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RUDIST FACIES DISTRIBUTION IN THE LATE CRETACEOUS OF CILENTO AND WESTERN BASILICATA (SOUTHERN ITALY)

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Abstract. Rudist bivalve assemblages and biofacies spanning from the Cenomanian to the Maastrichtian age interval have been detected in ten selected fossiliferous localities of Cilento and western Basilicata (southern Apennines, southern Italy). Their distribution shows a lateral transition from inner platform with mono-oligospecific radiolitid assemblages of the late Turonian - Coniacian, to more open depositional settings with well diversified fauna of the Santonian-Maastrichtian passing from south-western to eastern Cilento. In western Basilicata, prevailing grain-supported sediments and well diversified caprinid assemblages are indicative of open shelf and margin depositional settings of early - middle Cenomanian age. Furthermore, stratigraphic data point out (1) the lack of the Santonian - Maastrichtian deposits toward south is referred to incipient emersion of this sector of the Apennine Carbonate Platform (ACP), (2) the overall biofacies distribution also has to be related to the setting of the ACP as regards the paleooceanic circulation during the Late Cretaceous and (3) the occurrence of "out of context" radiolitid beds at Raparo Mt., up to now referred as a klippe, could be regarded as a still open point to discussion concerning its paleogeographic attribution.

Riassunto. Sono state studiate le principali associazioni a bivalvi rudiste e le biofacies del Cenomaniano - Maastrichtiano che affiorano in dieci località fossilifere selezionate del Cilento e della Basilicata occidentale (Italia meridionale). La loro distribuzione documenta una transizione laterale da ambienti di piattaforma interna, caratterizzati da associazioni mono-oligospecifiche a radiolitidi del Turoniano superiore - Coniaciano, nel settore sud-occidentale del Cilento, ad ambienti di piattaforma aperta con associazioni faunistiche ben differenziate del Santoniano -Maastrichtiano nel settore orientale. In Basilicata occidentale la presenza di sedimenti grano-sostenuti con associazioni a caprinidi ben diversificate documentano ambienti di piattaforma aperta e di margine del Cenomaniano inferiore - medio. Inoltre, i dati stratigrafici hanno accertato che (1) l'assenza dei depositi del Santoniano - Maastrichtiano verso sud è riferibile ad una precoce emersione di questo settore della Piattaforma Carbonatica Appenninica (PCA), (2) la generale distribuzione delle biofacies deve essere riferita anche alla esposizione della PCA rispetto la circolazione paleooceanica e (3) il ritrovamento, nei dintorni del Monte Raparo, di biofacies a radiolitidi "fuori contesto" induce a discutere l'interpretazione paleogeografica di questa struttura, fino ad oggi considerata come klippe.

Introduction

In the Late Cretaceous, well diversified rudist bivalves flourished in diverse shallow water sedimentary settings along the peri-Tethys carbonate platforms (Dercourt et al. 2000; Philip 2003) forming the Mediterranean Seuil (Vrielynck et al. 1994; Gaetani et al. 2002) which today corresponds to the central Mediterranean area. In southern Italy, Mesozoic carbonate sequences crop out extensively along the Apennines (Fig. 1) and testify the prolonged existence of a large shallow-water paleogeographic domain until the Liassic tectonic pulses began to break the old Triassic platform into a series of elongate NW-SE trending carbonate platforms (Bosellini 2004; Parotto & Praturlon 2004; Patacca & Scandone 2007 and ref. therein). The related lithobiofacies were characterized, especially in Late Cretaceous times, by a large spreading of rudist communities in association with other mollusks (mainly nerineids, acteonids and bivalves) and subordinately with corals, stromatoporoids, echinoderms and other benthic taxa. In particular, complex lithosomes dominated by radiolitids, hippuritids, caprinids and, in a minor manner, solitary and colonial corals are well diffused in grain-supported substrate in more open environments under medium to high hydrodynamic regimes. Whereas sheet-like litho-

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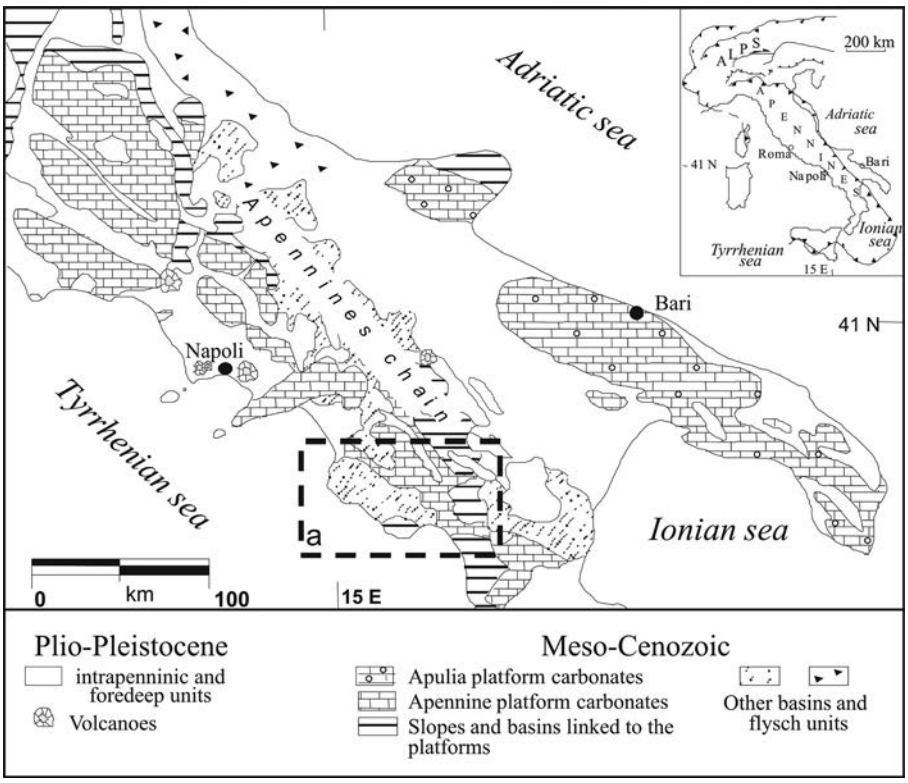

Fig. 1 - Schematic location map of Cilento and western Basilicata (inset a) in southern Apennines (Italy).

somes, made up of radiolitid mono-oligospecific associations embedded mainly in mud-supported substrate, appear to be limited in inner platform settings under moderate to low hydrodynamic conditions (Carannante et al. 1999, 2001, 2008; Simone et al. 2003).

This study is aimed to give detailed information regarding the distribution, composition and paleoenvironmental setting of the main rudist assemblages detected in Cilento and of the adjacent western Basilicata during the Late Cretaceous (Fig. 2), re-evaluating some of the information previously discussed (Laviano & Palladino 2002; Ruberti & Toscano 2002; Cestari & Pons 2004; Ruberti et al. 2007; Cestari 2009). Ten localities, six with original data, have been considered in order to delineate the depositional systems and the paleogeographic features of this part of the Apennine platform (Mostardini & Merlini 1986; Menardi-Noguera & Rea 2000) before to be involved in the thrust belt formation.

Geologic framework

Cilento and western Basilicata are mountainous areas located in the southern Apennines, facing the Tyrrhenian sea in the south and west, limited by the Sele river in the north and by the Agri valley in the east. The outcropping rocks are mainly represented by marine carbonate deposits belonging to the Alburno-Cervati stratigraphic-structural Unit (ACU) of the Apennine Carbonate Platform (ACP) that was involved in the complex kinematic evolution of the southern Apennine belt (Patacca & Scandone 2007 and ref. therein). The related slope deposits crop out on the eastern side of ACU and along the Marzano Mts. and Maddalena Mts. while Upper Cretaceous pelagic sediments of the Bulgheria Unit in southern Cilento have been referred to as the transition facies from the ACP to the adjacent basin (Carannante et al. 1999; Patacca & Scandone 2007). The ACU is composed of a thick carbonate succession that starts with dolomitic limestones, Late Triassic in age, followed by Jurassic-Cretaceous well bedded limestones showing, from bottom to top, mainly shallow marine settings. In western Cilento, among the facies representative of Upper Cretaceous inner platform and ramp environments (Cestari & Pons 2007; Ruberti et al. 2006) a plattenkalk rich in crustaceans and a platy-dolomite type horizons containing the remains of an Albian - Cenomanian continental paleoflora have been studied by Bravi & Garassino (1997) and by Bravi et al. (2004, 2010). Grain-supported sediments, Santonian-early Campanian in age, have been described in the eastern side of Cilento in the Alburni Mountains along the Madonna del Carmine road (Pappone 1990; Carannante et al. 1999; Cestari et al. 2001; Laviano & Palladino 2002). In the Geological mapping of the area the upper Albian - Cenomanian p.p. limestones are grouped in the Calcari a rudiste e orbitoline Formation while the Turonian - Campanian carbonates in the Calcari di Monte Varco Cervone and Calcare a Radiolitidi Formations (i.e. Sheets n. 503 “Vallo della Lucania” and n. 504 “Sala

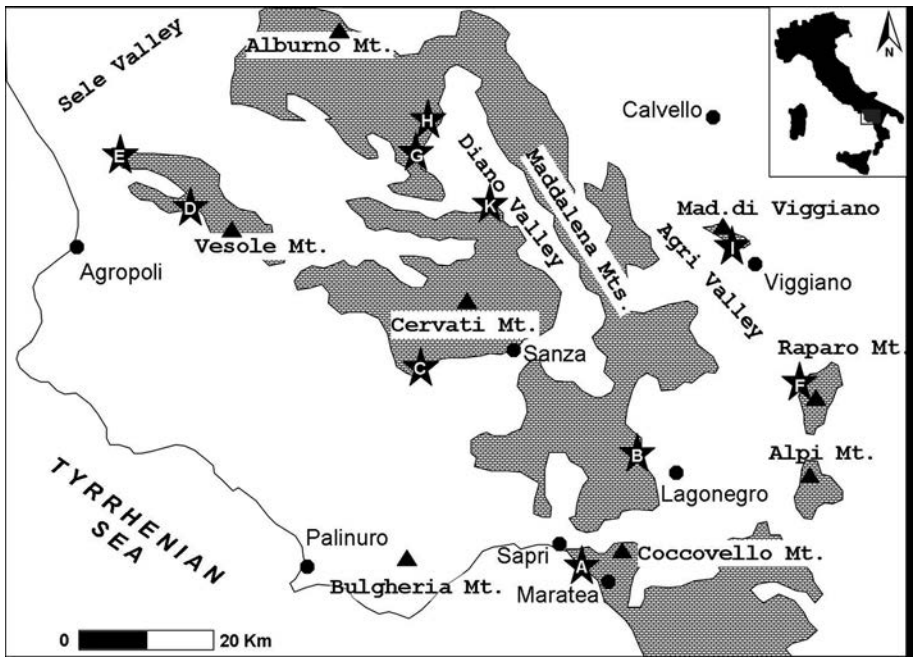

Fig. 2 - Location map of the studied carbonate successions. (A) Acquafredda, near Maratea. (B) Il Fortino, near Lagonegro. (C) La Raia del Pedale Mt. (D) Trentinara. (E) Capaccio Vecchio. (F) La Mandra, Raparo Mt. (G) Carmelo Mt., near Sant'Arsenio village. (H) Acqua dei Tassi, near San Pietro al Tanagro. (K) Teggiano. (I) Madonna di Viggiano Mt., near Viggiano.

Consilina" of the Carta Geologica d'Italia, scale 1:50,000). Tectono-eustatic pulses, starting from the Santonian up to the uppermost Palaeocene, caused the non deposition or emersion of the southern and western area of Cilento as reported in Cestari & Pons (2004). After the Late Cretaceous gap, a new transgressive phase gave rise to the Trentinara Formation of Late Palaeocene - Eocene age (Selli 1962) that sealed the Mesozoic paleomorphology composed by different-aged carbonates. From the Early Miocene, the tectonics progressively involved this sector of the Apennines with the consequent final drowning of the meso-cenozoic platform that was covered by siliciclastic deposits (Carannante et al. 1988). The Plio - Pleistocene evolution brought this area into an extensional tectonic regime with the development of transtensive faults that cut the original structure into homoclinal ridges (Critelli 1999 and ref. therein; Barchi et al. 2007; Cippitelli 2007). Paleomagnetic investigations indicate a general 60° post Middle-Late Miocene anticlockwise rotation of the Upper Cretaceous carbonate successions, together with large horizontal displacements (Gattacceca & Speranza 2007).

Rudist assemblage distribution and stratigraphy

Different rudist communities have been sampled and studied in successions and localities that, among others, show good outcrop conditions and abundant fossil content. For each of the sites the geographic GPS on WGS84 coordinates are given. On the basis of detailed field investigation and biofacies analyses, two main rudist-rich depositional settings belonging to different areas have been recognized (Fig. 2). From a biostratigraphic point of view, both micropalaeontological and rudist data (Cestari & Pons 2004; Ruberti et al. 2006) allowed to identify four depositional intervals (biozones in Chiocchini et al. 1994, 2009) (Fig. 3):

– CE interval (Cenomanian), between the *Orbitolina (Conicorbitolina) conica* and the *Chrysalidina gradata - Pseudolituonella reicheli* biozones;

– CO interval (Turonian - Coniacian), in the *Nezzazatinella* cf. *aegyptiaca - Nummoloculina* cf. *irregularis* pro parte and lower part of the *Accordiella conica - Rotorbinella scarsellai* biozones;

– SA interval (Late Coniacian - Santonian), in the *Accordiella conica - Rotorbinella scarsellai* biozone;

– CA interval (Late Santonian - Campanian), in the uppermost part of the *Accordiella conica - Rotorbinella scarsellai* and Discorbidae-Ostracoda *pro parte* biozones.

In these depositional intervals five main rudist assemblages have been detected:

(I) CE1 assemblage (early - middle Cenomanian), marked by the occurrence of caprinids [*Orthoptychus striatus* Futterer, *Sphaerucaprina forojuliensis* (Boehm)], ichthyosarcolitids such as *Ichthyosarcolites bicarinatus* (Gemmellaro) and radiolitids [*Eoradiolites liratus* (Conrad), *Sauvagesia sharpei* (Bayle)] together with benthic forams such as *Conicorbitolina conica* (d'Archiac), set in outer platform and margin bioclastic carbonates;

(II) CE2 assemblage (late Cenomanian), mainly marked by the occurrence of radiolitids [*Eoradiolites liratus* (Conrad) and *Sauvagesia nicaisei* (Coquand)], Ichthyosarcolitids (*Ichthyosarcolites* sp.) and the genus *Caprinula* [*Caprinula boissyi* (d'Orbigny), *Caprinula*

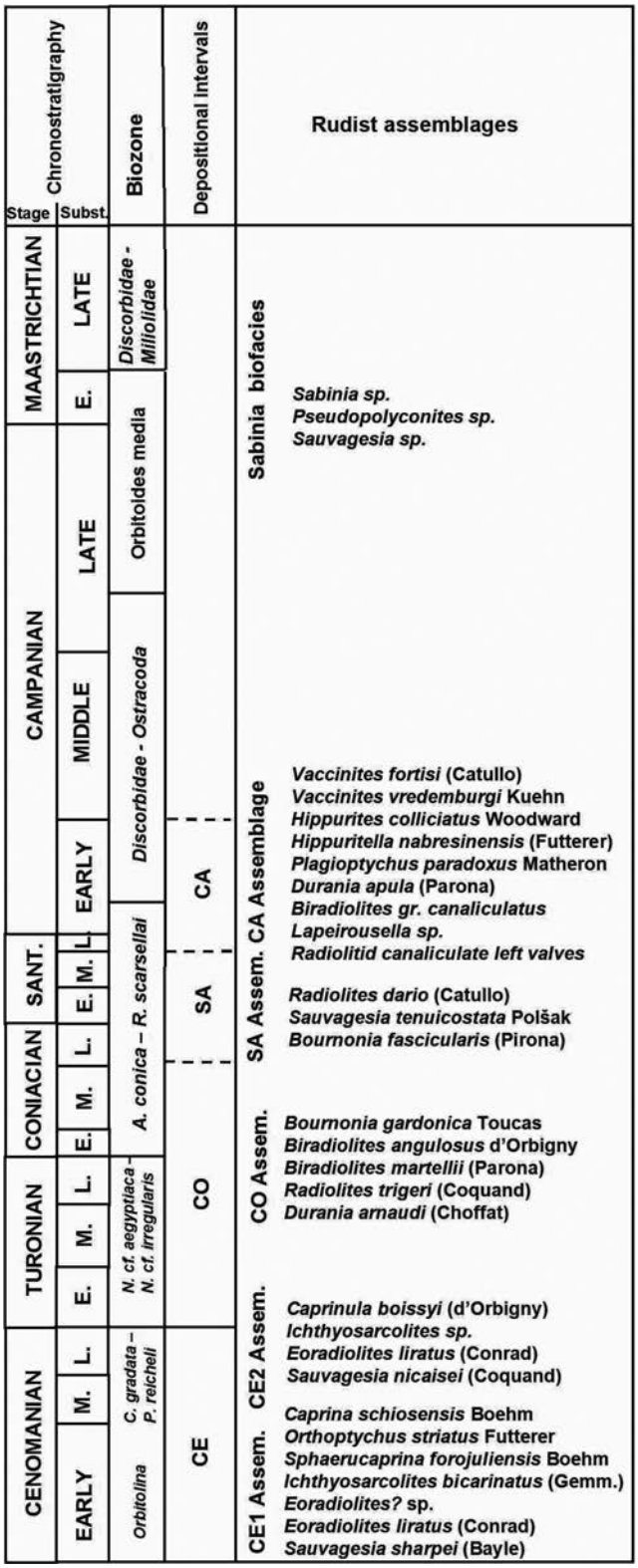

Fig. 3 - Biostratigraphic scheme for the Late Cretaceous of Cilento and western Basilicata with rudist assemblages (biozones from Chiocchini et al. 2009).

sp.] associated with non-rudist bivalves and gastropods [*Eunerinea ernesti* (Parona)]; this assemblage is mainly found in lagoonal settings both with muddy and grainy facies together with the benthic foram *Cisalveolina fraasi* (Gumbel);

(III) CO assemblage (late Turonian – Coniacian), marked by oligospecific communities of radiolitids [*Bournonia gardonica* Toucas (similar to *B. excavata* d'Orbigny), *Biradiolites angulosus* d'Orbigny, *Biradiolites martellii* (Parona), *Radiolites trigeri* (Coquand), *Durania arnaudi* (Choffat)] mainly found in mud-supported limestone of inner platform settings (micropaleontologic assemblage in Cestari & Pons, 2004);

(IV) SA assemblage (late Coniacian - Santonian), marked by oligospecific rudist communities with radiolitids [*Radiolites dario* (Catullo) formerly "*Gorjanovicia*"], *Sauvagesia tenuicostata* Polšak and *Bournonia fascicularis* (Pirona) set in mainly mud-supported limestone in inner platform settings;

(V) CA assemblage (latest Santonian - early Campanian), marked by well diversified rudist communities with very elongate hippuritids such as *Vaccinites fortisi* (Catullo), *Vaccinites vredenburgi* Kuehn together with radiolitids (*Sauvagesia* sp., *Lapeirousella* sp.) also with canaliculate left valve and specimens of *Plagioptychus paradoxus* Matheron, set in carbonates with grain-supported texture of outer platform and margin.

In addition, a late Campanian – Maastrichtian biofacies can be identified marked by biointraclastic and brecciated limestone with fragments of *Sabinia* sp., *Pseudopolyconites* sp., *Sauvagesia* sp. found in outer ramp and slope settings ("Pseudosaccaroide" limestone with benthic forams such as *Orbitoides media* (d'Archiac) and *Siderolites calcitrapoides* Lamarck; Scandone 1971).

Area 1 stratigraphy

In south-west Basilicata, a well exposed section with caprinids of the late Cenomanian is described in the lower part of the Acquafredda section (near Maratea) while in its upper part and at Il Fortino (near Lagonegro), fossil communities dominated by rudists often in oligospecific assemblages of the late Turonian - Coniacian mainly set in mud-supported limestone have been analyzed (Fig. 2, A-F). Other observations have been reappraised in south-west Cilento at La Raia del Pedale Mt., Trentinara and Capaccio Vecchio- sections where shallow water, well stratified micritic limestones crop out and in scattered outcrops on the western side of Raparo Mt. In this area three sections separated into three depositional intervals of Cenomanian – Santonian age have been considered:

- CE interval, characterized by massive bioclastic grainstones passing upward into packstones, partly bioturbated, with radiolitids and caprinids;

- CO interval, marked by cyclically-arranged carbonates with mud supported texture yielding mono- and oligospecific radiolitid communities of lagoonal to peritidal settings;

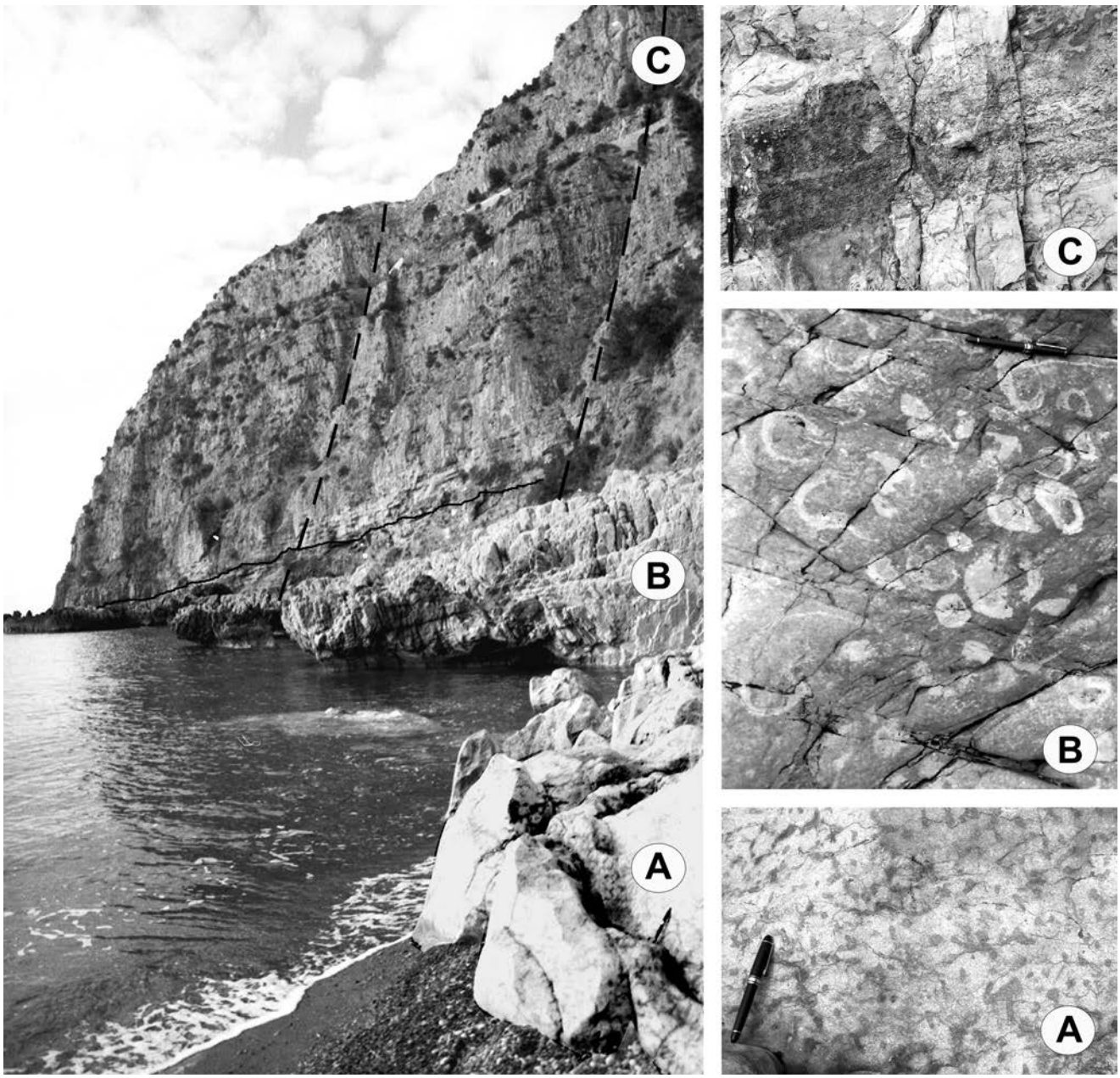

Fig. 4 - Acquafredda succession near Grotta del Sogno, Maratea. At the base (A) domichnia fossil traces *Thalassinoides* sp. overlain by middle-upper Cenomanian *Caprinula*-rich limestone (B) of the CE2 assemblage. At the top, along the road, reworked radiolitid fragments (C) with *Biradiolites angulosus* of the CO assemblage, late Turonian - Coniacian age. Continuous line: unconformity at the Cenomanian - Turonian boundary; shaded line: joints.

- SA interval, marked by radiolitids organized in clusters and thickets indicating lagoon to open lagoon facies that are frequently associated to high energy events (tempestites). This is nearly completely lacking in south Cilento while northwestward it passes into peritidal and supratidal dolomitic facies (e.g. at the Capaccio Vecchio succession).

Acquafredda section (Maratea). Coordinates: 40°02'21"N 15°39'53"E, 2 m s. l. A calcareous succession, approximately 150 m thick, has been studied (Fig. 4) along the national road n. 18, km 220-223.5, between Acquafredda and Torre dei Crivi localities, near Maratea village, and along the Acquafredda beach towards Grotta del Sogno. The succession spans from the Cenomanian to the Coniacian (CE and CO intervals) and is overlain paraconformably by the Upper Palaeogene carbonates of the Trentinara Fm. At its base, near the shore line and toward Grotta del Sogno, whitish muddy limestone, partly dolomitized, shows well preserved decapod burrows *Thalassinoides* and *Ophiomorpha*? (Fig. 4A) which are related to the bioturbated *Thalassinoides* limestones overlying the middle Cenomanian platy dolostone with vegetal remain reported at the Chianello Mt. (near the Vesole Mt.) by Bravi et al. (2004). According to Parente et al. (2007) these bioturbarted intervals

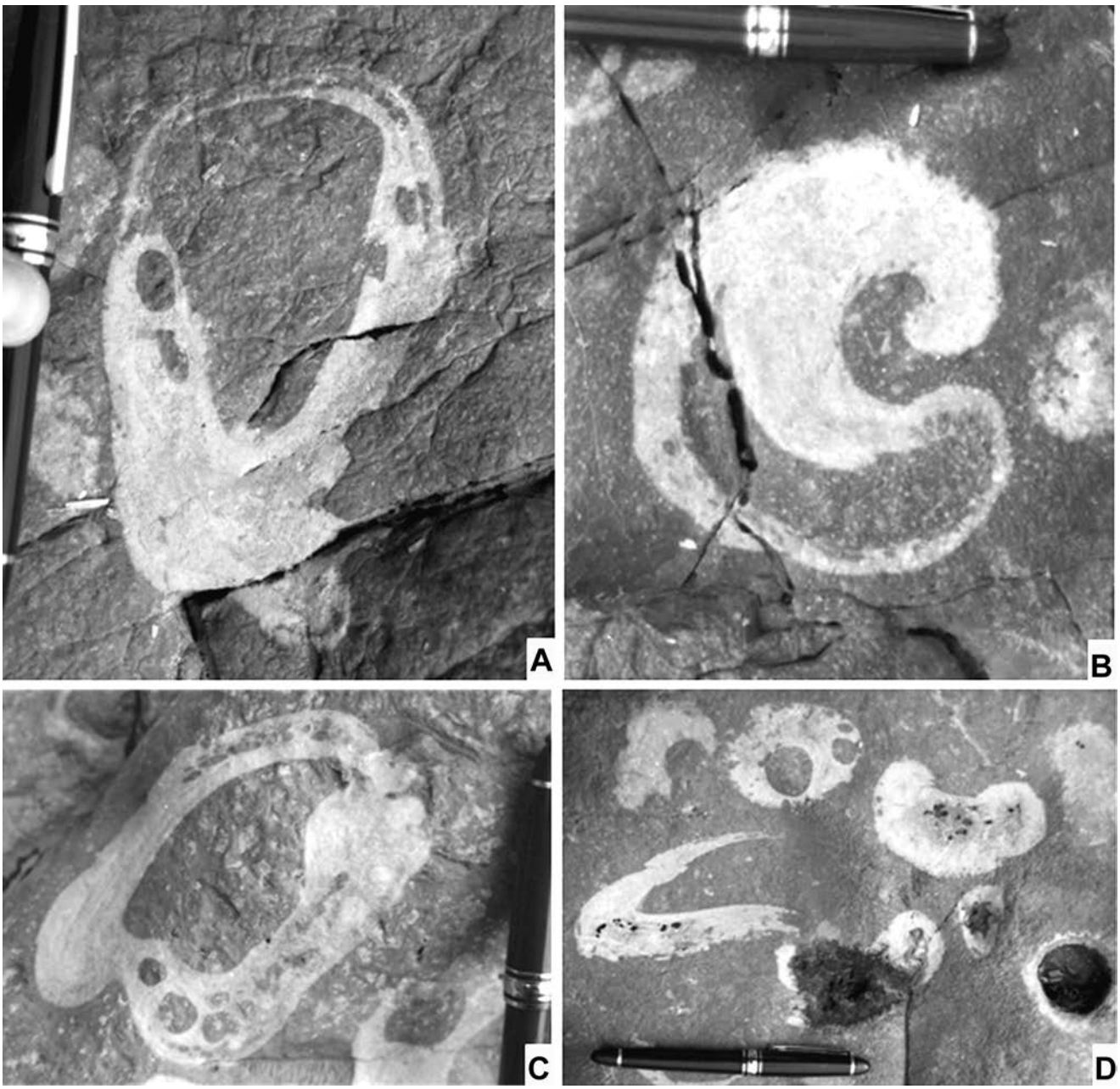

Fig. 5 - CE2 assemblage (Late Cenomanian) in fine bioclastic limestone along the near-shore at Acquafredda, Maratea. (A) Radial, partly oblique section of both the valves of a small *Caprinula* sp. specimen. The shell is marked by white calcite, substituting the original thick inner shell layer made of aragonite. (B) Tangential section of the spirally enrolled upper valve of a *Caprinula* cf. *boissyi*. (C) Transverse-oblique section of part of the fixed valve of *Caprinula* cf. *boissyi* showing accessory cavities. (D) Bouquet of isolate specimens of caprinids (*Caprinula* sp.) and radiolitids (*Eoradiolites* sp., right corner) seen from above.

represent a marker level that can be regionally correlated over a large part of the Campania-Lucania Apennines and coincides with the upper Cenomanian *Cisalveolina fraasi* level (De Castro 1983; Parente & Iannace 2003). These sediments are overlain by greyish, mainly mud-supported carbonates with a well diversified rudist assemblage in fine-grained, dark greyish limestone (Fig. 4B). The rudist shells are made of white calcite, substituting the original aragonite, that contrasts with the greyish matrix. They are usually small sized (Fig. 5A), often spyrogyrate (Fig. 5B) with canals in both the valves and are referred to *Caprinula* sp. and *Caprinula* cf. *boissyi* (d'Orbigny) (Fig. 5C-D). In association isolated specimens and small bouquets of radiolitids such as *Sauvagesia* cf. *sharpei* (Bayle) (Fig. 5E) and requienids (*Apricardia* sp.) (Fig. 5F) have been found. The assemblage is assigned to the late Cenomanian due to the occurrence of *Caprinula* beds together with the benthic foram *Cisalveolina fraasi* (Gümbel) (CE2 assemblage). Stratigraphically above, a carbonate breccia with green marly matrix marks a major unconformity at the end of the Cenomanian. Upward, the succession

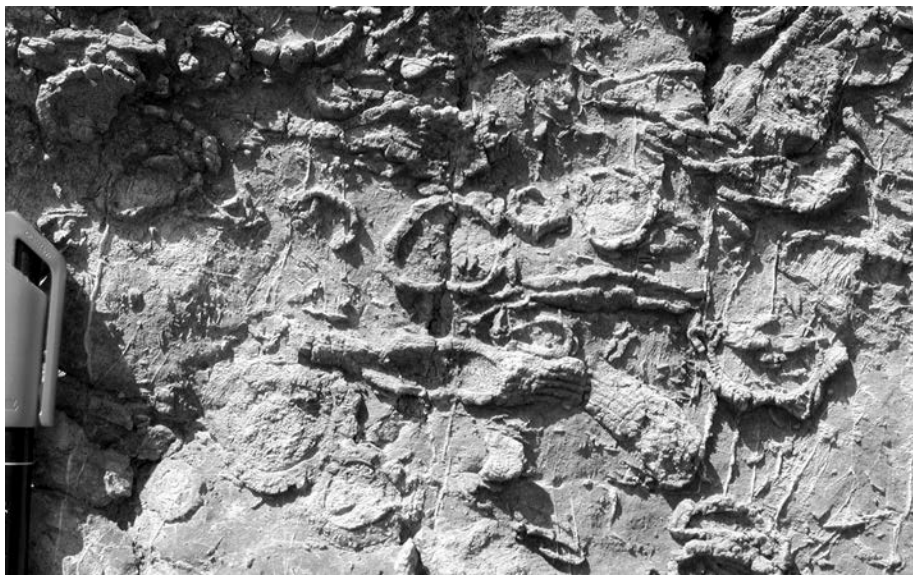

Fig. 6 - Parautochthonous accumulation of elongate right valves of *Radiolites trigeri* in muddy limestone, part of a possible tidal channel system. CO assemblage (late Turonian - Coniacian) Il Fortino, west of Lagonegro.

(about 80 m thick) shows dark grey, well stratified limestone, partly laminated; it is visible along the national road n. 18 (Fig. 4C). Radiolitid shell concentrations are observable, the assemblage consists of reworked shells of *Biradiolites angulosus* d'Orbigny and *Radiolites trigeri* (Coquand) that are attributed to the late Turonian - Coniacian (CO assemblage). At the top of the succession, the Paleogene Trentinara Fm. cuts paraconformably the Upper Cretaceous succession.

Il Fortino (Lagonegro). Coordinates: 40°09'16"N 15°41'32"E, 746 m s.l. Observations have been made near Buviero Mt. where a 50 m thick succession has been analyzed along the provincial road n. 349, 2.2 km from Il Fortino locality, NW from Lagonegro village, underlying the Trentinara Fm. (at Juncolo Mt.). The base of the succession is marked by well stratified dark grey limestone, partly dolomitized, with emersion surfaces. The depositional environment is referred to shallow subtidal facies with mud-supported texture bearing radiolitids and scattered requienids. In the lower part of the succession, the presence of small bouquets and clusters of *Biradiolites angulosus* d'Orbigny and of *Radiolites trigeri* (Coquand) (Fig. 6A) is recorded in association with small bouquets of *Sauvagesia* sp. and isolate specimens of the requienid *Apricardia* sp. (Fig. 6B). The assemblage, distinctive of shallow subtidal conditions of lagoon environments with low to medium hydrodynamic regime, indicates a late Turonian – Coniacian age (CO assemblage). The upper part of the succession is marked by fine grainstone with small benthic foraminifera and by light to dark gray laminated carbonates with reworked radiolitid shell lags and channelized geometries (Fig. 7) that have been inferred to inter-supratidal environments, possibly a tidal system.

La Raia del Pedale Mt. Coordinates: 40°13'50"N 15°26'33"E, 780 m s.l. The CO interval is well exposed along km 18-20 of the Rofrano-Sanza provincial road n.18 (Fig. 2C). Here mono- and oligotypical bouquets and clusters, composed of radiolitid species, are embedded in well stratified limestone for a thickness of 150 m. The assemblage is composed of *Biradiolites angulosus* d'Orbigny, *Biradiolites martellii* (Parona), *Radiolites trigeri* (Coquand), *Durania arnaudi* (Choffat) and *Sauvagesia* sp. of the CO assemblage. Scarce *Bournonia fascicularis* (Pirona) and *Radiolites* sp. fragments, referred to the SA assemblage, have been found above, near the Palaeocene unconformity.

Trentinara. Coordinates: 40°23'35"N 15°08'18"E, 445 m s.l. The post-Cenomanian succession is 400 m thick and is well exposed between Giungano and Trentinara villages and between Madonna of Loreto and Cretella localities (Fig. 2D) (CO and SA intervals). Rudist limestones are characterized by two radiolitid assemblages: the first one is marked by *Biradiolites angulosus* d'Orbigny, *Radiolites trigeri* (Coquand), *Durania arnaudi* (Choffat), *Biradiolites martelli* (Parona) and *Bournonia gardonica* (Toucas) with this last very similar to *B. excavata* d'Orbigny, of late Turonian – Coniacian age (CO assemblage). The second one, visible above, is constituted of radiolitid assemblages marked by an outstanding number of specimens showing high phenotypic variability, forming sheet-like bioconstructions, and is marked by *Radiolites dario* (Catullo) (Fig. 8A-B), *Bournonia fascicularis* (Pirona) (Fig. 8C-D), *Sauvagesia tenuicostata* (Polšak) and scarce reworked hippuritids (*Vaccinites* cf. *sulcatus*) found in high energy layers (tempestites) of Santonian age (SA assemblage). *Radiolites dario* (Catullo, 1834), is a taxon characterized by

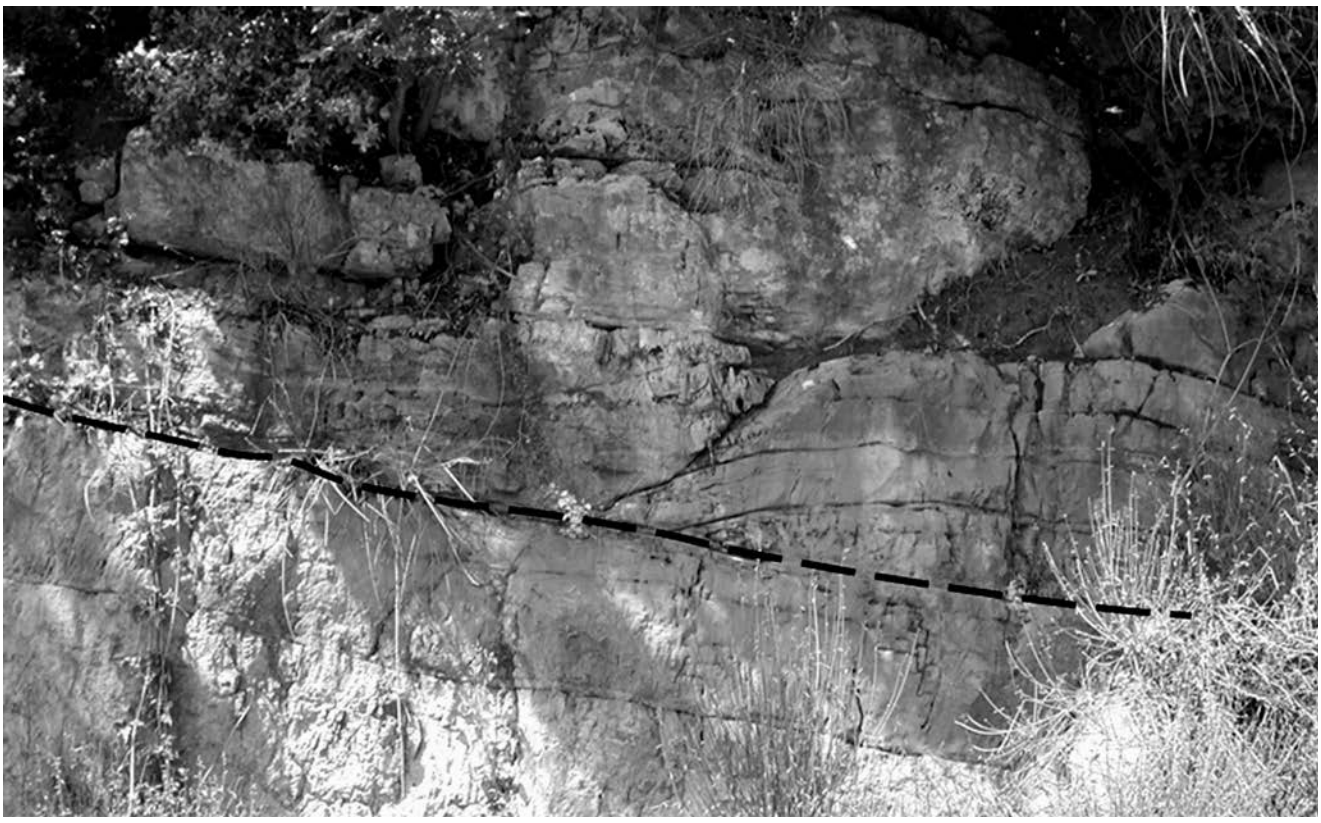

Fig. 7 - Well stratified mud-supported limestone with radiolitid beds (below the dashed line) passing upward into fine grainstone with foraminifera showing channellized geometry. Il Fortino, west of Lagonegro.

eco-phenotypic variability and has been considered to have priority on "*Gorjanovicia*" (in Cestari, 1992). Instead, Fenerci-Masse et al. (2011) consider the type species *G. costata* Polšak, 1967 as a younger synonym of "*Radiolites*" *endrissi* Boehm, 1927 by taking into account a quantitative approach and thus validating the genus *Gorjanovicia*.

Capaccio Vecchio. Coordinates: 40°26'31"N 15°03'17"E, 180 m s. l. Near the old village (Fig. 2E), rudists, concentrated in decimetre-thick layers, characterize the post-Cenomanian, nearly 350 m thick, carbonate succession referable to the CO interval. Radiolitids and subordinate requienids occur as solitary specimens and/or in bouquets, often toppled. Radiolitids are represented by *Radiolites trigeri* (Coquand), *Durania arnaudi* (Choffat), *Biradiolites martellii* (Parona) *Sauvagesia* sp., and small clusters of *Biradiolites angulosus* d'Orbigny. This assemblage is indicative of late Turonian – Coniacian age (CO assemblage). Going upward, an increasing of laminated facies, with thinner beds (20-30 cm thick) is observable. Here monospecific radiolitid layers, dominated by small bouquets of in situ *Bournonia gardonica* Toucas (similar to *B. excavata* d'Orbigny) and scattered requienids, can be recognized. In the upper part of the succession dolomitic limestone showing emersion-related features with some root moulds is prevalent, indicating a general shallowing trend. Above, the Paleocene Trentinara Fm. cuts paraconformably into the Cretaceous succession.

La Mandra (Raparo Mt.). Coordinates: 40°12'20"N 15°58'35"E, 1680 m s. l. Scattered carbonate outcrops along the western side of the Raparo Mt. have been studied (Fig. 2F). The succession is nearly 100 m thick, dipping nearly 10° east and marked by greyish, well bedded limestone with prevalent mud-supported texture, bearing few fossiliferous beds. Along the path near La Mandra locality, the rudist fauna is scarce and marked by a paucispecific oligotypic radiolitid assemblage composed of isolate small specimens of *Bournonia fascicularis* (Pirona) and by few clusters of *Radiolites dario* (Catullo) with elongate shells up to 30 cm in mud-supported limestone. Bioclastic beds with *Sauvagesia tenuicostata* Polšak (Fig. 9) and other radiolitid shell fragments are interbedded, testifying high energy events such as storm layers. The assemblage is ascribed to the late Coniacian - Santonian (SA assemblage). The base of the succession has been reported as pertaining to the *Cuneolina camposaurii* Cenozone, Cenomanian in age; it is followed by the *C. pavonia parva* Cenozone and by the *C. pavonia parva* and *D. schlumbergeri* Cenozone, early Senonian in age (Sartoni & Crescenti 1962). This succession represents the easternmost out-

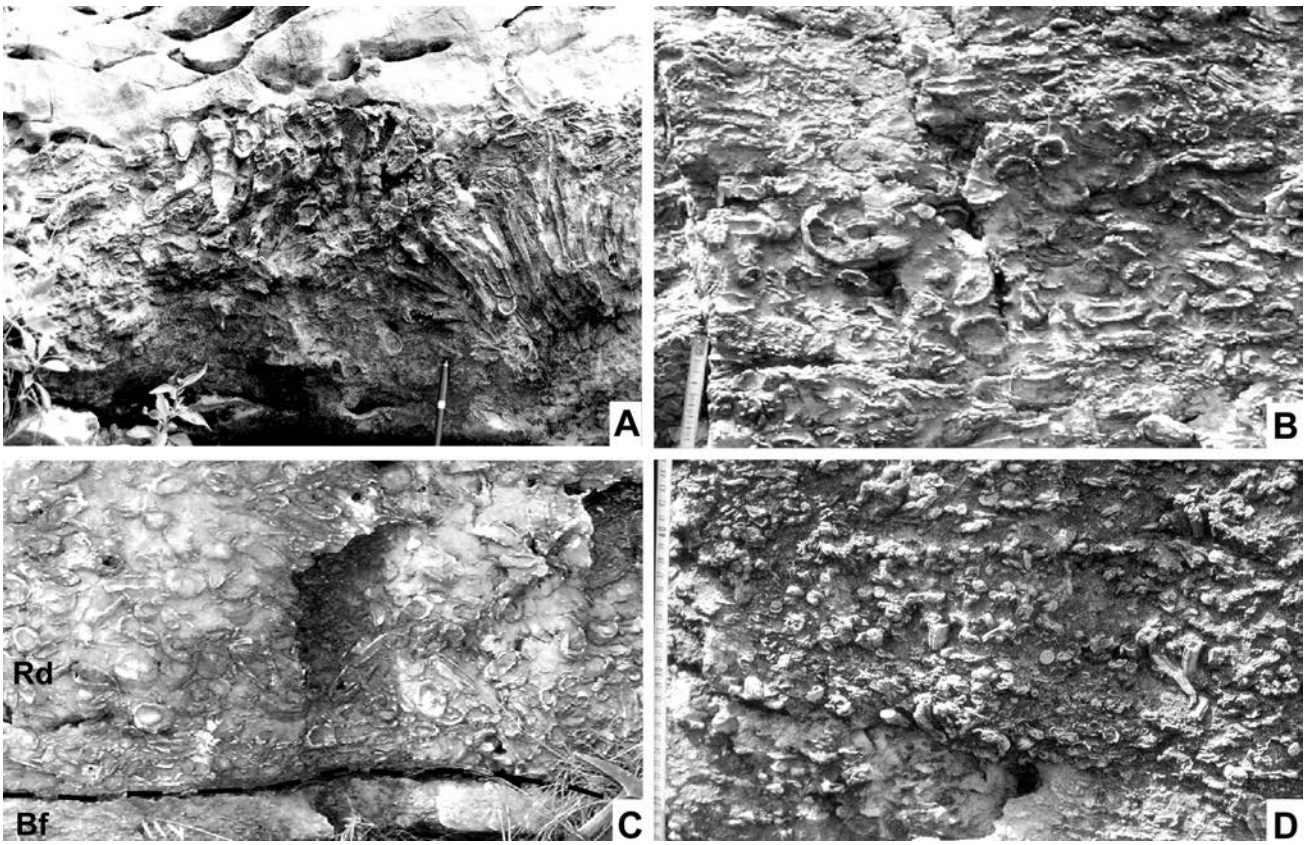

Fig. 8 - SA assemblage in inner platform carbonates of Santonian age along the Vesole Mt.-La Raia del Pedale Mt. carbonate ridge. (A) *Radiolites dario* monospecific cluster, part of a sheet-like lithosome. Madonna di Loreto, Trentinara. (B) Parautochtonous radiolitid shell bed with *R. dario* and *Sauvagesia tenuicostata*. Madonna di Loreto, Trentinara. (C) *Bournonia fascicularis* bed (Bf) overlain by *R. dario* shell accumulation (Rd). Madonna di Loreto, Trentinara. (D) *B. fascicularis* thicket composed of several generations of small-sized specimens. Madonna di Loreto, Trentinara.

Fig. 9 - Bioclastic layer with two specimens of *Sauvagesia tenuicostata* showing well stacked growth laminae and cellular structure. La Mandra, Raparo Mt.

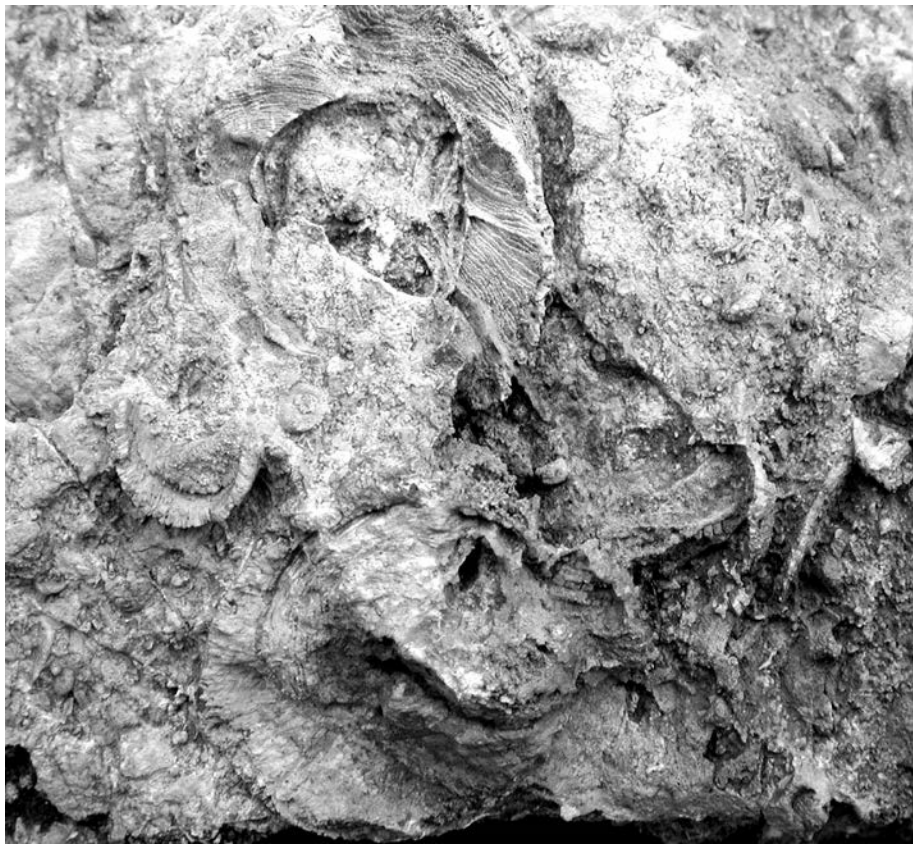

Fig. 10 - CE1 assemblages (early-middle Cenomanian) in bioclastic limestone at Acqua dei Tassi, San Pietro al Tanagro. (A) *Eoradiolites?* sp. bouquet of elongate specimens, tabulae can be observed in radial section as well as the transverse section of a right valve (RV). (B) *Eoradiolites liratus* in association with nerineids, middle part of the succession. (C) Tangential section of *Sphaerucaprina* left valve showing canals filled by vadose cements. Upper part of the succession.

crop of carbonates with post-Cenomanian rudists; up to now it is thought to pertain to the Apennine Carbonate Platform (Carbone et al. 1991; Nicolai & Gambini 2007) even if similarities have been found which relate this succession to those cropping out in the Murge area (i.e. the Apulia Platform) where well bedded limestone with prevalent mud-supported texture, bearing radiolitids such as *Bournonia*, *Radiolites* and *Sauvagesia* are well described in the Altamura Fm. (Laviano 1984; Luperto Sinni & Borgomano 1994; Cestari & Laviano 2006). Rudist assemblages of this succession are set in an isolated position if compared to other assemblages of the ACP and far from a shelf edge complex. Therefore this area could be ascribed to a different palaeogeographic domain similar to that of the adjacent Alpi Mt. (Apulia platform).

Area 2 stratigraphy (eastern Cilento and western Basilicata)

This area is marked by well diversified rudist communities, mainly set in bioclastic and biointraclastic limestone (Fig. 2G-I). These have been studied along the side of the Alburno - Cervati Unit facing the Diano Valley at Carmelo Mt. (near the Sant'Arsenio village), along the road toward Acqua dei Tassi locality (near San Pietro al Tanagro village) and near Teggiano village. Other observations have been made along the Madonna di Viggiano Mt. (near Viggiano village).

Along the ridge of the Alburni Mts. to part of the Cervati Mt., rich and highly diversified rudist assemblages in grain-supported sediments have been studied. Observations have been made in four sections where bioclastic limestones referable to the CE, and CA intervals are well exposed, while the mud-supported carbonates of the CO and SA intervals are lacking.

Acqua Dei Tassi (San Pietro al Tanagro). Coordinates: 40°27'41"N 15°28'07", 780 m s. l. Near the village, along the road that leads to Acqua dei Tassi locality, a 100 m thick carbonate sedimentary succession is exposed (Fig. 2H). It is composed of shallow water limestones rich in molluscs among which rudists, ostreids and nerineids dominate. The basal and middle portion of the succession (70 m thick) shows a lithobiofacies association characterized by grain-supported bioclastic limestones whose constituents are essentially

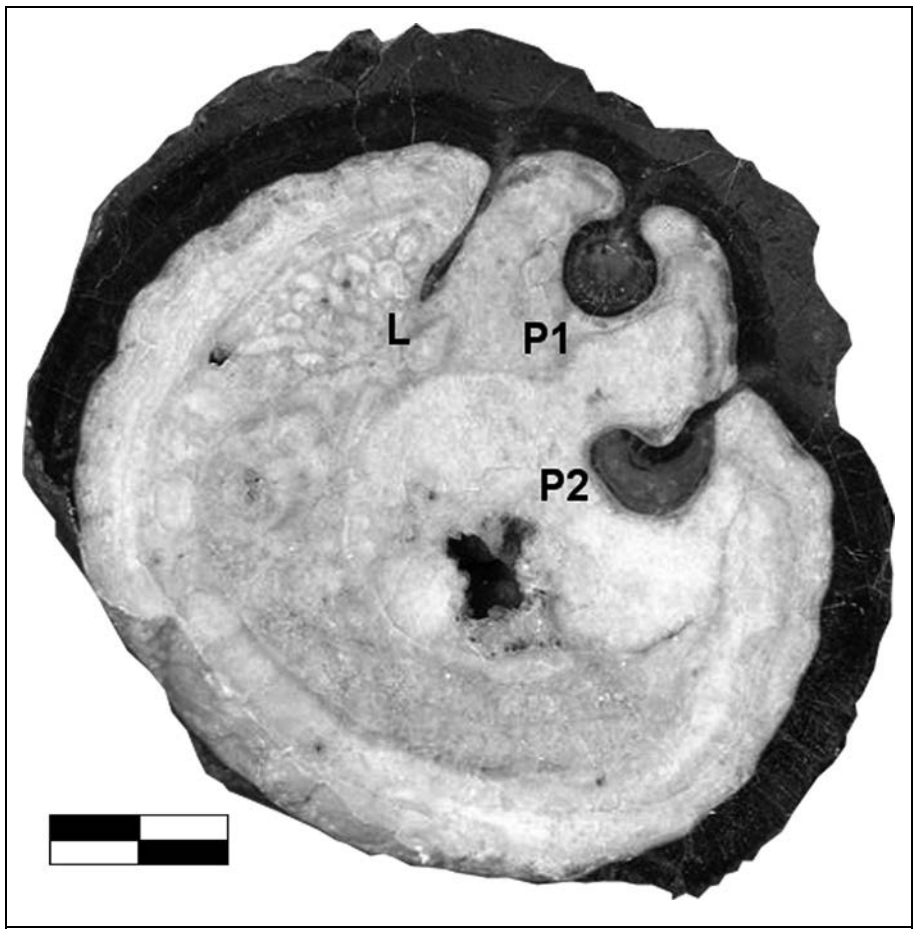

Fig. 11 - *Vaccinites fortisi* transverse section of the right valve with well developed ligament crest (L) and pillars (P1 and P2). Santonian - early Campanian, Carmelo Mt. near Sant'Arsenio, lower part of the succession. Sample I-437.

mollusc fragments, organized in layers of variable thickness comprised between 50 cm to a few meters. Basal erosive surfaces and granular gradation characterize some strata. Mollusc floatstones show solitary and clustered rudists mostly *Eoradiolites?* sp. (Fig. 10A), *Eoradiolites liratus* (Conrad) (Fig. 10B) and abundant loosely-packed *Chondrodonta* and nerineids among which specimens of *Eunerinea ernesti* (Parona) have been recognized together with benthic forams such as *Conicorbitolina conica* (d'Archiac) (CE1 assemblage). In the upper part of the succession (nearly 50 m thick) the organization of the lithofacies consists of interbedded grain-supported sediments. At different levels skeletal grainstone-rudstone beds are characterized by erosive surfaces, grading and grain orientation. The fossil community changes with respect to that previously described with an increase of rudists which, more diversified, become dominant. Moreover, they represent the main source of skeletal material that formed mobile sandy bodies. Large caprinids typified by *Sphaerucaprina* sp. (Fig. 10C), *Orthoptychus striatus* Futterer, *Schiosa* sp., radiolitids among which *Sauvagesia sharpei* (Bayle), *Sauvagesia nicasei* (Coquand), and ichthyosarcolitids such as *Ichthyosarcolites bicarinatus* (Gemmellaro) have been found. These limestones were deposited within a shoal environment characterized by a relatively high-energy regime. The macrofossil assemblage indicates an early-middle Cenomanian age, confirmed by the presence of benthic forams such as *C. conica* in the lower part of the succession and by *Pseudorhapydionina dubia* (De Castro) in the uppermost part.

Carmelo Mt. (Sant'Arsenio). Coordinates: 40°29' 11"N 15°27'23", 1065 m s. l. A nearly 200 m thick carbonate succession is exposed along the roadcut leading from the village to Carmelo Mt. The lowermost portion of the succession (15 m thick) shows rudstone-grainstone repetitions with sharp erosive basal surfaces. Among fossils, gastropods, radiolitids and isolated *Vaccinites fortisi* (Catullo) are diffused, referable to the SA interval. Proceeding upward, the succession (about 100 m thick) shows well-bedded alternations of mollusc floatstones with bioclastic packstone-grainstones and subordinately rudstones. Beds are typically tabular ranging in thickness from 10 cm to 150 cm. The general fossil content of floatstones is constituted of radiolitids and hippuritids either solitary or forming clusters, i.e. large specimens of *Vaccinites fortisi* (Fig. 11), *Paronella ostunensis* Laviano (Fig. 12A), *Lapeirousella* sp. (Fig. 12B) and plagioptychids such as *Plagioptychus paradoxus* Matheron. A progressive thickening upward trend of beds has been observed. In the uppermost por-

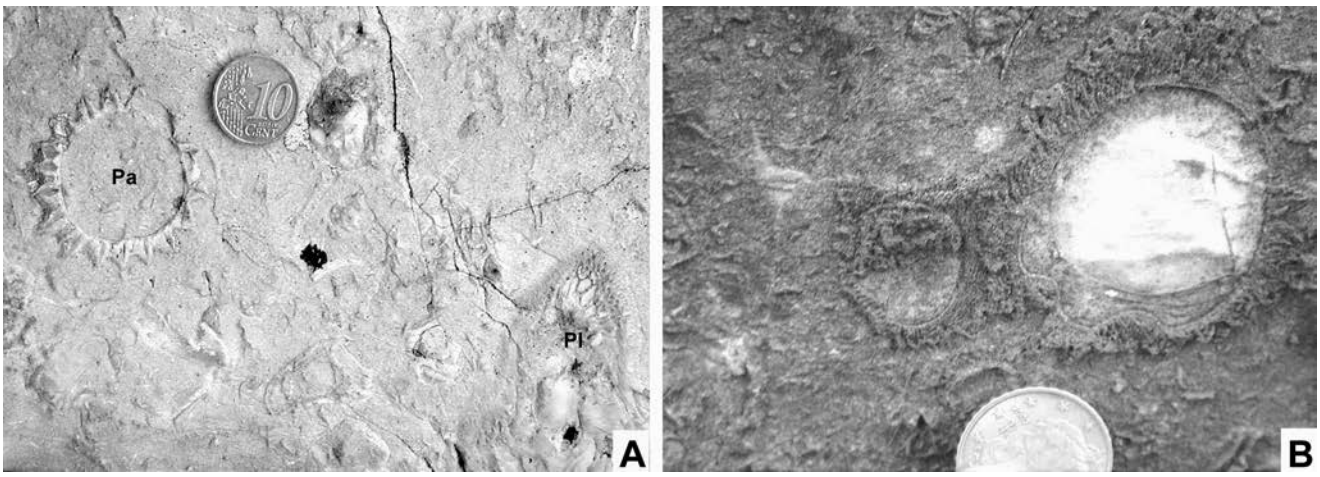

Fig. 12 - CA assemblage (late Santonian - early Campanian) in bioclastic limestone at Madonna del Carmine succession, near Sant'Arsenio. (A) Slender elongate radiolitid (*Paronella ostunensis*), transverse section of the right valve (Pa) associated with *Plagioptychus paradoxus* Matheron (Pl). Middle part of the succession. (B) *Lapeirousella* sp. transverse section of two right valves. Pseudopillars (Ps) can be observed in the cellular outer shell layer. Middle part of the succession.

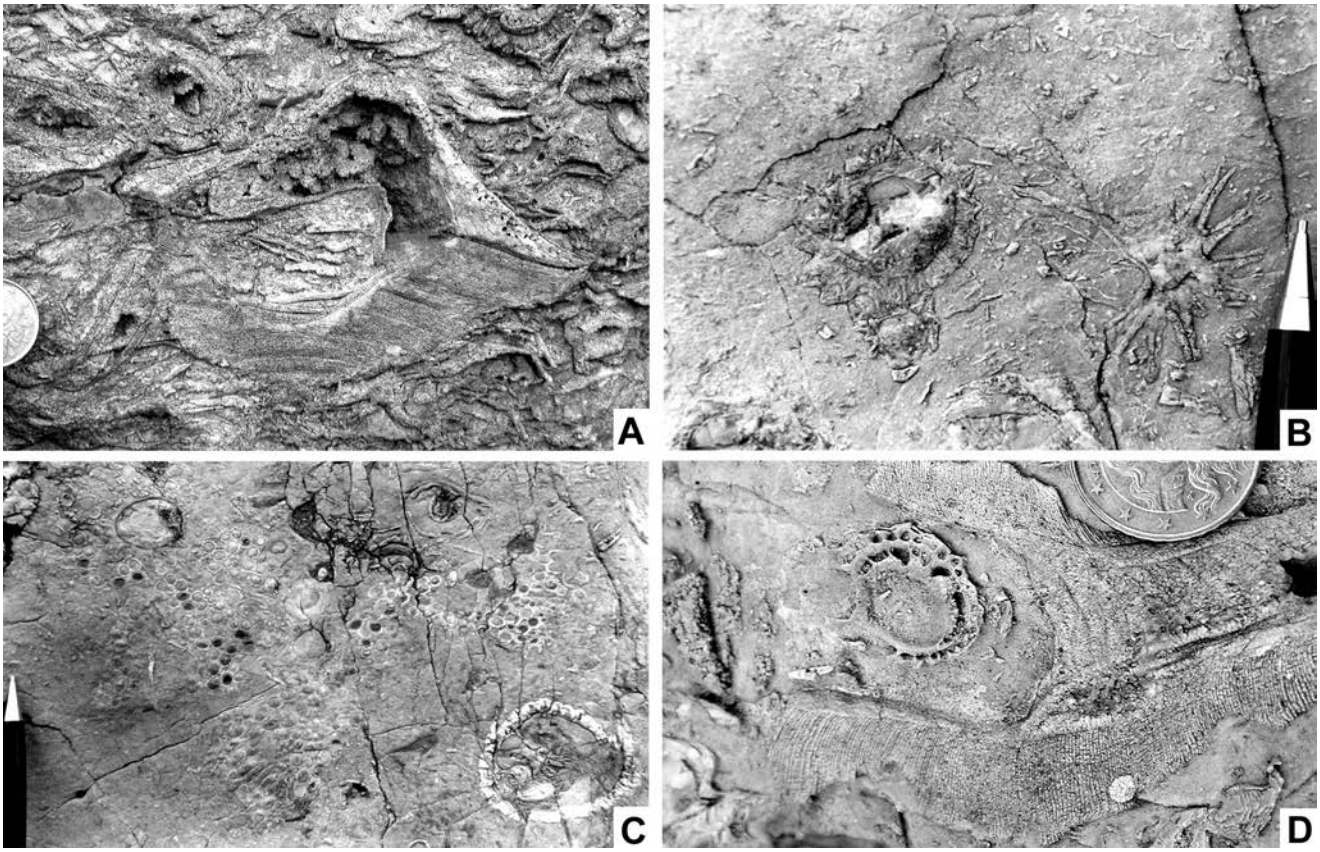

Fig. 13 - CA assemblage (late Santonian - early Campanian) in bioclastic limestone with well diversified rudist communities at Carmelo Mt., near Sant'Arsenio. (A) *Sauvagesia* cf. *tenuicostata* radial section of both the valves in coarse bioclastic limestone. (B) *Biradiolites* gr. *canaliculatus* transverse section of a small right valve with spiny shape. (C) *Bournonia fascicularis* thickets in growth position and *Vaccinites sulcatus* (at the right-lower corner). (D) Transverse section of a radiolitid left valve provided of well developed canals (ca) (cf. "*Kuehnia* sp.").

tion of the succession (about 70 m thick), rudists are largely dominant and form biostromes that interfinger with bioclastic grainstones. These rudist-rich bodies, with maximum thickness of about 3 m, are characterized by large specimens of hippuritids, radiolitids and plagioptychids. The radiolitid build-ups were growing in bouquets and clusters of more or less packed individuals that frequently have both valves preserved. Specimens of *Durania apula* Parona, *Sauvagesia* cf. *tenuicostata* Polšak (Fig. 13A), *Biradiolites* gr. *canaliculatus* (Fig. 13B), *Bournonia fascicularis* (Fig. 13D) and radiolitids with canaliculated left valves (cf. "*Kuehnia* sp.") (Fig.

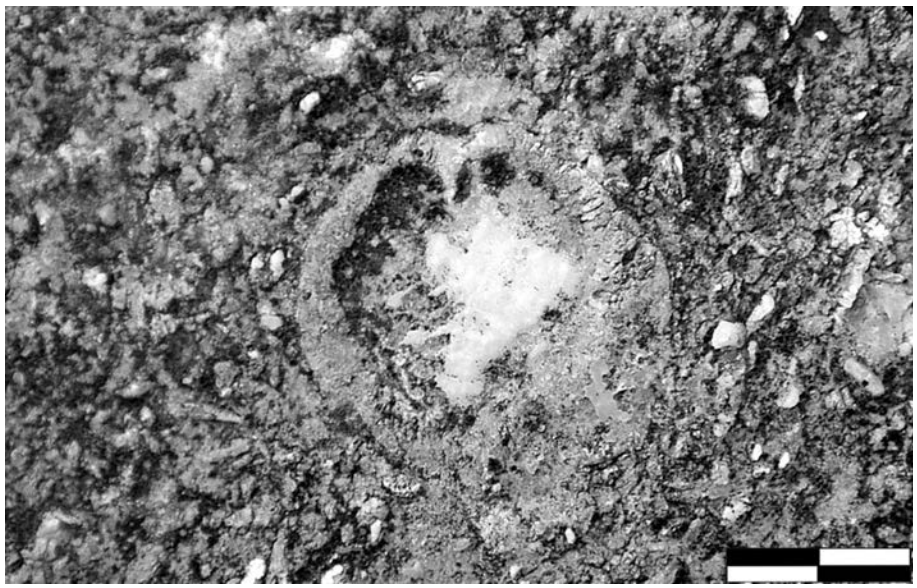

Fig. 14 - Biointraclastic limestone at Teggiano (late Campanian - Maastrichtian). *Pseudopolyconites* sp. transverse section of the right valve with well developed ligament ridge in poorly sorted, partly rounded bioclasts made of rudist fragments.

12C) have been recognized. Upward, *Vaccinites vredenburgi* Kuehn, *Vaccinites fortisi* (Catullo), *V. sulcatus* (Defrance) and smaller specimens of *Hippurites colliciatus* Woodward formed small thickets. Laterally, in grain-supported sediments solitary specimens of *Hippuritella nabresinensis* (Futterer), small elongate radiolitid clusters mainly made of *Bournonia* cf. *fascicularis* and colonial corals are present. On the whole, rudist assemblages that characterize this succession are indicative of a late Santonian – early Campanian age (CA assemblage). According to the grain-supported sediments, the coarsening-upward trend, the distribution and physiography of the rudist lithosomes, the described successions are interpreted as subtidal deposits of an open platform setting.

Teggiano. Coordinates: 40°23'01"N 15°32'43"E, 445 m s. l. Along the eastern side of the Cervati Mt., in the south-western side of the Diano Valley, the Teggiano village (Fig. 2K) lays over an isolate outcrop made of massive and clinostratified biointraclastic limestone at least 100 m-thick of the "Calcari pseudosaccaroidi" in the Carta Geologica d'Italia, scale 1:100.000, sheet n. 199 Potenza - 210 "Lauria" and "Calcari bio-litoclastici con frammenti di rudiste" in the sheet n. 504 scale 1:50.000 that extends for nearly 1.5 km^2 of Cretaceous - Palaeogene p.p. age. These are composed of fine to coarse clastic carbonates and bioclastic debris, largely composed of benthic organisms (rudist fragments, hydrozoans and forams) and subordinate carbonate lithoclasts up to 10 cm wide. In the Upper Cretaceous part of the succession, the bioclastic fraction is mainly composed of rudist fragments embedded in a grain-supported texture. Large *Sabinia* sp. fragments and abundant radiolitid fragments belonging to *Pseudopolyconites* sp. (Fig. 14) and *Sauvagesia* sp. have been recognized among rudist bioclasts while *Orbitoides media* (d'Archiac) and *Siderolites calcitrapoides* Lamarck benthic forams are reported, indicating a late Campanian – Maastrichtian age. These findings represent the first occurrence of these taxa in the southern Apennines and testify the presence of biodetritic flows of the CA interval in this area.

Madonna di Viggiano (Viggiano). Coordinates: 40°22'37"N 15°51'49"E, 1530 m s. l. This outcrop is located in the eastern side of the Agri Valley (Fig. 2 I), at the easternmost part of the Mesozoic Apennine chain, and extends for a few square kilometres for a thickness of nearly 100 m. The Upper Cretaceous carbonate succession is mainly constituted of bioclastic and biointraclastic whitish limestones with a rich and well diversified fossil fauna typified by rudists, chondrodontids and nerineid gastropods referable to the CE interval. At the base, large caprinid shells of *Sphaerucaprina forojuliensis* Boehm crop out in a grain-supported matrix (Fig. 15A) while, above, radiolitid shells belonging to *Eoradiolites liratus* (Conrad) and *Sauvagesia* sp., prevail in a fine bioclastic matrix with benthic forams such as *Conicorbitolina conica* (d'Archiac) (Fig. 15B) of early Cenomanian age (CE1 assemblage). In the upper part of the succession some pelagic beds with muddy limestone with planctonic organisms (*Rotalipora* sp. and Calcisphaerulidae) indicate a pelagic influx. Here, well preserved elongate specimens of *Eoradiolites?* sp. in a fine bioclastic matrix have been found in small bouquets composed of a few specimens with elongated right valves (up to 15 cm). This part of the succession represents the most external, intensively tectonized margin-to- slope deposits of the Apennine Platform.

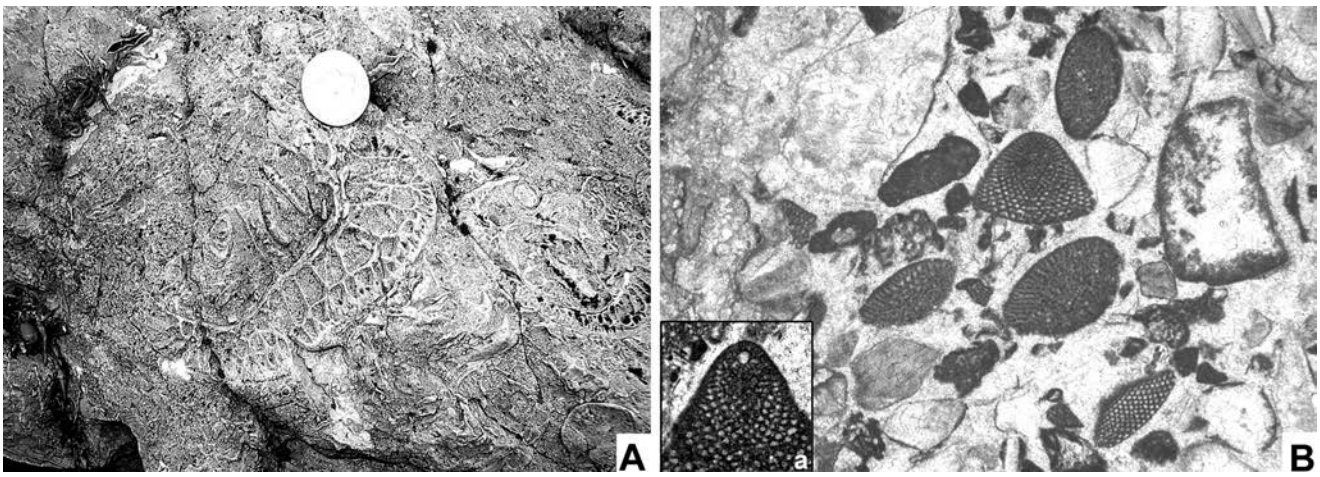

Fig. 15 - CE1 assemblage (early-middle Cenomanian) in biointraclastic limestone at Madonna di Viggiano Mt., near Viggiano. (A) Large caprinid shells of *Sphaerucaprina forojuliensis* in bioclastic limestone. (B) Bioclasts made of orbitolinid forams (*Conicorbitolina conica*) showing the embryonic apparatus (inset a) and rudist fragments. Base is 13 mm. Thin section MV2.

Discussion

On a global scale, one of the main characteristics of the Late Cretaceous biologic events is the spreading of rudist bivalves in shallow-water environments throughout the Tethys. In the isolated carbonate platform successions of the Apennines (sensu Tucker & Wright 1990), faunal composition reflects a decrease in overall species diversity and in their organization, moving from the outer to inner platform settings. In the Area 1, a Cenomanian - Santonian thick succession of carbonates crop out, characterized by well stratified rudist lithosomes (about one meter thick) with mainly mud-supported texture and a sheet-like geometry also in channel-like systems (Ruberti et al. 2006) of inner platform environments. Their fossil content is of low taxonomic diversity and consists mainly of radiolitid assemblages marked by high phenotypic variability (e.g. in the CO interval) with specimens occurring both in growth position and in parautochtonous concentrations of shells. In the Area 2 the predominant facies type consists of rudist lithosomes made of massive and weakly stratified bioclastic limestone mainly with grain-supported texture and a lense-shaped geometry, yielding hippuritids, radiolitids, caprinids, plagioptychids, hydrozoans and gastropods of outer platform environments (e.g. the CE and CA intervals). Fossil communities are much diversified with rudists as the main faunal constituents although accessory organisms (e.g. other bivalves, gastropods, corals, algae, and foraminifers) are commonly present.

In this paper, the vertical and spatial distribution of fossiliferous beds allow to recognize three new rudist assemblages that add to the CO and SA assemblages previously known (Cestari & Pons 2004):

– CE1 assemblage, marked by the occurrence of caprinids (*Orthoptychus striatus* Futterer, *Sphaerucaprina forojuliensis* Boehm) and Radiolitidae [*Eoradiolites liratus* (Conrad), *Sauvagesia sharpei* (Bayle)] of outer platform and margin bioclastic carbonates, early - middle Cenomanian in age.

– CE2 assemblage, with radiolitids such as *Eoradiolites liratus* (Conrad), *Sauvagesia nicaisei* (Coquand), the genus *Caprinula* [*Caprinula boissyi* (d'Orbigny)] and ichtyosarcolitids, together with other bivalves and gastropods mainly of lagoonal facies, late Cenomanian in age.

– CO assemblage, marked by low diversified communities nearly exclusively composed of radiolitids such as *Biradiolites angulosus* d'Orbigny, *Radiolites trigeri* (Coquand), *Bournonia gardonica* Toucas (similar to *B. excavata* d'Orbigny), *Durania arnaudi* (Choffat) of inner platform setting, late Turonian - Coniacian in age.

– SA assemblage, marked by paucispecific radiolitid communities with *Radiolites dario* (Catullo) (species considered belonging to "*Gorjanovicia*" in Fenerci-Masse et al. 2011), *Sauvagesia tenuicostata* Polšak, *Bournonia fascicularis* (Pirona) of inner platform settings, late Coniacian -Santonian in age.

– CA assemblage, with well diversified rudist communities composed of hippuritids (*Vaccinites fortisi*, *Vaccinites vredenburgi*), plagioptychids (*Plagioptychus paradoxus*), radiolitids (*Sauvagesia* sp., *Lapeirousella* sp.) and other radiolitids with canaliculate left valve set in carbonates with grain-supported texture of outer platform setting, late Santonian - early Campanian in age.

The occurrence of *Sabinia* sp., *Pseudopolyconites* sp., *Sauvagesia* sp. fragmented in biointraclastic deposits has to be noted in outer platform and slope setting, late Campanian -Maastrichtian age.

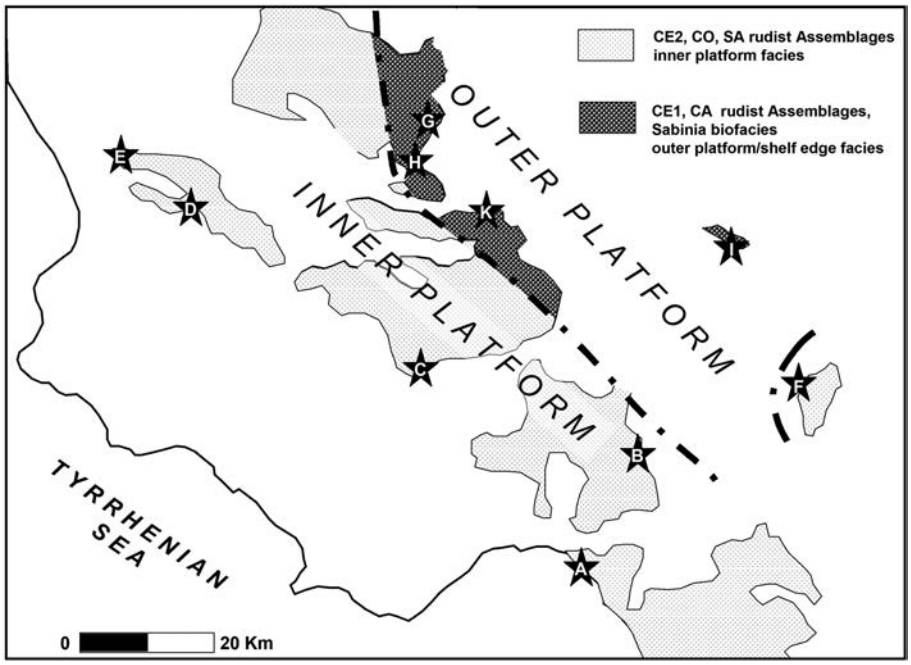

Fig. 16 - Distribution of detected rudist assemblage in Cilento and Western Basilicata. Inner platform biofacies are in the western area while the outer platform biofacies occur in the eastern area.

Data on the distribution of these biofacies help in the paleogeographic reconstruction of the studied area prior the strong rotations due to the kinematic and tectonic pulses. The Cenomanian outer platform and margin rudist biofacies can be followed from the eastern side of the Cilento area to Viggiano and southward to the Pollino Mts. (at Serra dell'Impiso, work in progress), eventually following paleotectonic lineaments. Meanwhile inner platform rudist facies of the middle Cenomanian have not been found in the studied areas. In the Turonian – Santonian there is no evidence of shelf margin development while in the late Santonian until the Maastrichtian shelf margin and slope deposits are well developed along the eastern side of the Alburni Mts., in the Maddalena Mts. and Teggiano (e.g. the "Pseudosaccaroide" limestone Auctt.).

With these data a first paleogeographic sketch of this part of the Apennine Carbonate Platform during the Late Cretaceous is attempted (Fig. 16) taking into account the general paleooceanic circulation pattern in the Late Cretaceous (as in Pucéat et al. 2005). A last consideration can be made regarding the peculiar sedimentary and palaeontological features of the Raparo Mt. where oligospecific elongate radiolitids occur in mud-supported limestone of inner platform or gently dipping ramp. They are far from a shelf edge complex and in an "isolated" position if compared to the coeval radiolitid assemblages of the Cilento area. This "out of context" radiolitid assemblage, embedded in carbonate biofacies that are currently ascribed to the Apenninic Unit (Nicolai & Gambini 2007), could suggest its assignment to a different paleogeographic unit because of its strong resemblance to the adjacent Alpi Mt. (i.e. of the Apulia Unit) drilled in the nearby Castelsaraceno 1 exploration well that encountered Barremian-Aptian limestones of a shallow carbonate platform (public database < *http://unmig.sviluppoeconomico.gov.it/videpi* >).

Conclusion

The vertical and lateral distribution both of rudist assemblages and their related biofacies cropping out in selected fossiliferous localities of Cilento and western Basilicata (southern Italy) supply original biostratigraphic and paleogeographic data regarding this part of the Apennine Carbonate Platform (ACP) during the Late Cretaceous. Five main rudist assemblages of Cenomanian to early Campanian age have been detected that can be also easily recognized in the field: (I) CE1 assemblage, caprinid-rich bioclastic limestone of outer platform and margin settings, early-middle Cenomanian in age; (II) CE2 assemblage, radiolitids and caprinids with other bivalves of mainly lagoonal facies, late Cenomanian in age; (III) CO assemblage, low-diversified radiolitid assemblages in muddy substrate of inner platform setting, of the late Turonian - Coniacian; (IV) SA assemblage, radiolitid low-diversified communities but often with an outstanding number of specimens set in muddy substrate of inner platform environments, of the late Coniacian - Santonian; (V) CA assemblage, highly diversified rudist communities with hippuritids, radiolitids, plagiopthychids and other benthic organisms found in limestones with mainly grain-supported texture of outer platform setting, late Santonian - early Campanian in age. Moreover, fossiliferous debris in biointraclastic and brecciated limestone

with plenty of rudist fragments is found in outer shelf and slope setting of the late Campanian-Maastrichtian.

Moving from the western area toward the southern and eastern one, the overall areal distribution of these rudist assemblages and their related lithobiofacies is synthetized in two types: (A) Type A, low diversified radiolitid-dominated communities set in mud-supported limestone, found in the western area i.e. the late Turonian - Santonian assemblages at Il Fortino, along the Vesole Mt.-La Raia del Pedale Mt. ridge and at the Raparo Mt. (CO and SA assemblages); (2) Type B, well diversified rudist communities with hippuritids, caprinids and radiolitids, well represented in limestones with grain-supported texture cropping out in the southern and eastern areas i.e. the Cenomanian assemblages of Acquafredda, Acqua dei Tassi, Madonna di Viggiano (CE1 and CE2 assemblages) and in the late Santonian - Maastrichtian assemblages and biofacies of Carmelo Mt., Teggiano and along the Maddalena Mts. (CA assemblage).

These data can be related to the general setting of the eastern side of the ACP and give information regarding its paleogeography and paleophysiography, in spite of its present complex tectonic structure:

(A) the lack of CO, SA, and CA assemblages and of their related deposits in southern area of Cilento and Basilicata should be referred to tectono-eustatic events that caused non-deposition or emersion of this part of the ACP, until the uppermost Palaeocene transgression of the Trentinara Fm. sealed a differentiated paleomorphology;

(B) at the Raparo Mt. the SA assemblage is found in inner platform or gently dipping ramp settings, far from a shelf edge complex and in an isolated position if compared to other assemblages of the ACP area. This "out of context" radiolitid assemblage is therefore to be ascribed to a different palaeogeographic domain, similar to that of the adjacent Alpi Mt.

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