelagic mudstone inserted in the shallow water facies sequence. Equally, small sea level falls cause temporary subaerial sea floor exposure evidenced by erosive surfaces and supratidal rock alteration.

The development of this sedimentary pattern is closely related to a progressive tectonic backstepping of the ramp indicated by the inward migration of skeletal marginal facies. This leads to the change of the ramp-to-basin geometric relationships with the formation of tectonic steps producing a pronounced increase in the outer slope gradient. The development of a fault-controlled architecture combined with an overproduction of rudist debris leads to the accumulation of calcidebrite wedges on lowered steps that accompany the progressive drowning of the ramp.

WPU - No outcrop

Stage 4 - Late Turonian-Maastrichtian

EPU- Progressive ramp tectonic sinking

The ramp segmentation, already highlighted during the Cenomanian, continued throughout the Upper Cretaceous with a progressive backstepping fault-controlled trend. The widespread accumulations in the outer ramp-proximal basin areas of thick calcidebrite-dominated deposits suggest periods of uplift with emersion and dismantling of some wide shallow water areas. Simultaneously, the complete drowning in other areas, linked to a notable increase of the accommodation space, is documented by marine onlap of the pelagic sequence on previous shallow water one. The progressive disappearance of the inner ramp facies is accompanied by the spread in shallow water areas of flourishing open marine radiolitid and hippuritid communities. Offshore, these give rise to very abundant skeletal debris generating gravity flows.

The establishment of deeper water sedimentation on lowered steps of previous shallow water areas, probably in correspondence with steep fault scarps, produces the local accumulations of calciclastic material embedded in a muddy matrix or a fine calcidebrite. These, in some places, especially during the late Campanian-Maastrichtian, combine with hard rock slidings and soft sediment slumpings (Fig. 9). At the end of the period, the progressive inward shifting of outer ramp facies causes the complete disappearance of quiet lagoon sedimentation in favor of the widespread rudist-dominated skeletal deposits (Fig. 10).

WPU - Flat-topped rimmed shelf breakup

A gradual reduction of the shallow water shelf area due to a progressive fault-controlled sinking is documented by the inward migration of the marginal rudist and larger foraminifera-dominated sandy sedimentation. The setup on the shelf edge of a well-diversified biota, related to mobile or stable bottoms, produces changes in facies type and distribution. The abundance of skeletal debris gives rise to two types of sediment accumulations: one substantially autochthonous rooted in shallow water environments, another linked to reworking and dispersion of skeletal debris in deeper water along the outer slope.

During this stage, the persistence of quieter water sedimentation of shelf lagoon is limited to the western sector of Lixouri Peninsula, where *Rhapydionina*-bearing sandy facies are typical, and to the northern part of Zakynthos mainly characterized by radiolitid-bearing muddy facies.

In these areas, the progressive margin backstepping is confirmed by the appearance, at the top of the Maastrichtian sequence, of skeletal coarse sandy facies rich in rudist shells and larger foraminifera remains (Fig. 11 b,c).

The tectonic down-faulting of peripheral areas produces steep outer slopes due to the quick increase of accommodation space not compensated by sediment supply. In the Lixouri Peninsula, the facies pattern shows a progressive drowning trend from east to west. Likewise in Zakynthos, an abrupt transition from shallow to deep water of facies sequences occurs from north to south, probably due to a most recent tectonic approach of different parts of an originally larger sedimentary unit. In the southern area, the setup of persistent steep tectonic margins, probably affected by sediment bypass, is responsible for the onset of the huge accumulation of calciclastic deposits, which will continue for most of the Cenozoic.

4.2.3 Paleogene-Neogene
Stage 5 - Paleocene - early Miocene

EPU - Final ramp demise

The sedimentary evolution suggests a sinking trend of the ramp with fine pelagic sedimentation disturbed by the emplacement of distal calciturbidite lobes and calcidebris beds, mainly containing reworked larger foraminifera tests increasingly rarefied upwards. At the same time, the progressive increase of a fine marly fraction and the appearance of bands and nodules of chert is significant.

The complete sinking of the ramp below the euphotic zone is achieved at different times in function of the kinematic behavior of the various sectors. Synsedimentary mass wasting deposits linked to tectonic shakings, evidenced by slumps and rockslides, still characterize in some places the lower part of the stratigraphic record, where large exotic limestone clasts are frequently packed in a fine skeletal matrix. The complete burial of the ramp coincides with the disappearance into the pelagic muddy sequence of the intercalations of the skeletal debris drifted off from shallow water areas.

WPU - Tectonically unstable distally steepened ramp

During Paleocene, a shallow water lagoon sedimentation persists only in some areas of the Lixouri Peninsula, west of Atheras thrust, and is characterized by both muddy facies with an oligotypic fauna, made of smaller benthic foraminifera and algae, and shallow subtidal sandy facies with abundant dasycladalean and *Polystrata alba* remains, typical of vegetated bottoms. Traces of subaerial exposure are highlighted by erosion cavities often filled by vadose silt and *Microcodium* encrustations.

In the Lixouri Peninsula, notable changes in the facies pattern occurred during the early Eocene with the appearance of grain-supported facies accompanied by the spread of larger foraminiferal assemblage communities (Fig. 12 c,d,e,f). This is due to a shift of open marine sedimentation towards the interior of the ramp. At the same time, the tectonic uplift of large segments of the former Cretaceous carbonate platform leads to the stop of sedimentation and the dismantling of some emerging areas.

After the Eocene spreads of alveolinid and nummulitid sandy facies, the biostratigraphic data indicate the existence of a conspicuous hiatus, followed, during the Chattian-Aquitanian, by the onset of shallow-water sedimentation evolving towards deeper water facies. The relative sea-level rise leads to the demise of shallow-water carbonate sedimentation and the appearance of the *Austrotrillina* marly-clayey deposits (Fig. 12 e,f,g,h), which completely differs from the previous carbonate ramp model.

Conversely, in the eastern sector of Lixouri Peninsula a Bartonian-Aquitanian pelagic lime muddy sequence, containing reworked larger foraminifera and lithoclasts still related to the outer ramp environment, directly covers the early Ypresian layers. This is in favor of structural separation between the two sectors which involves their different tectono-sedimentary behavior. In Zakynthos, the shallow ramp sedimentation, if any, was probably limited to narrow areas, now obliterated by the subsequent tectonic shortening, connected with the basin through a series of lowered fault steps. The consequence is the onset of a sedimentary sequence dominated by calciclastic deposits where allochthonous skeletal debris and conglomerate episodes, including large exotic lithoclasts alternating with pelagic mudstone layers, occur (Fig. 15). The stratigraphic framework of the island suggests the trigger of a distally steepened ramp geometry after the sudden sinking of part of the previously emerged Cretaceous carbonate platform. Generally, Lutetian layers directly overlie the Maastrichtian limestone with a pelagic lime muddy sequence periodically enriched by intercalations of shallow ramp-derived sand-to-gravel-sized skeletal sediments, locally added with variable percentages of carbonate neritic and pelagic lithoclasts. Furthermore, in different stratigraphic positions, thick chaotically arranged conglomerate episodes testify to repeated periods of intense erosion of uplifted areas (Fig. 16).

This Cenozoic toe of slope-proximal basin sedimentary sequence shows both a diachronic contact with the underlying Cretaceous shelf limestone and different temporal location of conglomerate episodes. Normally, these sedimentary bodies, often of considerable thickness, decrease upwards until their disappearance in late Aquitanian-Burdigalian time, when fine pelagic sedimentation spreads over the whole island. The new sedimentary model, replacing the previous Cretaceous rimmed shelf model, fits well with a low-angle distally steepened carbonate ramp, initially characterized by the presence of a sheltered shallow water inner belt with wide emerging areas. Over time these lagoon environments narrowed in favor of an expansion of the colonized middle ramp belt, where sand-gravel-sized sedimentation, containing well-diversified larger foraminiferal assemblages, dominates. Often, both increase and stop of the accommodation space in different areas of the ramp, together with variations in carbonate sediment supply, lead to a progressive change in the ramp geometry. The persistence for a long time of an unstable tectonic margin condition is suggested by the abundant supply of calciclastic sediments transported to the basin through gravity flows, while the types and age of the lithoclasts contained in the conglomerate bodies give information on the tectonic history of the source area and particularly the closer correspondence with Lixouri Peninsula stratigraphic record (Di Carlo et al., 2010; Accordi et al., 2014).

5. REGIONAL CORRELATIONS

The stratigraphic framework of the PAZ of the Ionian Islands can be closely related to the sedimentary evolution of two different crustal segments formerly located east of ACP and west of the IB. The sedimentary evolution of these areas, today fragmented and juxtaposed to form many outcrops of the islands, was influenced by regional and local tectonics, sea level variation, production, and sediment dispersion, interacting in variable ways over time. This led to the development of depositional systems that cannot be related to a single model of carbonate platform but reflect the geotectonic history of the neighboring areas.

According to the hypothesis of a different kinematic behavior over time of two originally contiguous shallow water tectono-sedimentary units with different drowning times, these two depositional systems can be related, to the west, to a persisting infra-oceanic flat-topped rimmed platform, and, to the east, to an earlier setting of carbonate ramp. These two areas show analogies with different paleo-geographic domains of Neo-Tethys: many stratigraphic characters of the first unit show affinity with ACP (Bosellini et al., 1999b; Graziano, 2001; Morsilli et al., 2017), while the second one fits well with an Ionian carbonate ramp directly connected with the IB (Getsos et al., 2007).

A stratigraphic correlation with ACP is highlighted by the sedimentary records cropping out in southern Italy (Murge and Salento) and corresponding to an uplifted undeformed or poorly deformed portion of a Meso-Cenozoic carbonate platform (Spalluto et al., 2008; Spalluto, 2012). This includes, to the east, the wide submerged area of the Apulian Swell (Maesano et al., 2020; Cicala et al., 2021), that reaches up to the CTF, and, to the south, it lengthens towards the Apulian and Strophades ridges (Argnani et al., 2001; Carayon et al., 2017). The whole region, consisting of a mostly carbonate Meso-Cenozoic stratigraphic record, shows a structural setting made of down-faulted blocks both to the west, towards the Bradanic Trough, and to the east in correspondence with the Adriatic Sea (Ippolito et al., 1975; Tropeano et al., 2002, 2004; Pieri et al., 2004). The sedimentary model corresponds to a typical intra-oceanic flat-topped carbonate platform where the architecture is mainly controlled by steep fault-controlled margins (Bosellini, 1989; Eberli et al., 2019). The progressive drowning of the ACP is recognizable by the appearance, in the Murge region, of upper Campanian-Maastrichtian outer slope deposits of rudist-bearing skeletal limestone (Ostuni Limestone Fm. and Caranna Limestone Fm.) (Ciaranfi et al., 1988; Luperto Sinni and Borgomano, 1989; Pieri et al., 2004). Towards the south, in Salento Peninsula, rudist-rich marginal facies of the same age (Melissano Limestone Fm), occupy a narrow belt facing the Ionian Sea (Cestari and Sirna, 1987; Steuber et al., 2006; Schlüter et al., 2008). The appearance during the Late Cretaceous of marginal facies in the inner zone of the ACP broadly fits with the sinking times found in the WPU (Accordi et al., 2014).

The overlying Cenozoic stratigraphic record of Salento shows a marked areal diversification due to the different kinematic behavior of single tectonic blocks and particularly with their structural relationship with basin areas. The Eocene sedimentary sequence, cropping out in the Salento Peninsula, is mainly represented by a shallow water environment of carbonate ramp dominated by larger foraminiferal assemblages (Bosellini et al., 1999b; Tomassetti et al., 2016).

Upward, Oligocene peri-reefal skeletal facies are characterized by a benthic foraminiferal assemblage associated with colonial coral, corallinacean algae and gastropod remains (Castro Limestone, and Porto Badisco Limestone fms.) (Bosellini and Russo, 1992; Bosellini et al., 1999b; Pomar et al., 2014; Parente and Less, 2019; Bosellini et al., 2021). These deposits, corresponding to an open mainly circalittoral marine environment, fit well with the sedimentary model of the carbonate ramp hypothesized for the WPU (Accordi et al., 1998; Di Carlo et al., 2010; Accordi et al., 2014). Furthermore, a possible structural connection of the western part of the PAZ of the Ionian Islands with the eastern margin of ACP is also corroborated by the late defusing of shallow water sedimentation in the crustal area comprising the Salento Peninsula. Conversely, the stratigraphic record of EPU shows marked similarities with the Cretaceous stratigraphic record usually attributed to the External Ionian Zone. Renz and Reichel (1945) described an *"Adriatische-Ionische"* zone roughly corresponding with the Ionian domain but also characterized by shallow-water microfauna.

On the mainland, in the western Epirus region, corresponding to the western margin of IB, the stratigraphic record shows the presence of Berriasian-Valanginian deposits related to a carbonate ramp environment (Getsos et al., 2007). The corresponding facies sequence is represented by radiolarian mudstones and wackestones containing layers with reworked echinoid, bivalve, and rare aptychus remains. Significant is also the presence of sandy layers containing small benthic foraminifera, coralline algae, and rare ooids. This makes them very similar to the layers present at the base of the EPU stratigraphic record. Indeed, according to Getsos et al. (2007), during the Hauterivian, a deeper outer ramp-proximal basin condition is highlighted by a transition from pelagic to hemipelagic sedimentation, influenced by the addition of shallow ramp-derived carbonates.

The persistence of this type of sedimentation during the Cretaceous is documented along the Epirus coast by globotruncanid-bearing mudstone sequence containing abundant calcidebrite episodes rich in rudist remains, followed during the Cenozoic by globorotaliid-bearing mudstones with abundant calciclastic episodes containing larger foraminifera (Bourli et al., 2019; Dimopoulos et al., 2019; Kontakiotis et al., 2020; Zoumpouli et al., 2022).

The sedimentary characters shown by the External Ionian Zone and attributed to a pelagic environment heavily influenced by the proximity of shallow water productive areas, allow us to speculate on a correlation between the carbonate ramp environment hypothesized by us for EPU and the external zone of the IB. This does not conflict with the possible presence of a wide pelagic trough separating the western Pre-Apulian unit (WPU) from the eastern one (EPU) since the Early Cretaceous. In favor of this hypothesis is the presence, in the northern part of Cephalonia, along the Enos thrust front, of a thick toe of slope sedimentary sequence containing abundant allodapic limestone intercalations. The succession starts with Upper Cretaceous pelagic mudstone containing frequent conglomeratic episodes formed by abundant rudist remains, and carbonate lithoclasts. This continues with layers rich in reworked, mainly Eocene larger foraminiferal fauna, followed by a probably incomplete Oligocene-Aquitanian sequence with depositional characters similar to the previous one (Accordi et al., 1998). The presence of an intermediate basin area can also be corroborated by the eastward transition to deeper waters shown by the facies pattern of the Lixouri Peninsula. In the same way, the persistent marginal condition evidenced by the stratigraphic record of Zakynthos indicates a deep marine environment close to the western margin of ACP. This agrees with the probable presence of a branch of the South Adriatic basin separating the pre-Apulian domain into two smaller units. In any case, according to Del Ben et al. (2015), the structural analysis, based on marine seismic profiles interpretation, suggests a complex trend of the margin between the ACP and a newly identified Apulian basin. Indeed, the southern part of this basin, which originated from an extensional phase, already acting during the Jurassic, corresponds to a deep pelagic trough that separated the ACP and a western unit of the PAZ, WPU was part of, from an easternmost unit including EPU.

6. DISCUSSION

The tectono-sedimentary evolution of the study area (Tab. 1) must be framed within the more general context of the geodynamics of the External Hellenides sector positioned southeast of CTF.

Many changes involved the carbonate sedimentary systems of the PAZ of the Ionian Islands during the Meso-Cenozoic because of the kinematic movements that led to the structural deformations of the Hellenic foreland during the west-verging migration of the Hellenic thrust sheets. The effects of these movements must be added or subtracted from eustatic sea-level variations. The result is a sedimentary framework that progressively evolves away from the initial model of a large isolated carbonate rimmed platform typical of the central Tethyan realm during the Jurassic. The sedimentary characters corresponding to this depositional system testify to the predominant role played by initial extensional tectonics that causes the segmentation of a larger carbonate platform into smaller units subject to progressive down-faulting and backstepping of marginal areas. This evolutionary trend is well-documented by the Upper Cretaceous and Paleogene stratigraphic record of the westernmost unit inclusive of the WPU. Conversely, the unit comprising the EPU is already affected in the Early Cretaceous by flexural deformations inducing a differential movement that causes uplift and tilting with the consequent development of a ramp geometry. The effects of differential tectonic movements and global sea-level variations cause clear changes in the architecture of the depositional systems over time. The dismantling of emerging areas, the margins that set back, and the repeated mobilization of loose sediments through gravity flows are all phenomena, already onset in some areas during the Early Cretaceous, that become more and more widespread with the increase of the west-verging translational movements which involved the External Hellenides.

Compressional deformation, evidenced by the modern fold-and-thrust belt style affecting the Ionian Islands (Getsos et al., 2007; Zelilidis et al., 2015; Bourli et al., 2022 and references therein), causes the development of minor sedimentary basins linked to the uplift and tilting of some crustal segments, and to the rapid subsidence of others. These repeated phases of tectonic instability, accompanied by mobilization and dispersion of a significant amount of incoherent detrital carbonate rich in skeletal debris, together with the processes of hard carbonate rock dismantling, are at the base of many stratigraphic gaps affecting the outcropping depositional sequences. In this kind of evolutionary framework, changes in the stratigraphic records can also occur over short distances, embracing different time intervals. Particularly, the areal diversification shown by the various facies sequences (Figs. 18, 19) inside WPU and EPU results from the tectonic deformation of depositional substratum, leading to different relationships between autochthonous and

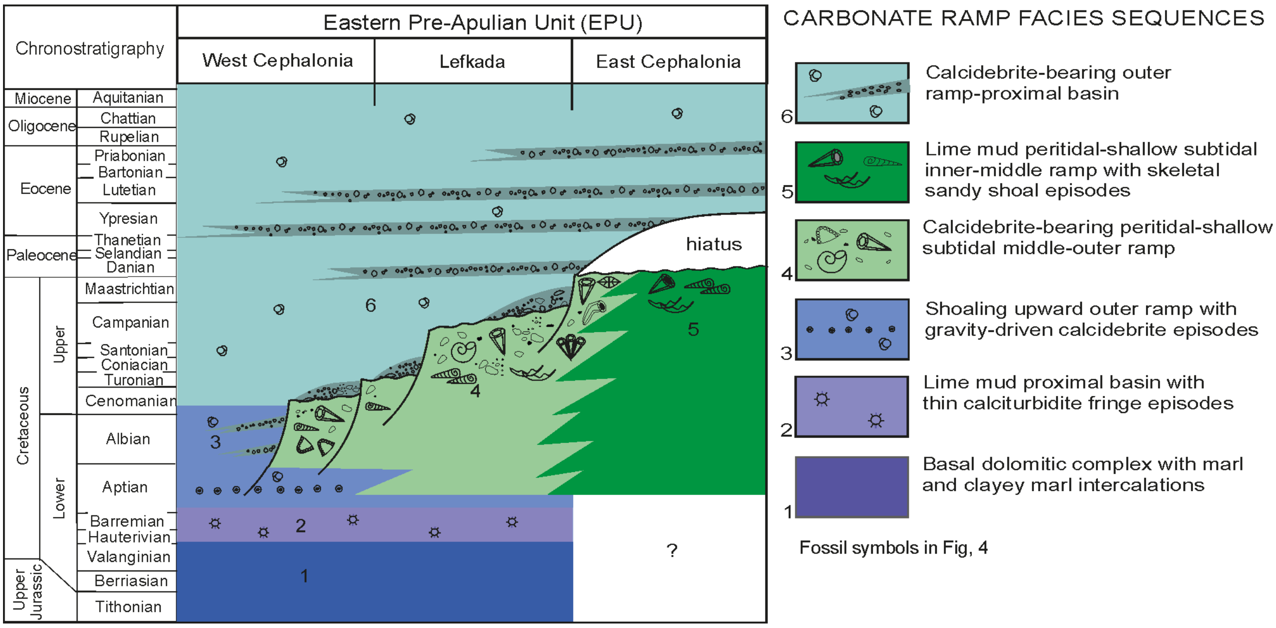


Fig. 18 - Chronostratigraphic panel of the Western Pre-Apulian Unit (WPU) showing the relationships in space and time among the carbonate facies sequences cropping out in the sectors of Cephalonia west of Enos thrust, and in Zakynthos island.

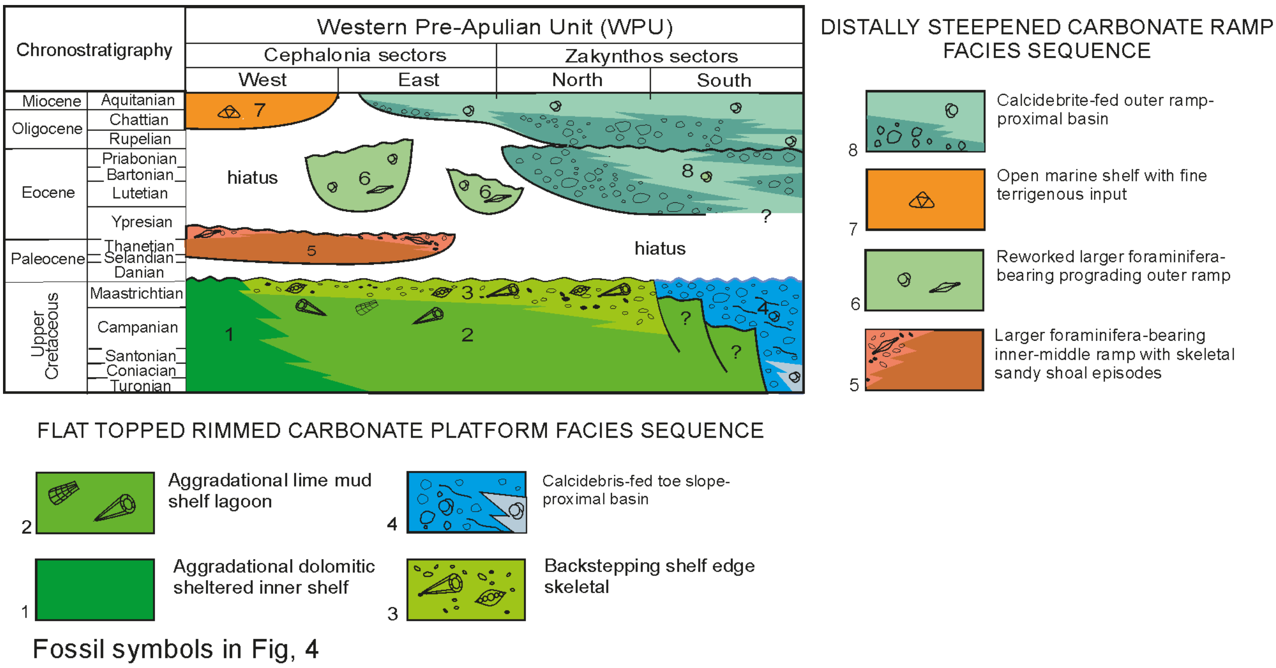


Fig. 19 - Chronostratigraphic panel of the Eastern Pre-Apulian Unit (WPU) showing the relationships in space and time among the carbonate facies sequences cropping out in the sectors of Cephalonia east of Enos thrust, and in Lefkada.

mass wasting deposits. Consequently, a clear distinction is evident between EPU, affected during the Early Cretaceous by sedimentation heavily influenced by gravity flows, and WPU, where conspicuous mass wasting spreads, in Zakynthos especially, since the middle Eocene.

7. CONCLUSIONS

The tectono-sedimentary evolution of the Pre-Apulian carbonate units of EPU and WPU shows a structural complexity which can be explained using the two flat-topped platform and ramp models, changing in time and

Western Pre-Apulian pulian Unit (WPU)

Stage	Structural setting	Main sedimentary event	Affected sector	Consequence	Facies stack
5 Paleocene-early Miocene	Tectonically unstable distally steepened ramp	Differential subsidence and uplift fault controlled combined to sea level changes	Lixouri peninsula	Ramp geometry variation in time and space	Larger foraminiferal sandy shoal carbonates
		Steep margin backstepping and bypassing	Zakynthos		interlayered fine pelagic and allodapic carbonates
4 late Turonian-Maastrichtian	Flat-topped rimmed shelf breack up	Downfaulting blocks with local uplift	West Lixouri peninsula	Set back of downfaulting steep margins	Interlayered peritidal-shallow subtidal carbonates
			East Lixouri peninsula and North Zakynthos		Rudist and Orbitoid sandy shoal deposits retrograding on shelf lagoon carbonates
			South Zakynthos		Outer slope pelagic carbonares with calcidebrite episodes
3 Cenomanian-early Turonian	No outcrops				
2 Aptian-Albian					
1 Barremian-Berriasian					

Eastern Pre-Apulian Unit (EPU)

Stage	Structural setting	Main sedimentary event	Affected sector	Consequence	Facies stack
5 Paleocene-early Miocene	Deepening basin funneled by detrital carbonates	Progressive accommodation space increase not balanced by sedimentation rate	West Cephalonia and Lefkada	Complete ramp sedimentation demise	Layered pelagic marly carbonates with progressive decrease of shelf-derived calcidebrite intercalations
			East Cephalonia		
4 late Turonian-Maastrichtian	Ramp marked by tectonic segments gradually drowning	Local syn-sedimentary tectonics combined with eustatic sea-level changes	West Cephalonia and Lefkada	Gradually areal ramp narrowing	Interlayered hemipelagic-pelagic carbonates and shelf-derived rudist-bearing calcidebrites
			East Cephalonia		Layered peritidal - shallow subtidal carbonates topped by deeper water rudist-bearing calcidebrites
3 Cenomanian-early Turonian	Prograding ramp marked by tectonic steps	Extensional tectonics with local uplift or incipient drowning	West Cephalonia and Lefkada	Marginal shallow water sedimentation with increase of gravity flows in deeper outer areas	Peritidal-shallow subtidal carbonates interlayered with rudist-bearing calcidebrites and fine lime pelagic beds
			East Cephalonia	Aggrading sedimentation periodically stopped by inbalances with the accommodation rate	Layered sheltered lagoon carbonates containing nerineid, bivalve, and radiolitid clumps
2 Aptian-Albian	Retrograding gently dipping ramp	Synsedimentary tectonics combined with eustatic seal-level changes	West Cephalonia and Lefkada	Shoaling upward sedimentation with local subaerial exposure and dismantling	Layered pelagic carbonates with calcidebrite and calciturbidite intercalations evolving to shallow water carbonates
			East Cephalonia		
1 Barremian-Berriasian	Proximal basin with progressive accommodation space decreasing	Relative sea level fall with periodic starved basin coditions	West Cephalonia and Lefkada	Pelagic basin fed by debris of gravity flow fringes or conturnites	Interlayered pelagic carbonates and thin ooidal or fine skeletal beds

Tab. 2 - Main characteristics of stratigraphic successions of the mapped tectono-sedimentary units of the Pre-Apulian zone of the Ionian Islands south of CTF.

space their architectural settings. Starting from the Early Cretaceous, the depositional systems of the two shallow-water carbonate units have been conditioned by the interaction of different factors:

i) Differential fault subsidence generates a flat-topped rimmed shelf with raised margins and marked breaks of slope geometry mainly dominated by in situ sediment accumulation.

ii) Gradual sea-level change generates gently dipping ramp geometry, not necessarily protected by raised self-margin, mainly dominated by inward or outward sediment transport.

iii) Substantial relative sea-level fall generates abrupt changes in depositional model geometry dominated by dismantling, remobilization, and dispersion of large amounts of calciclastic carbonate.

The role played by these factors over time allowed us to distinguish a series of evolutionary stages of stratigraphic records (Fig. 17) that form the geologic framework of the islands (Figs. 18, 19, 20; Tab. 2). The EPU shows different types of well-defined sedimentary records linked to the Mesozoic-Cenozoic evolutionary trend of a carbonate ramp depositional system. This is represented by both peritidal-shallow subtidal facies stacks and coeval hemipelagic-pelagic facies stacks rich in shelf-derived skeletal calcidebrites and calciturbidites typical of the outer slope-proximal basin environment (Fig. 2). The WPU depositional succession is related to a rimmed shelf depositional system evolving to ramp only at the end of the Cretaceous. Moreover, in this unit, sharp differences in stratigraphic records are present between the Lixouri Peninsula and Zakynthos island. In the Lixouri Peninsula, facies changes occur within a prevailing shallow water ramp environment, whereas while in Zakynthos a strong accumulation of calciclastic deposits of deep ramp-proximal basin environment dominates (Fig. 3).

Synthetically, the development of the ramp depositional system attributed to EPU can be divided into two main stages: one of upward-shoaling, lasting until the early Cenomanian, and another of progressive tectonic segmentation and drowning, completed at the end of Maastrichtian. The first stage coincides with a progressive increase in detrital carbonate sediments transported toward the basin through various types of gravity flows. The second stage instead is accompanied by the narrowing and dismantling of the rudist-populated shallow water ramp areas and by the setup of an outer ramp-basin environment with active sediment storage of mass wasting deposits rich in internal slumps and large exotic limestone blocks. The rimmed shelf depositional system related to WPU shows an abrupt change in the depositional model only at the end of the Cretaceous with the emplacement of the ramp morphology marked by evolutionary stages heavily influenced by tectonics.

During the Cenozoic, the Lixouri Peninsula shows prolonged subaerial exposure periods, at least from the late Thanetian-early Ypresian, followed by a drowning trend from east to west starting from the middle Eocene. Conversely, the entire Zakynthos island is affected by subaerial exposure, dismantling, and bypassing phenomena throughout the Paleocene-early Eocene, later becoming the outer ramp place where calciclastic-dominated deposits are stored. The structural relation between the two areas can be inferred by carbonate lithoclasts contained in the conglomerate episodes, coming from the dismantling of shallow water ramp areas. An eastern source area of the exotic material can be excluded as the EPU at the beginning of the Cenozoic was already completely sunk. Conversely, the age of the main conglomerate episodes of the WPU stratigraphic record can be related to two major tectonic events affecting the Pre-Apulian domain from the end of the Eocene and the beginning of the Miocene.

We can therefore assume during the Paleocene the

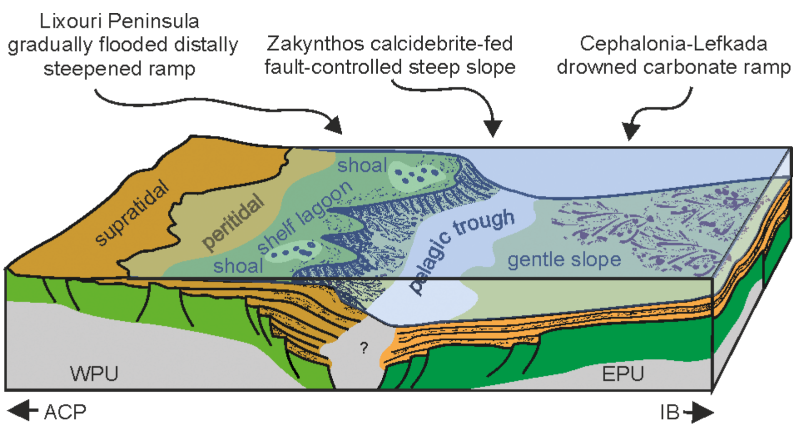


Fig. 20 - Simplified paleogeographic model of West Pre-Apulian Unit (WPU) and East Pre-Apulian Unit (EPU) at the Meso-Cenozoic boundary. The evolutionary trend arrangement of the two corresponding sedimentary patterns is largely influenced by a hypothetical pelagic trough, perhaps connected to the Ionian Basin (IB).

presence of a distally steepened east-verging carbonate ramp deriving from the evolution of the passive margin of the ACP and probably strictly related to a shallow water unit located south of the CTF, today partially identifiable with the Strophades Ridge (Fig. 1a).

Furthermore, the progressive areal reduction, from the Cretaceous to early Miocene, of the ancient Tethyan carbonate platforms located along the External Hellenides belt determines the contemporary development of deep pelagic troughs where the allodapic carbonates are largely stored. Probably these smaller basin areas were connected with the IB giving rise to complex paleogeography marked by the changing of spatial relationship among structural highs and lows traced by the progressive drowning tectonics (Fig. 20).

In conclusion, the exact position and original dimension of the Cretaceous shallow-water carbonate tectono-sedimentary units located southeast of CTF are uncertain because of the strong shortening and rotation movements over time and still partially in progress. Consequently, we can state that for the PAZ of the Ionian Islands the original extension and mutual relationship of the two identified depositional units remain largely conjectural especially because of the wealth of evidence of post-depositional compressive and strike-slip tectonics. Despite that, it should be noted that only the stratigraphic record of the WPU, limitedly to the Upper Cretaceous, can be attributed with certainty to an initially isolated flat-topped rimmed carbonate platform model, whereas for the EPU, the presence of a carbonate ramp architecture, more or less directly connected to an IB domain, can be invoked already for the oldest outcropping strata.

ACKNOWLEDGEMENTS - We dedicate this work to the memory of the late Giuseppe Sirna, with whom we worked in Greece and who studied the rudist fauna cited in this paper. The manuscript greatly benefited from the critical reviews by J. Pignatti and A. Zelilidis. The fieldwork was financially supported by CNR-Istituto di Geologia Ambientale e Geoingegneria.

REFERENCES

Accordi G., Carbone F., Sirna G., 1987. Some affinities between the Ionian Islands and the Apulian Upper Cretaceous rudists facies. Memorie della Società Geologica Italiana 40, 163-173.

Accordi G., Carbone F., 1992. Lithofacies map of the Hellenide Pre-Apulian zone (Ionian Islands, Greece), with explanatory notes. Special Publication, Centro di Studio per la Geologia dell'Italia Centrale, CNR, Roma.

Accordi G., Carbone F., Pignatti J., 1998. Depositional history of a Paleogene carbonate ramp (Western Cephalonia, Ionian Islands, Greece). Geologica Romana 34, 131–205.

Accordi G., Carbone F., Di Carlo M., Pignatti J., 2014. Microfacies analysis of deep-water breccia clasts: a tool for interpreting shallow-vs. deep-ramp Paleogene sedimentation in Cephalonia and Zakynthos (Ionian Islands, Greece). Facies 60, 445-466.

Ahr W.M., 1973. The carbonate ramp - an alternative to the shelf model. Transactions of the Gulf Coast Association of Geological Societies 23, 221-225.

Argnani A., 2013. The influence of Mesozoic palaeogeography on the variations in structural style along the front of the Albanide thrust-and-fold belt. Italian Journal of Geosciences 132, 175-185.

Argnani A., Frugoni F., Cosi R., Ligi M., Favali P., 2001. Tectonics and seismicity of the ApulianRidge south of Salento peninsula (Southern Italy). Annali di Geofisica 44, 527-540.

Aubouin, J., 1957. Essai de correlations stratigraphiques en Grece occidentale. Bulletin de la Société Géologique de France 6, 281-304.

Aubouin J., 1959. Contribution à l'étude géologique de la Grèce septentrionale: le confins de l'Epire et de la Thessalie. Annales Géologiques des Pays Helléniques 10, 1-484.

Aubouin J., Dercourt J., 1962. Zone préapulienne, zone ionienne et zone du Gavrovo en Péloponnèse occidental. Bulletin de la Société Géologique de France 7, 785-794.

Aubouin J., Bonneau M., Davidson J., Leboulenger P., Matesco S., Zambetakis A., 1976. Esquisse structurale de l'arc égéen externe: des Dinarides aux Taurides. Bulletin de la Societé Géologique de France 7, 327-336.

Auroux C., Mascle J., Rossi S., 1984. Geologia del margine ionico dalle isole Strofadi a Corfù (Estremità settentrionale dell'arco ellenico). Memorie della Società Geologica Italiana 27, 267-286.

Bega. Z., 2013. Deep seated platform carbonate reservoirs as new hydrocarbon plays in the NW Albania-Montenegro segment of the Adriatic Region. American Association of Petroleum Geologists Conference, Barcelona April 8-10, 2013, Search and Discovery Article #10497.

Bernoulli D., Renz O., 1970. Jurassic carbonate facies and new ammonite faunas from western Greece. Eclogae Geologicae Helvetiae 63, 573-607.

Biju-Duval B., Dercourt J., Le Pichon X., 1977. From the Tethys ocean to the Mediterranean Seas: a plate tectonic model of the evolution of the western Alpine system. In: Biju-Duval B., Montadert I. (Eds.), International Symposium on the Structural History of the Mediterranean Basins. Paris, Editions Technip, 143-164.

Bizon G., 1967. Contribution à la connoissance des foraminifères planctoniques d'Epire et des Iles Ioniennes (Grèce occidentale) depuis la Paléogène supérieur jusqu'au Pliocène. Éditions Technip, Publications Institut Français du Pétrole, 1-44.

Bornovas J., 1964. Geological study of Leukas Island. Publications Institute for Geology and Subsurface Research 10, 142.

Bosellini A., 1989. Dynamics of Tethyan carbonate platforms. In: Crevello P.D., Wilson J.L., Sarg J.F., Read J.F. (Eds.), Controls on Carbonate Platform and Basin Development. SEPM (Society for Sedimentary Geology) Special Publication 44, 3-13.

Bosellini A., Morsilli M., Neri C., 1999a. Long-term event stratigraphy of the Apulia Platform margin (Upper Jurassic to Eocene, Gargano, southern Italy). Journal of Sedimentary

Research 69, 1241-1252.
Bosellini A., Bosellini F.R., Colalongo M.L., Parente M., Russo A., Vescogni A., 1999b. Stratigraphic architecture of the Salento coast from Capo d'Otranto to S. Maria di Leuca (Apulia, southern Italy). Rivista Italiana di Paleontologia e Stratigrafia 105, 397-416.
Bosellini F.R., Russo A., 1992. Stratigraphy and facies of an Oligocene fringing reef (Castro Limestone, Salento Peninsula, southern Italy). Facies 26, 145-165.
Bosellini F.R., Vescogni A., Budd A.F., Papazzoni C.A., 2021. High coral diversity is coupled with reef-building capacity during the Late Oligocene Warming Event (Castro Limestone, Salento Peninsula, S Italy). Rivista Italiana di Paleontologia e Stratigrafia 127, 515-538.
Bosence D., 2005. A genetic classification of carbonate platforms based on their basinal and tectonic settings in the Cenozoic. Sedimentary Geology 175, 49-72.
Bourli N., Pantopoulos G., Maravelis A.G., Zoumpoulis E., Iliopoulos G., Pomoni-Papaioannou F., Kostopoulou S., Zelilidis A., 2019. Late Cretaceous to early Eocene geological history of the eastern Ionian Basin, southwestern Greece: a sedimentological approach. Cretaceous Research 98, 47-71.
Bourli N., Iliopoulos G., Zelilidis A., 2022. Reassessing Depositional Conditions of the Pre-Apulian Zone Based on Synsedimentary Deformation Structures during Upper Paleocene to Lower Miocene Carbonate Sedimentation, from Paxoi and Anti-Paxoi Islands, Northwestern End of Greece. Minerals 12, 201.
British Petroleum Co. Ltd., 1971. The geological results of petroleum exploration in western Greece. Institute of Geology and Subsurface Research Publ. 10, 1-73.
Brooks M., Clews J.E., Melis N.S., Underhill J.R., 1988. Structural development of Neogene basins in western Greece. Basin Research 1, 129-138.
Burchette T., Wright V., 1992. Carbonate ramp depositional systems. Sedimentary Geology 79, 3-57.
Burgess P.M., Williams H.D., Wright V.P., Della Porta G., Granjeon D., 2011. Investigating Carbonate Platform Types: Multiple Controls and a Continuum of Geometries. Journal of Sedimentary Research 81, 18-37.
Butler R.W., 2009. Relationships between the Apennine thrust belt, foredeep and foreland revealed by marine seismic data, offshore Calabria. Bollettino della Società Geologica Italiana 128, 269-278.
Carayon V., Montadert L., Allard J., Fournillon A., 2017. Extension of the Apulian Platform in the Northwest Greek Offshore: paleogeography update and impact on hydrocarbon prospectivity- Greece. Conference Proceedings, 79th EAGE Conference and Exhibition 2017 - Workshops, Jun 2017, cp-519-00084.
Catalano R., Doglioni C., Merlini S., 2001. On the mesozoic Ionian basin. Geophysical Journal International 144, 49-64.
Cestari R., Sirna G., 1987. Rudist fauna in the Maastrichtian deposits of southern Salento (Southern Italy). Memorie della Società Geologica Italiana 40, 133-147.
Ciaranfi N., Pieri P., Ricchetti G., 1988. Note alla carta geologica delle Murge e del Salento (Puglia centromeridionale). Memorie della Società Geologica Italiana 41, 449-460.
Cicala M., Festa V., Sabato L., Tropeano M., Doglioni C., 2021. Interference between Apennines and Hellenides foreland basins around the Apulian swell (Italy and Greece). Marine and Petroleum Geology 133, 105300.
Civitelli G., Corda L., Mariotti G., 1987. Some data on the platform-basin evolution in the Preapulian (Paxos) zone in Kefallinia (Ionian Islands, western Greece). Memorie della Società Geologica Italiana 40, 359-374.
Clément C., Hirn A., Charvis P., Sachpazi M., Marnelis F., 2000. Seismic structure and the active Hellenic subduction in the Ionian islands. Tectonophysics 329, 141-156.
Danelian T., Tsikos H., Gardin S., Baudin F., Bellier J.P., Emmanuel L., 2004. Global and regional palaeoceanographic changes as recorded in the mid-Cretaceous (Aptian-Albian) sequence of the Ionian zone (NW Greece). Journal of the Geological Society 161, 703-709.
De Castro P., Drobne K., Gušić I., 1994. Fleuryana adriatica n. gen., n. sp. (Foraminiferida) from the Uppermost Maastrichtian of the Brač Island (Croatia) and some other localities on the Adriatic carbonate platform. Rasprave IV. Razreda SAZU, 35, 129-149.
Del Ben A., Geletti R., Mocnik A., 2010. Relation between recent tectonics and inherited Mesozoic structures of the central-southern Adria plate. Bollettino di Geofisica Teorica ed Applicata 51, 99-115.
Del Ben A., Mocnik A., Volpi V., Karvelis P., 2015. Old domains in the South Adria plate and their relationship with theWest Hellenic front. Journal of Geodynamics 89, 15-28.
de Mulder E.F.J., 1975. Microfauna and sedimentary-tectonic history of the Oligo-Miocene of the Ionian Islands and Western Epirus (Greece). Doctoral dissertation, Utrecht University.
Di Carlo M., Accordi G., Carbone F., Pignatti J., 2010. Biostratigraphic analysis of Paleogene lowstand wedge conglomerates of a tectonically active platform margin (Zakynthos Island, Greece). Journal of Mediterranean Earth Sciences 2, 31-92.
Dimopoulos N., Georgoulas E., Peridis S., Iliopoulos G., Bourli N., Antoniou P., Zelilidis A., 2019. Re-assessment of depositional conditions of Cretaceous deposits around the Amfilochia and Arta areas. Bulletin of the Geological Society of Greece 55, 241-259.
Duermeijer C.E., Krijgsman W., Langereis C.G., Meulenkamp J.E., Triantaphyllou M.V., Zachariasse W.J., 1999. A Late Pleistocene clockwise rotation phase of Zakynthos (Greece) and implications for the evolution of the western Aegean arc. Earth and Planetary Science Letters 173, 315-331.
Duermeijer C.E., Nyst M., Meijer P.T., Langereis C.G., Spakman W., 2000. Neogene evolution of the Aegean arc: paleomagnetic and geodetic evidence for a rapid and young rotation phase. Earth and Planetary Science Letters 176, 509-525.
Eberli G.P., Bernoulli D., Vecsei A., Sekti R., Grasmueck M., Lüdmann T., Anselmetti F.S., Mutti M., Della Porta G., 2019. A Cretaceous carbonate delta drift in the Montagna della Maiella, Italy. Sedimentology 66, 1266-1301.
Erba E., 2004. Calcareous nannofossils and Mesozoic oceanic anoxic events. Marine Micropaleontology 52, 85-106.

Festa A., Pini G.A., Dilek Y., Codegone G., Vezzani L., Ghisetti F., Lucente C.C., Ogata K., 2010. Peri-Adriatic mélanges and their evolution in the Tethyan realm. International Geology Review 52, 369-403.

Finetti I., Del Ben A., 1986. Geophysical study of the Tyrrhenian opening. Bollettino di Geofisica Teorica Applicata 28, 75-155.

Garfunkel Z., 2004. Origin of the Eastern Mediterranean basin: a reevaluation. Tectonophysics 391, 11-34.

Getsos K., Pomoni-Papaioannou F., Zelilidis A., 2007. A carbonate ramp evolution in the transition from the apulia platform to the ionian basin during early to late cretaceous (nw greece). Bulletin of the Geological Society of Greece 40, 53-63.

Giese P., Reutter K.J., 1978. Crustal and structural features of the margins of Adria microplate. In: Closs H., Roeder D. Schmidt K. (Eds.), Alps, Apennines, Hellenides. Schweizerbart, Stuttgart, 565-588.

Gonzalez-Bonorino G., 1996. Foreland sedimentation and plate interaction during closure of the Tethys Ocean (Tertiary; Hellenides; western continental Greece). Journal of Sedimentary Research 66, 1148-1155.

Graziano R., 1999. The Early Cretaceous drowning unconformities of the Apulia carbonate platform (Gargano Promontory, southern Italy): local fingerprints of global palaeoceanographic events. Terra Nova 11, 245-250.

Graziano R., 2001. The Cretaceous megabreccias of the Gargano Promontory (Apulia, southern Italy): their stratigraphic and genetic meaning in the evolutionary framework of the Apulia Carbonate Platform. Terra Nova 13, 110-116.

Graziano R., 2013. Sedimentology, biostratigraphy and event stratigraphy of the Early Aptian Oceanic Anoxic Event (OAE1A) in the Apulia Carbonate Platform Margin-Ionian Basin System (Gargano Promontory, southern Italy). Cretaceous Research 39, 78-111.

Handy M.R., Giese J., Schmid S.M., Pleuger J., Spakman W., Onuzi K., Ustaszewski K., 2019. Coupled crust-mantle response to slab tearing, bending, and rollback along the Dinaride-Hellenide orogen. Tectonics 38, 2803-2828.

Hirn A., Sachpazi M., Siliqi R., Mc Bride J., Marnelis F., Cernobori L., 1996. A traverse of the Ionian islands front with coincident normal incidence and wide-angle seismics. Tectonophysics 264, 35-49.

Hosseinpour M., Williams S., Seton M., Barnett-Moore N., Müller R.D., 2016. Tectonic evolution of Western Tethys from Jurassic to present day: coupling geological and geophysical data with seismic tomography models. International Geology Review 58, 1616-1645.

I.F.P.-I.G.R.S., 1966. Etude geologique de l'Epire (Grece nord-occidentale). Ed. Technip, Paris, pp. 306.

Ippolito F., D'Argenio B., Pescatore T., Scandone P., 1975. Structural-stratigraphic units and tectonic framework of Southern Apennines. In: Squyres C. (Ed.), Geology of Italy. Earth Science Society Libyan Arab Republic, Tripoli, 317-328.

Jenkins D., 1972. Structural development of western Greece. American Association of Petroleum Geologists Bulletin 56, 128-149.

Jenkyns H.C., 1999. Mesozoic anoxic events and palaeoclimate. Zentralblatt für Geologie und Paläontologie 1997, 943-949.

Jenkyns H.C., 2010. Geochemistry of oceanic anoxic events. Geochemistry, Geophysics, Geosystems 11, Q03004.

Kahle H.G., Müller M.V., Geiger A., Danuser G., Mueller S., Veis G., Billiris H., Paradissis D., 1995. The strain field in northwestern Greece and the Ionian Islands: results inferred from GPS measurements. Tectonophysics 249, 41-52.

Karakitsios V., 2013. Western Greece and Ionian Sea petroleum systems. American Association of Petroleum Geologists Bulletin 97, 1567-1595.

Karakitsios V., Tsikos H., Van Breugel Y., Bakopoulos I., Koletti L., 2004. Cretaceous oceanic anoxic events in western continental Greece. Bulletin of the Geological Society of Greece 36, 846-855.

Karakitsios V., Rigakis N., 2007. Evolution and petroleum potential of western Greece. Journal of Petroleum Geology 30, 197-218.

Kati M., Scholle P.A., 2008. The porosity evolution of Eocene limestones in the Preapulian zone, Zakynthos Island, western Greece. American Association of Petroleum Geologists, Search and Discovery Article #50060 (2007).

Kendall C.G.S.C., Schlager W., 1981. Carbonates and relative changes in sea level. Marine Geology 44, 181-212.

Kilias A., 2021. The Hellenides: A Multiphase Deformed Orogenic Belt, its Structural Architecture, Kinematics and Geotectonic Setting during the Alpine Orogeny: Compression vs Extension the Dynamic Peer for the Orogen Making. A Synthesis. Journal of Geology and Geoscience 5, 1-56.

Kilias A.A., Tranos M.D., Chaves F.M.A., 2002. Extensional collapse of the Hellenides: a review. Revista de la Sociedad Geológica de España 15, 129-139.

Kissel C., Laj C., Müller C., 1985. Tertiary geodynamical evolution of northwestern Greece: paleomagnetic results. Earth and Planetary Science Letters 72, 190-204.

Kissel C., Laj C., 1988. The Tertiary geodynamical evolution of the Aegean arc: a paleomagnetic reconstruction. Tectonophysics 146, 183-201.

Kokinou E., Vafidis A., 2003. Seismic modeling of marine reflection data from Ionian Sea. Journal of the Balkan Geophysical Society 6, 21-36.

Kokinou E., Kamberis E., Vafidis A., Monopolis D., Ananiadis G., Zelilidis A., 2005. Deep seismic reflection data from offshore western Greece: a new crustal model for the Ionian Sea. Journal of Petroleum Geology 28, 185-202.

Kondopoulou D., 2000. Palaeomagnetism in Greece: Cenozoic and Mesozoic components and their geodynamic implications. Tectonophysics 326, 131-151.

Kontakiotis G., Moforis L., Karakitsios V., Antonarakou A., 2020. Sedimentary facies analysis, reservoir characteristics and paleogeography significance of the early Jurassic to Eocene carbonates in Epirus (Ionian Zone, Western Greece). Journal of Marine Science and Engineering 8, 706.

Le Goff J., Reijmer J.J.G., Cerepi A., Loisy C., Swennen R., Heba G., Cavailhes T., De Graaf S., 2019. The dismantling of the Apulian carbonate platform during the late Campanian-early Maastrichtian in Albania. Cretaceous Research 96, 83-106.

Le Pichon X., Lallemant S.J., Chamot-Rooke N., Lemeur D., Pascal G., 2002. The Mediterranean Ridge backstop and the Hellenic nappes. Marine Geology 186, 111-125.

Louvari E., Kiratzi A.A., Papazachos B.C., 1999. The Cephalonia transform fault and its extension to western Lefkada Island (Greece). Tectonophysics 308, 223-236.

Luperto Sinni E., Borgomano J., 1989. Le Crétacé supérieur des Murges sud-orientales (Italie méridionale): stratigraphie et évolution des paléoenvironnements. Rivista Italiana di Paleontologia e Stratigrafia 95, 95-136.

Maesano F.E., Volpi V., Civile D., Basili R., Conti A., Tiberti M.M., Accettella D., Conte R., Zigur F., Rossi G., 2020. Active extension in a Foreland trapped between two contractional chains: the South Apulia Fault System (SAFS). Tectonics 39, e2020TC006116.

Mantovani E., Babbucci D., Albarello D., Mucciarelli M., 1990. Deformation pattern in the central Mediterranean and behavior of the African/Adriatic promontory. Tectonophysics 179, 63-79.

Mantovani E., Albarello D., Tamburelli C., Babbucci D., Viti M., 1997. Plate convergence, crustal delamination, extrusion tectonics and minimization of shortening work as main controlling factors of the recent Mediterranean deformation pattern. Annals of Geophysics 40, 611-643.

Márton E., Zampieri D., Ćosović V., Moro A., Drobne K., 2017. Apparent polar wander path for Adria extended by new Jurassic paleomagnetic results from its stable core: Tectonic implications. Tectonophysics 700-701, 1-18.

Meulenkamp J.E., Sissingh W., 2003. Tertiary palaeogeography and tectonostratigraphic evolution of the Northern and Southern Peri-Tethys platforms and the intermediate domains of the African-Eurasian convergent plate boundary zone. Palaeogeography, Palaeoclimatology, Palaeoecology 196, 209-228.

Mikellidou I., Triantaphyllou M., Patruno S., 2018. The upper Cretaceous palaeo-slope transition: an integrated calcareous nannofossil and microfacies approach (Ionian Islands, Preapulian Zone, Western Greece). Geophysical Research Abstracts 20, EGU2018-396, European Geosciences Union General Assembly, 2018.

Morelli C., Pisani M., Gantar C., 1975. Geophysical studies in the Aegean Sea and in the Eastern Mediterranean. Bollettino di Geofisica Teorica e Applicata 18, 127-167.

Morsilli M., Hairabian A., Borgomano J., Nardon S., Adams E., Bracco Gartner G., 2017. The Apulia Carbonate Platform-Gargano Promontory, Italy (Upper Jurassic-Eocene). American Association of Petroleum Geologists Bulletin 101, 523-531.

Nicolai C., Gambini R., 2007. Structural architecture of the Adria platform-and-basin system. Bollettino della Società Geologica Italiana 7, 21-37.

Özbakır A.D., Govers R., Fichtner A., 2020. The Kefalonia Transform Fault: A STEP fault in the making. Tectonophysics 787, 228471.

Papanikolaou D., 2013. Tectonostratigraphic models of the Alpine terranes and subduction history of the Hellenides. Tectonophysics 595, 1-24.

Parente M., Less G., 2019. Nummulitids, Lepidocyclinids and strontium isotope stratigraphy of the Porto Badisco Calcarenite (Salento Peninsula, southern Italy). Implications for the biostratigraphy and paleobiogeography of Oligocene larger benthic foraminifera. Italian Journal of Geosciences 138, 239-261.

Picha F.J., 2002. Late orogenic strike-slip faulting and escape tectonics in frontal Dinarides-Hellenides, Croatia, Yugoslavia, Albania, and Greece. American Association of Petroleum Geologists Bulletin 86, 1659-1671.

Pignatti J., Di Carlo M., Benedetti A., Bottino C., Briguglio A., Falconi M., Matteucci R., Perugini G., Ragusa M., 2008. SBZ 2-6 larger foraminiferal assemblages from the Apulian and Pre-Apulian domains. Atti Museo Civico di Storia Naturale di Trieste 53 (Suppl.), 131-146.

Pieri P., Sabato L., Tropeano M., 2004. Plio-Pleistocene stratigraphic and tectonic evolution of the foreland-foredeep-chain system in southern Italy. Memorie Descrittive della Carta Geologica Italiana 63, Field Trip Guide Book, 32nd Int. Geol. Congress, August 20-28, 2004, Firenze, 1, P35, pp. 44, Roma.

Pomar L., 2001. Types of carbonate platforms: a genetic approach. Basin Research 13, 313-334.

Pomar L., Kendall C., 2007. Architecture of carbonate platforms: a response to hydrodynamics and evolving ecology. In: Lukas J., Simo J.A. (Toni) (Eds.), Controls on carbonate platform and reef development. SEPM (Society for Sedimentary Geology), Special Publication 89, 187-216.

Pomar L., Mateu-Vicens G., Morsilli M., Brandano M., 2014. Carbonate ramp evolution during the late Oligocene (Chattian), Salento Peninsula, southern Italy. Palaeogeography, Palaeoclimatology, Palaeoecology 404, 109-132.

Pomar L., Baceta J.I., Hallock P., Mateu-Vicens G., Basso D., 2017. Reef building and carbonate production modes in the west-central Tethys during the Cenozoic. Marine and Petroleum Geology 83, 261-304.

Read J.F., 1982. Carbonate platforms of passive (extensional) continental margins: types, characteristics and evolution. Tectonophysics 81, 195-212.

Read J.F., 1985. Carbonate platform facies models. American Association of Petroleum Geologists Bulletin 69, 1-12.

Reijmer J.J., Palmieri P., Groen R., Floquet M., 2015. Calciturbidites and calcidebrites: Sea-level variations or tectonic processes? Sedimentary Geology 317, 53-70.

Renz C., Reichel M., 1945. Beiträge zur Stratigraphie und Paläontologie des ostmediterranen Jungpaläozoikums und dessen Einordnung im griechischen Gebirgssystem. 1. und II. Teil: Geologie und Stratigraphie. Eclogae Geologicae Helvetiae 38, 211-313.

Robertson A., Shallo M., 2000. Mesozoic-Tertiary tectonic evolution of Albania in its regional Eastern Mediterranean context. Tectonophysics 316, 197-254.

Roeder D., 1980. Geodynamics of the Alpine-Mediterranean system - a synthesis. Eclogae Geologicae Helvetiae 73, 353-377.

Rosenbaum G., Lister G.S., Duboz C., 2004. The Mesozoic and Cenozoic motion of Adria (central Mediterranean): a review of constraints and limitations. Geodinamica Acta 17, 125-139.

Rubert Y., Jati M., Loisy C., Cerepi A., Foto G., Muska K., 2012. Sedimentology of resedimented carbonates: Facies and geometrical characterisation of an upper Cretaceous calciturbidite system in Albania. Sedimentary Geology 257, 63-77.

Schlüter M., Steuber T., Parente M., 2008. Chronostratigraphy of Campanian-Maastrichtian platform carbonates and rudist associations of Salento (Apulia, Italy). Cretaceous Research 29, 100-114.

Spalluto L., 2012. Facies evolution and sequence chronostratigraphy of a “mid”-Cretaceous shallow-water carbonate succession of the Apulia Carbonate Platform from the northern Murge area (Apulia, southern Italy). Facies 58, 17-36.

Spalluto L., Caffau M., De Giorgio G., 2008. The upper Albian-Lower Cenomanian inner shelf carbonate succession of the Calcare di Bari Fm. from the Murge area (Apulia, southern Italy): lithostratigraphy, biostratigraphy and facies analysis. Rendiconti online della Società Geologica Italiana, Note Brevi 2, 181-186.

Stampfli G.M., Kozur H.W., 2006. Europe from the Variscan to the Alpine cycles. Geological Society, London 32, 57-82.

Stampfli G.M., Hochard C., 2009. Plate tectonics of the Alpine realm. In: Murphy J.B., Keppie J.D., Hynes A.J. (Eds.), Ancient Orogens and Modern Analogues. Geological Society, London, Special Publication 327, 89-111.

Steuber T., Parente M., Hagmaier M., Immenhauser A., Van Der Kooij B., Frijia G., 2006. Latest Maastrichtian species-rich rudist associations of the Apulian margin of Salento (S Italy) and the Ionian Islands (Greece). In: Scott R.W. (Ed.), Cretaceous Rudists and Carbonate Platforms: Environmental Feedback. SEPM (Society for Sedimentary Geology) Special Publication 87, 151-157.

Stow D., Smillie Z., 2020. Distinguishing between deep-water sediment facies: turbidites, contourites and hemipelagites. Geosciences 10, 68.

Tomassetti L., Benedetti A., Brandano M., 2016. Middle Eocene seagrass facies from Apennine carbonate platforms (Italy). Sedimentary Geology 335, 136-149.

Tropeano M., Sabato L., Pieri P., 2002. Filling and cannibalization of a foredeep: the Bradanic Trough, Southern Italy. In: Jones S.J., Frostick L.E. (Eds.), Sediment Flux to Basins: Causes, Controls and Consequences. Geological Society, London, Special Publications, 191, 55-79.

Tropeano M., Spalluto L., Moretti M., Pieri P., Sabato L., 2004. Depositi carbonatici infrapleistocenici di tipo foramol in sistemi di scarpata (Salento-Italia meridionale). Il Quaternario, Italian Journal of Quaternary Sciences 17, 537-546.

Underhill J., 1989. Late Cenozoic deformation of the Hellenide foreland, western Greece. Geological Society of America Bulletin 101, 613-634.

van Hinsbergen D.V., Van der Meer D.G., Zachariasse W.J., Meulenkamp J.E., 2006. Deformation of western Greece during Neogene clockwise rotation and collision with Apulia. International Journal of Earth Sciences 95, 463-490.

van Hinsbergen D.J., Schmid S.M., 2012. Map view restoration of Aegean–West Anatolian accretion and extension since the Eocene. Tectonics 31, TC5005.

van Hinsbergen D.J.J., Mensink M., Langereis C.G., Maffione M., Spalluto L., Tropeano M., Sabato L., 2014. Did Adria rotate relative to Africa? Solid Earth 5, 611-629.

Vlahović I., Tišljar J., Velić I., Matičec D., 2005. Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics. Palaeogeography, Palaeoclimatology, Palaeoecology 220, 333-360.

Williams H.D., Burgess P.M., Wright V.P., Della Porta G., Granjeon D., 2011. Investigating carbonate platform types: multiple controls and a continuum of geometries. Journal of Sedimentary Research 81, 18-37.

Wright V.P., Burchette T.P., 1998. Carbonate ramps: an introduction. In: Wright V.P., Burchette T.P. (Eds.), Carbonate Ramps. Geological Society, London, Special Publications, 149, 1-5.

Zelilidis A., Maravelis A.G., Tserolas P., Konstantopoulos P.A., 2015. An overview of the petroleum systems in the Ionian Zone, onshore NW Greece and Albania. Journal of Petroleum Geology 38, 331-348.

Zoumpoulis E., Pomoni-Papaioannou F., Zelilidis A., 2010. Studying in the Paxos Zone the carbonate depositional environment changes during Upper Cretaceous, in Sami area of Kefallinia Island, Greece. Bulletin of the Geological Society of Greece 43, 793-803.

Zoumpoulis E., Maravelis A.G., Iliopoulos G., Botziolis C., Zygouri V., Zelilidis A., 2022. Re-Evaluation of the Ionian Basin Evolution during the Late Cretaceous to Eocene (Aetoloakarnania Area, Western Greece). Geosciences 12, 106.