doi: 10.3304/jmes.2020.16748 *Journal of Mediterranean Earth Sciences 12 (2020), 87-103*

Journal of Mediterranean Earth Sciences

Upper Cretaceous stratigraphy and rudist-bearing facies of the Simbruini Mts. (Central Apennines, Italy): new field data and a review

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ABSTRACT - The rudist-bearing carbonate platform succession of Marsia, in the northern Simbruini Mts. (Central Apennines), is described for the first time through the analysis of two stratigraphic sections, and better characterized by the study of three single significant outcrops located outside the sections. The identification of the rudist assemblages, related facies and micropaleontological analyses of the collected samples allowed to determine the age of this Upper Cretaceous succession, and the definition of a biostratigraphic frame for the of the entire study area. The Marsia composite stratigraphic section encompasses the late Turonian-early/middle Campanian interval, and records the evolution from inner platform-low hydrodynamic setting in the late Turonian, to an open platform setting characterized by high hydrodynamism in the late Santonian-early/middle Campanian. This succession has been compared to the already described Trevi, Santa Maria dei Bisognosi and Subiaco carbonate platform successions, and to regional bioevent schemes, in order to constrain the evolution of these carbonate facies in a wider sedimentological and stratigraphic context.

Since the late Turonian, a spreading of rudist facies occurred throughout the central-southern Apennines, representing the first Upper Cretaceous rudist bioevent. In the Simbruini area inner platform environments, characterized by soft fine-grained sediment, are widespread. The successions of Marsia and Trevi, which are marked by upper Turonian inner platform facies with a thriving oligospecific rradiolitid association characterized by semi-infaunal lifestyle, record this bioevent. During the Santonian and the early Campanian a gradual increase in hydrodynamic conditions is recorded by rudist assemblages with hippuritids and robust radiolitids, associated with rare corals and echinoids which mark the second and third Upper Cretaceous rudist bievent, recorded at Marsia, Trevi and Santa Maria dei Bisognosi. The middle Campanian-Maastrichtian bioevents are only represented at Santa Maria dei Bisognosi and Subiaco, where high energy bioclastic facies, dominated by the peculiar radiolitid *Sabinia* sp., occur.

Keywords: Rudist bivalves; Biostratigraphy; Central Apennines; Cretaceous; Carbonate platform.

Submitted: 19 May 2020-Accepted: 5 October 2020

1. INTRODUCTION

In this paper we discuss as yet undescribed rudist-bearing outcrops from Marsia (Fig. 1), in the northern Simbruini Mts. (Latium-Abruzzi Domain, Central Apennines), and we compare them to three known Turonian-Maastrichtian sections of the surrounding area (Santa Maria dei Bisognosi, Subiaco and Trevi).

The rudist facies of the Simbruini Mts. and neighbouring areas have been studied since the XIX century (Parona, 1908; Fabbi et al., 2018 and references therein). A renewed interest on this topic arose in the last two decades of the 20th century, when the stratigraphic features and paleogeographic/paleoecological significance of Upper Cretaceous rudist communities were studied in detail by Carbone and Sirna (1981), Mariotti (1982), Sirna and Cestari (1989), Cestari and Pantosti (1990), Cestari and Sirna (1991), Cestari et al. (1992), and Masse (1992).

In particular, upper Turonian-Maastrichtian rudist-dominated facies are well developed in the area, as observed in other peri-Adriatic carbonate platforms (e.g. Vlahović et al., 2005). This was interpreted as a response to hyper-greenhouse conditions in the early Turonian (Carannante et al., 2008), which caused a crisis and a subsequent biotic turnover among primary carbonate producers. The post-Turonian recovery of carbonate platform environments is characterized by the sharp decrease of corals and green algae, along with

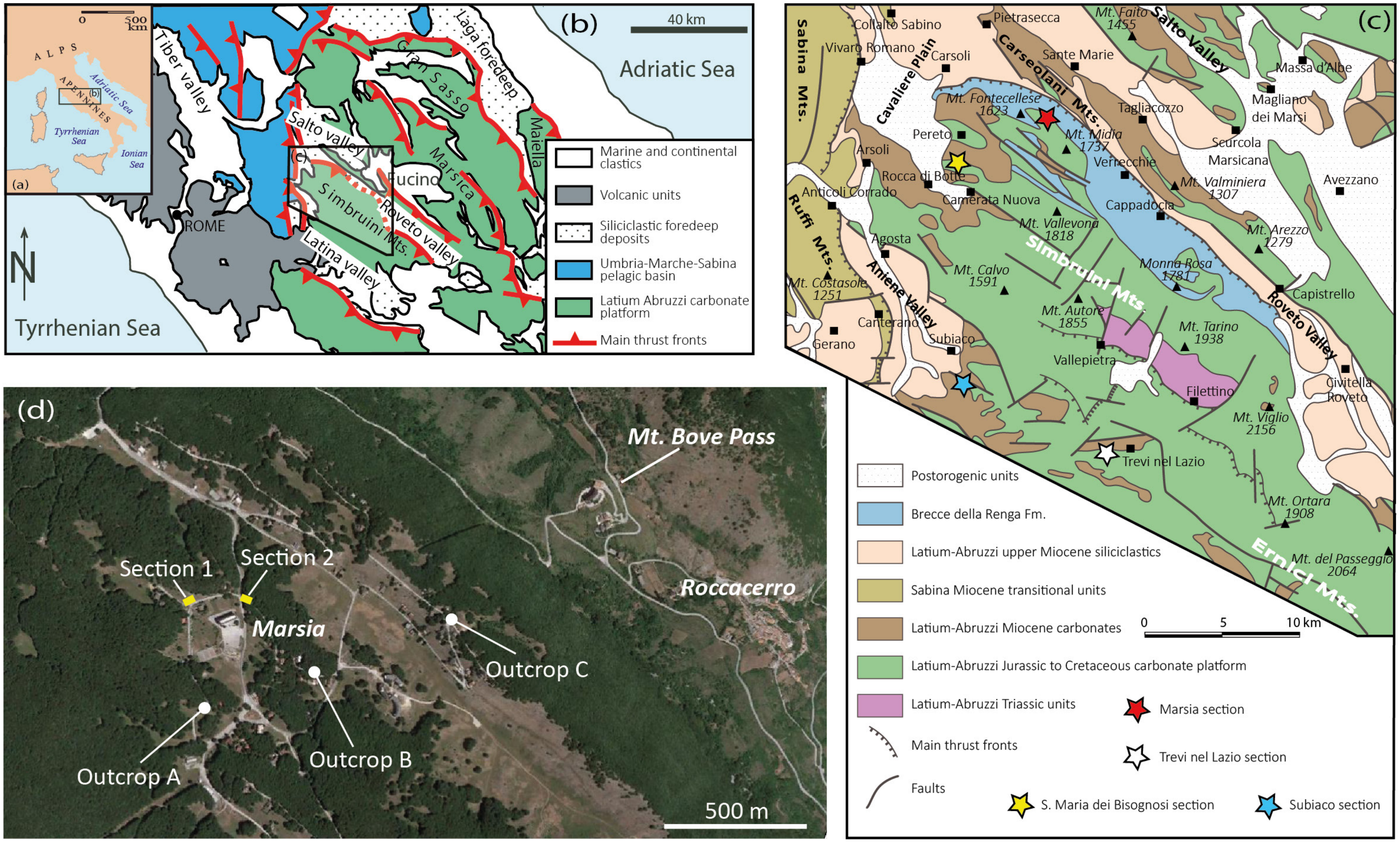

Fig. 1 a, b) Location and regional setting of the study area; c) geological sketch of the Simbruini Mts. and neighbouring areas, with the location of the study area and the compared sections (modified after Carminati et al., 2014); d) Aerial view of the area of Marsia (image retrieved from Google Earth) with the indication of the outcrops object of the present study.

aragonite-shelled organisms, and the rise of calcite-shelled rudists as dominant carbonate producers (Van de Poel and Schlager, 1994; Carannante et al., 2008). The development and facies organization in these Upper Cretaceous carbonate platforms seems to be essentially controlled by hydrodynamic conditions rather than other factors (Simone et al., 2003; Ruberti et al., 2006; Carannante et al., 2008). For the purpose of this work a composite stratigraphic section has been reconstructed analyzing the vertical distribution of benthic foraminifera and rudists and anchoring their occurrence with the biostratigraphic scheme of Chiocchini et al. (2012). This has been done also integrating the information given by facies analysis and comparing such stratigraphy to the sections available in the literature, in order to consider the carbonate platform cropping out in the surroundings of Marsia within a wider sedimentological context.

2. GEOLOGICAL BACKGROUND

The Simbruini Mts. are a large mountain ridge located between the Aniene valley and the Roveto valley (Fig. 1 b,c), in the Latium and Abruzzi Regions (Central Italy). The stratigraphic succession of the area is represented by a thick (>3500 m) Upper Triassic-middle Miocene carbonate platform succession (Parotto and Praturlon, 1975; Accordi and Carbone, 1988; Damiani et al., 1991; Chiocchini et al., 2008), which includes a wide hiatus encompassing the whole Paleogene (Damiani et al., 1990, 1991; Cipollari and Cosentino, 1995; Cosentino et al., 2010; Brandano, 2017).

The Cretaceous lithostratigraphic succession of the area (Fig. 2) is subdivided into four informal units, that are considered at formation rank (Damiani et al., 1998; Compagnoni et al., 2005; Fabbi, 2016, 2018). The Lower Cretaceous is characterized by a thick dolomitic succession ("fosso Fioio dolostone", Berriasian *p.p.*-Barremian), followed by an inner platform unit, with abundant microfauna dominated by benthic forams, including horizons rich in requieniid rudists ("requieniid limestone", Aptian-Cenomanian *p.p.*). The Upper Cretaceous is dominated by bioclastic facies essentially made of both whole and fragmented rudist shells, mostly radiolitids, interbedded with layers organized in peritidal cycles, also showing well-developed supratidal facies characterized by fenestral bindstones and ostracod-dominated olygotipic fauna ("radiolitid limestone", Turonian-Campanian *p.p.*). Within this unit, rudist bivalves often attain an elongate shape as mud (or sand) stickers (Seilacher, 1984, 1998) and may form well-preserved clusters or bouquets (Gili et al., 1995). The youngest Cretaceous unit is represented by discontinuous patches of upper Campanian-Maastrichtian deposits in typical grain-supported, recrystallized facies ("saccharoidal limestone"-Carbone and Catenacci, 1978). This is characterized by abundant *Orbitoides*, and macrofossils such as rudists and echinoid fragments (Damiani et al., 1990; Chiocchini and Mancinelli, 2001; Compagnoni et al., 2005; Fabbi et al., 2018).

A conspicuous Paleogene hiatus characterizes the area (Fig. 2); the Miocene transgressive deposits regionally overlie an articulated substrate made of units of different age (Civitelli and Brandano, 2005). In the Simbruini Mts. the substrate is Cretaceous ranging from the Coniacian to the Maastrichtian (Damiani et al., 1990; Cosentino et al., 2010; Fabbi, 2016).

3. MATERIAL AND METHODS

A composite ~20 m thick section was reconstructed measuring in the field two stratigraphic sections in the area of Marsia, and through micro- and macrofossil biostratigraphic analysis (Fig. 3). Each bed thinner than 30 cm was sampled, whereas multiple samplings were carried out for strata thicker than 30 cm. Rock samples were analyzed in thin section for the determination of the micropaleontological content, while rudists were mainly determined directly in the field only when the specimens are cleared from the embedding matrix by differential erosion. The results have been compared with coeval rudist-bearing outcrops over the region. The paleoenvironmental and stratigraphic significance of rudists have also been considered. The adopted biostratigraphic scheme is taken from Chiocchini et al. (2012) with few changes: the stratigraphic range of foraminifers has been re-calibrated after Frijia et al. (2015) and Arriaga et al. (2016), whereas the taxonomy follows the review of Consorti et al. (2017).

4. THE TURONIAN-CAMPANIAN STRATIGRAPHY OF MARSIA

The locality of Marsia falls within the municipality of Tagliacozzo (AQ, Abruzzi Region) at the northern end of the Simbruini Mts. (Fig. 1 c,d). Here, carbonate platform deposits, belonging to the Turonian-Campanian *p.p.* "radiolitid limestone" (Compagnoni et al., 2005; Fabbi, 2016, 2018), widely crop out. These rocks appear as whitish to brownish limestones and subordinately dolomitic limestone, organized into dm- to m- thick layers, with abundant rudist biostromes and subordinate gastropods, revealing a subtidal environment, showing very few evidence of inter-supratidal fenestral facies or desiccation structures. The vertical extent of the outcrops in the area is very limited and only in a few cases it has been possible to study in detail stratigraphic sections, through which we reconstructed a composite section. Besides the measured sections, sampling of single significant outcrops was carried out to better characterize the paleontological and biostratigraphical setting of the area.

The lower portion (Section 1) of the composite section (upper Turonian *p.p.*) consists of thin dolostone and limestone beds, containing oligotypic assemblages with Discorbidae sp. a, *Discorbis* cf. *turonicus* Said and Kenawy, miliolids and ostracods, which pass upwards

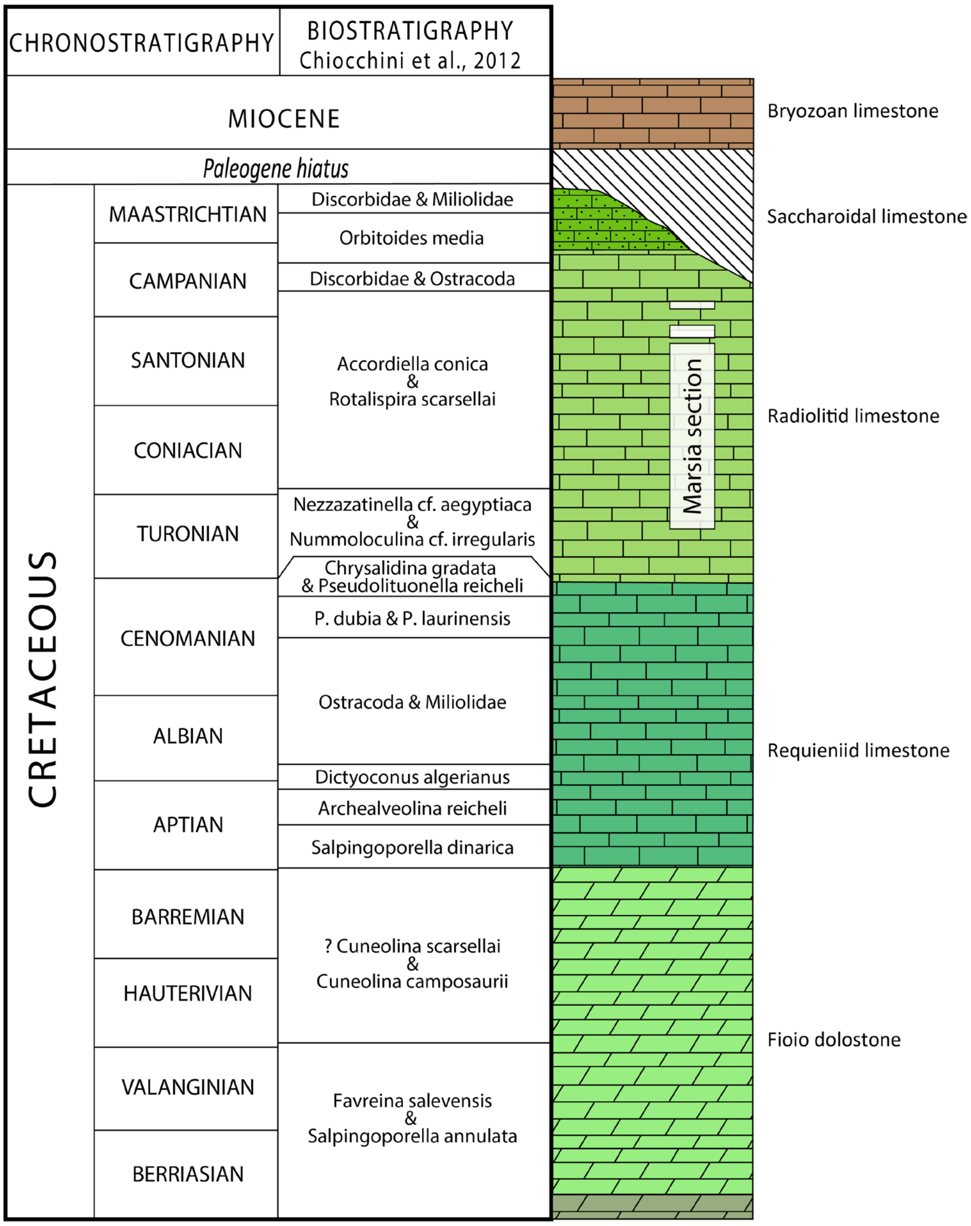

Fig. 2 - Cretaceous-middle Miocene lithostratigraphy of the Simbruini Mts. (not to scale, modified after Fabbi, 2018).

to decimetric layers of wackestone-packstone with abundant rudist remains and an olygotypic microfossil assemblage (see Arriaga et al., 2016 for an updated description and a stratigraphic calibration of Turonian significant smaller forams), composed of *Moncharmontia* sp., *Discorbis* cf. *turonicus*, *Decastronema barattoloi* (De Castro), *Nummoloculina* cf. *irregularis* Decrouez and Radoičić, *Nezzazatinella* cf. *aegyptiaca* Said and Kenawy and *Pseudocyclammina sphaeroidea* Gendrot, the latter constrains the age of this portion to the uppermost Turonian (Chiocchini et al., 2012). Above this interval, a thick (1.60 m) rudist-bearing rudstone/floatstone (Fig. 4 a,c) with erosional base occurs; this is a biostromal bed yielding oligotypic assemblages of elongated radiolitids dominated by *Radiolites trigeri* (Coquand) (Fig. 4 d,e), organized in several generations, also bearing coalescent individuals (Fig. 4b); the foraminiferal assemblage (Fig. 5 a-d) is characterized by *Moncharmontia* cf. *compressa* (De Castro) and *Spiroplectammina* cf. *multicamerata* Said and Kenawy. At the top of this portion, an ostreid-rich (*Chondrodonta* sp.) layer occurs, associated to *Nummoloculina* cf. *irregularis* Decrouez and Radoičić and *Thaumatoporella parvovesiculifera* (Raineri). The overall microfossil assemblage can be referred to the *Nezzazatinella* cf. *aegyptiaca* and *Nummoloculina* cf. *irregularis* biozone.

The lower portion of the section 2 (Fig. 6a, upper Turonian) is roughly correlatable to the section 1 showing similar facies and fossil assemblages (Fig. 3). The middle portion of the section (? Coniacian-lower Santonian) is characterized by metre-thick rudist bearing float-rudstone (Fig. 6a), with assemblages dominated by

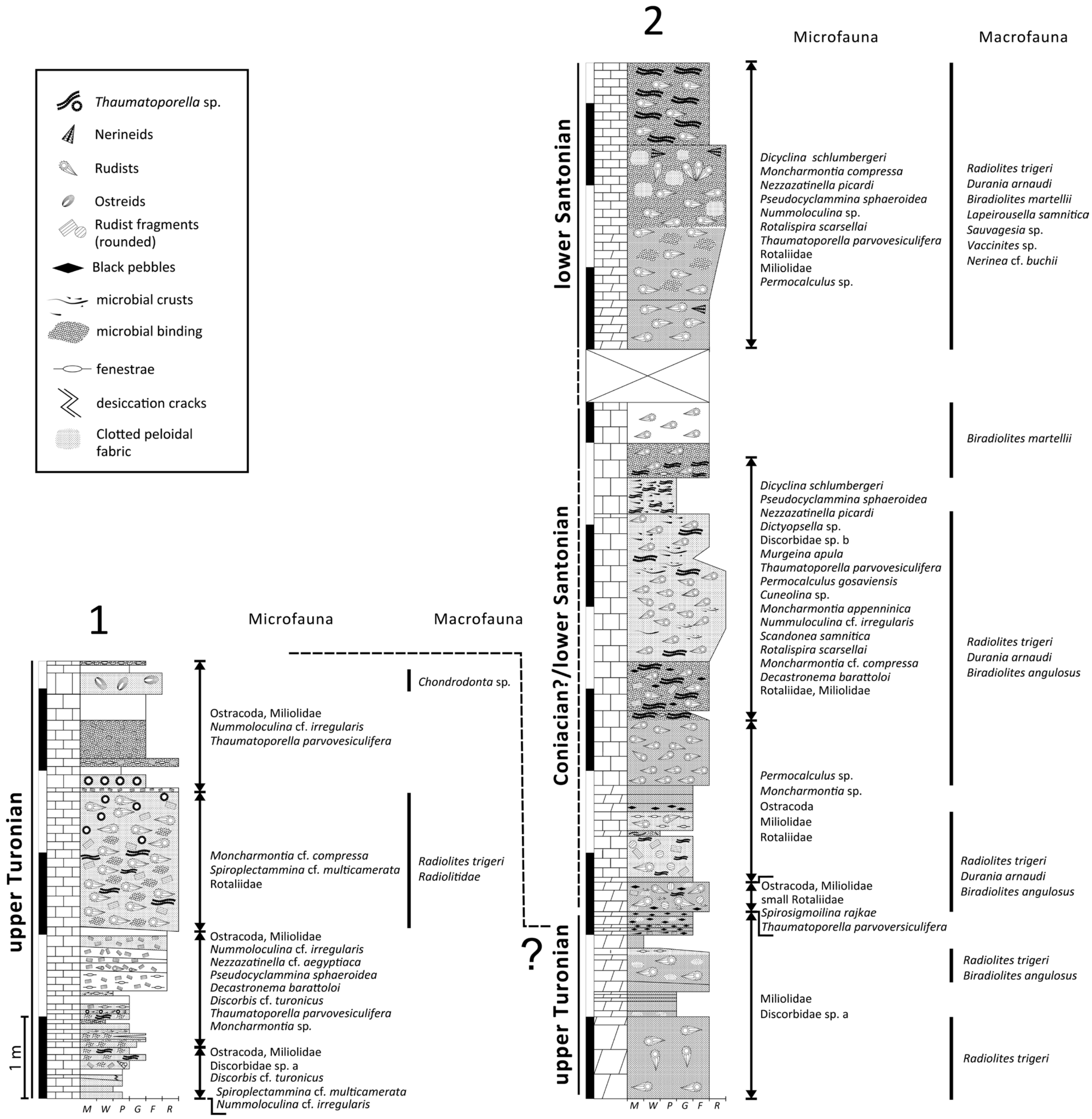

Fig. 3 - Stratigraphic logs of the study area.

Radiolites trigeri, in monospecific levels or associated with *Durania arnaudi* Choffat and *Biradiolites angulosus* d'Orbigny (Fig. 6 b,c). These thick beds are interbedded with fenestral bindstones with *Thaumatoporella parvovesiculifera*, and with bioclastic pack-grainstone. The floatstone microbiofacies (Fig. 5 e-j) is characterized by the occurrence of *Moncharmontia* cf. *compressa*, *M. apenninica* (De Castro), *Cuneolina* sp., *Dictyopsella* sp., *Rotalispira scarsellai* (Torre), *Nezzazatinella picardi* (Henson), *Dicyclina schlumbergeri* Munier-Chalmas, *Scandonea samnitica* De Castro, *Nummuloculina* cf. *Irregularis* Decrouez and Radoičić, *Spirosigmoilina rajkae* Chiocchini, *Permocalculus* sp. and rotaliids. The top of this portion is represented by float-rudstones organized in thick layers with monospecific assemblages of *Biradiolites martellii* (Parona) (Fig. 6d). Above a gap due to debris and anthropic cover, the uppermost portion of the section (Fig. 6e) is composed of float-rudstones with *Sauvagesia* sp., *Biradiolites martellii*, *Lapeirousella samnitica* (Parona) (Fig. 6h) and rare large hippuritids (*Vaccinites* sp.). Bioclastic nerineid-bearing (*Nerinea* cf. *buchii* Bronn) lenses also occur (Fig. 6f). The foraminiferal assemblages (Fig. 5 k-m) include *Dicyclina schlumbergeri*, *Moncharmontia compressa*, *Nezzazatinella picardi*, *Pseudocyclammina sphaeroidea*, *Nummoloculina* sp. and *Rotalispira scarsellai*. The microfossil assemblages

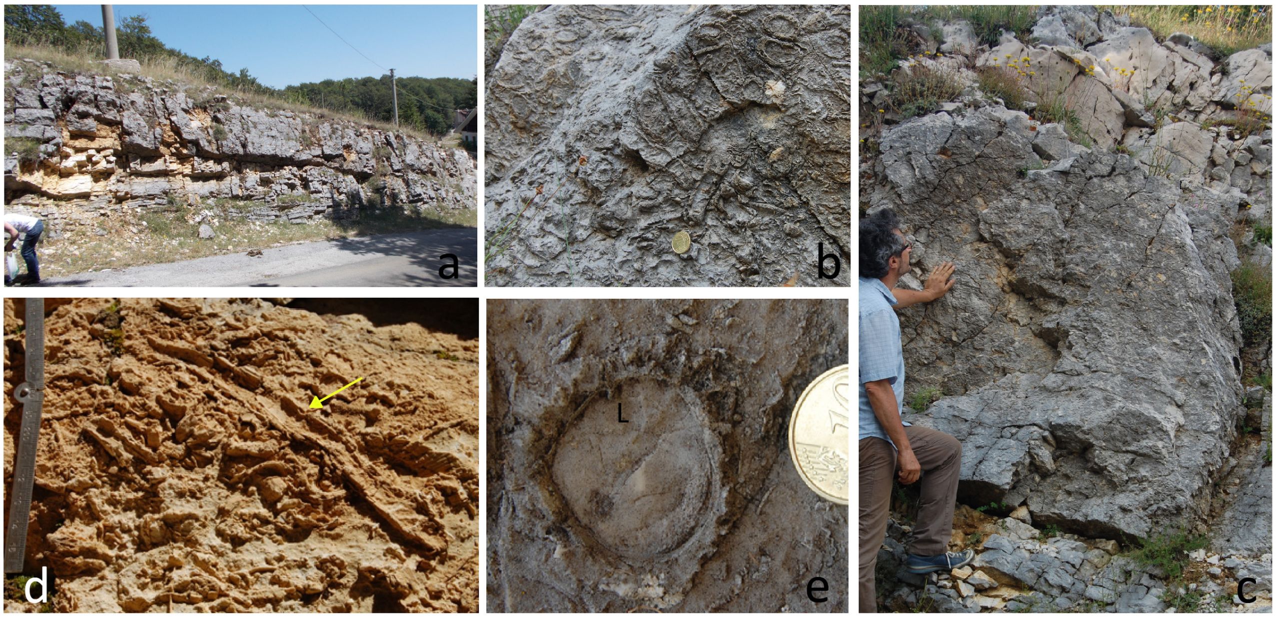

Fig. 4 - Section 1 - a) panoramic view of the stratigraphic section; b) *Radiolites trigeri* cluster with individuals in growth position; c) thick radiolitid biostromal bed with oligotypic assemblage dominated by *Radiolites trigeri*; d) elongated individuals of *Radiolites trigeri* (arrow); e) transverse section of a right valve of *Radiolites trigeri,* L=ligament ridge.

of the middle-upper portion (Fig. 3) are referred to the *Accordiella conica* and *Rotalispira scarsellai* biozone.

The stratigraphic succession of the area has been better characterized through the study of single outcrops, not included in the logs, described below (Fig. 1):

A) A Santonian interval (Fig. 7), rich in radiolitids within a mud-supported well-bedded limestone of inner platform environment, evolving upsection into higher hydrodynamic conditions. In this outcrop, a horizon (Fig. 7a) dominated by an oligotypic rudist assemblage with *Radiolites* (*"Gorjanovicia"*) *dario* (Catullo) can be observed. Some parautochthonous levels of rudists including *Biradiolites martellii, Lapeirousella samnitica*, *Sauvagesia* sp. and regular echinoids occur on top of this outcrop (Fig. 7 b-d).

B) Few meters thick upper Santonian deposits are characterized by rudist associations with *Sauvagesia* sp., *Biradiolites martellii*, *Lapeirousella samnitica* (Fig. 8), and by a microfacies characterized by *Accordiella conica* Farinacci, *Dicyclina schlumbergeri*, *Nezzazatinella picardi*, *Murgeina apula* (Luperto Sinni), and *Reticulinella fleuryi* Cvetko, Gušić and Schroeder (Fig. 5 n-q).

C) The stratigraphically higher outcrop is a massive bioclastic bed stack (Fig. 9a) characterized by grain-supported textures also bearing *Keramosphaerina tergestina* (Stache) (Fig. 5r), which marks a lower-middle Campanian biohorizon (Frijia et al., 2015; Consorti et al., 2017). This succession yields abundant rudist assemblages, including *Vaccinites sulcatus* Defrance, large isolated individuals of *Vaccinites fortisi* Catullo (Fig. 9b) and the plagioptychid *Plagioptychus paradoxus* Matheron (Fig. 9 e-e'); remarkably, also rare corals (Fig. 9c) and domical chaetetid sponges, which are considered as being clues of higher hydrodynamic conditions in open platform depositional systems (Kershaw and West, 1991), have been found.

The studied composite section records the evolution of the sedimentary environment from inner platform low-hydrodynamic conditions, characterized by fine-grained sediments and associated rudists in the late Turonian to an early-middle Campanian open platform, characterized by more turbulent hydrodynamic conditions. This is most likely a local evolution, which is in contrast with the regional trend recording a general decrease of the environmental energy, with the gradual shift from peritidal to subtidal cyclic sedimentation in the Turonian -Campanian (see Carannante et al., 2008).

5. COMPARISON WITH OTHER NEARBY STRATIGRAPHIC SECTIONS

The studied succession of Marsia has been compared with three published Upper Cretaceous rudist-bearing sections of the Simbruini Mts. (Sirna and Cestari, 1989; Damiani et al., 1990; Cestari and Sirna, 1991; Cestari et al., 1992), in order to consider the evolution of the rudist facies of a wider area (Fig. 10).

5.1. TREVI SECTION

About 1 km west of the village of Trevi nel Lazio (Fig. 1c), a ~200 m thick carbonate succession is characterized by laminated and well-bedded mud-wackestones containing mono- and olygotipic rudist assemblages, mostly composed of radiolitids organized in bouquets and clusters (Cestari et al., 1992).

In the lower part, composed of an alternation of

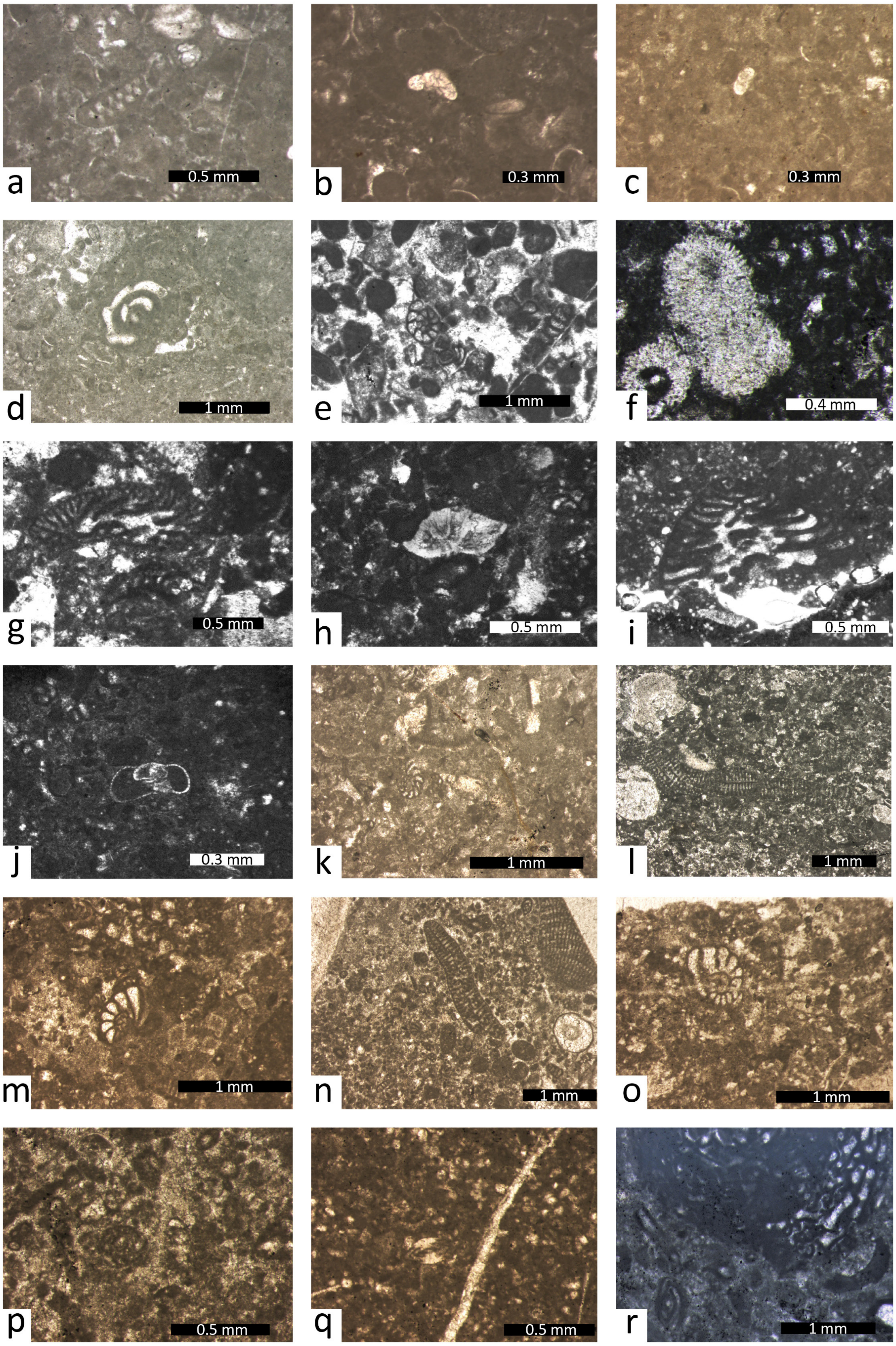

Fig. 5 - a) *Spiroplectammina multicamerata* (Sect. 1 bed 1); b) *Discorbis turonicus* (Sect. 1 bed 3); c) Discorbidae sp. a (sect. 1 bed 6); d) *Nummoloculina* cf. *irregularis* (Sect. 1 bed 32); e) *Moncharmontia* sp. (sect. 2 bed 19); f) *Permocalculus* sp. (sect. 2 bed 23); g) *Dictyopsella* sp. (sect. 2 bed 24); h) *Rotalispira scarsellai* (sect. 2 bed 25); i) *Dictyopsella* sp. (sect 2 bed 27); j) Discorbidae sp. b (sect. 2 bed 27); k) *Pseudocyclammina sphaeroidea* (sect. 2 bed 29); l) *Dicyclina schlumbergeri* (sect. 2 bed 29); m) *Nezzazatinella* cf. *picardi* (sect 2 bed 30); n) *Dicyclina schlumbergeri* (oucrop B); o) *Nezzazatinella picardi* (outcrop B); p) *Reticulinella fleuryi* (outcrop B); q) *Murgeina apula* (outcrop B); r) *Keramosphaerina tergestina* (outcrop C).

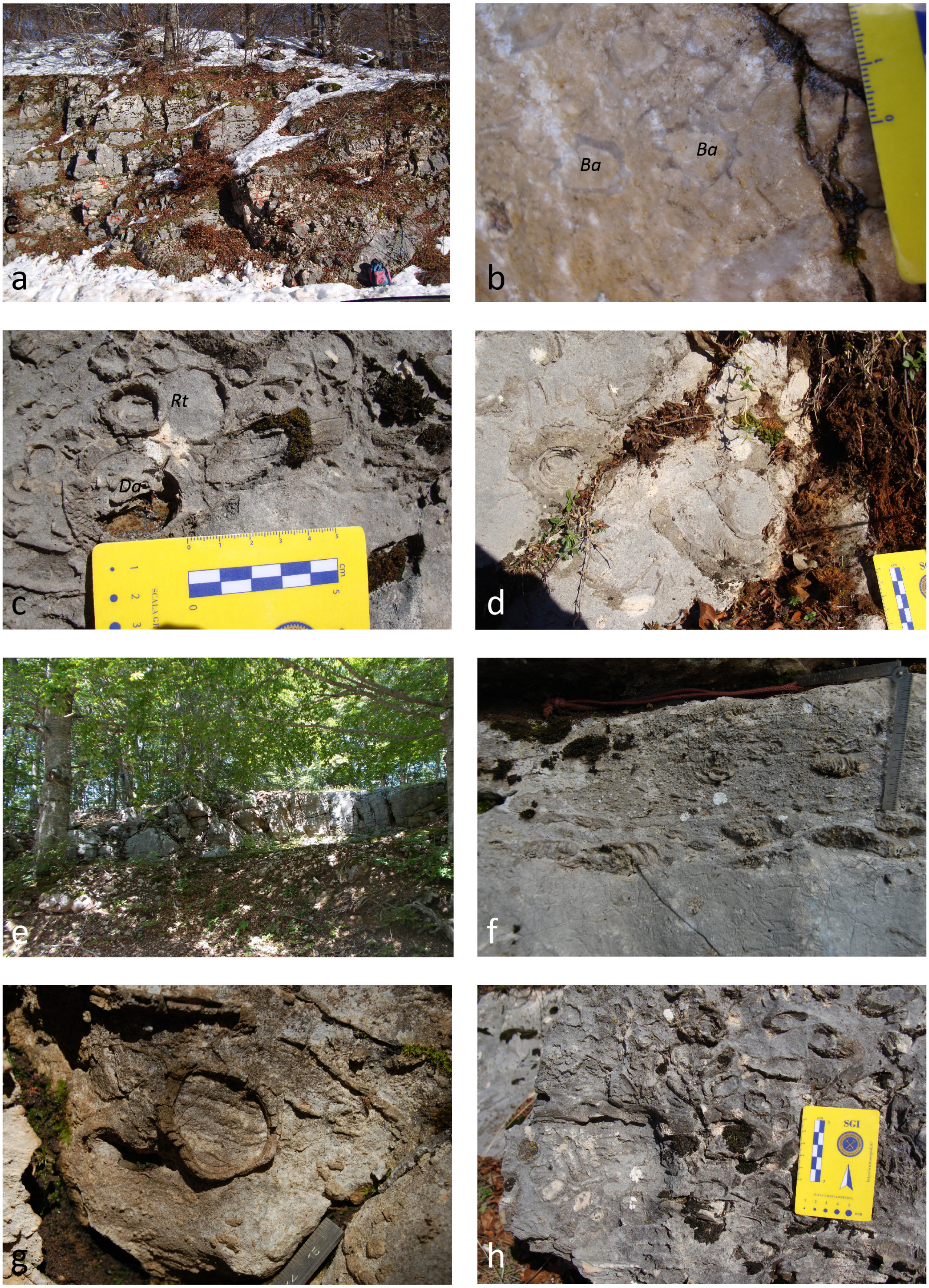

Fig. 6 - Section 2: - a) panoramic view of the lower and middle portion of the section; b) floastone with *Biradiolites angulosus* (Ba); c) Rudstone with *Durania arnaudi* (Da) and *Radiolites trigeri* (Rt); d) floatstone with *Biradiolites martellii*; e) view of the upper portion of the section; f) coarse grained lens with nerineids; g) Floatstone with thin shelled *Radiolites* sp.; h) rudstone with oligotypic rudist association, *Lapeirousella samnitica* and thick shelled *Biradioilites martelii* are present.

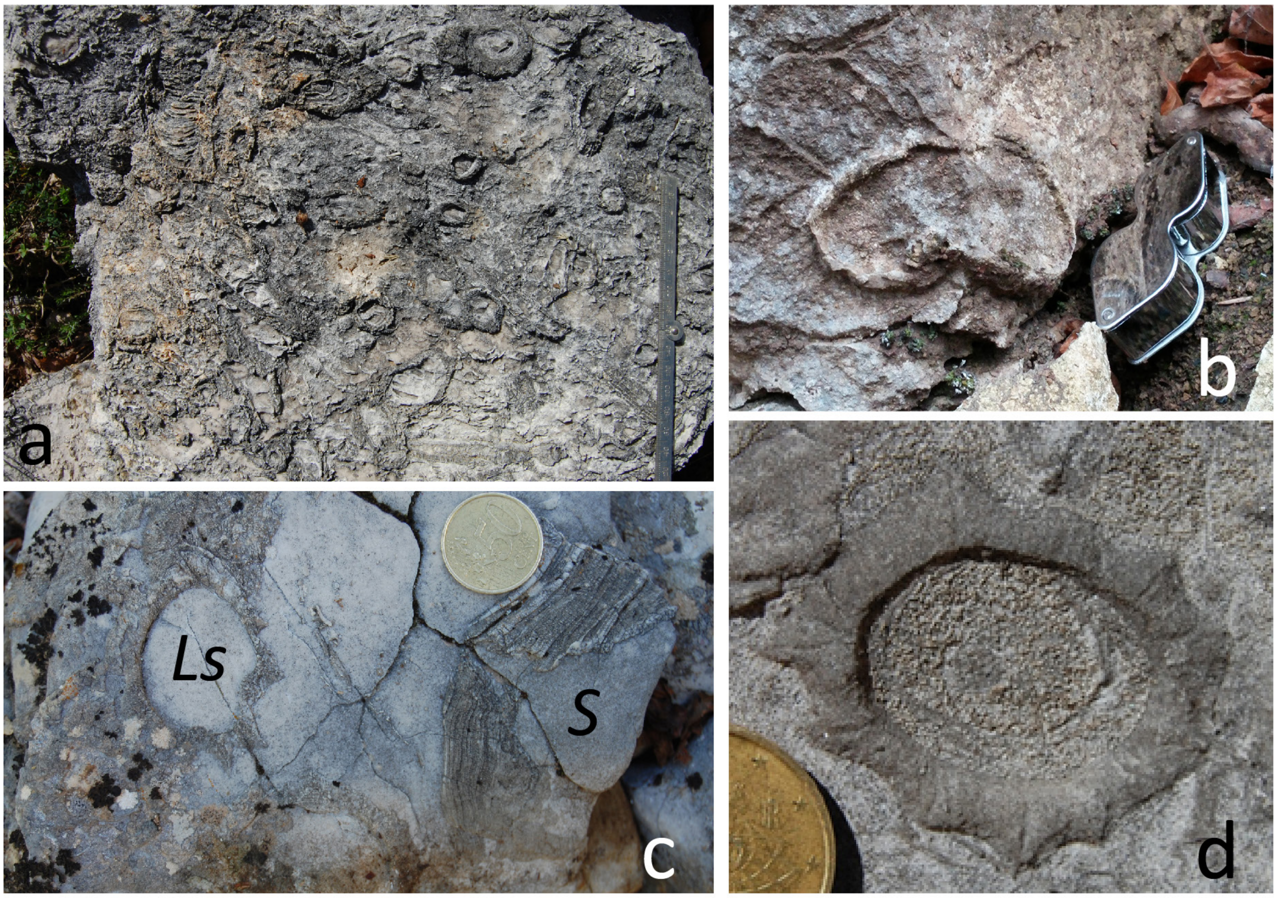

Fig. 7 - Outcrop A: a) Floatstone bed characterized by a Parautochthonous rudist assemblage dominated by *Radiolites dario* ("*Gorjanovicia*"); b) regular echinoid occurring in packstones at the top of the investigated interval; c) specimens of *Lapeirousella samnitica* and *Sauvagesia* fragment within a fine-grained limestone; d) transverse section of the right valve of *Biradiolites martellii*.

mudstone and laminated wackestone, olygotypic rudist assemblages composed of *Biradiolites angulosus*, *Radiolites trigeri*, *Durania arnaudi* and small *Hippurites* sp. (*Hippurites* cf. *resectus* Defrance). Sedimentological and paleontological evidence suggest that these rudists colonized lagoons and tidal flats during the late Turonian. In the middle part, characterized by mudstones, wackestones and floatstones, radiolitid-rich levels bear *Radiolites* ("*Gorjanovicia*") *dario*, *Bournonia* sp., *B. excavata* d'Orbigny, *Biradiolites fissicostatus* d'Orbigny, (in the upper part), *Sauvagesia tenuicostata* Polšak, *Radiolites* sp., *Durania* cf. *cornupastoris* (Des Moulins), associated with stromatolitic bindstone and peloidal wackestone with miliolids and ostracods. The micropaleontological assemblage is characterized by *Accordiella conica* and *Rotalispira scarsellai* and is referred to the *Accordiella conica* and *Rotalispira scarsellai* Biozone (Coniacian - Campanian *p.p.*). In the uppermost part of the succession, lower Campanian partly dolomitized limestones bear isolated *Pseudopolyconites* sp. and abundant tubules of the same organism that were everted from the shell in order to improve its adhesion to the muddy substrate.

5.2. SANTA MARIA DEI BISOGNOSI SECTION

At Santa Maria dei Bisognosi, in the northwestern Simbruini Mts. (Fig 1c), about 500 m of carbonate platform deposits crop out, ranging from the ? Coniacian to the Campanian *p.p.* (Cestari et al., 1992), overlain by Miocene bryozoan limestone (Civitelli and Brandano, 2005).

The Upper Cretaceous succession consists of limestone and dolomitized limestone in dm- to m-thick layers, characterized by coarse-grained laminated levels containing abundant rudist shells. The lower 220 m are characterized by peritidal cycles with mainly subtidal and intertidal deposits, whereas the following 200 m consist of lime-dolostone and limestone interpreted as formed in supratidal and inter-supratidal environments. High-energy episodes (marked by hummocky cross stratification, sharp base and normal gradation) occur, linked to storm waves (Compagnoni et al., 1991, 2005).

The rudist fauna of the lower part is characterized by oligotypic assemblages with *Radiolites dario*, *Bournonia excavata* and *Radiolites* aff. *angeiodes* (Sirna and Cestari), defining ?Coniacian-Santonian inner platform conditions, characterized by medium-low hydrodynamism (Sirna and Cestari, 1989), which evolve upwards to packstones and grainstones also bearing

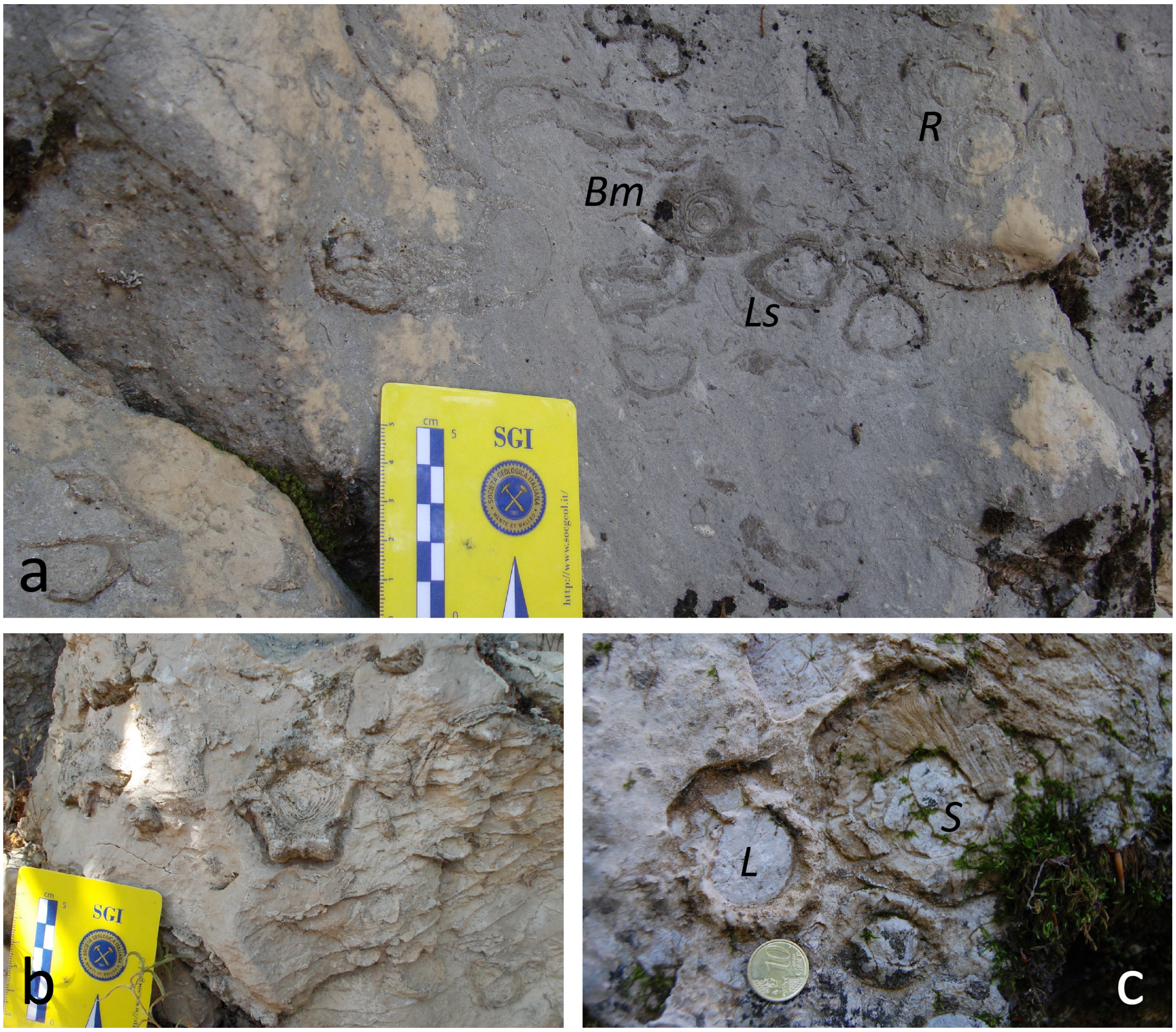

Fig. 8 - Outcrop B: a) Floatstone with radiolitids: Bm = *Biradiolites martellii*; Ls = *Lapeirousella samnitica*; R = radiolitids; b) Floatstone with transversal section of a right valve of *Biradiolites martellii*, concentric tabulae and dissepiments can be observed in the inner cavity; c) Radiolitid floatstone: L = *Lapeirousella*?; S = right valve of *Sauvagesia* cf. *tenuicostata*.

hippuritids, plagioptychids and corals (e.g. *Plagioptychus* cf. *paradoxus* Matheron, *Biradiolite*s sp., and *Sauvagesia tenuicostata*) suggesting higher energy conditions. This interval belongs to the *Accordiella conica* and *Rotalispira scarsellai* Biozone (Coniacian-Campanian *p.p.*).

In the upper part of the succession (Campanian *p.p.*) the rudist association is characterized by isolated large specimens of *Vaccinites vesiculosus* Woodward and *Vaccinites fortisi* Catullo, and by dense clusters of small *Hippurites colliciatus* Woodward and *Vaccinites* cf. *sulcatus* Defrance, along with *Sauvagesia* cf. *tenuicostata* (Fig. 11a) and *Pseudopolyconites* sp. In the uppermost portion of the section bioclastic levels are frequent, also bearing *Sabinia* sp. This interval belongs to the Discorbidae and Ostracoda biozone (Campanian *p.p.*), confirmed by the occurrence of *Cuvillierinella salentina* Papetti and Tedeschi (Fig. 11b).

5.3. SUBIACO SECTION

In the neighbourhood of Subiaco (Fig. 1c), a ca. 32 m thick succession of uppermost Cretaceous platform carbonates crops out within an hinactive quarry (Damiani et al., 1990; Fabbi et al., 2018). The outcrop is currently inaccessible due to rockfall along the quarry front and the partial filling of the quarry with inert wastes (Fig. 11c).

The lower part of the section is characterized by strongly recrystallized bioclastic grainstone (saccharoidal limestone), bearing, besides bioclasts, whole echinoids and rudists; the micropaleontological assemblages include *Orbitoides* spp. and *Hellenocyclina beotica* Reichel (Fig. 11d), referable to the *Orbitoides media* biozone of the Campanian *p.p.*-Maastrichtian *p.p.* (Chiocchini et al., 2012). The upper portion is characterized by incipiently dolomitized mudstones

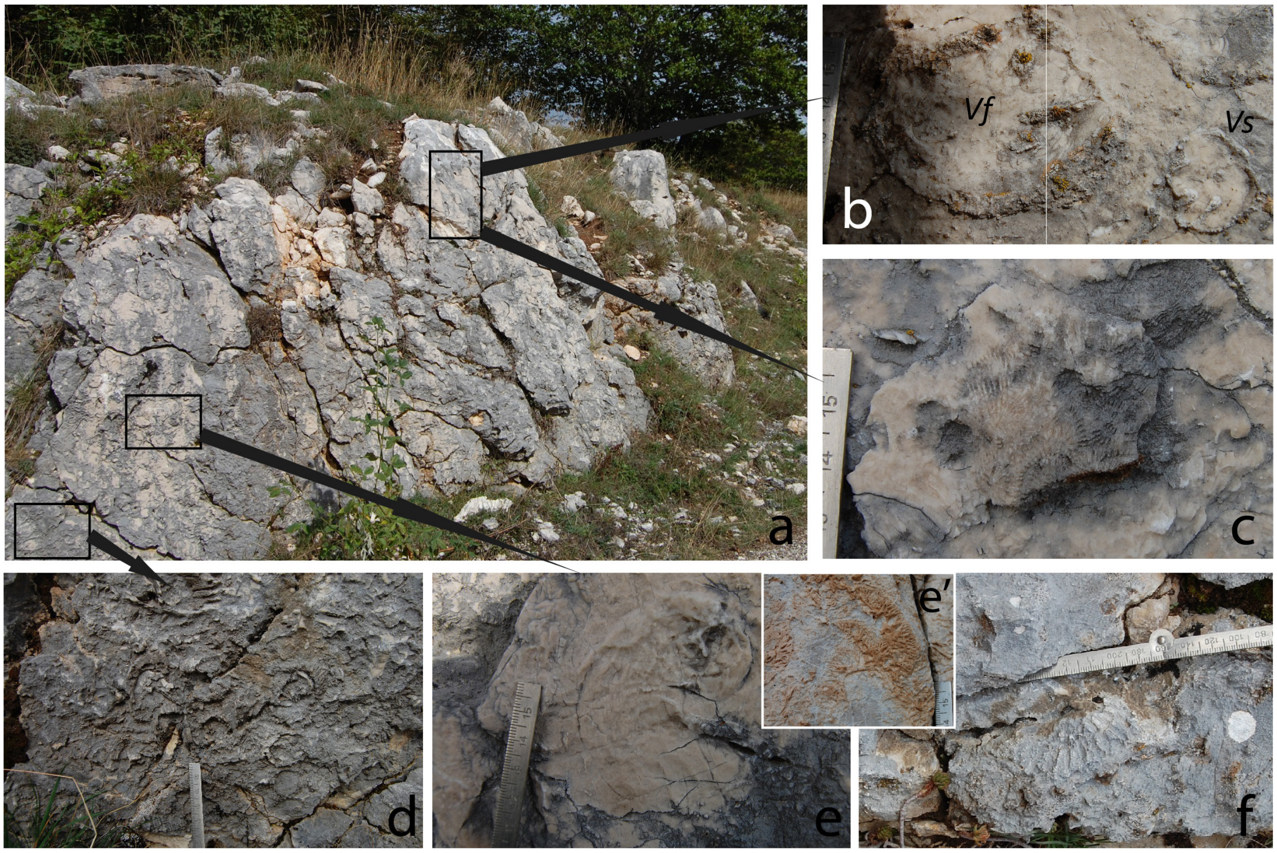

Fig. 9 - Outcrop C: a) general view of the outcrop; b) Vf = *Vaccinites* cf. *fortisi*, Vs = *Vaccinites sulcatus*; c) coral; d) radiolitid floatstone; e) *Plagioptychus paradoxus* showing rows of pyriform canals in the upper valve (inset e'); f) flat upper valve of *Vaccinites* sp. showing eroded radial system of canals.

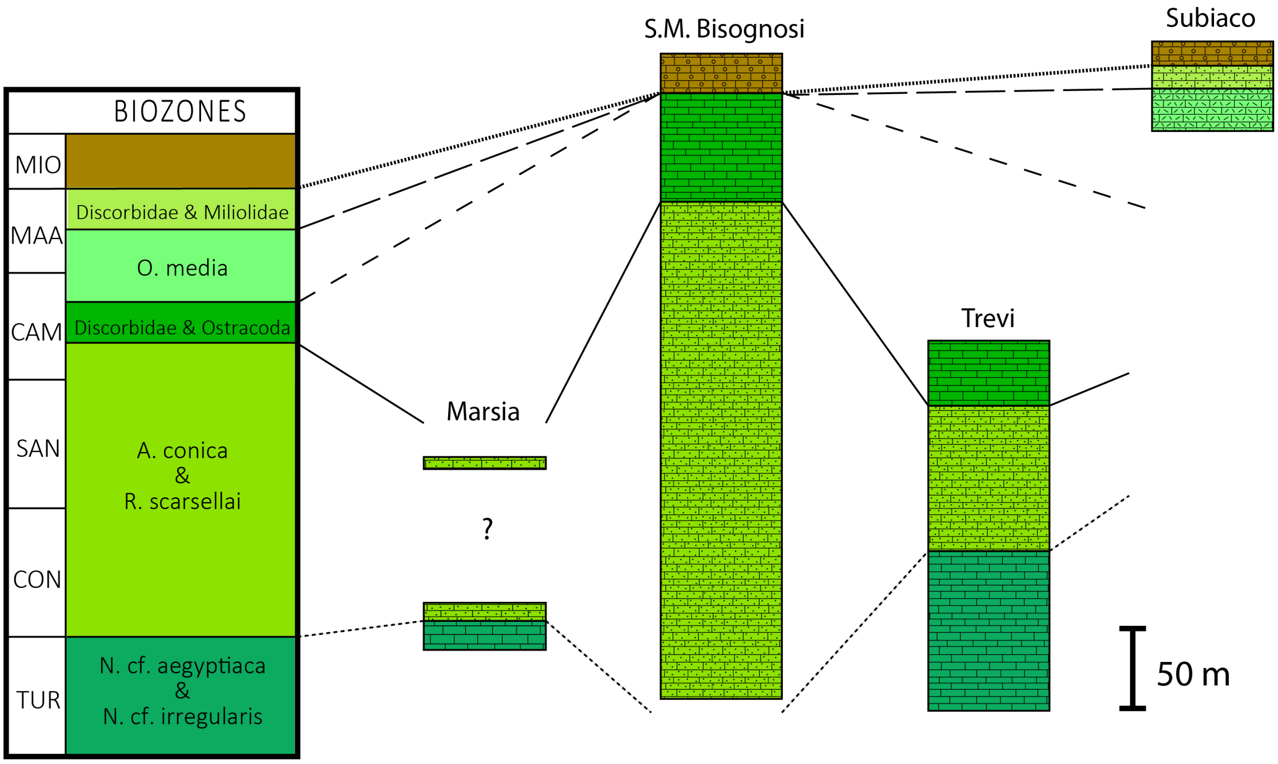

Fig. 10 - Correlation of the Simbruini Mts. stratigraphic sections considered in the present paper.

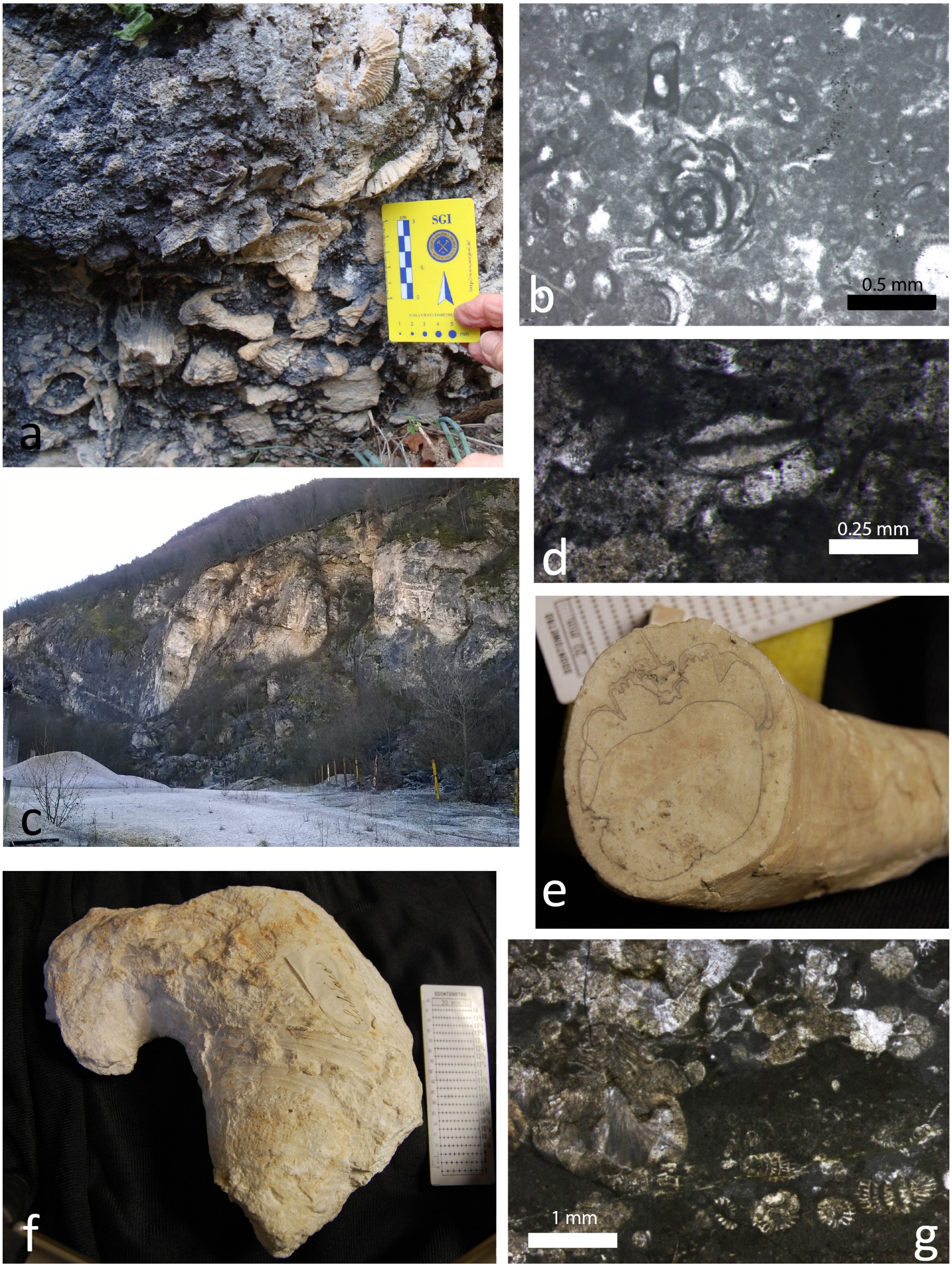

Fig. 11 - a) dense cluster with *Sauvagesia tenuicostata*, S. M. dei Bisognosi section; b) packstone with *Cuvillierinella salentina*, S.M. dei Bisognosi section; c) present-day conditions of the Subiaco quarry front; d) *Hellenocyclina beotica*, Subiaco section; e, f) topotypes of *Sabinia aniensis* (Natural History Museum of Florence University), Subiaco section; g) *Microcodium* mats and *Rhapydionina liburnica*, Subiaco section.

in thick beds, with Discorbidae sp. b, ostracods and miliolids referable to the Maastrichtian Discorbidae and Miliolidae biozone. The last 2 m of the Cretaceous succession are made of wackestones and dolostones with desiccation cavities, characterized by *Microcodium* mats and *Rhapydionina liburnica* Stache (Fig. 11c), which mark the upper Maastrichtian, directly overlain by Miocene calcarenites bearing Cretaceous rip-up clasts. The rudist fauna is composed of peculiar radiolitid taxa with a complex canal system in the upper (left) valve (genus *Sabinia*), typical of high energy settings, along with *Radiolites* sp. and *Sauvagesia* sp. The Subiaco quarry is the type-locality of three species, *Sabinia aniensis* Parona, *S. sublacensis* Parona and *Biradiolites affilanensis* Parona (Fig. 11 e,f, Parona, 1908; Fabbi et al., 2018). Other common macrofossils are *Acteonella crassa* (Dujardin), *Colveraia* sp. (interpreted as the upper, canaliculate, valve of a radiolitid taxon), *Inoceramus crispi* Mantell, *Lithodomus intermedius* d'Orbigny and massive corals fragments.

6. DISCUSSION

The Late Cretaceous evolution of the Latium-Abruzzi carbonate platform in the Simbruini-Ernici ridge was controlled by both global events and tectonics (Accordi and Carbone, 1988; Damiani et al., 1991; Carbone, 1993; Parotto and Praturlon, 2004; Carannante et al., 2008; D'Argenio et al., 2011). In the Albian-Cenomanian (or early Turonian) a tectonic uplift linked with the early stages of the Eoalpine orogenic phase (D'Argenio and Mindszenty, 1995; Vlahović et al., 2005; Carannante et al., 2008; D'Argenio et al., 2011) caused the emersion of large areas, marked by well-known bauxitic horizons (D'Argenio and Mindszenty, 1992; Cosentino et al., 2010). In the Simbruini Mts. no bauxitic deposits occur, and tectonic phases are likely responsible for strong thickness variability in the Upper Cretaceous carbonate platform deposits (Damiani et al., 1991; Cosentino et al., 2010; Cavinato et al., 2012; Fabbi, 2018).

In the early-middle Turonian, hyper-greenhouse conditions (Clarke and Jenkyns, 1999) resulted in a strong crisis and demise of the Aptian-Cenomanian carbonate factory, and in the development of platforms dominated by microbial sedimentation (Carannante et al., 2008) and characterized by poor and oligotypic faunas (e.g., Miliolidae and Discorbidae-Chiocchini et al., 2008, 2012), that are well represented in the Simbruini Mts. area, below the studied sections.

Beginning in the late Turonian, a spreading of rudist-dominated facies can be observed in the peri-Adriatic carbonate platforms (Laviano et al., 1997; Moro, 1997; Moro et al., 2002), caused by a regional transgression which produced the seawater encroaching of wide areas, and the onset of long-lasting shallow-water conditions (Vlahović et al., 2005; Carannante et al., 2008). Such event is recorded in the Simbruini Mts. area, where the late Turonian is characterized by fine-grained sediment, producing a soft substrate in sheltered settings or tidal flats, which were colonized by mono- or oligospecific rudist associations, as can be observed in the Marsia and Trevi sections (Fig. 12). Late Turonian rudist assemblages are dominated by radiolitids characterized by elongate shells, which suggest a semi-infaunal lifestyle with mud-sticker habit in low-energy environments (Moro, 1997; Cestari, 2005; Cestari and Pons, 2007). The Coniacian stage has proven difficult to detect, as is in most of the regional literature (e.g., Cestari et al., 1992; Pons and Sirna, 1992). This can be due to its limited thickness (arguably less than 10 m in the Marsia section, while in the Trevi and Santa Maria dei Bisognosi sections it has been only inferred) linked with the scarcity of unambiguous markers (e.g., Frijia et al., 2015).

In the Santonian-early Campanian, large unrimmed carbonate platforms developed in the peri-Adriatic region, dominated by grain-supported sedimentation and by calcite-shelled rudists (e.g. radiolitids and hippuritids), along with subordinate gastropods, echinoids, calcareous sponges and rare red algae (e.g. Carannante et al., 2008; Simone et al., 2012).

In the Simbruini Mts. open platform environments are well-represented, and characterized by facies mosaics made of coarse-grained sediments, rudist floatstones/rudstones and less common fine-grained sediments, depending from local hydrodynamism (e.g., Simone et al., 2003; Ruberti et al., 2006). A gradual increase in hydrodynamic conditions during the Santonian can be observed in the Marsia, Trevi and Santa Maria dei Bisognosi sections, as confirmed by rudist assemblages that include hippuritids and robust radiolitids, significantly associated at Marsia with rare corals and echinoids. These conditions persist at Marsia and Santa Maria dei Bisognosi through the early Campanian, which is represented by high energy facies with radiolitids, hippuritids and corals. Differently at Trevi low-energy conditions in the lower part of the Campanian are testified by abundant tubules everted from the shells of *Pseudopolyconites* sp. in order to improve the adhesion to the muddy substrate, again with a mud-sticker habit.

Since the late Campanian a reorganization of paleoenvironments is observed in the Latium-Abruzzi platform, with a strong reduction of productive areas and the consequent disappearance of inner platform facies (Accordi and Carbone, 1988; Damiani et al., 1991; Cestari and Sirna, 1991; Carannante et al., 2008).

In the Simbruini Mts. area the upper Campanian is well represented in the Santa Maria dei Bisognosi and Subiaco sections, and is characterized by high energy grain supported, bioclastic facies of the 'saccharoidal (or crystalline) limestone', and rudist assemblages dominated by peculiar radiolitids with canaliculate shell and well-developed upper valve (*Sabinia* sp.), suitable for living in high energy environments. Such conditions and faunal assemblages persist through the Maastrichtian, which is only represented in the Subiaco section.

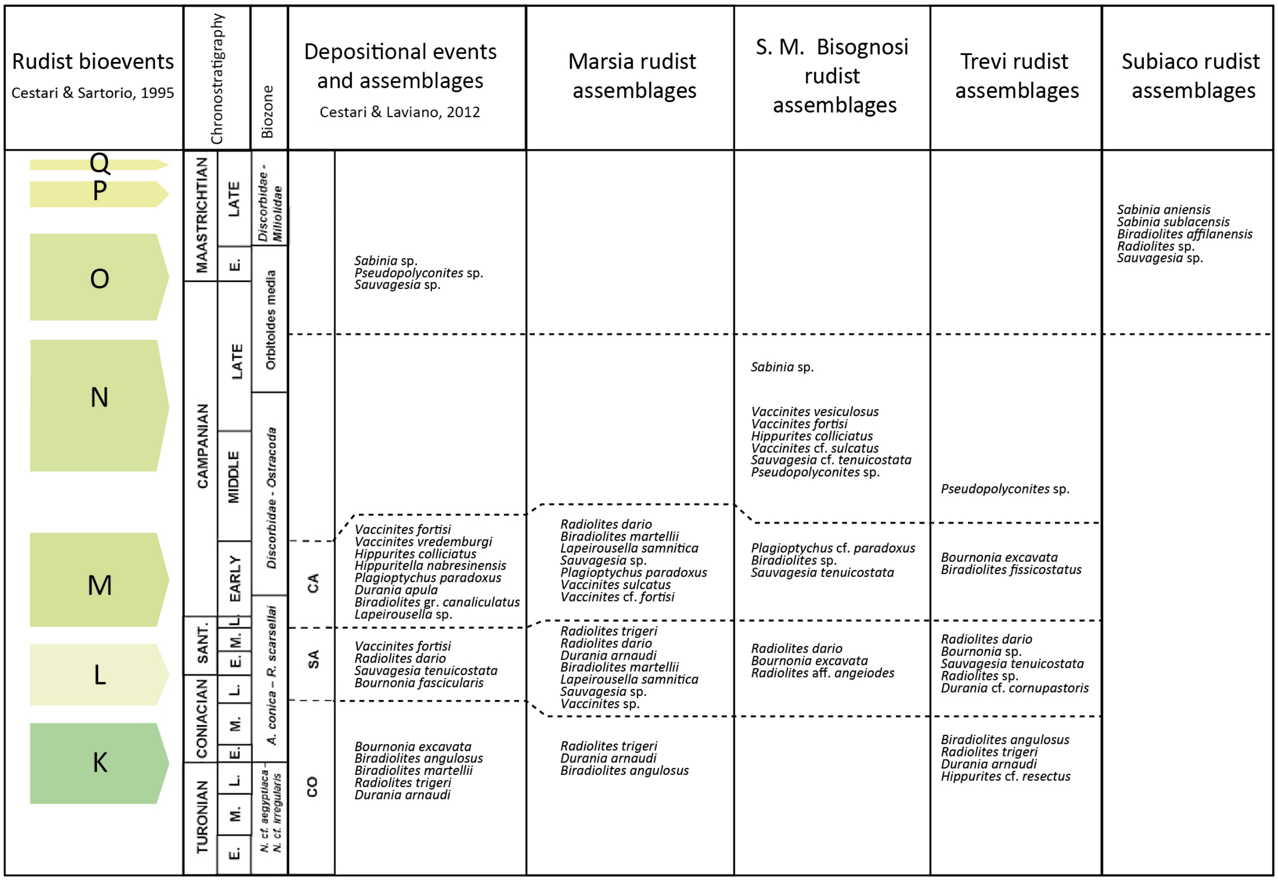

Fig. 12 - Upper Cretaceous rudist bioevents and correlation with the rudist faunas of considered sections.

6.1. BIOSTRATIGRAPHIC SIGNIFICANCE OF RUDIST ASSEMBLAGES

Besides the stratigraphic range of single taxa, several bioevents have been recognized in the peri-Adriatic carbonate platforms (Fig. 12), marked by rudist biocoenoses having a stratigraphic significance (Pons and Sirna, 1992; Cestari and Sartorio, 1995; Laviano et al., 1997; Cestari, 2002; Cestari and Laviano, 2012). A late Turonian-Coniacian bioevent in inner platform settings is marked by *Radiolites trigeri*, *Biradiolites angulosus*, *B. martellii*, *Bournonia*, *Durania* and rare Hippuritidae. This event is well represented in the Marsia sections 1 and 2 and in the Trevi section. A second late Coniacian-Santonian bioevent is characterized by *Radiolites dario*, *Sauvagesia tenuicostata, Vaccinites fortisi*, *Biradiolites*, and *Durania*; also this event is well represented in the study area in the upper portion of the section 2 and in the outcrop A. A third late Santonian bioevent is marked by *Plagioptychus paradoxus*, *Lapeirousella* sp., *Radiolites dario*, *Sauvagesia tenuicostata*, *Biradiolites*, *Pseudopolyconites* sp., *Vaccinites sulcatus and Vaccinites fortisi*. This event is also represented in the study area, in oucrops B and C, in the Trevi and Santa Maria dei Bisognosi sections (Fig. 12). The last bioevent is the "*Sabinia* event" in the late Campanian-Maastrichtian (events N and O in Cestari and Sartorio, 1995); this event, marked by the occurrence of abundant *Sabinia* associated with other Radiolitidae and Hippuritidae, is well represented in the S. Maria dei Bisognosi and Subiaco sections.

7. CONCLUSIONS

The study of the new rudist outcrop of Marsia and its comparison with other known outcrops allowed us to consider the evolution of rudist faunas in the context of the Simbruini Mts. carbonate platform succession.

The outcrops of Marsia and Trevi are characterized by inner platform associations of late Turonian age, rich in radiolitids, including *Biradiolites angulosus*, *Radiolites trigeri*, *Durania arnaudi*, *Biradiolites martellii*. In Marsia, as well as in Santa Maria dei Bisognosi, ?Coniacian-lower Campanian open platform facies occur, marked by hippuritids and corals (including *Vaccinites* cf. *sulcatus*, *Vaccinites fortisi*, *Plagioptychus paradoxus*) always associated with radiolitids including *Sauvagesia sp.* and *Radiolites ("Gorjanovicia") dario*. The middle Campanian is well represented and characterized by bioclastic facies with peculiar canaliculate radiolitid rudists, such as *Sabinia* spp., both in the Santa Maria dei Bisognosi and the Subiaco sections. In the last locality similar facies persist through the Maastrichtian.

ACKNOWLEDGEMENTS - The reviewers Lorenzo Consorti and Giovanni Rusciadelli are kindly acknowledged for their useful comments and suggestions as well as to Johannes Pignatti for his thorough copy editing. This paper is dedicated to the memory of Maurizio Chiocchini, a guide for us and a passionate paleontologist until the end of his days. The passion that he passed on us still stands.

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