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EOCENE SILICEOUS SPONGES (PORIFERA: HEXACTINELLIDA, DEMOSPONGEA) FROM EASTERN LESSINI MOUNTAINS (NORTHERN ITALY)

Direttore della Scuola : Ch.mo Prof. (Massimiliano Zattin)

Supervisore :Ch.mo Prof. (Nereo Preto)

Dottorando : (Viviana Frisone)

ABSTRACT

2 case studies of Eocene siliceous sponges from Eastern Lessini Mountains are reported.

Case study 1— Bartonian Mt. Duello isolated spicules (Verona).

This study documents exceptionally preserved isolated opaline spicules, unique for the Middle Eocene (Bartonian) of Italy. Interpretation of morphological types of spicules by comparison with living species lead to their attribution to 5 orders (Astrophorida, Hadromerida, Haplosclerida, Poecilosclerida, "Lithistida"), 7 families (Geodiidae, Placospongiidae, Tethyidae, Petrosiidae, Acarnidae, ?Corallistidae, Theonellidae) and 5 genera (*Geodia*, *Erylus*, *Placospongia*, *Chondrilla*, *Petrosia*, ?*Zyzyza*). All the described genera are first reported from the Eocene of Europe. This study expands the geographical range of these taxa and fills a chronological gap in their fossil record. The spicules are often fragmented and bear signs of corrosion. They show 2 types of preservation: glassy and translucent. X-ray powder diffraction analysis confirms that both types are opal-CT with probable presence of original opal-A. Despite of that, at SEM, the texture of freshly broken surfaces is different. Milky spicules show a porous structure with incipient lepispheres. This feature, together with surface corrosion and the constant presence of the zeolite heulandite/clinoptilolite, point to a certain degree of diagenetic transformation. Macro and micro facies analysis define the sedimentary environment as a rocky shore succession, deepening upward within the photic zone. The spicule-rich sandy grainstone represents the deepest facies and was deposited in middle-outer carbonate ramp environment, in part in a fairly high energy environment close to storm wave base, within the photic zone.

Case study 2 –Lutetian sponge fauna from Chiampo Valley (Vicenza).

The fauna consists of non-compressed bodily preserved sponges. More than 900 specimens housed in Italian Museums were studied. The original siliceous skeleton is dissolved and substituted by calcite. There is evidence of presence of sulfate reducing bacteria. Observations of both complete specimens and thin sections lead to taxonomical attributions of 32 species (15 Hexactinellida, 17 Demospongea). Among these taxa, the institution of 10 new species is proposed: *Stauractinella eocenica*, *Rigonia plicata*, *Hexactinella clampi*, *Camerospongia tuberculata*, *Camerospongia visentini*, *Toulminia italica*, *Coronispongia confossa*, *Cavispongia scarpae*, *Corallistes multiosculata*, *Bolidium bertii*. 24 genera are described, 2 of which new (*Rigonia* and *Coronispongia*). The specimens were photographed before sectioning, and 3-D models of fossils were produced. Delicate sponge attachments were documented. The presence of both attachments to soft and hard substrate indicate a mixed bottom. Juvenile sponges were recorded too. The sponge fauna is presumably parautochthonous. The taxonomical study shears a new light on the scarce fossil record of Eocene siliceous sponges. Petrographic investigations of the sponges and the embedding sediment contributed to clarify the sequence of taphonomic events and the sedimentary environment.

RIASSUNTO

Sono riportati 2 casi studio di spugne silicee eoceniche dei Monti Lessini orientali.

Caso di studio 1 — spicole isolate bartoniane del Monte Duello (Verona)

Questo studio documenta la presenza di spicole isolate opaline, eccezionalmente conservate che costituiscono un *unicum* per l'Eocene (Bartoniano) dell'Italia. L'interpretazione della morfologia dei tipi di spicole tramite il confronto con specie viventi ha portato all'attribuzione a 5 ordini (Astrophorida, Hadromerida, Haplosclerida, Poecilosclerida, "Lithistida"), 7 famiglie (Geodiidae, Placospongiidae, Tethyidae, Petrosiidae, Acarnidae, ?Corallistidae, Theonellidae) and 5 generi (*Geodia*, *Erylus*, *Placospongia*, *Chondrilla*, *Petrosia*, ?*Zyzya*). Tutti i generi descritti sono segnalati per la prima volta per l'Eocene dell'Europa. Il presente studio espande il range geografico di questi taxa e riempie un gap cronologico nel loro record fossile. Le spicole sono spesso frammentate e portano segni di corrosione. Esse mostrano 2 tipi di conservazione: una vitrea e una lattea. Le analisi alla diffrazione delle polveri ai raggi X confermano che entrambi i tipi sono formati da opale-CT con la probabile presenza di opale-A. Malgrado ciò, al SEM, la struttura delle superfici rotte di fresco, è differente. Le spicole lattiginose hanno una struttura porosa con lepisfere incipienti. Questa caratteristica, assieme alla corrosione della superficie e la costante presenza della zeolite heulandite/clinoptilolite, suggerisce un certo grado di trasformazione diagenetica. Macro e micro analisi di facies definiscono l'ambiente sedimentario come una successione di costa rocciosa, deepening upward, all'interno della zona fotica. Il grainstone sabbioso ricco di spicole rappresenta la facies più profonda e si è depositato in un ambiente di rampa mediana-esterna, in un ambiente di energia piuttosto alta vicino alla base d'onda di cattivo tempo, all'interno della zona fotica.

Caso studio 2— Fauna a spugne luteziano della Valle del Chiampo (Vicenza).

La fauna consiste in spugne intere non compresse. Sono stati studiati più di 900 esemplari conservati in Musei italiani. Lo scheletro siliceo originale si è dissolto ed è stato sostituito da calcite. C'è evidenza della presenza di batteri solfo-riduttori. L'osservazione sia di esemplari completi sia di sezioni sottili ha portato all'attribuzione di 32 specie (15 Hexactinellida, 17 Demospongea). Tra queste, è proposta l'istituzione di 10 nuove specie: *Stauractinella eocenica*, *Rigonia plicata*, *Hexactinella clampi*, *Camerospongia tuberculata*, *Camerospongia visentini*, *Toulminia italica*, *Coronispongia confossa*, *Cavispongia scarpae*, *Corallistes multiosculata*, *Bolidium bertii*. Sono inoltre descritti 24 generi, 2 dei quali nuovi per la Scienza: *Rigonia* e *Coronispongia*. Gli esemplari sono stati fotografati prima di essere sezionati e sono stati prodotti modelli 3-D. Sono stati inoltre documentate delicate strutture di ancoraggio al substrato. La presenza di strutture di ancoraggio sia di substrato molle che di substrato duro indicano un fondale di tipo misto. Sono state pure documentate spugne allo stato giovanile. La fauna a spugne è presumibilmente parautoctona. Questo studio tassonomico porta nuova luce sullo scarso record fossile delle spugne eoceniche. Le ricerche petrografiche sugli esemplari di spugne e sul sedimento inglobante ha contribuito a chiarire la sequenza di eventi tafonomici e l'ambiente sedimentario.

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CHAPTER 1 — Isolated spicules of Demospongiae from Mt. Duello (Eocene, Lessini Mts, northern Italy): preservation, taxonomy and depositional environment

Introduction

Demospongiae is the largest and most diverse class of the Porifera, including about 83 % of all Recent sponges (Van Soest et al. 2012a). In spite of that, the demosponge fossil record, especially for “soft” nonlithistid taxa, is rather scarce. Obviously, “soft” sponges have a low fossilization potential: their organic skeletons disintegrate after death and their only trace in the rock record are loose spicules which are usually scattered in sediment and difficult to isolate and identify. Even if spicules are common in marine sediments, sponge spicules have received little attention in the paleontological literature, in part due to the difficulties with their interpretation. A single sponge can possess a wide variety of spicules, and different combinations of quite similar spicules may belong to entirely distinct taxa, so that taxonomic attributions based upon isolated spicules are extremely difficult. Moreover, microscleres, which are of great diagnostic value in demosponge classification (Reid 1968; Hooper and van Soest 2002), are usually dissolved because of their small size, and are therefore very rare in sediments. As a consequence, there is a strong need of multi-disciplinary research to try to refine taxonomic attributions by comparison with living sponges which show complete spicules assemblages.

Regarding the Paleogene and the Neogene, spicules occurrences are common in ODP (Ocean Drilling Project) – DSDP (Deep Sea Drilling Project) sites, e.g., in the North Sea (Eidvin and Rundberg 2007), NW Atlantic (Burky 1980), W central Atlantic (McCartney 1987), W subtropical Atlantic (Palmer 1988 and literature therein), S Atlantic (Ivanik 1983), Antarctica (Ahlbach and McCartney 1992), Philippine Sea (Martini 1981), SW Pacific (Locker and Martini 1996) and W Tasmania (Kenneth et al. 1975). On the other hand, reports of inland occurrences are less common. For the Paleocene, sponge spicules are reported from Alabama (Rigby and Smith 1992) and the Landen Formation of Belgium (De Geyter and Willems 1982). For the Eocene, spicules are known from North Carolina (Finks et al. 2011 and literature therein), Western and South-Western Australia (Hinde 1910; Gammon et al. 2000), and New Zealand (Hinde and Holmes 1892; Edwards 1991). Finally, Miocene sponge spicules occur in land sections of Portugal (Pisera et al. 2006), Slovakia (Lukowiak et al. 2013) and the Carpathians (Riha 1982; Pisera and Hladilova 2002). In Italy, records of Cenozoic isolated demosponge spicules are mainly from the Miocene of the Ligurian Piedmont basin, the Apennines and SW Sardinia (Matteucci and Russo 2011). Bonci et al. (1993) found spicules in Pliocene sediments near Genova (Northern Italy). No Eocene findings were reported so far.

The aim of this study is to document exceptionally preserved isolated spicules, which are unique for the Eocene of Italy, and to undertake their taxonomic assignment by comparison with spicules of Recent sponges. The preservation of these spicules was assessed through mineralogical and petrographical analyses. Field sedimentology and microfacies analysis of spicule bearing rocks contributed to define their depositional environment. There is increasing evidence that siliceous sponges play a significant role in silicon cycling in the oceans with substantial contributions to the processes of biogenic silica production and dissolution in some continental shelf and slope habitats (Maldonado et al. 2005, 2010; Chu et al. 2011; Treguer and La Roca 2013). This study contributes to the knowledge of the distribution of siliceous sponge

in time and space, as well as in terms of sedimentary environments, and documents initial stages of in situ spicule dissolution.

Geological setting and historical significance of the site

The studied area is located in the eastern Lessini Mountains, a portion of the pre-Alps of North-Eastern Italy, on the SW side of Mt. Duello (45°28'48.24"N, 11°16'14.65"E), in the municipality of Montecchia di Crosara (Verona), 109 m above sea level. Mt. Duello is located West of Roncà, between Fiumicello and Alpone rivers. The Alpone is a tributary of Adige River (Fig. 1).

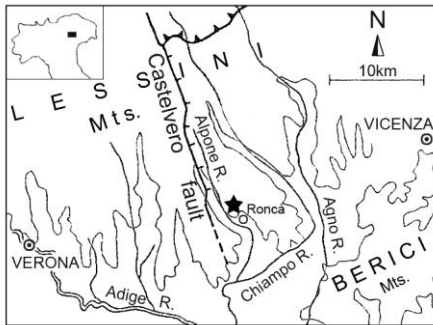


Fig.1 Location of the studied outcrop

The succession at Mt. Duello is mainly constituted of basalts, but it contains also nummulitic limestones alternated with volcanic and volcanoclastic deposits, which are known in literature as the "Roncà horizon". This horizon is about ten meters high and is laterally continuous in the south-eastern Lessini Mts. (De Zanche and Conterno 1972). The "Roncà horizon" is characterized by the larger foraminifer *Nummulites brongnarti* (d'Archiac and Haime, 1853) and is thus dated as late Middle Eocene (Bartonian, 40-37 Myr) (Fabiani 1915; De Zanche and Conterno 1972; Hottinger 1960; Schaub 1962; Barbieri et al. 1991). Extensive volcanic activity took place from Paleocene to Oligocene in the Venetian region, probably due to a local extensional tectonic setting which developed in the otherwise compressional South Alpine foreland, and was possibly related to a mantle plume (e.g. De Vecchi and Sedea 1995; Zampieri 1995; Macera 2008; Cannatelli 2011). Several magmatic pulses occurred, of a duration generally shorter than a planktonic foraminifera or nummulite biochronozone, i.e., less than 1–3 Myr, and were separated by periods of magmatic inactivity during which marine sedimentation took place (Barbieri et al. 1982, 1991). The "Roncà horizon" limestone is interbedded within volcanics of the Bartonian lava flows, which were first subaqueous and then subaerial (De Vecchi and Sedea 1995). These volcanics belong to the sixth volcanic pulse, the most important in the pre-Alps. As an example of subaerial volcanism, there is a major eruptive center, Mt. Calvarina, within few hundred meters from the studied locality (Piccoli 1966). Other evidences of emerged land in the surroundings are lignite deposits and fossils of terrestrial plants and vertebrates (see below).

Mt. Duello was located during the Bartonian within a NNW-trending extensional structure, the Alpone-Agno graben (or semi-graben) (Barbieri et al. 1982, 1991; Zampieri 1995), bound to the West by the Castelvero normal fault. This fault was crucial for the structural and palaeoenvironmental evolution of the central-eastern Lessini Mts. in late Paleocene–middle Eocene times (Papazzoni and Trevisani, 2006), as it was a threshold separating a western area, with thin and discontinuous volcanic deposits, from an eastern one, where volcanic rocks prevail. The Castelvero Fault determined higher subsidence in the eastern block and the onset of the Alpone-Agno graben (Barbieri et al. 1991). During the Bartonian, due to a local volcanism acme, the graben was filled and emerged volcanic areas were formed (Mietto 1997).

The fossiliferous locality of Roncà has historical significance. It has been studied from the paleontological and chronostratigraphic point of view since the eighteenth century (Fortis 1778).

Brongniart (1823) published the oldest geological description, while Massalongo (1857, 1859) thoroughly described the fossil plants. He also mentioned excavations at Costo (Church Valley) where - along with plants - fossil mollusks, fish scales and other vertebrate remains were found. Between 1875 and 1889, De Zigno described remains of the sirenid *Prototherium veronense* (De Zigno 1875), the crocodile *Megadontosuchus arduini* (De Zigno 1880), chelonians, snakes and a large wading bird. Besides these findings, De Zigno also gave a more detailed description of the stratigraphic sequence.

Other competent students of the area were those of Bayan (1870, 1873), Vinassa de Regny (1896) and De Gregorio (1896), but it was Fabiani (1915) that conducted the first biostratigraphic study. More recently, other authors have carried out further studies on the Roncà Horizon (Hottinger 1960; Schaub 1962; Piccoli and De Zanche 1968; Mellini 1989, 1993; Mellini and Quaggiotto 1990; Roghi 2012). Since 2010, after receiving an excavation licence from the Italian Ministry of Culture and Environment, researchers of the Roncà Museum carried out a series of paleontological excavations and investigations at Roncà (Zorzin et al. 2012). The sponge spicules that are the object of this study were discovered during one of these excavations (July 2011). In a preliminary study, Frisone and Zorzin (2012) observed that spicules were preserved as opaline silica and belong to Demospongiae, mostly "soft sponges" but also sponges with rigid skeletons (lithistids).

Material and methods

Approximately 240 g of bulk rock was separated into 60 g subsamples and various methods of extracting spicules were tested (Frisone and Zorzin, 2012). At the Micropalaeontology Laboratory of Padova University, a subsample was broken in pieces of 1-2 cm, heated in H₂O₂ 30% for few minutes and then washed with water using the decantation method. A low, disc-shaped bowl was used. First, the bowl was moved in small circles so that the sediment particles tended to shift to the outer part of the bowl; spicules tend to stay in the central part. Secondly, the water was let still for few minutes to allow spicules to sediment at the bottom. Thirdly, the top water was gently removed and clean water was added. This procedure was repeated for several times. Then the residue was dried for 2 hours in the oven at 55° C.

The sponge spicules were hand-picked and preliminarily studied using a Leica MZ 125 binocular microscope. Selected spicules were gold-coated and observed with a CamScan MX2500 Scanning Electron Microscope (SEM) at Padova University. At Museu Nacional of Universidade Federal do Rio de Janeiro, a JEOL 6390 LV SEM was used on samples coated with gold-palladium. The attribution of spicules to sponge taxa was achieved by comparison with characteristic spicules of Recent sponges, according to Pisera et al. (2006, and literature therein). Terminology of spicules can be found in Boury-Esnault and Rützler (1997) and Hooper and Van Soest (2002).

The investigated material (more than 500 isolated spicules) is housed in Museo di Archeologia e Scienze Naturali "G. Zannato"- Montecchio Maggiore (Vicenza), Italy, palaeontological collection, number MCZ-I 3473. Seventeen oriented thin sections were observed under the petrographic microscope for the description of microfacies. At Padova University, X-ray powder diffraction (XRPD) data were recorded on a Panalytical θ - θ diffractometer (Cu radiation) equipped with a long fine focus Cu X-ray tube (operating at 40kV and 40mA), sample spinner, Ni filter and a solid state detector (X'CeLerator). The system optics consist of fixed ½° divergent slit and 1° antiscatter slit on the incident beam path and soller slits (0,04 rad) on incident and diffracted beam path. The powders of bulk sample were mounted on 32 mm (internal diameter) circular sample holder. Scans were performed over the range 3-80° 2 θ with a virtual step size of 0.017° 2 θ and a counting time of 100 s/step. Spicules, 10-20 specimens selected by picking, were mounted directly on a silicon zero-background sample holder. Because of the small amount of material (< 1 mg), the counting time was increased to 2500 s/step. The clay-size components were separated by decantation and deposited on a silicon zero-background sample holder. The sample was analyzed before and after glycol treatment (Moore and Reynold 1997) over the range 2.5-42° 2 θ with a virtual step size of 0.033° 2 θ and a

counting time of 200 s/step. Fixed 1/8 divergent slit and 1/4° antiscatter slit were used for a better low angle description. The program High Score Plus (PANalytical) was used for phase identification.

Results

The assemblage of sponge spicules and their taxonomic assignments

The assemblage of spicules at Mt. Duello includes essentially large (> 1000 µm), or relatively large spicules (> 200 µm), most of which are classified as megascleres and play important structural roles in the skeleton of the sponges they come from. Spicules originated from Demospongiae, as inferred from the spectrum of morphotypes, and include monaxial and tetraxial spicules, of diactinal and tetractinal morphology. Among the microscleres, only relatively large forms were recovered (> 100 µm), these being mostly euasters, with a very few exceptions, as further detailed below. Direct examination of the untreated bulk sediment under SEM failed to highlight any isolated microscleres, apart from sterrasters.

The following morphological groups of spicules could be recognized:

Tetraxial/tetractinal megascleres – protriaenes, (ortho- and pro-)dichotriaenes, anatriaenes, phyllotriaenes. Trianaenes were commonly found (Fig. 2), including protriaenes of various morphologies (Fig. 2a–e, i–k). Rhabdomes (plural of rhabdome: ray of a triaene that is distinct from the other three, mostly in length) are 80-200 µm wide, with a maximum length, -albeit broken- of 1700 µm. Cladi (the other tree rays of a triaene, usually similar to each other and shorter than rhabdome) are 120-170 µm long. Cladi are straight or slightly curved, cylindrical or conical in section, and bear blunt or sharp terminations. It is not clear how much cladi vary within a single triaene, as most of them are broken.

Dichotriaenes also span considerable diversity, occurring as orthodichotriaene (Fig. 2f?, g) to prodichotriaene forms (Fig. 2l–m, ?n–o). Rhabdomes are 50-160 µm wide, cladi are 90-290 µm long. Cladi of dichotriaenes vary along the same lines as those of the protriaenes, but it has been possible to figure out further variations within a single cladome (Fig. 2m, o, q).

A single broken anatriaene was found (Fig. 2h).

Long-shafted triaenes (Fig. 2a–l) resemble those of Recent Astrophorida currently known from Ancorinidae, Corallistidae, Geodiidae, Theneidae and Vulcanellidae, (all of which are Astrophorida (Hooper and Van Soest 2002; Cárdenas et al. 2011)). A few phyllotriaenes or pseudophyllotriaenes were found, but in very poor state of preservation. The largest diameter is of ca. 430 µm, while the rhabdomes in cross section are about 40 µm wide. Phyllotriaenes are characteristic of Theonellidae, while pseudophyllotriaenes occur in the Neopeltidae; both these families are also Astrophorida. These morphotypes can only be distinguished by reference to their geometry (tetraxial or monaxial). These features are impossible to recognize in our material, because cladomes are always broken (Fig. 2r–t) preventing such a comparison to be carried out any further.

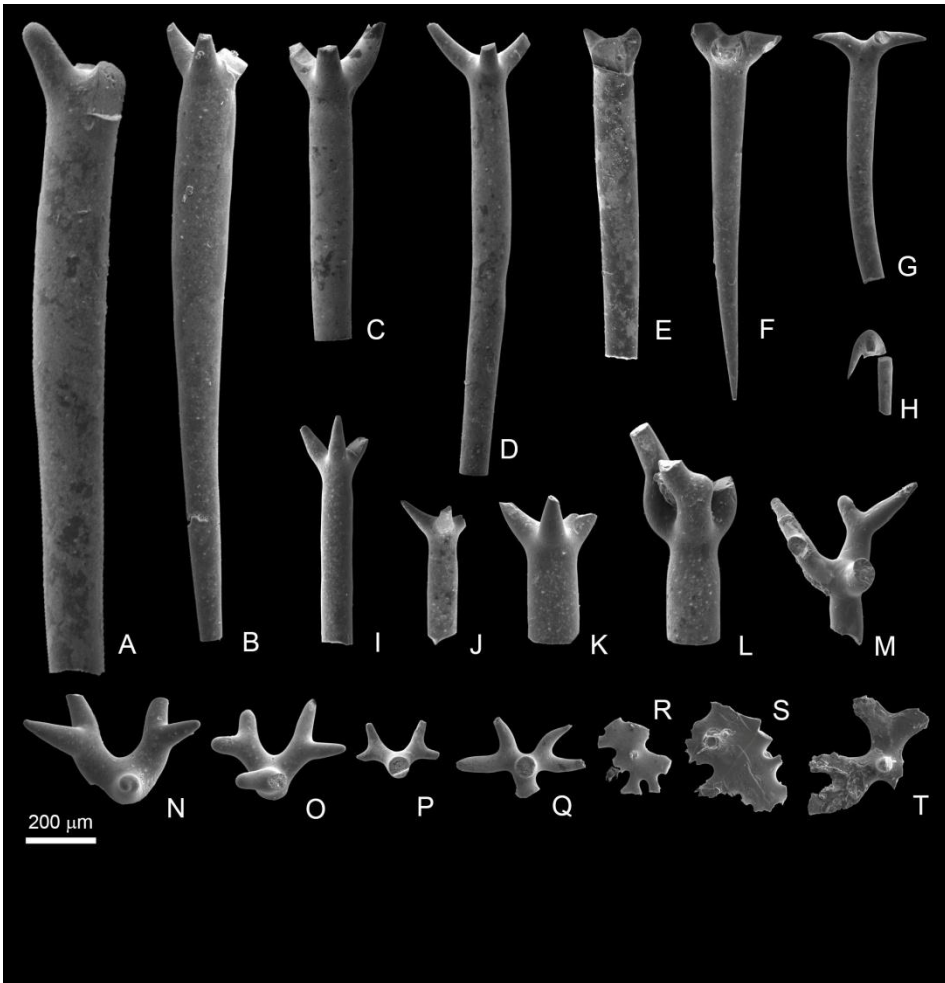


Fig. 2 Tetractinal megascleres from Mt. Duello. **(a–e, i–k)** Protriaenes of various morphology. **(f?, g)** orthodichotriaenes. **h** Anatriaene. **(l – m, ?n – o)** Prodichotriaenes. **(p, q)** Cladome of orthodichotriaenes. **(r–t)** Cladome of pseudophyllotriaenes or phyllotriaenes. Scale bar 200 μm.

Desmas (articulated spicules of demosponge lithistids) are scarce in our sample (Fig. 3). As the material was strongly fragmented, the assignment of desmas to a specific taxon is impossible. Nevertheless some tetracles are present (Fig. 3a–b) that belong to family Theonellidae Lendenfeld, 1903. A possible dicranoclone (Fig. 3d) is attributable to family Corallistidae Sollas, 1888.

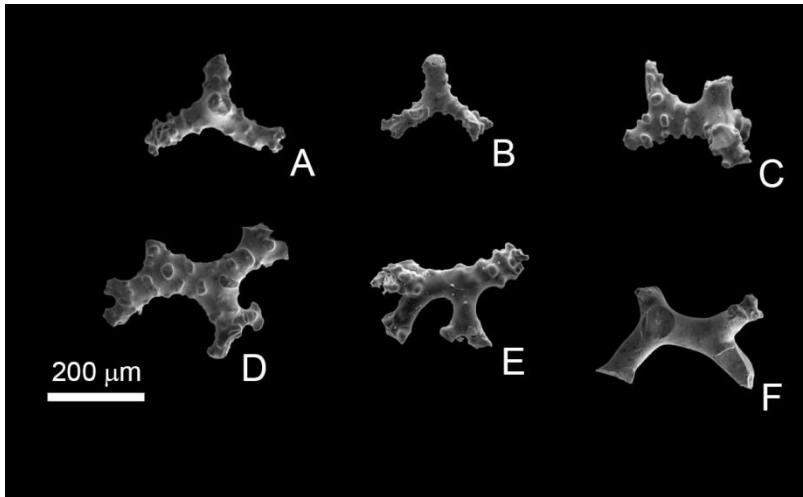


Fig. 3 Desmas from Mt. Duello. **(a–b)** Tetraclones. **(c, e, f)** Indeterminate desmas. **(d)** Possible dicranoclone. Scale bar 200 µm.

Monaxial megascleres — oxeas, strongyloid oxeas, strongyles, verticillated acanthostrongyles. Broken fragments of seemingly monaxial megascleres were reported as dominant in the Duello spicule-rich sediment by Frisone and Zorzin (2012). Nevertheless, whole, unbroken monaxial megascleres are relatively rare. All complete monoaxial megascleres have diactinal morphology. The large dimensions attained by the oxeas, up to 2500 µm in length, point to astrophorid affinity, although an attribution to hadromerid or spirophorid sponges is also possible. Oxeas are 70–90 µm wide and 750–2500 µm long (Fig. 4a–e, h). Smooth strongyles, on the other hand, varied only from 370 to 830 µm in length, and were 50 – 80 µm wide (Fig. 4 ?f–g, i–l). Strongyles are spicules less common than the oxeas, but even so, widespread in various demosponge orders. Based on their width, length and curvature, the strongyles of Mt. Duello resemble those of Recent *Petrosia* (*Strongylophora*). Verticillated strongyles (Fig. 4m–q), 150–250 µm in length, 26–40 µm wide, were already associated to the poecilosclerid genus *Zyzyza* by Frisone and Zorzin (2012).

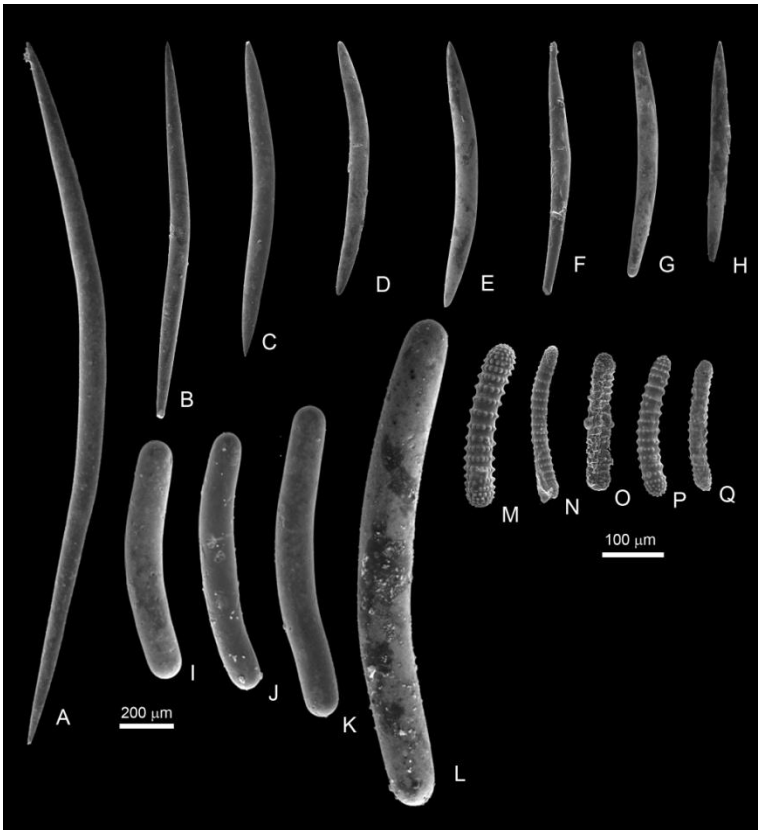


Fig. 4 Monaxial megascleres from Mt.

Duello. (a – e, h) Oxeas. (**?f – g, i – l**) Strongyles. (**m–q**) Verticillated acanthostrongyles. (**a–l**) Scale bar 200 μm . (**m–q**) Scale bar 100 μm .

Sterraster microscleres (Fig. 5) are by far the most common spicules at Mt. Duello, occurring in a variety of sizes, shapes and preservation conditions. Their shape varies from rather elliptical (Fig. 5 c,e,g,,i–n) to nearly spherical (Fig. 5a, k). Measurements of 32 sterrasters showed a bimodal distribution within a range of 107–257 μm in maximum diameter with a median value of 184 μm (mean: 180 μm). Most sterrasters lost apical starry external ornamentation of their rays, which is only preserved in few spicules (e.g., Fig.5d). In our material, surface terminations are generally rounded (Fig. 5a, f, h) and sometimes so strongly dissolved that terminal structures are effaced and the distal terminations of the canals are opened (Fig. 8a). All sterrasters have a hollow center and a body crossed by many canals (Fig. 8i).

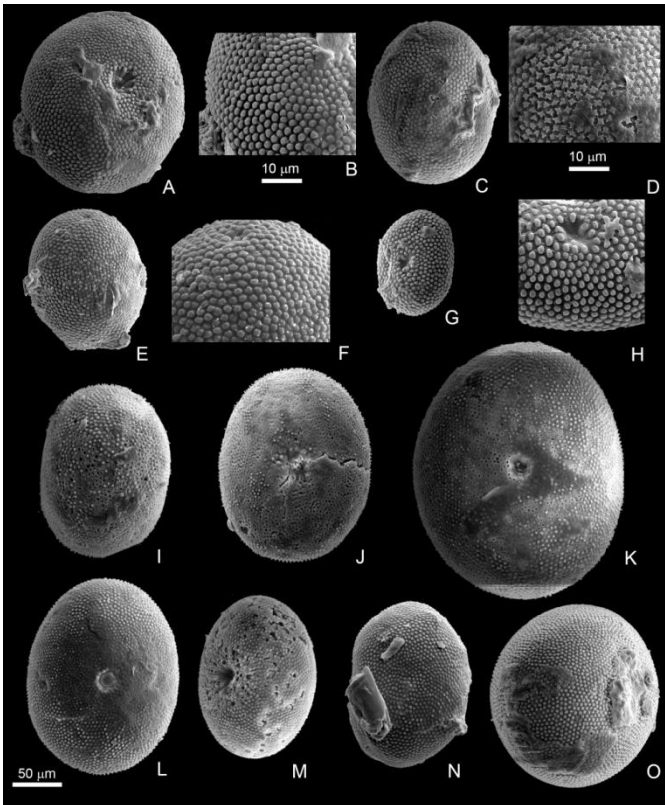


Fig. 5 Sterrasters microscleres from Mt. Duello. **(a, c, e, g, i–o)** Sterrasters. **(b, d, f, h)** Close up of sterrasters. Scale bar 10 µm. **(b)** detail of the surface of **(a)**. **(d)** detail of **(c)**, **(f)** detail of **(e)**, **(h)** detail of **(g)**. **(a;c, e, g, i–o)** Scale bar 50 µm. **(b, d, f, h)** Scale bar 10 µm.

Aspidaster microscleres. This category of spicules is diagnostic for the genus *Erylus* (Erylinae, Geodiidae). The assemblage found at Mt. Duello is diverse (Fig. 6a–g), with maximum diameter 116–248 µm. Similarly to sterrasters, Recent aspidasters carry a plethora of starry-shaped distal ends of their rays, among which short monticulate projections, presumably unfinished rays, are to be found (e.g. Vieira et al., 2010). Mt. Duello aspidasters either have only the monticulate projections, or no projections at all. The absence of projections (Fig 6h) could be interpreted as the result of corrosion.

Selenaster microscleres. Massive ellipsoidal and kidney-shaped spicule or bean-shaped spicules (Fig. 6i–j) with ornamentations of short outgrowths connected one to the other by ridges creating a polygonal surface are selenasters and derived from *Placospongia* sp., a hadromerid sponge of the family Placospongiidae. In general these sponges occur in shallow tropical and subtropical waters (Rützler 2002, Becking 2013).

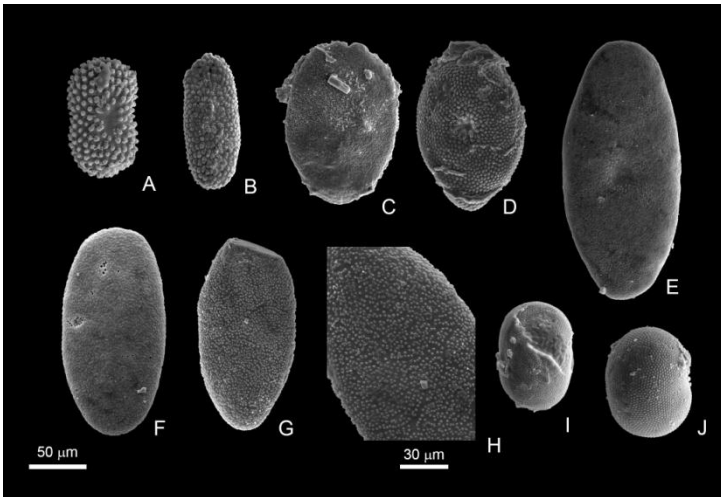


Fig.6 Aspidasters and selenasters microscleres from Mt. Duello. **(a–g)** Aspidasters. **(h)** Detail of aspidasters microsclere shown in **(g)** showing reduced projections probably due to corrosion. **(i–j)** Selenasters microsclere. Scale bar 50 μm .

Additional forms of euasters – spherasters, spheroxyasters, oxyspherasters. The remaining euasters retrieved from Mt. Duello are spherasters (Fig. 7a–b) and oxysphaerasters (Fig. 7c–f) with rather large diameters of up to 300 μm . Such large asters are quite common in several genera of Tethyidae (Hadromerida), while the smaller sphaerasters are more akin those of *Chondrilla* (Chondrillidae, Chondrosida) (Boury-Esnault 2002).

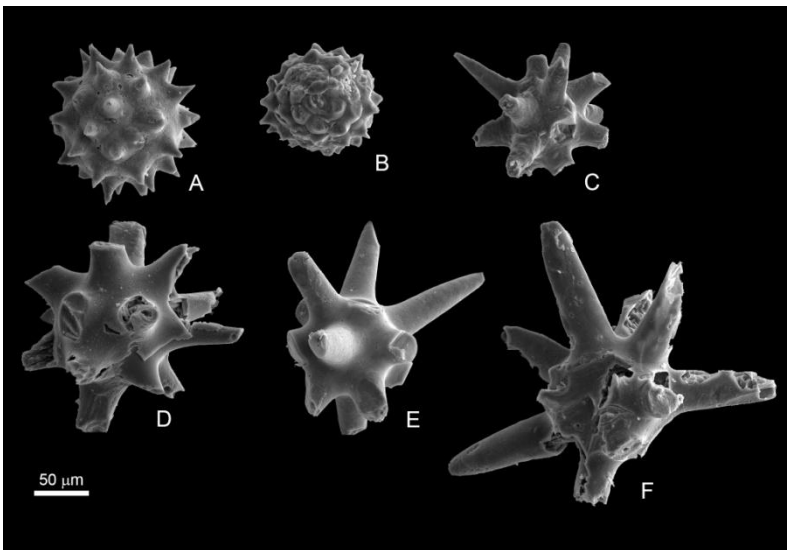


Fig.7 Spherasters and oxysphaerasters from Mt. Duello. **(a–b)** Spherasters. **(c–f)** Oxysphaerasters. Scale bar 50 μm .

Preservation of sponge spicules

In order to evaluate the preservation of sponge spicules, we performed a suite of morphological and mineralogical analyses that included observations at the binocular and petrographic microscopes, Scanning Electron Microscopy (SEM) and X-ray powder diffraction (XRPD).

Despite extreme caution taken in sampling and treatment of the sediment, the majority of the spicules were broken when observed under the binocular microscope and under the SEM. This is particularly true for triaene megascleres that constantly lacked some of their ends (Fig. 2). Smaller monaxial scleres (e.g. strongyles, acanthostrongyles, Fig. 4i–q) are more intact as well as sterrasters (Fig. 5) and aspidasters (Fig. 6). Oxyspherasters lack long rays (Fig. 7c–f) while short-rayed forms (spherrasters) tend to be intact (Fig. 7a–b). Desmas lost the distal ends by which they were interlocked together (Fig. 3). Generally, spicules are corroded. This is particularly visible in sterrasters (Figs 5m, 8a). The outer surface of both monaxial and tetraxial megascleres is very commonly covered with circular pits, 2–3 μm in diameter (Fig. 8b), reaching in few cases 6 μm . Many spicules show the axial canal (Fig. 8c). Some spicules are glassy and translucent, often with the axial canal clearly visible (Fig. 8c), while others are milky (Fig. 8d). Both types of preservation occur sometimes in the same spicule (Fig. 8e) (Frisone & Zorzin 2012). Under the SEM, most translucent spicules are massive on the fresh-broken surface, that is, they appear dense and break along an irregular fracture (Fig. 8f). Freshly cleaved milky spicules are instead porous, and might develop small spheroidal-shaped aggregates (Fig. 8g). Most translucent spicules are massive, however, transitional terms from massive to porous spicules are rather common.

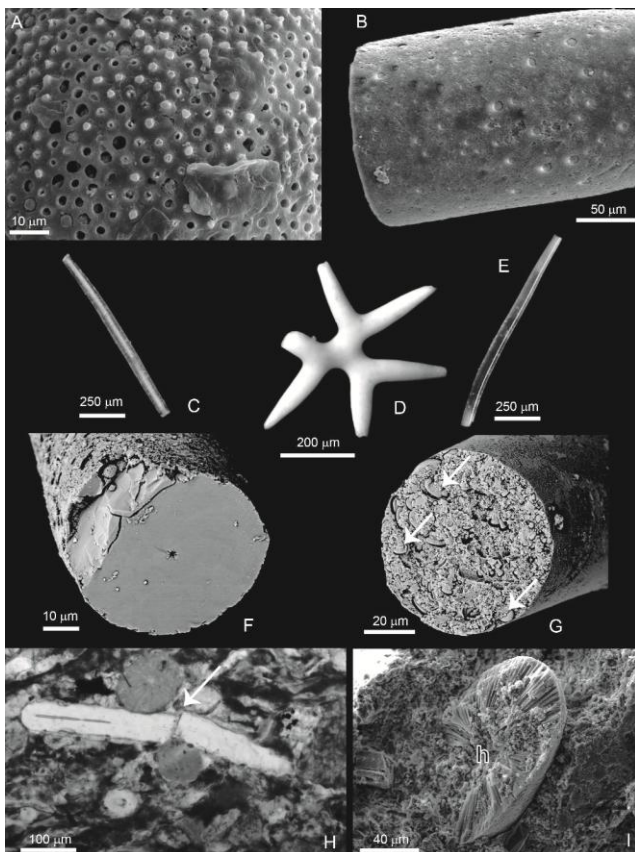


Fig. 8 Spicules preservation. **a** Sterraster surface showing signs of corrosion. The terminal structures are effaced and the distal part of the canals is open. **b** Monaxial fragment showing circular pittings. **c** Glassy translucent monaxial spicule with enlarged axial canal. **d** Milky tetraxial spicule (triaene). **e** Monaxial fragment showing two different kinds of preservation: the central part is translucent while the terminations are milky. **f** Massive and dense fresh-broken surface of a translucent spicule. **g** Fresh-broken surface of a milky spicule showing micropores and spheroid-shaped aggregates interpreted as incipient opal-CT lepispheres (arrowed). **h** Thin section showing a spicule broken by compaction (arrowed). **i** Broken sterraster showing the typical hollow center (h) and a wall crossed by many canals.

A selection of 20 spicules were observed at high enlargement (100X) under a petrographic oil-immersion microscope. Most spicules showed no birefringence, appearing completely dark under crossed polarizers. Four spicules revealed instead diffuse birefringence. XRPD analysis was undertaken on larger spicules, which could be broken monaxial spicules or fragments of large triaenes). Translucent and milky spicules were analyzed separately, along with samples of the bulk sediment and of the clay fraction. The four spicules exhibiting birefringence were also analyzed. XRPD patterns (Fig. 9) did not reveal a clear distinction between translucent and milky spicules: all samples had the typical peaks of opal-CT (4.09 Å, 4.28 Å and 2.50 Å) with the same shape and relative intensities. Comparing XRPD patterns with patterns reported in Graetsch et al. (1994), Herdianita et al. (2000a), Lynne and Campbell (2004), Lynne et al. (2005) and Jones and Renault (2007) we can consider our samples constituted by opal-CT. The broadening of the peak at 4.09 Å (FWHM 0.80°-0.90° 2θ) reveals a small crystallite size and high grade of lattice disorder of opal-CT, typical of the initial stages of transformation from opal-A. We can not exclude the presence of opal-A, because its typical diffraction pattern broadly overlaps with opal-CT peaks. The absence of birefringence is in agreement with the optical isotropic nature of opal-A and the pseudo-isotropic nature of most opal-CT due to the very small crystallite size (Cady 1996). Clinoptilolite/heulandite is always associated with opal in spicules. The few spicules showing birefringence under the optical microscope showed XRDP peaks of opal-C and quartz. The bulk sediment does not show clear peaks of opal, and the peaks of clinoptilolite/heulandite are dumped. Instead, the major minerals in the bulk sediment are calcite and a clay mineral of the smectite group. Along with clinoptilolite/heulandite, also plagioclase, apatite and anatase occur in minor amounts. Peaks of calcite are split for the co-existence of calcite and low-Mg calcite. The clay fraction was separated, oriented and glicolated for the determination of clay minerals. It resulted to be prevalingly composed of a dioctaedric smectite with calcian composition.

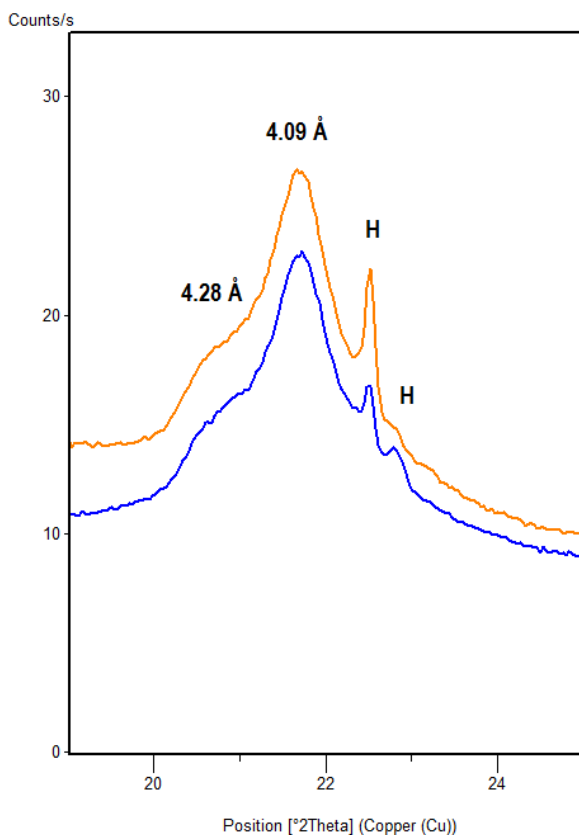


Fig. 9 X-ray powder diffraction profiles of milky spicules (orange) and translucent spicules (blue). Heulandite/c clinoptilolite peaks are labeled with H.

Facies and microfacies description

The stratigraphic succession of Mt. Duello was described by Fabiani (1915) as a few meters of marginal marine sediments intercalated within basalts. We here report the results of field and petrographic investigations on the portion of the sedimentary succession that was exhumed during paleontological excavations.

Basalts crop out few meters below the base of the logged section. The top of these lower basalts is strongly altered into clays and oxides. The sedimentary succession begins on top of altered basalts with a irregular erosive surface and a conglomerate of basalt and altered basalt pebbles (Fig. 10c; facies D1). Some clasts are reduced to clay chips by compaction. Basalt pebbles are associated with macrofossils (mainly oysters) and embedded in a carbonate sandstone (grainstone) matrix. The components of the sandstone matrix are worn carbonate grains as red algae, benthic foraminifers, fragments of crustacean skeletons and ostreid bivalves.

The following beds are made of mollusk-coral-larger foraminifer rudstones, with rough normal gradation (Fig. 10a,b, facies D2). Larger fossils are concentrated at the base of beds and form shell-bed accumulations. Bed joints are irregularly undulated, erosive, but are often masked by amalgamation. The paleontological excavations of years 2011–2012 targeted these beds, because of the abundance of large fossil remains.

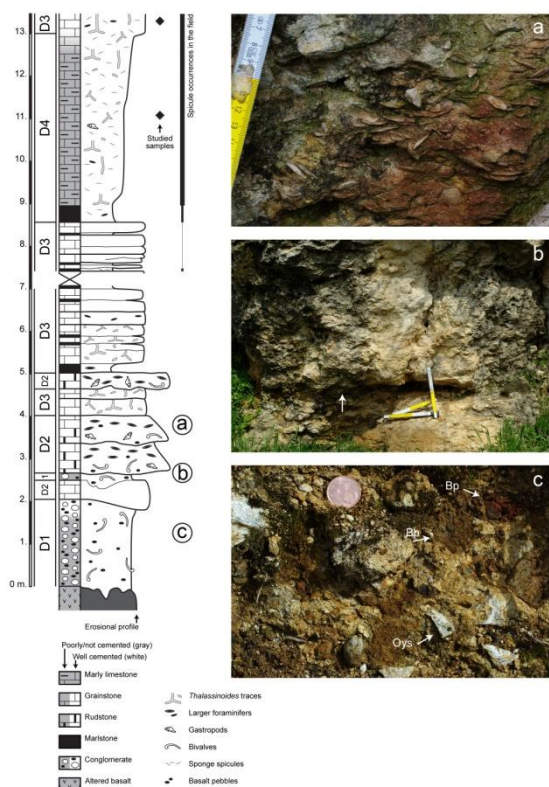


Fig. 10 Stratigraphic section logged at Mt. Duello, and main lithofacies as seen in the field. The outline of the log represents an erosive profile, influenced by variable cementation as well as by grain size. The base of the metric scale is set at the main ravinement surface, at the boundary between altered basalt and marine conglomerates. Facies codes are provided on the left of the stratigraphic column. **a** Rudstone with large *Nummulites*, the most typical facies of the marine limestone succession of Roncà (Facies D2). **b** Rudstone bed (Facies D2) with corals, mollusks, larger foraminifers and rare basalt pebbles, and sharp erosive base (arrow). **c** Conglomerate with fragmented and complete oyster shells (Oys) and mostly altered basalt pebbles (Bp) of facies D1.

Beds of facies D2 give way to dm-scale beds of grainstones with larger foraminifera, rare mollusks and frequent bioturbations (burrows). Bed joints are undulated and often correspond to thin clay interlayers (facies D3). Clay content increases upward, and clays may contain isolated, mm-sized larger foraminifers and rare sponge spicules. A few meters above, the spicule-rich facies crops out (Fig. 11). This spicule-rich interval is non cemented at its base, and burrowed. The upper cemented part is substantially identical to facies D3, being a bioturbated grainstone with rare larger foraminifera as small *Nummulites* (Fig. 11b), but in addition to typical components of facies D3, calcified spicules (Fig. 11b) and rarer siliceous spicules (Fig. 11d, f) are present. In association and sometimes attached to calcified spicules, peloids and patches of irregularly clotted peloidal micrite occur (Fig. 11b). The lower, non lithified portion of the spicule-rich facies is also a fine carbonate sediment with burrows (Fig. 11a), but is characterized by a high proportion of non-carbonate grains as strongly altered volcanic rocks (lithics) and rare quartz, biotite and feldspars. This loose spicule facies (D4) is grain-supported, but a clay matrix is present especially in its lower portion. This clay, which has been determined as a calcian smectite by XRPD, derives from the alteration of basalts and can be a detrital matrix, or a pseudo-matrix formed by compaction of altered basalt lithic grains. In its upper portion, the clay matrix gradually disappears and facies D4 gradually fades into a less carbonate variety of facies D3. The volume proportion of spicules and carbonate VS siliciclastic grains was evaluated via modal analysis (Table 1). Point counting shows that spicules are relatively abundant, but not so abundant as to define the facies a spiculite. Lithics and their alteration products are more abundant (56% VS 13%) in the uncemented spicule-bearing facies D4 with respect to the cemented facies D3. The absence of cement filling pore space and the mechanical weakness of altered lithics imply that grains were densely packed in facies D4 (Fig. 11e). This compaction, that was prevented in the upper cemented portion, resulted commonly in the fragmentation of spicules which were probably the most fragile component in the sediment. Spicules are siliceous (opaline) in the uncemented portion of the bed, but are often calcified in the upper, cemented portion (Fig. 11). Microfacies of facies D2 and D3 are similar. Prevailing carbonate grains are foraminifers, including abundant *Nummulites* (Fig. 10a), and fragments of red algae. In the uppermost portion, sponge spicules are also abundant. There is no fine component; textures vary from grainstones to floatstone-rudstones with grainstone matrix.

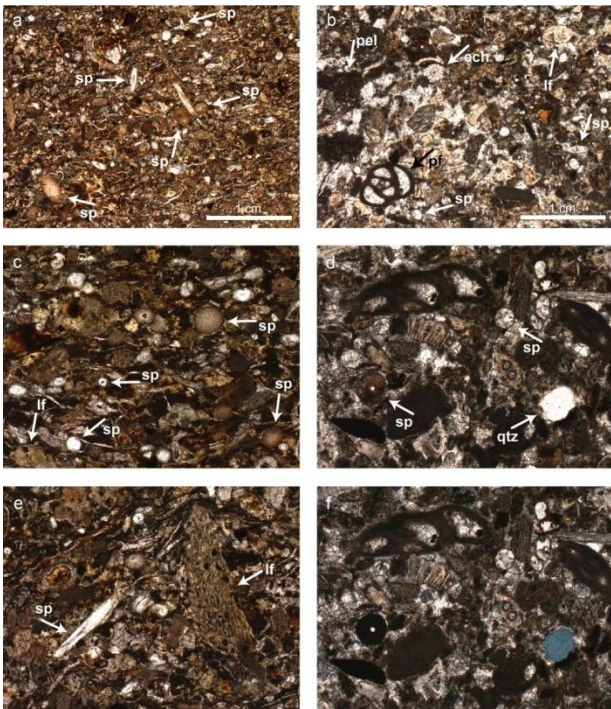


Fig. 11 Microfacies of the spicule-bearing facies of Mt.

Duello. **a** Non lithified spicule-bearing facies (D4), with abundant spicules preserved in silica (sp). **b** Lithified spicule-bearing facies (D3), with irregular peloids (pel), echinoderms (ech), porcelanous foraminifers (pf) and larger foraminifers (lf), and calcified spicules (sp). **c** Close-up of facies D4 highlighting the abundance of spicules (sp) and the different degrees of preservation: transparent spicules are probably mostly amorphous (opal-A), while in brownish spicules the transformation of amorphous silica into opal-CT is already more advanced. A fragment of a larger foraminifer is also visible (lf). **d** Close-up of facies D3 with spicules (sp), foraminifers and minor siliciclastic grains as quartz (qtz). Spicules are calcified or, more rarely, still preserved in silica (spicule in the left bottom corner). **e** Evidence of compaction in the non lithified facies D4, highlighted by a fragment of a larger foraminifer (lf) standing in vertical position. elongated grains, including spicules (sp), are deflected from horizontal near the foraminifer because of pressure shadow zones. **f** Same as (a), with crossed polarizers.

Macrofossils are common throughout the section. More specifically, *Nummulites* are found in all facies, although more commonly in facies D2 and D3. Other larger foraminifera are found, as *Discocyclus* and *Alveolina*, but are always subordinated to *Nummulites*. Colonial scleractinian corals are common in facies D2, along with oysters. Fragments of red algae are also common throughout the section, but never form rhodoliths.

sample Facies	Skeletal grains %	Sponge spicules %	Lithics %	Alteration clays %	Peloidal micrite %	Cement %	N
D3	37.3±4.9	3.8±1.9	12.9±3.4	0	17.8±3.9	28.2±4.5	394
D4	31.0±4.8	10.5±3.2	22.1±4.3	33.7±4.9	0	2.7±1.7	371

Table 1 Modal analysis of cemented (D3) and uncemented (D4) spicule-bearing facies, from thin section point-counting. Skeletal grains are often highly fragmented and difficult to determine, and were thus lumped together in one category. In the sample of facies D4 (uncemented and compacted), cement is only present in intragranular spaces as within gastropod shells, and a clayey interstitial component is present. Clays often form the alteration rim of lithic grains. The clayey interstitial component was interpreted as partly formed by altered lithic grains, deformed by compaction.

Discussion

Taxonomy

A biological interpretation of the spicule association was attempted, based on a comparison with living sponges. The taxa recognized are listed in Table 2. The sponge assemblage bears 2 genera (*Chondrilla* and *Placospongia*) today reported exclusively for shallow water (Rützler 2002; Becking 2013; Desqueyroux-Faúndez and Valentine 2002). The other genera are eurybathic (Wiedenmayer 1994; Hooper and Van Soest 2002).

Table 2 Demosponge taxa recognized, based on spicules type observed (see text for details):

Taxa	Spicule type
Order Astrophorida	Long-shafted triaenes
Family Geodiidae	Sterrasters(<i>Geodia</i> sp.), aspidasters (<i>Erylus</i> sp.)
Order Hadromerida	
Family Placospongiidae	Selenasters (<i>Placospongia</i> sp.)
Family Tethyidae	Oxysphaerasters
Order Chondrosida	
Family Chondrillidae	Sphaerasters (<i>Chondrilla</i> sp.)

Order Haplosclerida	
Family Petrosiidae	Strongyles (<i>Petrosia</i> sp.)
Order Poecilosclerida	
Family Acarnidae	Verticillate acanthostrongyles (? <i>Zyzyza</i> sp.)
Order "Lithistida"	
?Family Corallistidae	?Dicranoclone desmas, orthodichotriaene
Family Theonellidae	Tetraclone desmas, phyllotriaenes

A comprehensive stratigraphical and geographical distribution of the sponge taxa reported here and of their loose spicules can be found in Wiedenmayer (1994); Kaesler (2004), Pisera et al. (2006); Lukowiak et al. (2013). Only some specific aspects are here discussed.

Euasters

Nearly 95% of Recent species bearing sterrasters are classified in *Geodia* (Van Soest et al. 2012b), the remaining belonging to *Caminus* and *Pachymatisma*. It is thus very probable that the Mt. Duello sponges were also *Geodia* spp.

The sterrasters found at Mt. Duello repeated the feat reported for Miocene deposits of Capella Montei (Bonci et al. 1997), where this spicule category was also common. These authors reported the observed Miocene sterrasters to be larger than those occurring in Recent *Geodia* spp. known from the Mediterranean. Their sterrasters reached a maximum of 207 μm in diameter, being thus only a little smaller than the 257 μm found at Mt. Duello. Bonci et al. (1997) pointed out that sterrasters as large as 250 μm have been reported from *G. avicula*, a species from the Spanish Miocene, but we can add here that a few Recent species also show comparably large sterrasters. This is the case of *G. pachydermata*, originally reported from the Bermudas, but subsequently found in the Azores and the Ibero-Moroccan Gulf, which has sterrasters as large as 256 μm (cf. Sollas 1886, Boury-Esnault et al. 1994, Silva 2002). In the South-western Atlantic, *G. australis* possesses sterrasters up to 350 μm in diameter (Silva 2002).

The surface terminations on sterrasters (globose to starry, Fig. 5 b, d, e, h) could reflect different phases of development of the spicule (e.g. Ledenfeld 1910; Bonci et al. 1997).

The aspidasters from Mt. Duello also fit into the variability known for this category of spicules in Recent species. A survey of Mediterranean, Red Sea and Western Indian Ocean *Erylus* spp. revealed aspidasters ranging from disk-shaped to flat football-shaped, the smaller spicules being 28 or 40 μm in diameter (Topsent 1928), and the largest being up to 280 μm long (Pulitzer-Finali, 1983; Ridley, 1884). We could not find any overall morphologic distinction setting the specimens from Mt. Duello apart from those of the Recent.

Sarà and Sarà (2002) listed several genera of Tethyidae with megasters (sphaerasters, spheroxyasters or oxysphaerasters) reaching at least 150 µm in maximum diameter. The type species of *Stellitethya*, *Tethyastra* and *Tethytimea* possess such asters reaching 200 µm, while those in *Burtonitethya* can reach 300 µm, thus approaching quite closely the Mt. Duello oxysphaeraster shown in Fig. 7f.

Verticillated acanthostrongyles

The verticillated acanthostrongyles found in the Duello sediment showed a considerable variability in overall morphology. Nevertheless their dimensions, the presence of spines clustered in regular verticils and the pattern of spines at rounded ends point to the boring sponge *Zyzyza* sp. (e.g. Burton 1959, Calcinai et al. 2000). However, it should be noted that in Recent *Zyzyza* acanthostyles can be not verticillated at all. While obvious verticillation has been reported from *Z. invemar*, *Z. papillata*, it is only subtly present in *Z. fuliginosa*, the type species, as illustrated by Dendy (1922) and Hooper and Krasochin (1989), and absent from *Z. coriacea* and *Z. criceta*. Uncertainties on the assignment of Recent species to *Zyzyza* hamper a definitive attribution to a sponge genus for the acanthostrongyles of Mt. Duello. Recent *Zyzyza* possess, next to the acanthostrongyles, terminally microspined strongyles to subtylotes but these spicules are absent at Mt. Duello, probably because they were originally too small and fragile to be preserved in this high-energy environment. It is worth mentioning that the Duello acanthostrongyle illustrated in figure 6 N is nearly indistinguishable from the Eocene spicules from New Zealand (Hinde and Holmes 1892, Pl. VII, Fig. 30), W Australia (Hinde 1910, Pl. I, Fig. 10), W central Atlantic (McCartney 1987).

Preservation

Spicules of Mt. Duello are fractured. This could be due either to transport and/or sediment compaction, but petrographic observation of the sediment with spicules clearly indicate that compaction played an important role (Fig. 9h). Fragmentation affected heavily the delicate and needle-like structures, like the ends of triaenes and oxyspherrasters. Spherical to elliptical microscleres like sterrasters, aspidasters, spherrasters resisted better to mechanical breaking. The majority of broken spicules show sharp edges (e.g. Figs. 2; 7c–e), which suggest that the fragmentation was caused more by compaction than by transport. On the other hand, the presence of disarticulated spicules, especially lithistid desmas that lost their ends, together with the lack of bodily preserved lithistids, points to a certain degree of transport. This is in agreement with the results of facies analysis, which indicates an overall high energy environment.

Most interesting is the alteration of spicules. Spicules of living Demosponges are composed of amorphous hydrated silica, opal-A (among others Hartman 1981; Zimmerle, 1991). Opaline biosilica form nanospheres to microspheres which are arranged in concentric layers to form the spicules (Weaver et al. 2003; Pisera 2003; Uriz 2006). During diagenesis, non crystalline opal-A is gradually transformed to paracrystalline opal-CT/opal-C and eventually to microcrystalline quartz (Williams and Crerar 1985; Herdianita et al., 2000b; Lynne and Campbell, 2003; Lynne et al. 2005; Jones and Renaut 2007). This diagenetic sequence is characterized by increasing structural order, crystallinity and crystal size. Basically, the distinction of the three hydrous silica phases, opal-A, opal-CT and opal-C is based on different X-ray diffraction patterns related to different crystal structures (Jones and Segnit 1971; Smith 1998). Opal-A (amorphous) is characterized by a very broad band of moderate intensity centered about 4.1 Å. Opal-CT consists of disordered cristobalite with significant trydimitic stacking (Graetsch 1994; Guthrie et al. 1995; Elzea and Rice 1996). The most intense reflection may occur anywhere from 4.07 Å to 4.10 Å with a wide range of peak widths (Elzea et al. 1994; Elzea and Rice 1996). In addition a peak near 4.30 Å and a shoulder near 3.87 Å are present, which correspond to Bragg reflection of trydimite (Ilieva et al. 2007). The X-ray diffraction pattern of Opal-C is almost identical to that of α-cristobalite but differs from this for peak broadening and

slightly larger d-spacing (Elzea and Rice 1996). Morphologically, opal-CT is characterized by typical bladed lepispheres, less than 10 μm in diameter (Herdianita et al. 2000a; Lynne and Campbell 2004; Lynne et al. 2005), although Jones and Renaut (2007) documented a broad array of textures.

Spicules of Mt. Duello appear either translucent or milky, and the question arises whether this is the result of a different degree of diagenetic transformation of biosilica, with translucent spicules being preserved in opal-A and milky ones being already transformed into opal-CT or opal-C. This type of uneven preservation is common and was already noticed in the Eocene spicules from W Australia (Hinde 1910) but also in Cretaceous spicules of S England (Hinde 1885) and NW Germany (Schrammen 1924). As spicules from Recent sponges are glassy translucent, we can consider the milky spicules as the most altered in our samples.

Translucent and milky spicules yielded similar diffractograms (Fig. 9), with peaks of opal-CT and a high continuous background indicating the probable presence of a original opal-A residue. Peaks of clinoptilolite/heulandite were always observed.

Spicules that show birefringence under the petrographic microscope have distinctive diffraction patterns with peaks of quartz and opal-C. Differences between translucent and milky spicules are only evident in their texture under the SEM. The massive appearance of transverse surfaces of freshly broken translucent spicules is similar to that of spicules of living sponges (e.g. Weaver et al. 2003). The porous structure of milky spicules is here interpreted as the result of incipient diagenetic alteration, i.e., an early phase of the transformation into opal-CT. Spheroidal shapes may be interpreted as incipient lepispheres, although tridimite crystals could not be observed. The cross section of milky spicules is very similar to that observed by Richter and Baszio (2000, 2001, 2009) in the spongillid spicules from the Middle Eocene lacustrine sediments of Grube Messel (Germany).

Richter & Baszio (2000, 2009) distinguished between three preservation stages:

1. More or less strongly corroded original spicule;
2. Completely dissolved spicule, replaced by a replica in opal CT (with lepispheres) being identical in shape and size to the original spicule;
3. Moldic pores (casts) being left by dissolved sponge spicules. The casts can be filled with opal CT.

The presence of surface corrosion (e.g. circular pitting) and the evidence of incipient lepispheres in milky spicules suggest that Mt. Duello specimens probably represent a degree of alteration intermediate between stages 1 and 2.

Incipient diagenetic transformation is also suggested by the ubiquitous occurrence of clinoptilolite/heulandite. Clinoptilolite is a Na-K-Ca zeolite commonly associated with biogenic or abiotic amorphous silica. For example, Rigby and Smith (1992) found that the initially opaline sterraster spicules have been converted to clinoptilolite in the Paleocene of Alabama.

Diagenetic opal-CT and clinoptilolite have been also recorded in the middle Eocene Wittering Formation, Isle of Wight, UK and explained as a byproduct of dissolution of siliceous sponge spicules that raised silica activity in presence of alkali and cations from associated silicates, including clays (Huggett et al. 2005).

De Geyter and Willems (1982) found authigenic clinoptilolite in Landen Formation (Belgium) and indicated siliceous sponge spicules as the most probable source of silica.

Gammon and James (2003) also observed early diagenetic clinoptilolite in association with clay and sponge spicules, and deemed the excess SiO_2 provided by the dissolution of spicules essential for the precipitation of this mineral.

In general, low-temperature formation of clinoptilolite is favoured by the presence of smectite clays and high SiO₂ activity, higher than in the presence of quartz only (Bowers and Burns 1990).

The common presence of smectitic clay (from altered volcanic rocks, e.g. Deer et al. 1992) and opal in the studied samples thus could have favored the precipitation of clinoptilolite. Sponge-rich sediments are commonly associated with smectitic clays, poorly crystallized silica, zeolites such as clinoptilolite or analcime, glauconite, phosphates and/or volcanogenic sediments (Zimmerle 1991).

Sedimentary environment

The facies association of Mt. Duello can be interpreted as a transgressive, deepening-upward rocky shore succession, deposited on a substrate of basalt during a marine transgression.

Conglomerates with carbonate sand matrix (facies D1) are deposits of the foreshore and proximal shoreface, and probably accumulated on a marine terrace. Abundant shells of sessile bivalves as oysters confirm the availability of hard substrate as this facies was depositing. Coral-mollusk-larger foraminiferal rudstones (facies D2) should have deposited in the same portion of the coast profile, with the basal erosive surfaces representing ravinement surfaces of high-frequency sedimentary cycles (Walker 1992; Cattaneo and Steel 2003). Above, facies D3 (burrowed grainstones with larger foraminifera) also deposited above the wave base, as suggested by the absence of fine matrix, but marly intercalations become increasingly common upwards: beds of grainstones with clayey interlayers should have deposited at or below the fair weather wave base, and the whole sequence is deepening upward. Spicules are already present in this alternation of grainstones and marlstones. Higher up, the clay fraction becomes dominant in facies D4. This facies likely represents the deepest sedimentary environment, and deposited close or below the storm wave base. The disappearance of the fine fraction in the upper part of the section should be interpreted as a shallowing trend, and deposition again above the storm wave base, i.e., in the middle ramp. The whole succession must have been deposited within the photic zone, as suggested by the common occurrence of photosynthesizing organisms as colonial corals and red algae. Among corals, massive morphologies comparable to those of Recent *Porites* are common in facies D2. Microfacies can be compared to the algal debris and large nummulite facies of Nebelsick et al. (2005), which are suggested to form in the inner and middle shelf. This is also confirmed by the micropaleontological content (Frisone & Zorzin, 2013). A low-diversity small benthic foraminiferal assemblage including cibicides, *Pararotalia* cf. *audouini* (d'Orbigny, 1850), bolivinids, miliolid and ?*Asterigerina* is associated with small gastropods, ostracods and echinoid spines. The presence of *Pararotalia* and the absence of planktonic foraminifera further suggests shallow water depositional environment (Murray, 1991).

The spicule –rich deposit of Mt. Duello should have thus formed in a carbonate-clastic coastal profile, near and slightly below the storm wave base, within the photic zone. In terms of a carbonate ramp profile, sponges were thriving in the middle to outer ramp. Episodic high-energy events (e.g., storms) contributed to the disarticulation and fragmentation of spicules.

The non-lithified portion of the spicule-rich horizon (subfacies D4), which yielded the best preserved spicules, differs from Facies D3 for a high proportion of clay and altered volcanic lithic grains in the sediment. Volcanic lithics were altered into clay minerals and were plastically deformed by lithostatic load, so that clay occupied many pore spaces. This probably hampered the infiltration of diagenetic fluids during burial, prevented lithification and permitted the preservation of the opaline silica of spicules.

Similar sedimentary environments can be found in S Australia, from Cenozoic (including Recent) temperate shelves. Facies rich in demosponge spicules belong to a high-energy, storm-dominated shoreface of an open-platform margin. Two faunal associations are described: one with bryozoa, sponge and foraminifera (James

and von der Borch 1991; James et al. 1994) and one with seagrasses and sponges (Pufah 2004) that might be comparable to facies D4 of Mt. Duello. Nowadays, Southern Ocean benthos is often dominated by demosponges. Potential reasons for this include favourable nutrient and hydrochemical conditions, with silica levels being particularly high (Nelson and Gordon 1982; Downey et al. 2012).

Conclusions

The Bartonian spicule-rich deposit of Mt. Duello (Lessini Mts., Verona) is the first fossil record of sponge spicules for the Eocene of Italy. It contains a siliceous sponge spicule assemblage, indicating the existence of a diverse sponge fauna, mainly composed of “soft” demosponge but also including lithistid demosponges.

Spicules are strongly fragmented, partly due to sediment compaction, and show signs of corrosion. Some spicules are glassy translucent - often with visible axial canal, - others are milky. Spicules are preserved as opal-CT, with a probable presence of original opal-A, and are constantly associated to clinoptilolite/heulandite. The porous structure of milky spicules and the presence of incipient lepispheres support an initial diagenetic alteration. The common presence of clay (from altered volcanic rocks) and opal in the studied samples probably favored the precipitation of clinoptilolite.

Among the spicules, most belong to *Geodia* sp. (Order Astrophorida). Other geodiids are present too, e.g., *Erylus* sp. of the Family Placospongiidae (Hadromerida) is also recognized. Poecilosclerida were present as well as the boring sponge *Zyzya* sp. Overall we recognize a fair diversity among non-lithistid Demospongiae, while lithistid Demospongiae are less represented.

Two genera (*Chondrilla* and *Petrosia*) are today reported exclusively for shallow water while the other ones are eurybathic.

The facies association of Mt. Duello can be interpreted as a rocky shore succession, accumulated on a substrate of basalt during a marine transgression (see also Fabiani 1915; Conterno and De Zanche 1972). The spicule-rich sediment of Mt. Duello formed in a middle-outer carbonate ramp environment, in part in a fairly high energy environment close to storm wave base, within the photic zone. Similar depositional environments may be found today in the high-silica, high-nutrient Australian coasts of the Southern Ocean.

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CHAPTER 2 — Siliceous sponges (Porifera: Hexactinella, Demospongea) from Chiampo Valley (Eocene, Lessini Mts, northern Italy): taxonomy, taphonomy and paleoecology.

Introduction

Sponges are among the most ancient extant multicellular animals. They appeared in the Precambrian and were already well established by the Cambrian, to become major reef builders during the Paleozoic and Mesozoic (Brunton & Dixon 1994). Due to the low preservation potential of many taxa, especially those with organic skeleton, the fossil record of sponges is rather incomplete. Only those sponges with a rigid skeleton, e.g. lithistids (demosponges with desmas), Hexactinosida and Lychniscosida (class Hexactinellida) (Fig. 1) and sponges with a massive calcareous skeleton (polyphyletic demosponges and Calcarea), have a more or less continuous fossil record that is, however, inadequately studied, especially for the Cenozoic (Pisera, 2006). For siliceous sponges (lithistids and hexactinellids), the fossil record is very rich in the Cretaceous of Europe (e.g. Schrammer 1910, 1912; Moret 1926, Lagnau-Herenger 1962; Reid 1968). Many diverse sponge faunas are known from the Miocene, both in South and North western Tethys (e.g. Pomel 1872; Moret, 1924; Brimaud & Vachard 1986a, 1986b, Matteucci & Russo 2011 and literature therein). On the contrary, the record of the Paleogene is rather scarce. Focusing in Eocene bodily preserved sponge faunas, only a few records are known worldwide:

1. Spain (Pisera & Busquets, 2002; Astibia et al. 2013 and literature therein)
2. France (d'Archiac 1846; 1850)
3. USA, North Carolina (Finks et al. 2011 and literature therein)
4. New Zealand (Buckeridge 1993; Buckeridge et al. 2013, Kelly & Buckeridge 2005; Consoli et al. 2009).
5. SW Australia (Pickett 1983, Gammon et al. 2000; Pisera & Bitner 2007 and literature therein)

Only 3 publications exist so far about the Chiampo Valley Eocene sponges: Menin (1972), Visentin (1994) and Matteucci & Russo (2005). All these publications report of a siliceous sponge fauna. Matteucci & Russo (2005) offered a preliminary illustration and determination of 23 species, many of which are left in open nomenclature. No new genera or species are designated. The scarce knowledge of the Chiampo sponge fauna is in contrast with the richness of public collections of Museums of the Veneto region. These collections were never studied nor catalogued. In this study, the taxonomy of Chiampo siliceous sponges is depicted, and new genera and species are proposed. It thus sheds a new light on the siliceous sponges of the Eocene. Petrology of the specimens and a functional morphology study contributed to clarify the taphonomic and diagenetic events that led to the preservation of this unique sponge fauna, and provided new information on the sedimentary environment where sponges lived and deposited.

Sponges play a significant role in marine ecosystems, especially by contributing to the regulation of the Silicon cycle (Maldonado et al. 2005, 2010; Chu et al. 2011; Treguer and La Roca 2013), however, little is known about their abundance and diversity in the geological past. By assessing the sponge diversity of the Eocene of this region, this study contributes to the knowledge of sponge distribution through time, and provides unedited information on their role in Eocene marine ecosystems.

Lithistida and Hexactinellida Diversity

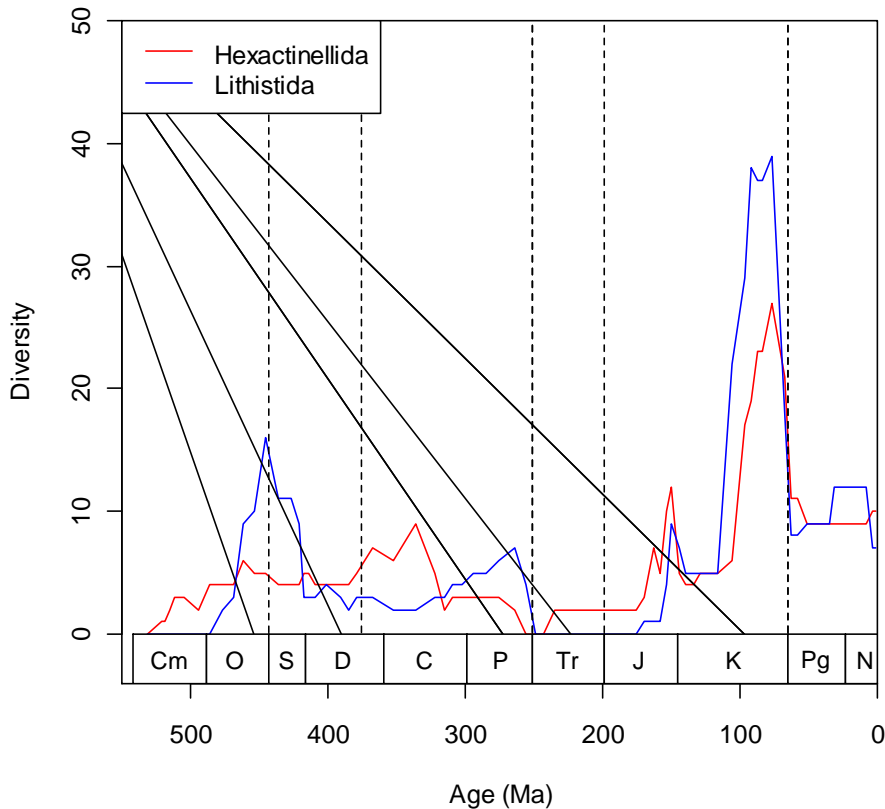


Figure 1. Genus-level diversity of lithistid and hexactinellid during the Phanerozoic. Data from Sepkoski (2002). Elaborated by V. Frisone & W Kiessling.

Geological settings

The studied area is located in the eastern Lessini Mountains (Mts), a portion of the Prealps of North-Eastern Italy, on the W side of Chiampo Valley (Fig. 2).

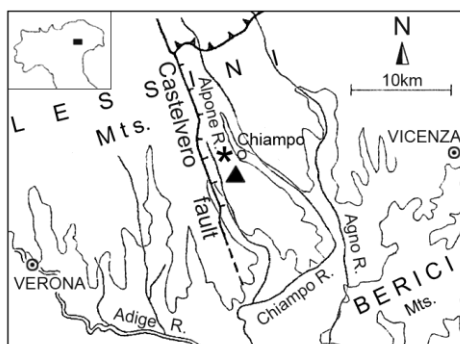


Figure 2. Location of the studied area. “Cengio dell’Orbo” quarry is indicated with an asterisk while “Lovara” quarry with a triangle.

The Lessini Mountains are a triangular-shaped tableland, which occupies some 800 km² in the western Venetian Region, at the transition between the Prealps and the Po Plain. The Lessini Mts. belonged in the

Cenozoic to the so-called “Lessini shelf”, a carbonate platform circumscribed northwards by lands and surrounded by deeper water marine settings (Bosellini, 1989). This carbonate platform grew on the Mesozoic Trento Platform, a fundamental element in the Jurassic-Cretaceous evolution of Southern Alps (among others Bernoulli & Jenkyns, 1974; Bernoulli et al. 1979; Winterer & Bosellini, 1981). Since the Trento Platform reacted rigidly during the complex collision between Europe and Adriatic plates, it became an uplifted block that acted as center of shallow-water carbonate sedimentation giving rise to the “Lessini shelf”, a resurrected platform with scattered reefs, lagoons, islands and volcanoes (Bosellini, 1989). From a structural point of view, the Lessini Mts. are today interpreted, together with Berici and Euganei Hills, as belonging to Adige embayment, the least deformed foreland of the Southern Alps (Bigi et al., 1990; Castellarin et al., 2006; Fantoni and Franciosi, 2009, Martòn et al. 2001) and thus the autochthonous core of the Adriatic plate.

The studied area belongs also to the Veneto Volcanic Province (VVP), identified by principally mafic and ultramafic rocks erupted during the Paleocene–Oligocene, mainly in submarine environments. Several magmatic pulses occurred, all of short duration (generally shorter than a planktonic foraminifera or nummulite biochronozone, i.e., less than 1–3 Myr) and separated by periods of magmatic inactivity during which marine sedimentation took place (Barbieri et al., 1982, 1991; De Vecchi and Sedeà, 1995; Piccoli, 1966). The volcanic activity is interpreted as due to a local extensional tectonic setting which developed in the otherwise compressional South Alpine foreland (De Vecchi and Sedeà, 1995; Zampieri, 1995) or, more recently, to a mantle plume event related to the subduction of the European plate under the Adriatic plate (Macera, 2003, 2008; Cannatelli, 2011).

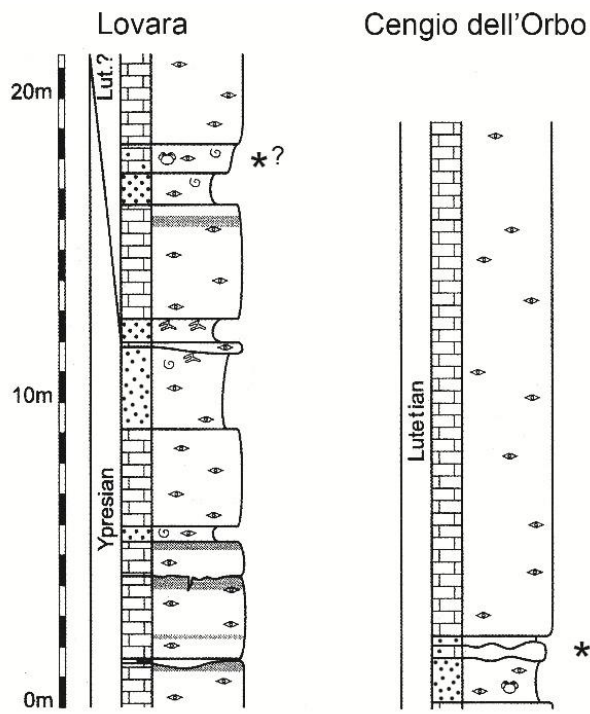
The sediments cropping out in the studied quarries of the Chiampo Valley were located, during the lower-middle Eocene, within a NNW-trending extensional structure, the Alpone-Agno graben or semi-graben (Barbieri et al., 1982, 1991; Zampieri, 1995), bounded to the West by the NNW- SSE Castelveo normal fault. This fault was crucial for the structural and palaeoenvironmental evolution of the central-eastern Lessini Mts. in late Paleocene–middle Eocene times, as it was a threshold separating a western area, with thin and discontinuous volcanic deposits, from an eastern one, where volcanic rocks prevail. The activity of the Castelveo Fault determined higher subsidence in the eastern blocks and the onset of the Alpone-Agno graben (Barbieri et al. 1991). Large volumes of mainly subaqueous volcanics and their penecontemporaneous reworking products (hyaloclastites and tuffites) accumulated in the Alpone-Agno graben. Moreover, the eruptive centers of Eastern Lessini Mts. were aligned with the Castelveo fault (Piccoli, 1966; Barbieri et al. 1982, 1991). The full extent of the graben is unknown because it is truncated northward by the Neogene Marana Thrust and on the eastern side by the Schio-Vicenza fault, both active during recent phases of the Alpine orogeny. Assuming that the eastern border fault might be located just E of the Schio-Vicenza fault, Zampieri (1995) proposed that the Alpone-Agno graben was 20 km wide and at least 35 km long.

The Castelveo fault reactivated periodically causing synsedimentary tectonics and volcanism (Barbieri et al. 1991). As a result of alternated volcanic activity and sedimentation, there are, intercalated within volcanic rocks (reaching 200 m), thick beds of limestone, called locally “Chiampo limestone”. This unit was quarried until the 1990s as a building stone. It belongs to the lower–middle Eocene informal unit named “Nummulitic limestone”, widespread in the western part of Veneto (among others Fabiani 1915, 1930, 1931). This lithostratigraphic unit is not well-constrained, and includes limestones with *Nummulites* of different ages and depositional settings. A comprehensive revision on a regional scale of these rocks is needed, because there are various distinct Paleogene carbonate platforms which were formed after the deposition of the pelagic sediments of the underlying Upper Cretaceous–Eocene Scaglia Rossa Fm. (Papazzoni & Trevisani, 2006). Beccaro et al. (1999) interpreted the “Nummulitic limestone” as belonging to a carbonate ramp, of which only the outermost facies are represented. Volcanoclastic debris, tuffites or reworked tuff beds are intercalated between the “Nummulitic limestone”. These beds are included in a classical ramp succession dominated by *Nummulites*, but exhibit a faunal association more complete than

usual. Some volcanoclastic levels are extremely rich in very well-preserved fossils (e.g. three-dimensional crustaceans complete with appendages and ventral parts), that belong to several "endemic" species (e.g. Beschin et al. 1991, De Angeli & Garassino, 2006). In a few sections, sponges constitute the most common macrofaunal element, especially in a relatively thin horizon of volcanoclastics enclosed in the Nummulitic limestones of a few quarries on the Western flank of the Chiampo Valley. Sponges are absent or rare in all other Eocene localities of the Venetian Prealps.

Beccaro et al. (1999) interpreted the volcanoclastic debris as transported by sediment gravity flows (debris flows and turbidites). These kinds of sediment would suggest the presence of steep slopes. A certain level of penecontemporaneous transport by nearby areas was noticed in some biocalcarenes–biocalcirudites facies in Bolca (Papazzoni & Trevisani, 2006). The world-famous Fossil-Lagerstätte is few kilometers afar the studied locality, it is close in age (late Ypresian) and was also located inside the Alpone-Agno graben. Moreover, in the studied area, there are evidences of paleocurrents: volcanoclastic sediments often have a lens shape and channelized morphology (Martòn et al. 2011). Pelagic fossils (e.g. pteropoda) are commonly found and locally ("Lovara" quarry) there is accumulation of off shore organisms (e.g. shark teeth, planktonic foraminifera) (Beccaro et al. 1999). To explain some anoxic facies documented nearby the studied area, a possible presence of upwelling currents was proposed by Beccaro et al. (1999).

The material comes from 2 adjacent quarries: "Cengio dell'Orbo", 45° 32' 25.56"N, 11° 15' 44.47"E (called "Boschetto di Chiampo" in Beccaro et al. 1999; Beschin et al. 1991 and other references) and "Lovara" 45°32'11.87"N, 11°15'58.92"E (part of which named "Zanconato" in some references, e.g., Ancona, 1966; Visentini, 1994) (Fig. 3), both located in the municipality of Chiampo (Vicenza).



Legend

- | | | | |
|---|------------------|---|---------------------|
|  | Limestone |  | Larger foraminifera |
|  | Cemented tuffite |  | Pteropoda |
|  | Tuffite |  | Crustaceans |
| | |  | Thalassinoides sp. |
| | |  | Hardground |

Figure 3. Simplified stratigraphic sections of Lovara and Cengio dell'Orbo quarries, with sponge-bearing horizons (asterisks). Facies codes are provided on the left of the stratigraphic column. Lovara quarry sponge level has a question mark as sponges were not found during field work in this study. The data thus rely on labels of Museum specimens and personal communications (Claudio Beschin, Antonio De Angeli and Andrea Checchi). (from Beccaro 1999, modified).

The sponge fauna that is object of the study comes from a horizon of tuffites and hyaloclastites, 50-200 cm thick, rich in iron silicates (Menin, 1972; Agostini 1991; Visentin, 1994; Matteucci & Russo, 2005). The rock is typically a tuffite with arenaceous grain size, composed of rounded volcanic fragments, calcareous bioclasts and calcitic cement. The associate fauna is mainly composed by smaller –benthic and plank- and larger foraminifera (*Miliolidae*, *Rotalidae*, *Nummulites*, *Discocyclina*, *Asterocyclina*, ecc.). There are also crustaceans (decapods and ostracods), echinoids, bryozoans, mollusks (gastropods –especially pteropods-, rare cephalopods, bivalves), red algae and rare corals (this study and, among others, Fabiani 1915; Schaub 1962, De Zanche 1965; Ancona 1966; Beschin et al. 1991; Fornasiero & Vicariotto, 1997; Beccaro et al. 1999; Matteucci & Russo 2005; De Angeli & Beschin, 2010; Pacaud & Quaggiotto, 2011).

Material and methods

The study material consists of more than 900 specimens (Table 1), housed in six Italian public museums.

MUSEUM	N.
Museo Civico "G. Zannato", Montecchio Maggiore (MCZ-I)	110
Museo di Storia Naturale, Venezia (MSNV)	274
Museo Civico "D. Dal Lago", Valdagno (MCV)	11
Museo Naturalistico Archeologico, Vicenza (IG-VI)	12
Museo "P. Aurelio Menin", Chiampo (MMC)	41
Museo di Geologia e Paleontologia, Università degli Studi di Padova (MGP-PD)	37
Museo di Geologia e Paleontologia, Università degli Studi di Padova (IG-PD)	447
TOTAL	932

Table 1. Number of Chiampo sponge specimens studied in Italian Museums (acronym in brackets). In order to have an adequate amount of material for study, a survey of Chiampo sponges collections in local Museums was performed (Table 1). When necessary, cataloguing was performed using ICCD fields (Istituto Centrale per il Catalogo e la Documentazione- Scheda BNP Beni Naturalistici – Paleontologia versione 3.01) (Fornasiero & Favero, 2008).

All material comes from “Cengio dell’Orbo” and “Lovara” quarries which are closed since the 90s. The sponge-bearing level is now inaccessible, being dangerous due to collapse hazard of toping beds in “Lovara” quarry and covered by debris in “Cengio dell’Orbo” quarry.

Only a small outcropping section was found (less than 3 m) that yielded fossil sponges, near “Cengio dell’Orbo” quarry. Only a few specimens were collected from this locality. The study material was mainly collected by amateur palaeontologists between the 1960s and 1990s. In order to isolate the fossil from the volcanoclastic matrix, collectors used mainly mechanical preparations. In many cases the sponge surface was smoothed too much, destroying important characters of the dermal surface (e.g. rim around canal openings, small outgrowths, papillae). However, museums provided also unprepared material on which

some preparation techniques have been tested (Finks, 2003). Best results were obtained with potassium hydroxide.

As methods of study depend on sponge preservation, the petrology of the specimens had to be preliminary investigated. Therefore, some specimens were etched (with diluted acetic acid) and revealed strongly calcified spicules. As the cement around the spicules is a carbonate too, the study technique chosen for the present study was by polished hand sections and thin sections. In order to dissociate spicules from the entire specimen, various etching was also tested on some sponge fragments but didn't bring any result. Neither the treatment of the sediment (e.g., Lukoviak et al. 2012) yielded any spicules. Initially, spicules were searched for in each specimen under a binocular microscope. In some specimens with no evident megasclere on the surface, a polished section was prepared, and in many cases, a fused or articulated skeleton was recognized. A selection of specimens was chosen for thin sections. All observations were tracked in a database .

The specimens were photographed, and 3-D models of the 39 fossils were produced before sectioning with photogrammetry techniques (software Agisoft Photo) at the Scientific Photography Laboratory, University of Padova (Fig. 4).

Observations on entire specimens were performed with an optical binocular microscope, Leica MZ 125, reflected light. Thin sections were studied with optical microscopes , transmitted (LEICA DM EP T and ZEISS Axiophot) and fluorescent (Leica 5000B) light. All the facilities are located at Padova University.

Classification and terminology follows generally that proposed in the Treatise on Invertebrate Paleontology, Part E, Porifera (Revised), Volume 3 (Kaesler et al. 2004), Systema Porifera (Hooper & Van Soest, 2002) and Thesaurus of Sponge Morphology (Boury-Esnault & Rutzel,1997).



Figure 4. 3-D models of Chiampo fossil sponges.

Results

Sponge preservation

The fauna consists in bodily preserved sponges with skeleton replaced with calcite. It was observed, in thin section, that the space between spicules is often partially filled by clotted peloidal micrite. A veil of micrite

and peloidal micrite always form coatings around spicules (Fig.5A) Clotted peloidal micrite is systematically more abundant in lithistid sponges with respect to hexactinellids. At least 2 cement generations grow on the spicular skeleton and on clotted peloidal micrite; a cloudy early cement and then a second generation of clear mosaic sparite (Fig. 5B). Generally, volcanoclastic granules are not present in sponge spicules meshes and internal canals (that can be up to 1 mm) but only in spongocoel.

Eleven thin sections were observed also with fluorescent light microscopy. Spicules and cement sparite are not fluorescent while spicules axial canals (when present) are slightly fluorescent and clotted peloidal micrite is bright fluorescent. Sometimes, a fluorescent thin veil was observed around spicules (Fig. 5C, D). In thin section, small (2-10 μm) pyrite crystals and framboids pyrite are recurrent in association with clotted peloidal micrite in lithistid sponges (Fig. E).

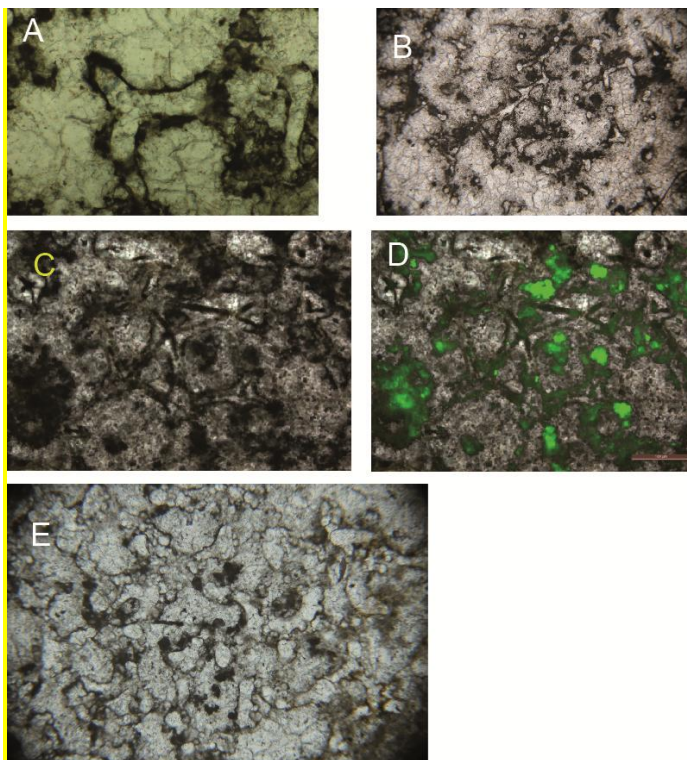


Figure 5. A–E Thin sections of lithistid and hexactinellid sponges. **A**, lithistid, space between spicules (desmas) is often partially filled by clotted peloidal micrite. A veil of micrite and peloidal micrite always form coatings around spicules; **B**, hexactinellid,. Two cement generations grow on the spicular skeleton and on clotted peloidal micrite; a cloudy early cement and then a second generation of clear mosaic sparite; hexactinellid sponge at normal (**C**) and fluorescent (**D**) light; in (**D**) spicules and cement sparite are not fluorescent while spicules axial canals are slightly fluorescent and clotted peloidal micrite is bright fluorescent. There is a fluorescent thin veil around spicules; **E**, lithistid, small (2-10 μm) pyrite crystals and framboids pyrite are in association with clotted peloidal micrite.

Some sponges, (e.g. *Camerospongia canalata* sp. nov., *Coronispongia confossa* sp. nov., *Toulminia italica* sp. nov.) show the external, originally siliceous, membrane.

The bad preservation of the spicular skeleton and the lack of many diagnostic internal characters (cortex, spicules sculputers etc.) contribute to harden taxonomic assignment . This was particularly true for for

lithistid spicules. Sometimes even their shape was difficult to observe in these sections. Moreover, it is generally difficult to determine desmas shape in thin sections as the 2-dimensional vision does not always permit to discern the spicule type (e.g. monaxial, tetraxial).

The embedding sediment

The sediment around sponges is a tuffite with arenaceous grain size, composed of rounded volcanic fragments, calcareous bioclasts, and calcitic cement (Fig. 6A–C). The volcanic clasts are strongly altered, with palagonitized glass in vesicles (Fig. 6A). A bioclast qualitative analysis was done on 25 thin sections of sediment surrounding the studied sponges. Preliminary results highlighted benthic smaller and larger forams (*Miliolidae*, *Rotalidae*, *Nummulites*, *Discocyclusina*) —dominant, planktic forams —abundant, red algae —common, bivalvs —rare, pteropoda —rare, echinoderms —rare, crustaceans —rare. The bioclasts, especially larger benthic foraminifera, were often fragmented. This feature was also observed by Beschin et al. (1991) at Lovara Quarry. A preliminary analysis of calcareous nannofossil was done on the sediment surrounding the sponges (Agnini, pers. comm.) Marker species defining biohorizons used in the standard zonations of Martini (1971) and Okada and Bukry (1980) are not present in the study samples. Nevertheless, the presence of two specimens of *Nannotetrina cristata* and the absence of specimens ascribable to *Sphenolithus furcatolithoides* indicate that the investigated interval belongs to Zones CNE8–CNE9 of Agnini et al. (in review). This datum is likely correlative with upper part of NP14 –lower part of NP15 (Martini, 1971) and CP12b - lower part of CP13 (Okada and Bukry, 1980), which means early Lutetian in term of chronostratigraphy. Lutetian age of the sponge horizon is consistent with Beccato et al. (1999) and Matteucci and Russo (2005).

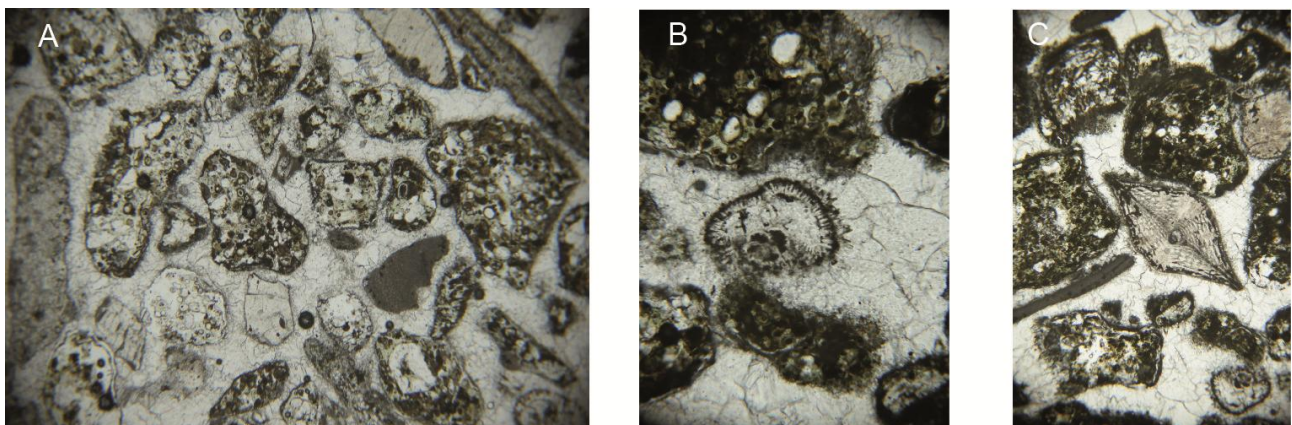


Figure 6. Thin sections of the tuffite surrounding the sponges. **A**, rounded volcanic fragments, calcareous bioclasts (a red algae), and calcitic cement. The volcanic clasts are strongly altered, with palagonitized glass in vesicles; **B**, volcanic clasts and a planktonic foraminifera fragment; **C**, a larger foraminifera (*Discocyclusina* sp.), a red algae fragment and volcanic clast.

Systematic Paleontology

The studied material is housed in six Italian museums: Museo di Storia Naturale di Venezia (museum acronym: MSNV); Museo di Archeologia e Scienze Naturali “G. Zannato”, Montecchio Maggiore (MCZ-I);

Museo Civico "D. Dal Lago", Valdagno (MCV); Museo "Padre Aurelio Menin", Chiampo (MMC); Museo di Geologia e Paleontologia dell'Università degli Studi di Padova (MGP-PD and IG-PD); Museo Naturalistico Archeologico, Vicenza (IG-VI).

Phylum **Porifera** Grant 1836
Class **Hexactinellida** Schmidt, 1870
Subclass **Hexasterophora** Schulze, 1887
Order **Lyssacosida** Zittel 1877
Family **Stauractinellidae** de Laubenfelds, 1955
Genus **Stauractinella** Zittel 1877

Type species. *Stauractinella jurassica* Zittel, 1877 p. 60

Stauractinella eocenica sp. nov.
(Fig. 7A–G)

pp. 1972 Indeterminate sponge; Menin: 68, pl. 6

Diagnosis. Globular to compressed sub-globular sponge. Rounded terminal osculum that can be eroded in some specimens so that the wall of spongocoel is visible. Spongocoel is divided in by radial folds of the wall. Dermalia, atralia, gastralia are mostly pentactines while choanosomalmegascleres are mostly diactines and hexactines.

Derivation of name. For the Eocene deposits.

Material. 35specimens. MCZ-I 1377, MCZ-I 1378, MCZ-I 3734, MCZ-I 3740, MCZ-I 3743, MCZ-I 3793, MCZ-I 3795; MSNVE-22816, MSNVE-22817, MSNVE-22819, MSNVE-22820, MSNVE-22851, MSNVE-22855, MSNVE-22858, MSNVE-22859, MSNVE-22860, MSNVE-22861, MSNVE-22974, MSNVE-22985, MSNVE-22986, MSNVE-23063, MSNVE-23065, MSNVE-23090, MSNVE-23097, IG-PD 366219, IG-PD 366220, IG-PD 366221, MCV 266, MCV 386, MCV 387, MCV 399, MMC 35, MMC 37, IG-VI 272199.

Type specimens. Holotype: MCZ-I 3795. Paratypes: MCZ-I 3743, MSNVE-22974, IG-PD 366220, IG-PD 366221.

Type locality and stratum. Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description.The smallest specimen (BB55) is 2.1 cm height and 2.8 cm in diameter while the larger (MMC35) measure 18 and 20 cm. Wall thickness varies from 1.35 to 4 cm. Osculum is generally rounded(Fig. 7A) and measure 0.75-12 cm. Some specimens show on the external surface rounded canal openings of 4-6 mm in diameter.The external surface can be eroded in some specimen so the interior of spongocoel is visible. Spongocoel is divided by radial folds of the wall forming large radial to irregular canals that can be up to 9 cm long and 4 wide(Fig. 7B).On the sponge surface,dermalia(Fig. 7C) are mostly pentactines. They are mainly observed as imprints. The tangential rays are usually parallel to the sponge surface and have tangential rays 2-8 mm long. Dermalia proximal rays are 1.6-4.0 mm long (Fig. 7D). Choanosomalmegascleres are mostly diactines and hexactines. Their length is difficult to measure precisely as they are very calcified and often spicules' ends are not well visible. Nevertheless, their dimensions are

extremely variable, ranging from 2.4-4.8 mm for diactines, to 0.4-4 mm for hexactines and their derivatives (Fig. 7E-F). Gastralial rays are pentactines, with 2 rays tangential to the spongocoel wall and the proximal ray towards the choanosome (hypogastralia). Proximal rays are 0.8-1.2 mm long (Fig. 7G).

Remarks. Genus *Stauractinella* is recorded mainly for Late Jurassic of Europe (among others Gugenberg 1928; Schrammen 1937; Pisera 1997). Reid (2004) reported a Paleogene–Neogene distribution but without any data. Hinde (1880, Plate 5, figs. 9, 10, 10a, 11); erected *S. cretacea* for the Upper Cretaceous of England on the base of isolated spicules. In our material, morphology and spiculation are very similar to *S. jurassica* (illustrated in Quenstedt 1878, tav. 130 fig. 17–18). Moreover in *S. jurassica* (Pisera unpublished) the spongocoel is divided by folds of the wall as in our specimens. Differently to the first species, our material lacks of “breast-like” outgrowths (Schrammen 1937) showing a smooth surface. *Stauractinella eocenica* sp. nov. is similar in shape to recent *Pheronema* Leidy, 1868. Nevertheless family Pheronematidae Gray, 1870 is characterized by the prevalence of pentactines as choanosomal megascleres (Tabachnick & Menshenina, 2002) while our material has mostly diactines and hexactines as choanosomal megascleres.

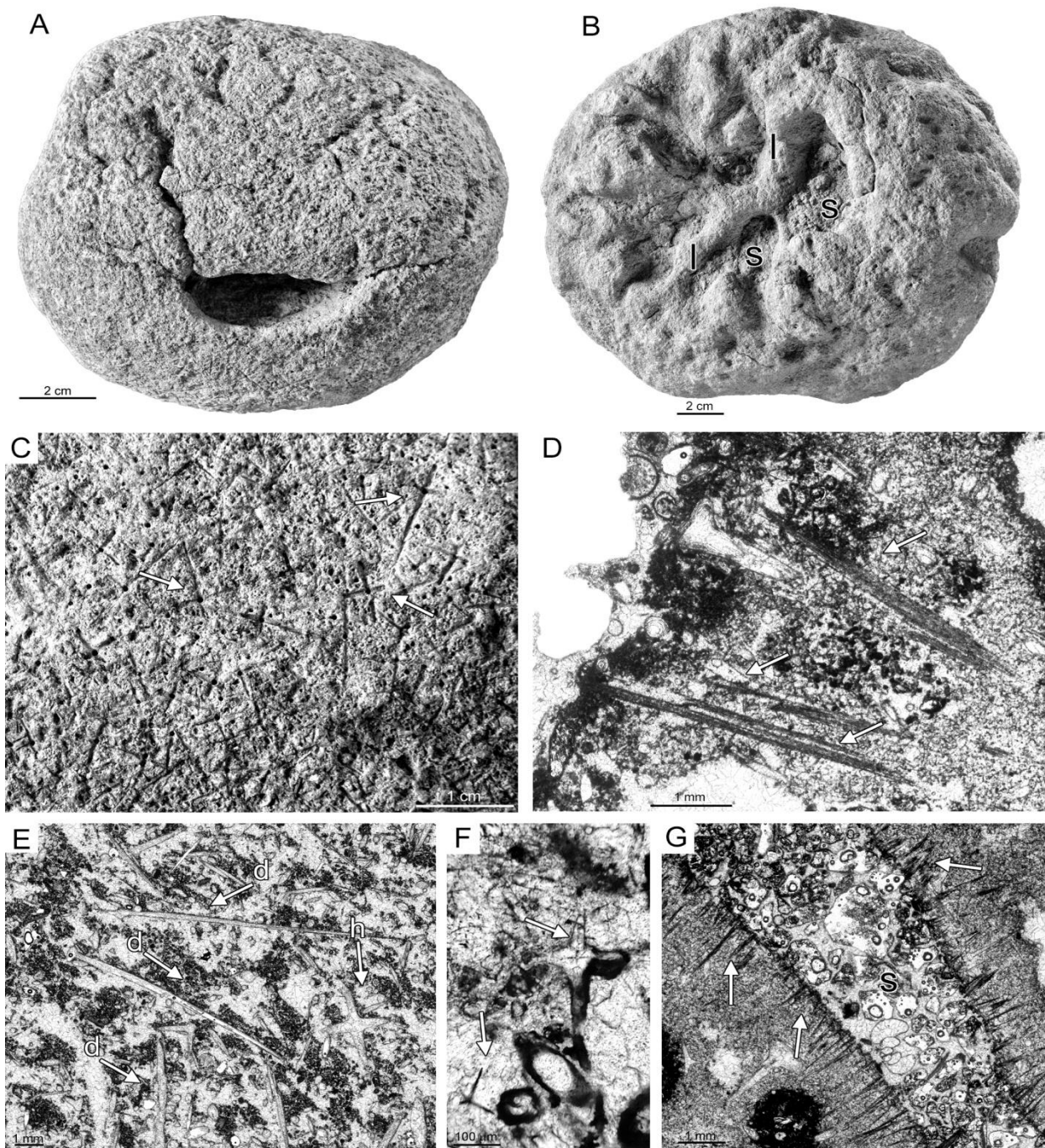


Figure 7. *Stauractinella eocenica* sp. nov. **A, C, E** MCZ-I 3795 holotype. **A**, MCZ-I 3795 holotype top view; **B**, IG-PD 366221 paratype top view, spongocoel (s) is divided in lamellae (l) by folds (f) of walls; **C** MCZ-I 3795 holotype, pentactine (dermalia) imprints (arrowed) on sponge dermal surface tangential rays are parallel to the sponge surface; **D** IG-PD 366220 paratype transversal thin section, dermalia proximal rays (arrowed) are perpendicular to the sponge surface; **E** MCZ-I 3795 holotype longitudinal thin section, large diactines (d) and hexactines derivatives (h); **F** MCZ-I 3743 paratype longitudinal section, various forms of hexactine and their derivatives (arrowed); **G** IG-PD 366220 paratype transversal thin section, pentactines (hypogastralia) with proximal ray towards the choanosome (arrowed) and the other ones oriented tangentially to spongocoel (s) wall.

Family **Craticulariidae** Rauff, 1893 emend. Reid, 1964

Genus **Laocoetis** Pomel, 1872

Type species: *Laocoetis crassipes* Pomel, 1872, p.93

Laocoetis patula Pomel, 1872 emended Pisera & Busquets, 2002

(Fig. 8A-D)

1872 *Laocoetis patula* Pomel; 95, pl. 2, figs 1–3

1872 *Laocoetis obconoidea* Pomel; 97, pl. 1, fig. 1, pl. 1 ter, figs 3–5

1972 *Craticularia* sp.; Menin: 65, figs 1–3

2002 *Laocoetis patula* Pomel; Pisera & Busquets: 329, pl. 6, figs 3–6, pl. 11, figs 3–6 *cum syn.*

2005 *Laocoetis patula* Pomel; Matteucci & Russo: 59, pl. 2, figs 3a–3c

Material. 30 specimens: MCZ-I 3711, MCZ-I 3713, MCZ-I 3727, MCZ-I 3744, MCZ-I 3745, MCZ-I 3746, MCZ-I 3747, MCZ-I 3749, MCZ-I 3782a, MSNVE-22869, MSNVE-22871, MSNVE-22883, MSNVE-22897, MSNVE-22898, MSNVE-22899, MSNVE-22936, MSNVE-22938, MSNVE-23009, MSNVE-23012, MSNVE-23013, MSNVE-23014, MSNVE-23015, MSNVE-23016, MSNVE-23017, MSNVE-23018, MSNVE-23019, MMC 20, MMC 21, MMC 22, MGP-PD1072

Description. Narrow to wide conical or plate-like sponge (Fig. 8A-B). The smallest specimen MCZ-I 3744 is 1.1 cm height and 1 cm in diameter. The largest (MMC22) is 16 and 18 cm respectively. In some specimens, there is a massive, tuberoso base reaching 5.8 cm in height and 4.6 cm in diameter. Wall thickness 4–6 mm. Canal openings in quadrate arrangement on both surfaces. On external surface canal openings are rectangular (0.8–1 x 1.5–2.00 mm, skeletal bridges 0.5–0.8 mm) while on the inner surface (when observable) are rounded to elliptical (0.8–1.2 mm diameter or major axis, horizontal skeletal bridges 0.5–2 mm). Some longitudinal canals (1 mm large) are present on the base (Fig. 8C). Euretoid skeletal net with mainly quadratedictyonal meshes of 300 x 300 μ m (Fig. 8D).

Remarks. As reported by Pisera & Busquets, 2002 (p.335) Pomel (1872) erected numerous species of his genus *Laocoetis* (= *Craticularia* Zittel, 1877 sensu Reischwig 2002) from the Miocene of Algeria based mostly on slight differences in general growth form. Moret (1924), in extreme action, did not take into account skeletal differences, and synonymized all Pomel's species into one *Laocoetis crassipes* Pomel. In fact, aside from shape differences, there are differences in basic skeletal structure among Pomel's species and differences in the shapes of canal openings on both surfaces. Pisera & Busquets distinguished in Pomel's material, at least three different *Laocoetis* species. One has round to elongated canal openings on both surfaces, another has canal openings on the outer surface with rectangular shapes and rounded canal openings on the inner surface, and, finally, the third one has rounded canal openings on the outer surface and rectangular ones on the inner surface.

Our material could then be assigned to *Laocoetis patula* Pomel, 1872 emended Pisera & Busquets, 2002 because of the rectangular canal opening on the outer surface and the rounded to oval openings on the inner surface. Unfortunately in many specimens internal canals opening are not observable as the spongocoel is encrusted by sediment or poorly preserved. Nevertheless the clear presence of rounded canal openings on the inner surface of some specimens supported the assignment to *L. patula* with a reasonable confidence. *Craticularia stellata* Lagneau-Hérenge, 1962 from the Lower Cretaceous of SE France, shows the same canal openings pattern: rectangular in the external, rounded in the internal. Additionally, some specimens show rounded external pores but we suspect that could be due to abrasion caused by preparation.

On the reverse, in few specimens, due to poor preservation, only the internal surface with rounded openings, is visible, making the assignment uncertain. In fact *Laocoetis crassipes* Pomel, 1872 is characterized by rounded canal opening on both surfaces. Moreover, the tuberoso base, present in some specimens, is

nearly identical in shape and for the longitudinal canals, with the *L. crassipes* specimens illustrated in literature (see Miocene of Algeria: Pomel, 1872; Moret, 1924; Miocene South Spain: Ott d'Estevou, 1979; Pliocene of Sardinia, Italy: Matteucci, 1989). Bulbose attachment are adaptation to the substrate and do not have, in our opinion, a taxonomic value. The tuberosity base observed in our material is also similar to the ones present in the species described by Malfatti (1900) from the Middle Miocene of Emilia Romagna, (Northern Italy): *C. manzonii*, *C. globularis*, *C. ranzorei*. These species are not longer valid as Moret (1924) in his contribution to the Miocene of Algeria synonymised all the species with "*Craticularia crassipes*".

Laocoetis represents the longest living genus of Hexactinellida, with accepted range from the upper Jurassic to the Recent (Mehl 1992; Reiswig 2002).

Regarding the Eocene, d'Archiac (1850) reported *Laocoetis samueli* from the Biarritz area (southwestern Aquitaine Basin, Basque Country). The same species occurs in the Pamplona Basin (western Pyrenees) (Astibia et al. 2013). Finks et al. (2011) reported badly preserved *Laocoetis* sp. cf. *L. crassipes* from Caste Hayne (North Carolina, U.S.). Pisera and Busquets (2002) reported *L. patula* from Ebro Basin (Spain). In our material the "hemispherical enlarged nodes" on the surfaces of the dictyonal skeleton observed by Pisera & Busquets (2002) are not present but this could be due to poor preservation.

Regarding the shape, there are many examples in fossil (e.g. Reid 1963, Pisera 1997) and Recent (e.g. Lèvi 1986) *Laocoetis* that are cone-like as juveniles and then become more plate-like. The variety of shapes in the studied material can thus be interpreted as different ontogenetic stages.

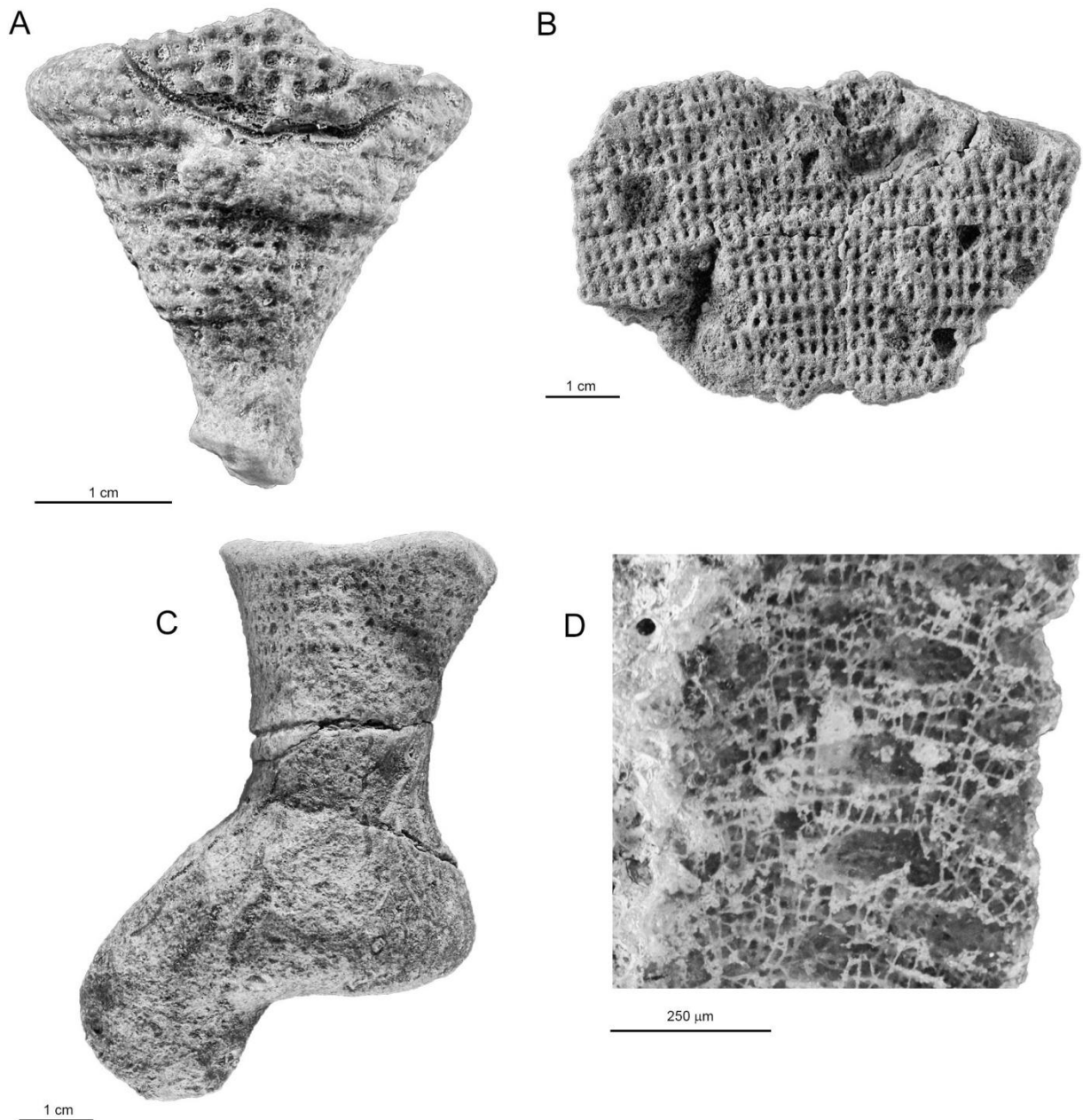


Figure 8. *Laocoetis patula* Pomel, 1872. **A**, lateral view of a conical specimen (MCZ-I 3711) with characteristic canal openings in quadrate arrangement; **B**, Plate-like specimen (MCZ-3727) showing rectangular canal openings in quadrate arrangement; **C**, MSNVE-22891 lateral view showing massive, tuberoso base with some longitudinal canals; **D**, longitudinal section showing quadrate dictyonal meshes.

Laocoetis emiliana? (Malfatti, 1900)
(Fig. 9A-C)

1900 *Craticularia emiliana*; Malfatti: 285, pl. 20 (1), figs 1–6, pl. 20 (2), fig. 13, pl. 22(3), figs 1, 4
2005 *Paracraticularia* sp.; Matteucci & Russo: 59, pl. 2, figs 5a–5b

Material. 4 specimens: MSNVE-22903, MSNVE-23010, MSNVE-23011, MSNVE-23020 from Cengio dell'Orbo quarry.

Description.—Tubular-branched craticularid up to 16.1 cm height and 12 cm in diameter (Fig. 9A) that is composed of 3 to 9 cylindrical to subconical tubes (Fig. 9B) of 1.3–3.5 cm in diameter. Rounded to subrounded terminal oscula 0.7–1.8 cm in diameter. Wall thickness 4–6 mm. Canal openings on outer surface are in quadrate arrangement and measure 0.7–0.8 mm × 1.5–2. They are separated by skeletal bridges 1–1.5 mm wide (horizontally) and 1 mm (vertically). Canal openings of the inner surface are rectangular as well and measure 0.5 mm × 1.0–1.5, and are separated by skeletal bands 0.5–1 mm wide horizontally, to 1 mm wide vertically. Radial canals are 720–900 µm wide and cross almost entirely the sponge wall (Fig. 9C). Euretoid skeletal net with mainly quadrate dictyonal meshes 200–399 µm in size. Dictyonal strands diverging toward both surfaces.

Remarks. Malfatti (1900), in description of *Craticularia emiliana* from Miocene of Italy considers fragments of sponges that could correspond to singular tubes of our material. Nevertheless the external canal openings are mainly rectangular while in Miocene material they are subrounded. Moreover, in our material, radial canals cross nearly completely the sponge wall, while in Malfatti's material they are shorter. The species was illustrated and preliminary described by Matteucci & Russo (2005) as *Paracraticularia* sp. This genus, originally described by Schrammen (1937) was synonymised by Reid (2004) with *Craticularia* Zittel, 1877. We agree that branching habitus has no generic value.

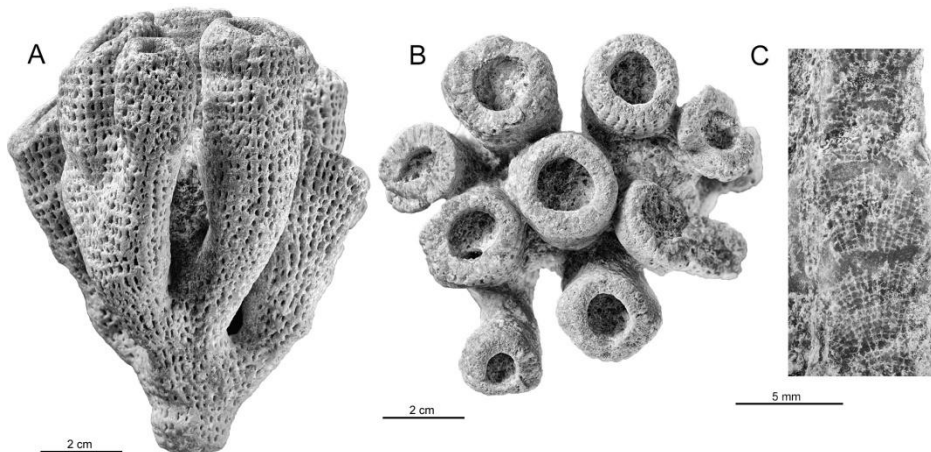


Figure 9. *Laocoetis emiliana?* (Malfatti, 1900) **A**, Lateral view of MSNVE-23020 with branched habitus and canal openings in quadrate arrangement (craticularid pattern); **B**, Top view of MSNVE-23020 with rounded tubes; **C**, Detail of MSNVE-22903 showing quadrate dictyonal meshes and radial canals crossing almost entirely the sponge wall. Dictyonal strands diverging toward both surfaces.

Family **Craticulariidae** Rauff, 1893
Genus **Pleuroguettardia** Reid, 1963

Type species: *Guettardia stumpeli* Schrammen, 1912

Pleuroguettardia iberica Pisera & Busquets, 2002
(Fig. 10A)

2002 *Pleuroguettardia iberica* Pisera & Busquets: 335, pl. 7, figs 1-6, pl.8, figs 5-7, pl. 12. fig. 4-6.
2005 *Pleuroguettardia* aff. *iberica*; Matteucci & Russo: 59, pl. 2, figs 7a-c.

and/or

Family **Cribrospongiidae** Roemer, 1864
Genus **Guettardiscyphia** de Fromental, 1860

Type species: *Guettardia stellata* Michelin, 1847 p. 121

Guettardiscyphia thiolati (d'Archiac, 1846)
(Fig. 10A)

Material. 11 specimens: MCZ-I 3765, MCZ-I 3768, MSNVE-22873, MSNVE-23041; MSNVE-23042, MSNVE-23044, MSNVE-23048, MSNVE-23050, MSNVE-23051, MCV 384, MGP-PD 1073 from Cava Cengio dell'Orbo.

Description. Stellate in cross section sponges up to 11.2 cm high and 7 cm in diameter, with 5-11 wings. The wings are 5-10 mm thick and have walls 1-4 mm thick. The surface of specimens are poorly preserved and/or finely encrusted by sediment so that the canal openings are not visible. As a consequence the assignment is not precise.

Remarks. The studied material may belong to the homeomorphic species/genera *Guettardiscyphia thiolati* (d'Archiac, 1846) and/or *Pleuroguettardia iberica* Pisera and Busquets, 2002, that are very similar in general morphology but belong to different families having different canalization patterns, i.e. Cribrospongiidae (cribrospongiid or irregular pattern) and Craticulariidae (quadrangular, craticulariid pattern). This pattern is often disturbed in both genera, especially near parietal gaps, so assignment to either of the genera of poorly preserved/fragmentary material may be difficult. (Pisera and Busquets 2002), and assignment is rather difficult without detailed studies (Astibia et al. 2014). Matteucci & Russo (2005) assigned some specimens from Chiampo Valley to *Pleuroguettardia* sp. and *Pleuroguettardia* aff. *iberica*. The last species is also known from the Eocene of the Vic Marls Formation (Pisera and Busquets 2002).



Figure 10. *Guettardiscyphia thiolati* (d'Archiac, 1846) and/or *Pleuroguettardia iberica* Pisera and Busquets, 2002.
A, MSNVE-23041 lateral view with lateral wings.

Family **Cribrospongiidae** Roemer, 1864
Genus **Guettardiscyphia** de Fromentel, 1860

Type species. *Guettardia stellata* Michelin, 1847 p. 121

Guettardiscyphia thiolati (d'Archiac, 1846)
(Fig. 11 A-G)

1846 *Guettardia thiolati* D'Archiac.; pl. 5, fig. 15, pl. 8, figs 5–6, non fig. 7.

1847 *Scyphia quinquelobata* D'Archiac: 413–414, pl. 9, fig. 13.

1925 *Pseudoguettardia thiolati* var. *gurbensis* nov. var.; Moret: 9–10, pl. 1, fig. 9.

1972 *Guettardia* sp.; Menin: 65, fig. 5

2002 *Guettardiscyphia thiolati* (d'Archiac, 1846); Pisera & Busquets: 337, pl. 7, figs 7–13, pl. 12, figs 1–3

2005 *Guettardiscyphia thiolati* (d'Archiac, 1846); Matteucci & Russo: 59, pl. 1, figs. 8a-c

Material. 19 specimens: MCZ-I 3764, MCZ-I 3766, MCZ-I 3767, MCZ-I 3784b, MCZ-I 3786, MCZ-I 3787, MCZ-I 3803, MSNVE-22870 MSNVE-22872 MSNVE-22874, MSNVE-22875, MSNVE-22876, MSNVE-23040, MSNVE-23043, MSNVE-23045, MSNVE-23046, MSNVE-23047, MSNVE-23049, MSNVE-23091 from Cengio dell'Orbo quarry.

Description. Stellate in cross section sponges that are, 4.6–8.8 cm high, 4.2–11.5 large 2.8– 10.2 long, and usually composed of 5–6 wings. These wings are united in the lower part, but may be completely separated, forming elongated branches directed upward and outward in the upper part (Fig. 11A, B). Largest specimen (MCZ-I 3784b 5.5 high, 15.3 cm large, 8.5 long) show irregular fins instead of wings (Fig. 11C). Radial fins may be considered as an adaptation to improve stability, due to large dimensions (Finks, 2003) (see below, paleoecology paragraph). Along the edges of the wings there are some papilliform outgrowths (4 mm in height) with rounded oscula of 0.6–2 mm in diameter (Fig. 11A, D). The wings are 9–17 mm thick and have walls 2–7 mm thick. Canals opening on the outer surface rounded to subrounded, 200–400 µm in diameter, either irregularly distributed (Fig. 11E) or in quincuncal arrangement. Dictyonal skeleton of euretoid type with regular node to node meshes, from square (140–200 µm) to triangular (120–200 µm) (Fig. 11 F). In transversal section both canals systems (that can be interpreted as epirhyses and aporhyses sensu Reid, 1963) perforate the wall in opposite directions and generally terminate immediately below the opposite surface (Fig. 11G).

Remarks. As clearly explained by Pisera & Busquets, 2002, Reid (1961, 1963) separated the species earlier referred to as *Guettardia* Michelin, 1847 (*non* Nardo, 1833) into two different but homeomorphic -in habitus- genera based on ostia/canals organization. One is *Guettardiscyphia* De Fromentel, 1860 (= *Guettardia* Michelin, 1847), with ostia alternating in particular vertical rows or irregularly arranged, and postica in the regular quadrangular pattern; this genus belongs to the family Cribrospongiidae. The second genus is characterized by both ostia and postica in regular quadrangular (craticulariid) pattern, and it belongs to the family Craticulariidae. Reid proposed the name *Pleuroguettardia* for the latter genus Reid (1963 p. 227).

Reid (1961) p. 745: “ the stellate sponges formerly treated as species “*Guettardia*” are thus of two types: (a) forms which each longitudinal series of circulatory cavities consists of alternating epirhyses and aporhyses, and the epirhyses perforate the framework; and (b) forms in which epirhyses and aporhyses occur in separate and alternating longitudinal series, and the epirhyses are normal (i.e. blind). The former are *Guettardiscyphia* species, but the latter are species of Craticulariid homeomorph of this genus”. The papilliform outgrowths observed in some specimens, complies with Reid's redefinition (1961, p. 743) of genus *Guettardiscyphia* De Fromentel, 1860 that includes occurrence of accessory parietal oscula along margins of flanges or branches.

The fossil record of the species is for the Eocene of France (d'Archiac 1846, 1847), Spain (Moret 1925; Pisera & Busquets 2002; Astibia et al. 2014) and Italy (Matteucci and Russo 2005, 2011; this work). The genus is widespread in the Cretaceous of Europe: United Kingdom (Reid 1961, 1968), Germany (e.g. Schrammen 1910 as *Guettardia*), France (Lagneau-Hérenger 1962), and Czech Republic (Zitt et al. 2006).

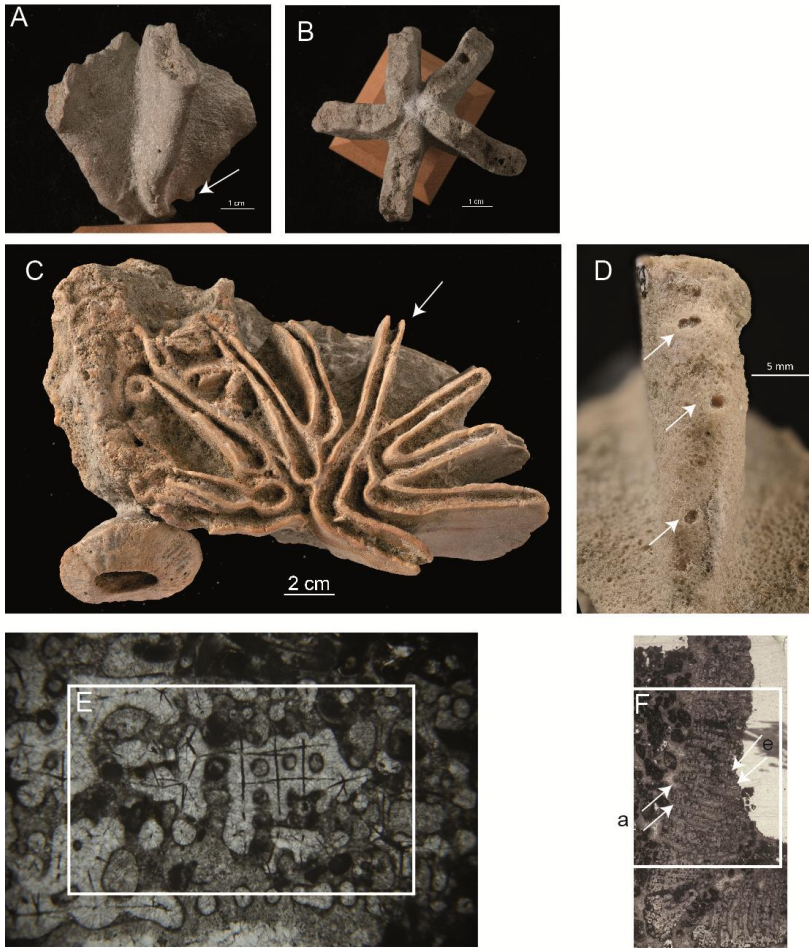


Figure 11. *Guettardiscyphia thiolati* (d'Archiac, 1846). **A**, MCZ-I 3786 lateral view, papilliform outgrowths (arrow) along the edges of the wings; **B**, MCZ-I 3786 top view showing stellate shape in cross section; **C**, MCZ-I 3784b *G. thiolati* (arrow) with plicate, irregular fins; **D**, MSNVE-22874 detail of wing's edge, papilliform outgrowths with small rounded oscula (arrows); **E**, MSNVE-23040 detail of a wing's external surface showing irregularly distributed canal openings, **F**, MCZ-I 3764 detail of longitudinal thin section of one wing. Square to triangular meshes; **G**, MCZ-I 3764 detail of transversal thin section. Epirhyses (e) and aporhyses (a) perforate sponge wall in opposite directions and generally terminate immediately below the opposite surface.

Family ?**Auloplacidae** Schrammen, 1912 (sensu Reiswig & Kelly 2011)

Genus *Rigonia* gen nov.

Type species. *Rigonia plicata* sp. nov.

Diagnosis. Fan-shape sponge, consisting of thin strongly plicated wall on one side forming deep narrow furrows and rounded ridges. On the other side labyrinthic pattern of folds with large openings leading the caviedial spaces. Walls perforated by deep and closely spaced canals. Choanosomal skeleton composed by triangular meshes.

Derivation of name. In honor of Francesco Giuseppe Rigoni (Vicenza–Ankara) who inspired this work

Type locality and stratum. Chiampo (Vicenza), Cengio dell’Orbo quarry, volcanoclastics, Lutetian

Remarks. Our material is similar in the fanlike shape to tretodyctid *Ramalmerina* Brimaud and Vachard, 1986 from Miocene of Spain but lacks schizorhyses and do not show oscula at the point of branches bifurcation. Moreover in *R. fisheri* Brimaud and Vachard 1986 (p. 426) dictyonalia are mainly rectangular and large (700 x 200 µm) while in our material they are triangular and small (110-150 µm). Our material shows affinities in morphology to a badly preserved *Auloplax*? sp from from the Takatika Grit (Campanian-Danian), Chatham Islands, New Zealand (Consoli et al. 2009).

Genus *Auloplax* Schultze 1904 was traditionally considered in family Tretodictyidae but Reiswig (2002 p. 1358) transferred it to Dactylocalycidae because it completely lacks schizorhyses. Reiswig & Kelly (2001), in a study on Recent hexactinellids from New Zealand, proposed (p. 136) to move the genus *Auloplax* Schulze, 1904, from the Dactylocalycidae to the resurrected family Auloplacidae. They made a new diagnosis for this monogeneric family. Their diagnosis can be applied to our material: body consisting of several vertical plates or fans composed of conjoined thin walled tubes dividing acutely and remaining tightly connected side-by-side; one exposed side of each tube has a very thin dictyonal frame composed of large apertures. Specifically, *Auloplax breviscopulata* Reiswig and Kelly 2011 show a choanosomal skeleton with oval apertures similar to our material. Moreover, choanosomal skeleton meshes length is comparable: approximately 110 µm for both genera.

Nevertheless, there are fundamental differences in skeleton framework between *Auloplax* and *Rigonia* genera: 1. wall with very shallow canalization in the first genus while the second is deeply canalized. 2. *Rigonia* choanosomal skeleton has mainly triangular meshes while in *Auloplax* rectangular and polygonal polygonal forms are also common.

Rigonia plicata nov sp.
(Fig. 12A–I)

Diagnosis. As for the genus

Derivation of the name. From latin “plicatus” (= folded)

Type specimens. 2 fragments; holotype MSNVE-22980 , paratype MCZ-I 3780

Type locality and stratum. Chiampo (Vicenza), Cengio dell’Orbo quarry, volcanoclastics, Lutetian

Description. Fan-shaped fragments 5-8-8.1 cm high, 4.7-10.3 large, 3.1-3.6 long. The wall is 1-1.2 mm thick and strongly plicated (Fig X E,F) forming on one side 4–5 rounded ridges (7-10 mm large) separated by deep narrow furrows. (Fig. X A, B). The other side shows a labyrinthic pattern of folds (6 mm large) with rounded (3-4 mm in diameter) to elongated openings (Fig. X C, D).

Walls perforated by closely spaced canals (250-350 μm in diameter) separated by skeletal bridges of 150-250 μm). (Fig. X G). Canals deep crossing nearly the whole wall (Fig. H). Skeleton composed of mainly triangular meshes 120-140 μm in length (node to node) (Fig. I).

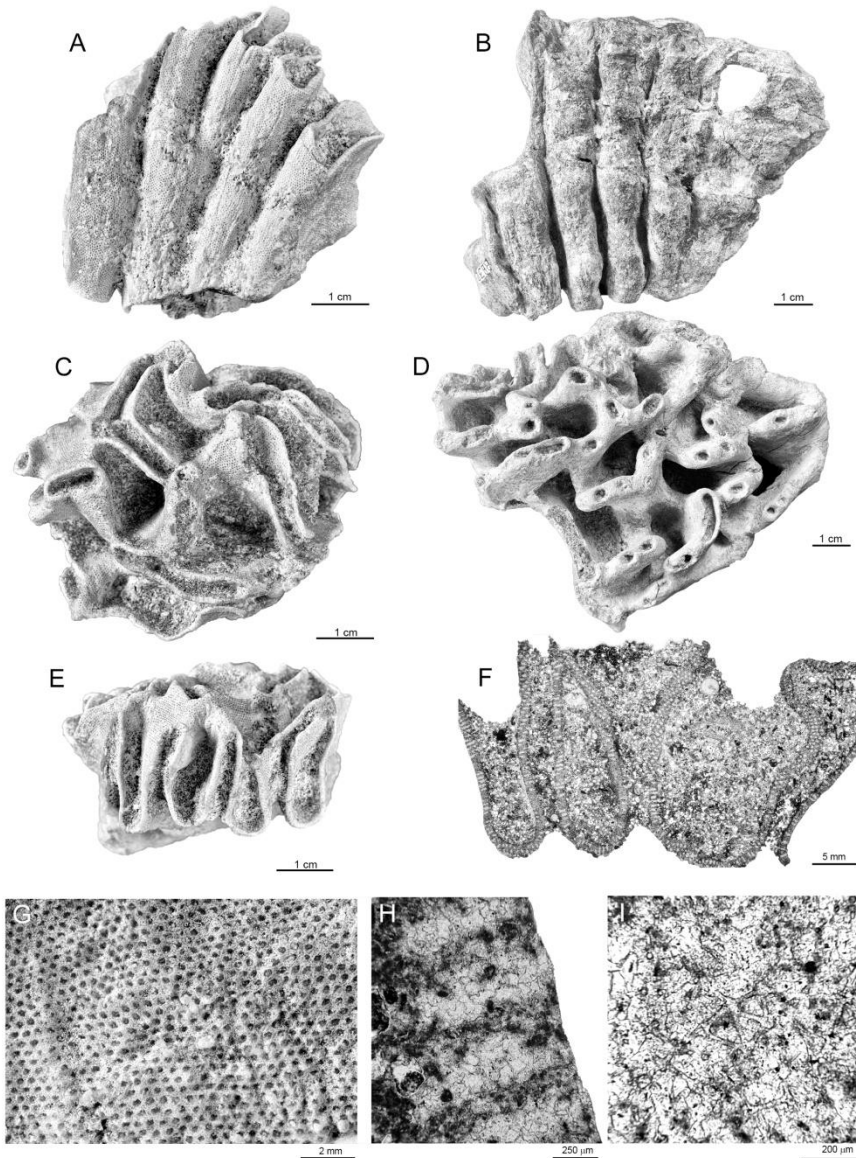


Figure 12. *Rigonia plicata* gen et sp. nov. **B, C**, MSNVE-2298 holotype; **A, C, E-I** MCZ 3780 paratype; **A, B** side view of fan-shaped fragments composed of rounded ridges divided by deep and narrow furrows; **C, D**, opposite side view with labyrinthic pattern of folds opening rounded to elongate openings (arrow) leading the cavodial spaces; **E** upper view and **(F)** transverse thin section showing the strongly plicated wall; **G** detail of wall structure with deep and closely packed canals; **I** detail of transverse thin section. Skeleton composed of mainly triangular meshes.

Order **Hexactinosida** Schrammen, 1903
 Family **Tretodictyidae** Schulze, 1887
 Genus **Anomochone** Ijima, 1927

Type species: *Anomochone expansa* Ijima, 1927 p. 269

cf. *Anomochone* sp.
 (Fig. 13A–D)

Material. MCZ-I 3708 from Cengio dell'Orbo quarry.

Description. Fragment of a group of two branching tubular sponges (10.6 high, 4–4.1 cm in maximum diameter), with rounded (1.6 cm) to elliptical (2.5 x 0.9) terminal oscula (Fig. 13A). On dermal surface, irregularly distributed rounded to subrounded canal openings 1–2 mm in diameter separated by skeletal bridges 0.5–2 mm wide (Fig. 13B). Sponge wall (0.9-1.4 cm in thickness) deeply canalized, with cleft-like to labyrinthine cavities (schizorhyses) (Fig. 13C). Dictyonal skeleton with mainly triangular meshes of 120–180 µm in length. Swollen nodes (Fig. 13D).

Remarks. The presence of an euretoid skeleton with schizorhyses support the assignment to family Tretodictyidae. The possession of swollen dictyonal nodes strongly suggests affinity to the living genera: *Anomochone* Ijima, 1927, *Psilocalyx* Ijima, 1927 and *Cyrtaulon* Schulze, 1886 (Reiswig 2002). *Psilocalyx* body, however, is composed of small tubes which are not present in our material (e.g. *P. nitidus* Schrammen 1936). On the other hand *Cyrtaulon* lacks central spongocoel. The skeleton of our specimen is very similar to *Anomochone* but with less plicate morphology. On the other hand, in the branching habit the studied specimen is similar to another tretodictyid, genus *Sclerothamnopsis* Wilson, 1904 but this genus lacks swollen nodes. *S. collina* Brimaud & Vachard 1986 has a branching habit too, but the diameter of the branch is significant smaller (10 mm) and the spiculation is unknown.

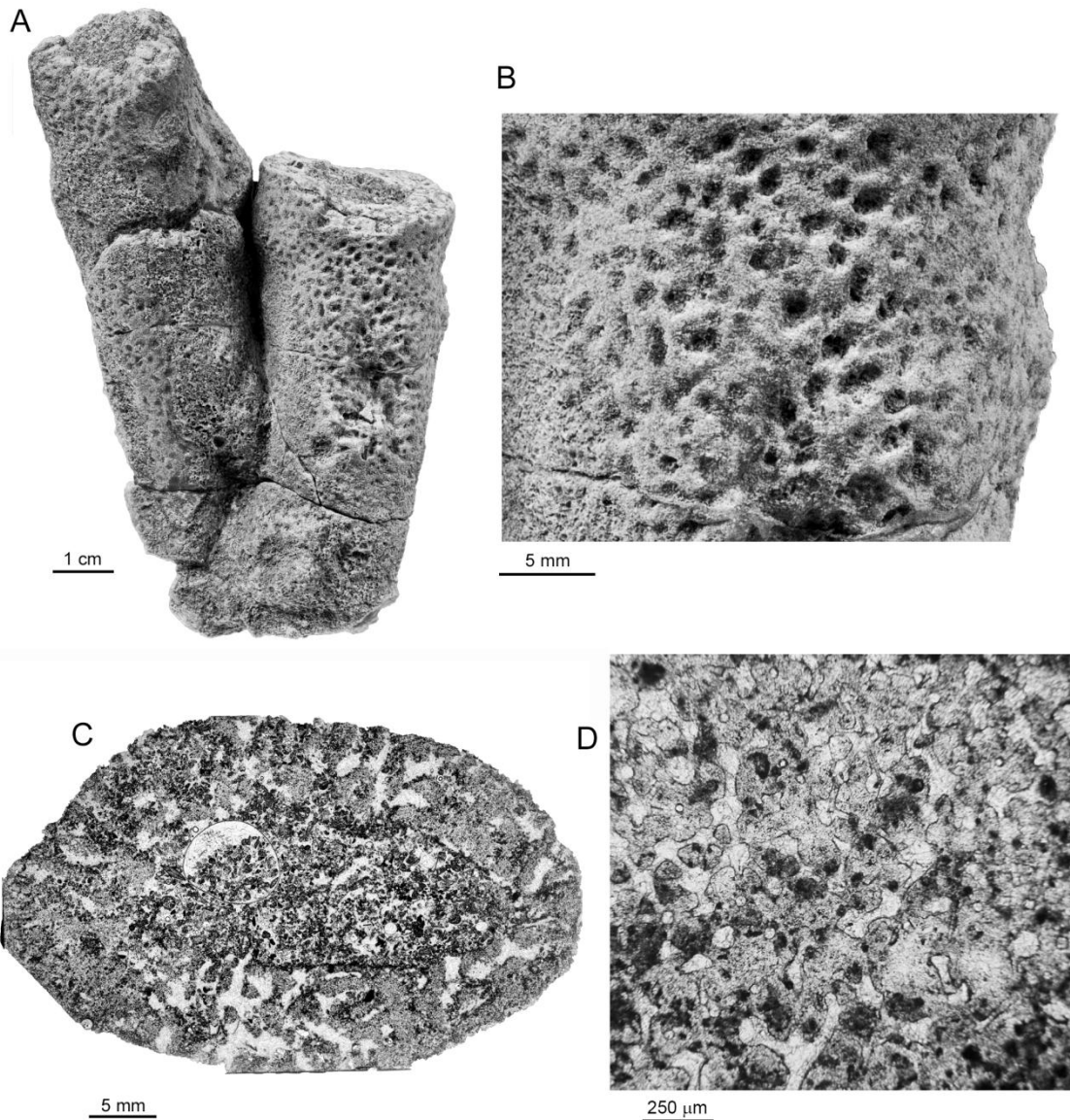


Figure 13. cf. *Anomochone* sp. MCZ-I 3708. **A**, Branching tubular sponges with rounded to elliptical terminal oscula; **B**, Dermal surface with rounded to subrounded irregularly distributed canal openings; **C**, Transverse thin section of a branch, with deep, labyrinthine canals (schizorhyses) (arrow). **D**, Detail of transverse thin section showing dictyonal skeleton with swollen nodes and mainly triangular meshes.

Order **Hexactinosida** Schrammen, 1903
 Family **Tretodictyidae** Schulze, 1887

Genus *Hexactinella ventilabrum* Carter, 1885

Type species. *Hexactinella ventilabrum* Carter, 1885 p. 397

***Hexactinella clampi* sp. nov.**
(Fig. 14A–G)

Diagnosis. Funnel to plate-like sponge with thick wall deeply chanelized with schizorhyzes. Irregular elliptical terminal osculum. On dermal surface subrounded canal openings are irregularly distributed. Euretoid dictyonal skeleton with mainly quadrate meshes.

Derivation of name. From “Clampus” latin name of Chiampo.

Material. 5 specimens. MCZ-I 3725, MCZ-I 3728, MCZ-I 3729, MCZ-I 3804, MSNVE-22890
MCZ 3804

Type specimens. Holotype: MCZ-I 3804. Paratypes: MCZ-I 3725, MCZ-I 3729

Type locality and stratum. Chiampo (Vicenza), Cengio dell’Orbo quarry, volcanoclastics, Lutetian.

Description. Funnel to plate-like sponge, 7.5- 17 cm high, 5.1-12 large, 3.5- 9 long with irregular elliptical terminal osculum (maximum diameter 2.5–7.5 cm). Wall thickness 0.9-1.7 cm. On dermal surface, irregularly distributed subround canal openings 0.7-2.0 mm in diameter separated by skeletal bridges 0.5-1.5 mm wide. Dictyonal skeleton euretoid with mainly quadrate (120-180 μ m) meshes, deeply canalized, with cleft-like to labyrinthine cavities (schizorhyzes).

Remarks. The presence of an euretoid skeleton with schizorhyzes support the assignment to family Tretodictyidae. The studied specimens has a thick-walled funnel to flabellate shape; subround openings in coarsely reticulate surface that suggest attribution to the genus *Hexactinella*.

In the study material there are both nearly complete specimens and platy fragments. We interpret the latter as fragments of larger sponges. Actually, as many hexactinellid, smaller individuals of this species could have a funnel-like shape and latter become platy.. Certain hexactinellid sponges such as Recent *Tretocalyx polae* Schulze, 1901 have initially funnel-like habit that is subsequently modified through an increas of size by peripheral growth so the gastral surface become everted (Reid,1964 p lii). Platy fragments are similar to Miocene *H. calolepsis* Brimaud & Vachard 1986.

This species differ from *H. clampi* in having larger skeletal bridges between canal openings and longer dictyonal meshes. On the other side, the studied specimens differ from other platy taxa, the Eocene (Bartonian) *H. informis* Pisera & Busquets, 2002 from having larger skeletal bridges and more regular subrounded shape of canal openings. *H. informis* is in fact characterized by irregular or polygonal canal openings which are not observed in our material.

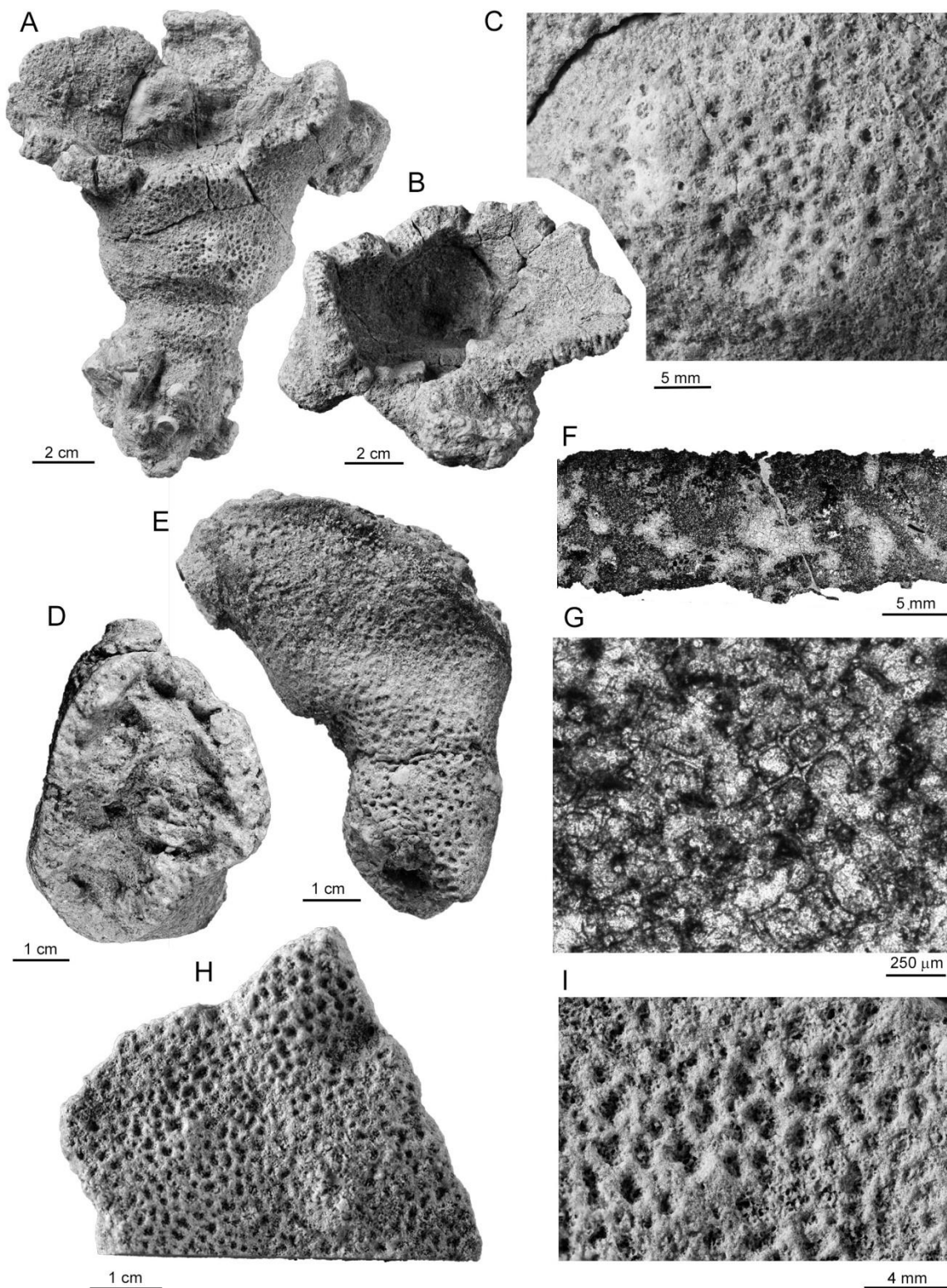


Figure 14. *Hexactinella clampi* sp. nov. **A–C** MCZ-I 3804 holotype; **D, E** MCZ 3728-I paratype; **F–I** MCZ 3725-I paratype. **A, D** lateral view of funnel shape specimens; **B, E** top view with irregular elliptical terminal osculum; **F**, platy specimen; **C, G**, irregularly distributed subround canal openings; **H**, longitudinal thin section of the sponge wall with schizorhyses (arrow); **I**, detail of thin section. Dictyonal skeleton with quadrate meshes (arrow).

Order **Lychniscosida** Schrammen, 1903
Family **Callodictyonidae** Zittel, 1877
Genus **Callicylix** Schrammen, 1912

Type species. *Callicylix farreides* Schrammen, 1912 p. 302

Callicylix eocenicus Pisera & Busquets, 2002
Fig. 15 (A–F)

1993 *Placoscyphia roemeri*; Raffi & Serpagli: p. 69, pl. 2.37, fig. a

2002 *Callicylix eocenicus* Pisera & Busquets: p. 342, pl. 10, figs 8, 9, pl. 14, figs 3, 4

Cf. 2005 *Centrosia* aff. *viquensis*; Matteucci & Russo: p. 57 Pl. 1 fig. 4

Cf. 2005 *Callicylix* aff. *eocenicus*; Matteucci & Russo: p. 57 Pl. 1 fig. 3

Material. 32 specimens: MCZ-I 3710, MCZ-I 3714, MCZ-I 3778, MCZ-I 3784a, MCZ-I 3788, MCZ-I 3789, MSNVE-22821, MSNVE-22822, MSNVE-22824, MSNVE-22825, MSNVE-22826, MSNVE-22827, MSNVE-22829, ?MCNVE-22830, MSNVE-22831, MSNVE-22834, MSNVE-22835, MSNVE-22837, MSNVE-22838, MSNVE-22839, MSNVE-22840, MSNVE-22841, MSNVE-22842, MSNVE-22831, MSNVE-23057, MSNVE-23058

MSNVE-23087, MSNVE-23094, MSNVE-23095, IG-PD 366225, IG-VI 272203, IG-VI 272230 from Cava Cengio dell'Orbo quarry.

Description. Ovoid to globose sponges (Fig. 15A, B) that are 4.2–8.3 cm high, 5.4–10.7 wide and 3.9–8.3 long. Smallest specimen (MSNVE-22842) is 3.6 x 4 x 3.3. Largest specimen (MCZ-I 1380) is 12.7 x 12.4 x 10.6 cm. A possible juvenile specimen (MSNVE-22830) is 2.4 cm high and 2 in diameter (Fig. 15C). The body is composed of anatomizing tubes and lamellae. Tubes openings from subcircular 5–8 mm in diameter, to elongated 10–18 mm in size. Tubes walls on the outer surface are 2–4 mm thick without intradictyonal canal system (Fig. 15D). On cross section tube walls are either meandriform or anastomosing forming lamellae (4–6 mm thick), or bowl shaped structures (Fig. 15E). Meshes of dictyonal skeleton with lychniscs from rectangular (300–375 x 360–425 μm – node to node-) to quadrate (250–425 μm – node to node-) (Fig. 15F).

Remarks:

The studied specimens show two morphological varieties: one with more mandriform openings and thinner walls (Fig. 15A), the other with mainly subcircular openings and thicker tubes walls (Fig. 15B). One cannot reject the idea that they belong to 2 different species. On the other hand, considering that 1) one large specimen (MCZ-I 1380) show both morphological features and 2) wall thickness variability could also depend on fossil preparation; we regard rather that all material belongs to the same species.

Traditionally, meandriform sponges have been classified as *Placoscyphia* Reuss, 1846 but Reid (1962) clearly demonstrated that different sponges occur under this generic name (Pisera & Busquets, 2002 p. 341). The studied specimens are homeomorphs of *Exanthesis* Regnart in Moret, 1926 and *Robinia* Finks, Hollocher, Thies, 2011 but they lack the labyrinthine canal system characteristic for these genera. The studied specimens are also morphologically nearly identical to *Callicylix farreides* Schrammen, 1912 but differ in the absence of spongocoel. They show also affinities with genera *Brachiolites* Smith, 1848 and *Centrosia* Schrammen, 1912.

In assigning the material we encountered two problems: a) a general one about classification b) a specific one about material preservation.

a. Generally callodyctid sponges are poorly described in literature and a revision of the family is needed. In fact there is a lot of fossil genera that are similar and there is not a clear cut differences between them.

b. Specifically, in our material the bad preservation and the lack of diagnostic characters (e.g. cortex, peripheral capsule, lychniscs sculptures) make the assignment difficult if possible at all.

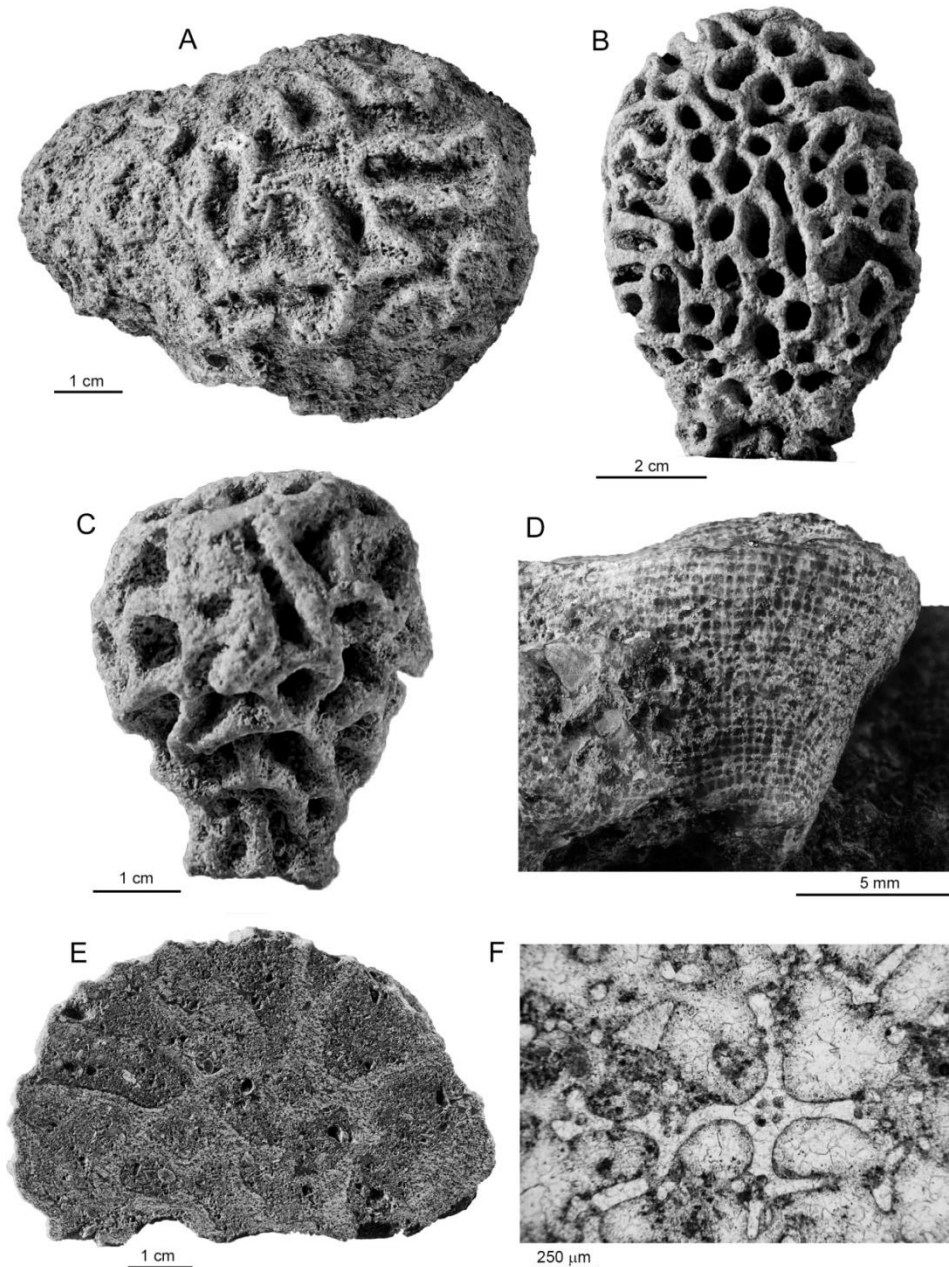


Figure 15. *Callicylix eocenicus* Pisera & Busquets, 2002. **A**, MCZ-I 3714 top view with dominant maendriform openings; **B**, MCZ-I 3789 top view with mainly subcircular openings; **C**, MSNVE- 22830, juvenile?; **D**, MCZ 3778-I Detail of dermal surface without intradictyonal canal system, **E**, MCZ-I 3710 longitudinal section. Tube walls are either meandriform or anastomozing forming pillars or bowl shaped structures. Note absence of spongocoel; **F**, IG-PD 366225 lychniscs and quadrate meshes as seen in longitudinal thin section.

Family **Camerospongiidae** Schrammen, 1912

Genus ***Camerospongia*** d'Orbigny, 1849

Type specie. *Scyphia fungiformis* Goldfuss, 1831 p. 218

Camerospongia tuberculata sp. nov.

(Fig. 16 A–F)

Diagnosis. Cylindrical *Camerospongia* with large rounded terminal osculum. Lateral outer surface covered with large low conical outgrowths irregularly distributed.

Derivation of the name. from latin adjective “tuberculatum“, bearing tubercules.

Material. 7 specimens: MCZ-I 3706, MCZ-I 3753, MCZ-I 3754, MSNVE-22907, MSNVE-22976, MSNVE-22973, MSNVE-22916

Type specimens. Holotype MSNVE-22973. Paratypes MSNVE-22976, MCZ-I 3753.

Type locality and horizon: Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description: Cylindrical sponges slightly narrowing towards the base with large rounded terminal osculum (7-11 mm), 2.4 -2.8 cm in diameter and 1.7- 4.1 cm high. Narrow and cylindrical spongocoel running through the entire sponge. Uppermost part of the sponge has larger diameter than the rest and forms an overhang over lateral surface. The surface around the terminal osculum is flat and smooth suggesting the original presence of siliceous membrane. On the lateral surface there are outgrowths (4-5 mm in diameter, 3-4 mm tall). Skeleton with lychniscs and quadrate (200-300 μ m, node to node) to rectangular (150 x 300 μ m) meshes. Intradictyonal canals 800–1600 μ m in diameter.

Remarks. In general shape the specimen resembles the Jurassic *Multiloqua fungiformis* (Goldfuss) , but that species has hexactines not lychniscs. The closest morphologically species is *Camerospongia elongata* Lagneau-Hérenger, 1962 from Cretaceous of France. Our specimens differ in having a flat top while *C. elongata* being rounded (Lagneau-Hérenger, 1962 p. 111). Moreover our specimens have solid low conical outgrowths while *C. elongata* shows large tubular openings. The type species *C. fungiformis* on the other hand differs strongly in shape being biconical to hemispherical or pyriform and supplied with a stalk.

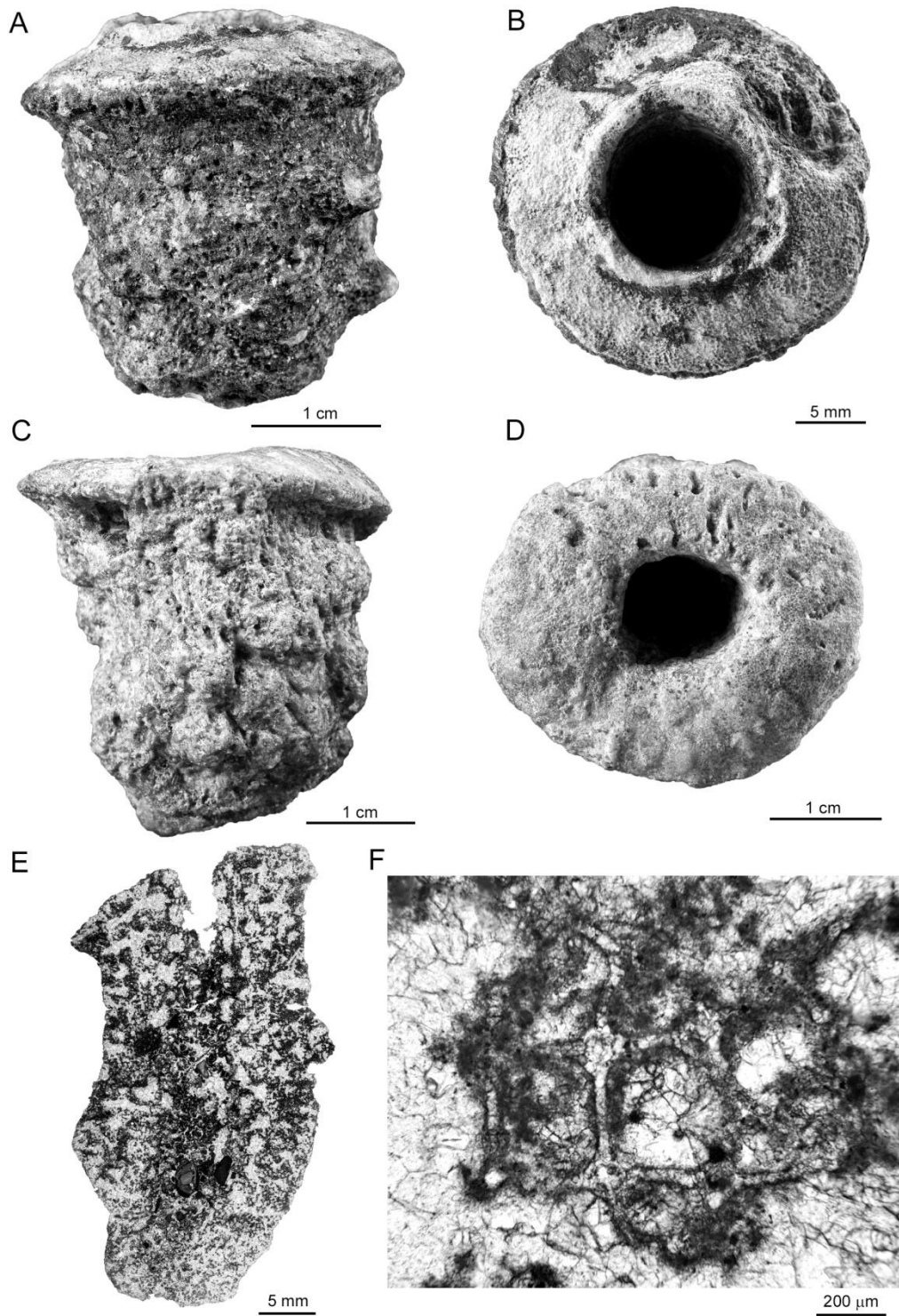


Figure 16. *Camerospongia tuberculata* sp. nov. **A, B**, MSNVE-22973 holotype. **C, D** MSNVE-22976 paratype. **A, C** lateral views, to show cylindrical shape with an overhang of uppermost part, and low conical outgrowths on sides; **B, D**, top views with rounded terminal osculum surrounded by finely porous siliceous membrane; **E**, MCZ-I 3753 longitudinal thin section, narrow and cylindrical spongocoel running through the entire sponge, note intradictyonal radial canals; **F**, MCZ-I 3753 detail of thin section, square meshes with lychniscs.

Camerospongia visentini sp. nov.
(Fig. 17A–H)

Diagnosis. Low-conical *Camerospongia* with rounded to elliptical terminal osculum around which a small elevated rim is present. The top surface is either flat or slightly inclined and covered with siliceous membrane. On the lateral surface, there are large subrhomboidal to irregular canal openings, in quincuncal or irregular arrangement. The base may be supplied with a ledge.

Derivation of the name. In honor of Marina Visentin, one of the first students of Chiampo sponge fauna.

Material. 22 specimens: MCZ-I 1382, MCZ-I 1385, MCZ-I 3712, MCZ-I 3715, MCZ-I 3775, MCZ-I 3779, MCZ-I 3781, MCZ-I 3784c, MSNVE-22814, MSNVE-22884, MSNVE-22886, MSNVE-22887, MSNVE-22888, MSNVE-22975, MSNVE-23052, MSNVE-23054, MSNVE-23055, MCV 383, MGPD 1067, IG-VI 272204, IG-VI 272232, IG-VI 272237.

Type specimens. Holotype: MCZ-I 3784c. Paratypes: MCZ-I 3712, MCZ-I 3775, MCZ-I 3781. **Type locality and horizon.** Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Low-conical sponges (Fig. 17A, C) that are 3.3–7.6 cm high, 4.7–12.9 cm large, 3.6–9.8 cm long. Conical spongocoel extended to the base of the sponge. Terminal osculum elliptical (1.0–1.3 x 2.3–6.2 cm, (Fig. 17B, D, E) to rounded (1.8–1.9 cm, Fig. 17E) supplied with a narrow elevated rim 2–4 mm in height. Top surface of the sponge covered with smooth siliceous membrane; this membrane may appear also at the base of the sponge. Uppermost part of the sponge has larger diameter than the rest and forms an overhang of lateral surface (Fig. 17A). Lateral surface of the sponge displays densely distributed large elongated longitudinally subrhomboidal to irregular canal openings that are 1.5–2.5 mm in diameter (Fig. 17G). Canal openings are quincuncally or irregularly arranged. The base, when present, is encrusting, sometimes edged with a ledge 3 mm wide (Fig. 17D). Sponge wall reach up of 1.8–2.2 cm in thickness. The wall is pierced by large radial canals of 600–1200 µm in diameter (Fig. 17H). Choanosomal skeleton has mainly quadratic meshes 400 µm (node to node) in size. On the dermal side, meshes range from 300 to 500 µm, and are more irregular shape.

Remarks. The investigated specimen differs from *C. fungiformis* (Goldfuss) in having a low-conical shape, a flat or slightly inclined rather than convex top surface, a ledge at the base, large subrhomboidal to irregular canal openings, in quincuncal or irregular arrangement. On the other hand *Camerospongia tuberculata* sp. nov. has a cylindrical shape, low conical outgrowths and no ledge at the base. Although genus *Camerospongia* have root in the Jurassic (Pisera 1997, Gaillard 1983), its fossil record is mainly for Cretaceous of Europe: Germany (Schrammen 1912), Poland (Swierczewska-Gładysz. 2010) France and Spain (Lagneau-Hérengeur 1962), United Kingdom (Reid 1968). This study is the first record of *Camerospongia* for the Eocene. As a consequence Lutetian becomes the last appearance of the genus. Another camerospongid, *Robinia striatopunctata* Finks, Hollocher & Thies, 2011 was described for the Middle and Upper Eocene of Castle Hayne Formation, North Carolina.

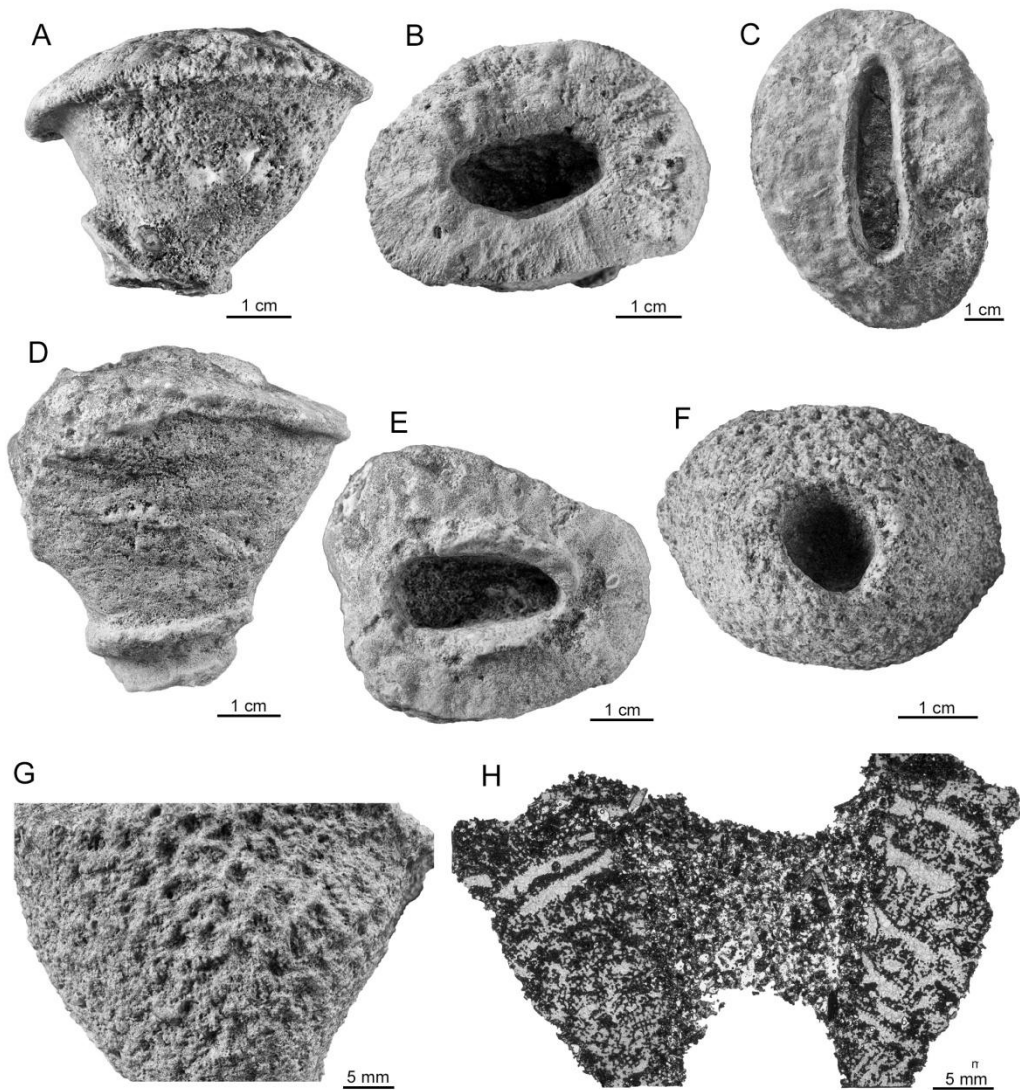


Figure 17. *Camerospongia visentini* sp. nov. **A, B**, MCZ-I 3784c holotype; **C, D** MCZ-I 3712 paratype; **E–G** MCZ-I 3781 paratype. **A**, lateral view, low conical shape, uppermost part of the sponge forms an overhang of lateral surface; **B**, top view, elliptical terminal osculum surrounded by a smooth membrane; **C**, lateral view, ledge at the base of the sponge; **D**, top view, elliptical osculum around which a small elevated rim is present; **E**, MCZ-I 3775 top view, elliptical osculum with elevated rim; **F**, top view, rounded terminal osculum; **G**, detail of lateral dermal surface with irregularly distributed subrhomboidal canal openings; **H**, longitudinal thin section. Large radial canals cross the sponge wall. Conical spongocoel extends to the base of sponge.

Type specie *Cephalites catenifer* Smith 1848 p. 78 pl.14 fig. 9, 14-16 designated by de Laubenfels 1955, p. 90

***Toulminia italica* sp. nov.**
(Fig. 18A–G)

Diagnosis. Narrow to irregularly conical *Toulminia* with large elliptical terminal osculum and sometimes a second lateral one. Thick wall composed of fused tubes that forms, on sponge lateral surface, low conical outgrows with rounded ends. At sponge's sides, Tongue-like external siliceous membrane showing horizontal concentric lines on lateral surface. Dictyonal skeleton with quadrate to rectangular meshes.

Derivation of the name. From Italy (latin).

Material. 5 specimens: MCZ-I 3792, MCZ-I3800, MSNVE-22910, MSNVE-22972, MGPD 1044.

Type specimens. Holotype MSNVE-22972. Paratypes: MCZ-I 3800, MSNVE-22910.

Type locality and horizon. Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Narrow to irregularly conical (Fig. 18A, D, F) sponge that is 3.1–7 cm high, 1.7–3.1 wide, and 2–4 long. Elliptical terminal osculum 0.2–0.5 x 0.7–1.5 cm (Fig. 18C, E, H). Some specimen has a second osculum on one side (Fig. 18B). Spongocoel narrow and elliptical in cross section Thick wall (up to 1.5 cm) composed of tubes that are 0.3–0.5 cm in diameter. Low conical lateral outgrows 5 mm in diameter, 3–5 mm in height, with rounded ends (Fig. 18A, G). External siliceous membrane on the upper part of the sponge developed in the holotype (Fig. 18C). On sides of all specimens there is a characteristic tongue-like external siliceous membrane showing horizontal concentric lineation (Fig. 18A, D, F). Choanosomal skeleton composed of lychniscs. In transversal section, meshes of the dictyonal skeleton are quadrate (400–500 µm, node to node) to rectangular (400 x 500 µm).

Remarks. The smooth surface around terminal osculum support the assignment to family Camerospongiidae Schrammen, 1912 (Reid, 2004, p. 537) while the thick wall composed of tubes and the lateral outgrows points to the genus *Toulminia* Zittel 1877. As observed by Olszewska-Nejbert, and Świerczewska-Gładysz (2012) all currently known species of *Toulminia* (see Mantell 1822; Toulmin Smith 1848; Hinde 1883; Schrammen 1912, all Cretaceous) differ in the development of terminal ends of tubes. The type specie *Cephalites catenifer* Smith 1848, for example, show horseshoe terminations while *Toulminia polonica* Dunikowski, 1889 is characterized by rounded openings on terminations. Our material show low conical outgrows with blind rounded ends similar to *T. wollemanni* Schrammen 1912 from Cretaceous of N Germany but the latter are more elongated and never exceed 2–3 mm in diameter. This is the first record of *Toulminia* for the Eocene. As a consequence Lutetian becomes the last appearance of the genus.

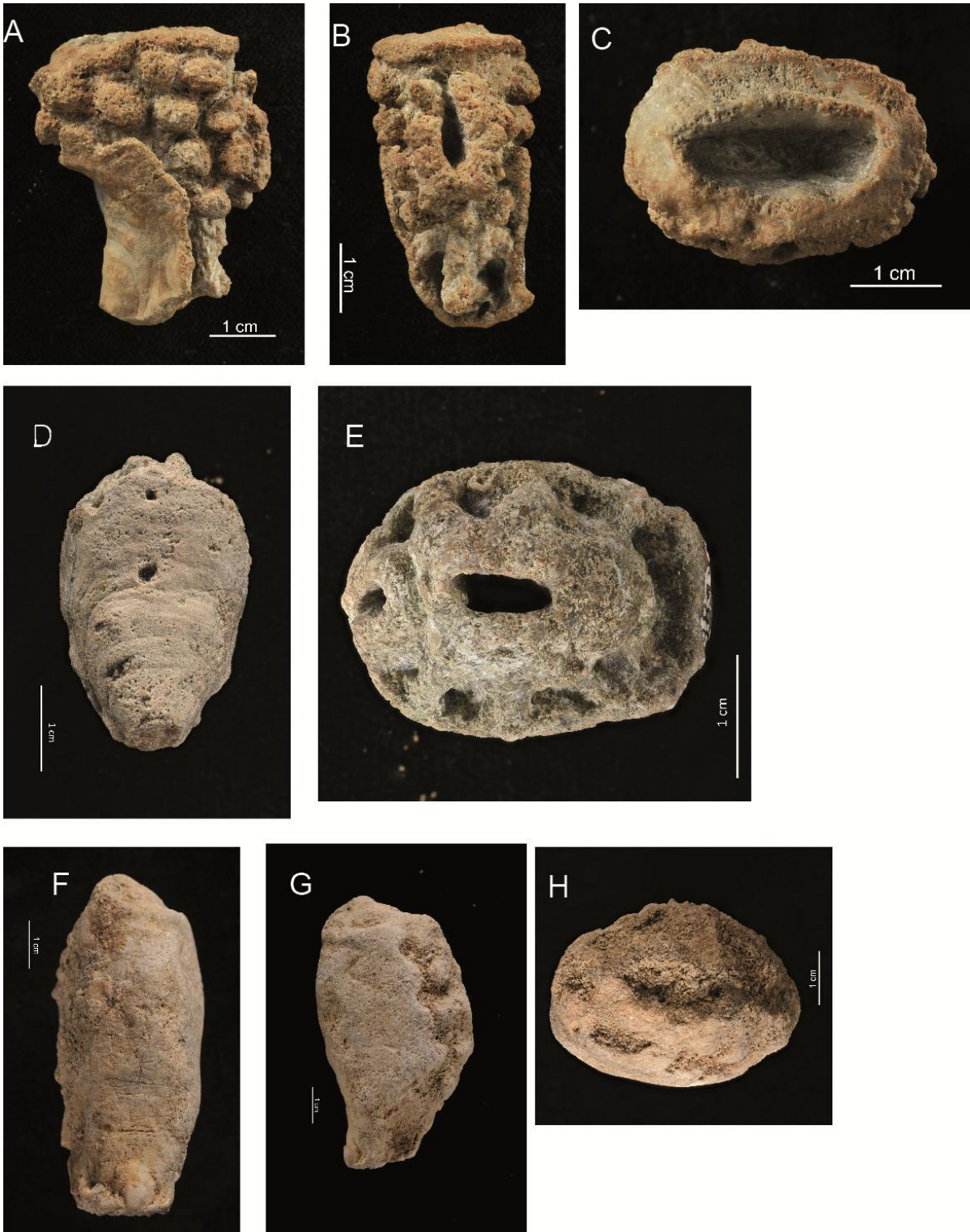


Figure 18. *Toulminia italica* sp. nov. **A–C**, MSNVE-22972 holotype. **D, E**, MSNVE-22910 paratype; **F–H**, MCZ-13800 paratype. **A**, side view, on lateral surfaces conical outgrowths with rounded ends and tongue-like siliceous membrane with horizontal concentric lineation at the base of the sponge; **B**, lateral view with a second lateral osculum; **C**, top view with elliptical osculum surrounded by a siliceous membrane; **D**, lateral view, tongue-like siliceous membrane with horizontal concentric lineation; **E**, Top view, elliptical terminal osculum; **F**, lateral view, siliceous membrane with horizontal concentric lines; **G**, lateral view, siliceous membrane on the left side and outgrowths with rounded end on the right side.

Order **Lychniscosida** Schrammen, 1903

Family ?**Diapleuridae** Ijima, 1927
Genus **Coronispongia** gen. nov.

Type species. *Coronispongia confossa* sp. nov.

Coronispongia n. gen.

Derivation of name. From the latin *corona* (=crown) for the general shape.

Diagnosis. Conical to cup-shaped sponge composed of branching and radiating tubes, with a deep atrial cavity. Lychniscosid dictyonal skeleton generally irregular. Intradictyonal skeletal with canalization. Canals openings on dermal surface rounded to elongated.

Type locality and stratum. Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Remarks. The assignment to a family is quite critical as there is a different point of view between 2 main bibliographic references: Treatise and Systema Porifera. In Treatise (Reid, 2004b), the only truly canalized Lychniscosid family is the Dactylocalycidae Gray, 1867. This family has a complex history and was traditionally consider as Hexactinosa. Reid (1957, 1962) made a "suprising transfer to the Lychniscosa" (Reiswig 1991). Reiswig (1991, 2002) who studied the problem in details returned the family from Lychniscosida to Hexactinosida due to lack of any lychniscs in the dictyonal skeleton. Recent Lychniscosida contains only two families: Aulocystidae and Diapleuridae. Taking into account the lack of loose spiculation and many diagnostic characters - due to the bad preservation of our material - we tentatively locate the studied specimens in the Recent family Diapleuridae Ijima, 1927. This decision is made for the similarity in skeletal canalization and the irregular framework of dictyonalia.

Coronispongia confossa nov. sp.

(Fig. 19A-I)

2005 *Brachiolites* sp.; Matteucci & Russo, p. 57, pl. 1, fig. 2 a, b

Diagnosis. As for the genus.

Derivation of name. From the latin *confossus* (=bearing holes) for the intradictyonal skeletal canals

Material. 8 specimens MCZ-I 3783, MCZ-1 1381, MSNVE-22979, MSNVE-22971, MSNVE-23058, MCV 382, MCV 385, MMC 16 from Cengio dall'Orbo and Lovara quarry.

Type specimens. Holotype MSNVE-22971. Paratypes MSNVE-22979, MCZ-I 3783.

Type locality and stratum. Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Conical (Fig. 19A,C) to cup-shaped (Fig. 19E) sponges that are 5.4–9 cm high, 5.2–13.1 cm wide and 5.6–16 cm long. Wall thickness up to 3 cm. Wall composed of branching and anastomosing network of tubes (5–7 mm thick) (Fig. 19A, C, E,). Tubes circumscribe external cavities approximately of their own thickness. Tubes can be rounded at their ends (Fig. 19B, D). In the larger specimens, the wall is folded and fused to form a series of radial parietal tubes around the atrial cavity (Fig. 19F). Radiating tubes are up to 1.5 cm wide and 4 cm long and have, distally, a circular opening (0.5–1.0 cm in diameter). Conical to cup shaped central depression 3–6 cm height. Dictyonal framework irregular or, locally, with triangular to quadrate meshes (200 µm node to node). Rounded (1–3 mm) to elongate (up to 5 mm in length) intradictyonal canals (Fig. 19G, H). Dictyonal skeleton with lychniscs (Fig. 19I).

Remarks. The studied sponges are nearly identical in shape to Recent hexactinoid *Myliusia callocyathus* Gray, 1859. Nevertheless our specimens show lychniscs and thus should be considered as a homeomorph of *M. callocyathus*. Homeomorphs are widespread in different siliceous sponges. Reisinger & Wheeler (2002) reconstructed the tortuous taxonomic history of the genus *Myliusia*. Our specimens are also very similar in shape to *Myliusia cancellata* Brimaud & Vachard 1986 from the Miocene of Spain but differ in spiculation (no lychniscs in *Myliusia*). Brimaud & Vachard 1986 synonymized the species with a question mark with *Tretostamnia favosa* Pomel 1872 from Miocene of Algeria suggesting a revision of the taxon too briefly described by Pomel (1872, p. 70–71, pl. 2 bis, fig. 1). Matteucci & Russo (2005) assigned the specimens to the lychniscoid genus *Brachiolites* sp. This assignment should be treated with caution for the reason that intradictyonal canal system was observed in it while *Brachiolites* is generally unchanneled (Reid 1962 p. 34; 2004b). Moreover *C. confossa* is very similar in shape to another lychniscoid, *Plocoscyphia tenuilobata* Leonhard, 1897 (Cretaceous of Upper Silesia, Poland) but the latter species do not show the typical radiating tubes on the upper margin.

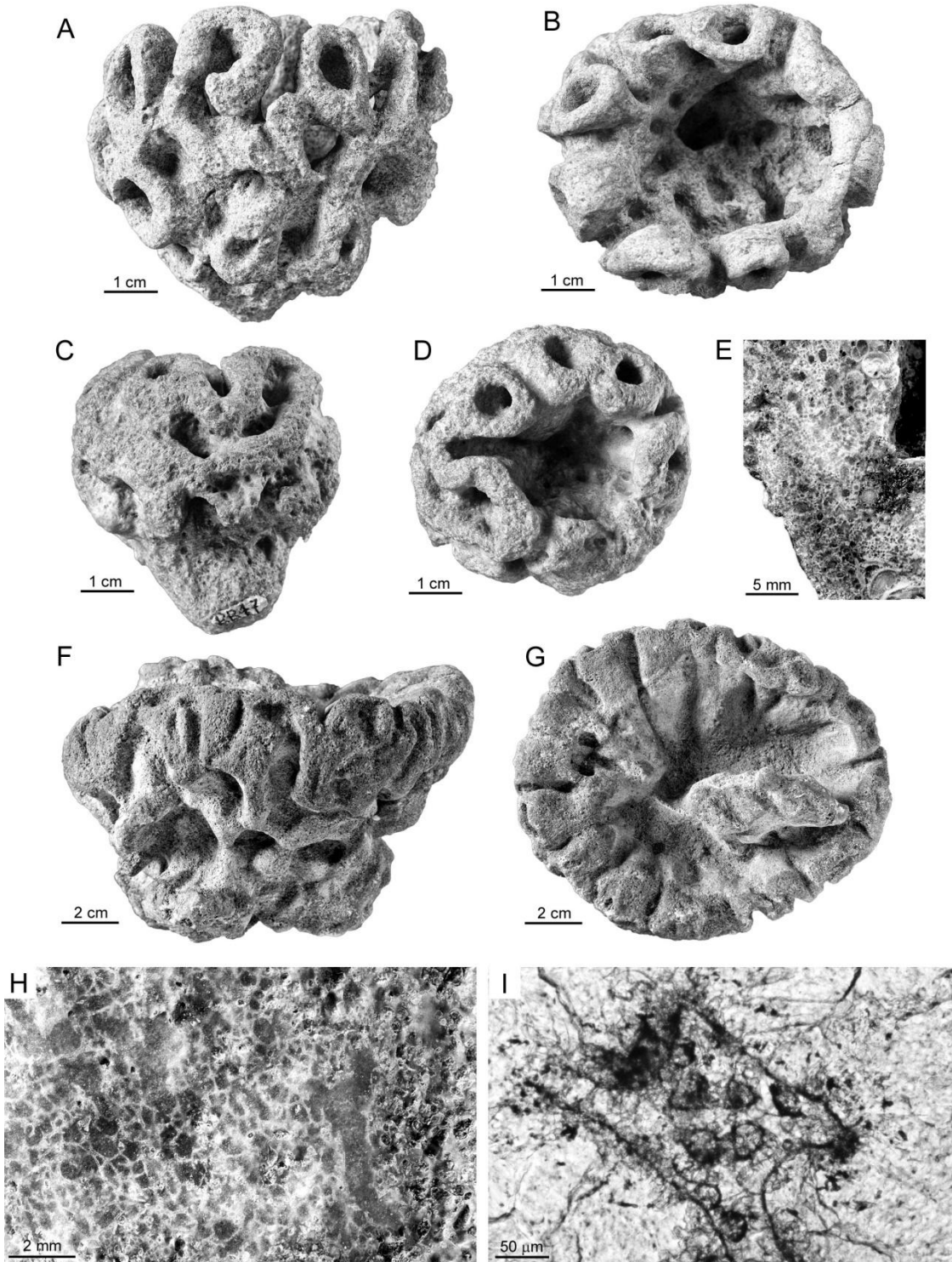


Figure 19. A, B MSNVE-22971 holotype; C, D, H–I MSNVE-22979 paratype; E–G, MCZ-I 3783 paratype. A, C, E lateral view, conical (A, C) or cup (E) sponge composed of branching and radiating tubes; B, top view, deep atrial cavity, circular openings of tubes; F top view, note radial parietal tubes fused side by side around the atrial cavity; G, detail of the upper surface of a parietal tube with elongated canal openings; H, detail of longitudinal section with rounded intradictyonal canals and irregular skeletal framework; I, lychnisc.

Family **Neoaulocystidae** Zhuravleva, 1962

Genus **Cavispongia** Quensted, 1877

Type species: *Spongites cylindrata* Quensted 1843 p. 418

Cavispongia scarpae sp. nov.

(Fig. 20A–E)

cf. 2005 *Becksia* (?); Matteucci & Russo: 57, pl. 1, figs. 1a,b.

Diagnosis. Conical lychniscosan sponge composed of vertically packed cylindrical branches with regular to irregular circular terminal oscula. Knobby external surface. Small tubular stalk could be present. Dictyonal skeleton with quadrate meshes.

Derivation of name. Dedicated to the amateur paleontologist Giancarlo Scarpa (Mestre).

Material. 18 specimens: MCZ-I 3716, MCZ-I 3717, MCZ-I 3718, MCZ-I 3719, MCZ-I 3794, MSNVE-22843, MSNVE-22844 MSNVE-22845 MSNVE-22846 MSNVE-22847 MSNVE-22849 MSNVE-22987 MSNVE-23003 MSNVE-23004 MSNVE-23005 MSNVE-23006 MSNVE-23007 MSNVE-23008.

Type specimens. Holotype: MSNVE-23003. Paratypes: MSNVE-22843, MCZ-I 3716, MCZ-I 3794.

Type locality and horizon: Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Conical sponge (Fig. XA, C, E) 6.1–11.8 cm in height, 4.1–14.5 wide and 2.4–9.5 long. The body is composed of 2 to 4 (largest specimen reaching 12) cylindrical branches with generally circular terminal oscula 6–14 mm in diameter (Fig. X B, D), and wall 4–6 mm thick.. Outer surface with rounded to roughly elongated knobs (Fig. XA, C) 3–5 mm high, 6–8 mm wide, and 9–21 mm long. The knobs are sometimes fused and separated by meandering furrows 3–6 mm wide. Some specimens show a small tubular stalk (Fig. XE). in diameter. Dictyonal meshes mainly quadrate, 300 μm —node to node— in size.

Remarks: Matteucci & Russo (2005) identified with uncertainty this sponge as *Becksia* sp. In our material cylindrical tubes are mainly vertically packed while in *Becksia* sp. they are anastomosing, so we do not agree with their assignment. General shape and knobby external surface are similar to genera *Mastospongia* Quensted, 1877 and *Trochobolus* Zittel 1877. Diagnostic for these genera are labyrinthine intradyctional skeletal canals that were not observed in our material. However, there is possibility that this is due to the poor preservation of the spicular skeleton. Yet, the features such as general morphology, body composed of vertically packed tubes, lateral surface with irregular outgrowths separated by meandriform furrows, suggest affinity with the Jurassic genus *Cavispongia* Quensted, 1877. In comparison with *C. cilindrata* Quensted 1877 from the Upper Jurassic of the Swabian Alb (Southern Germany) (see also Kolb 1910; Pisera 1997) our specimens show thicker walls of tubes and have generally larger size.

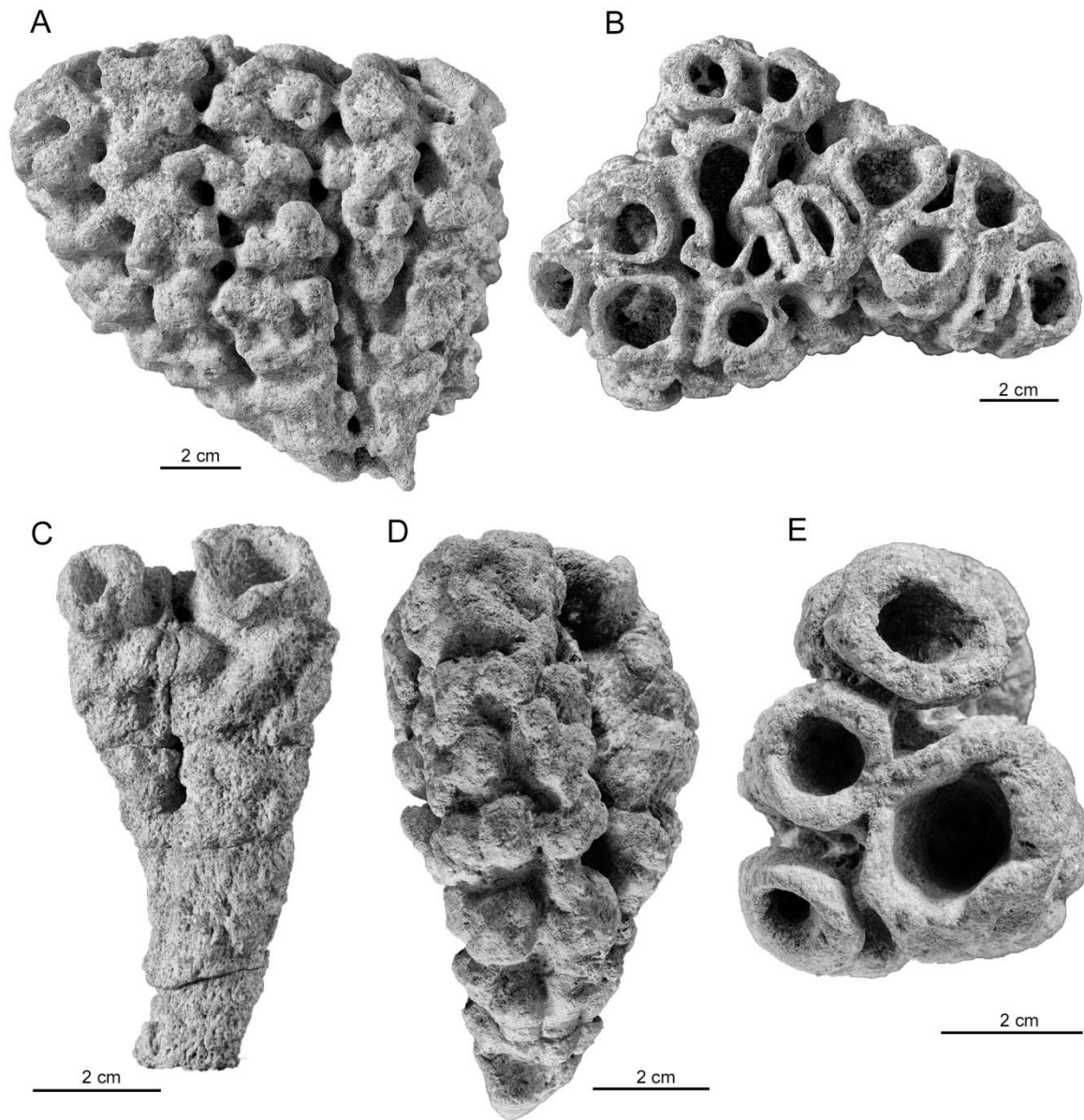


Figure 20. A, B, MSNVE-23003 holotype. C, D, MSNVE-22843 paratype (photo: B. Favaretto). A, C, lateral views, conical shape, knobby external surface, with meandering furrows; B, D, top views, body composed of vertically packed tubes with regular to irregular circular terminal oscula; E, MCZ-I 3794 paratype, side view, tubular stalk at the base of the sponge.

Class **Demospongiae** Sollas, 1885
"Lithistida"
Suborder **Tetracladina** Zittel, 1878
Family **Siphoniidae** D'Orbigny, 1851
Genus **Siphonia** Goldfuss, 1826

Type species. *Siphonia piriformis* Hinde, 1884 p. 63 (subsequent designation)

Siphonia? sp.
(Fig. 21 A-E)

Material. 9 specimens from Cengio dell'Orbo quarry: MCZ-I 3738, MSNVE-22811, MSNVE-22810, MSNVE-22894, MSNVE-22988, MSNVE-23000, MSNVE-23096, IG-VI 272200, MGP-PD 1068.

Description. Subglobular sponge 4.1–8.3 cm height, 4.2–7.5 in diameter. Wall 1.8–2.7 cm thick. Short stalk of 7–10 mm. Large terminal osculum 1–2 cm in diameter around which there are radial canals 1.5–2 mm wide, 1–3.5 cm long. On the outer surface irregularly distributed rounded canal openings 1–1.5 mm in diameter. Tetraclones.

Remarks. Typical stalked and subglobular habitus, presence of shallow central depression, rounded canal openings on the outer surface support the assignment to genus *Siphonia* Goldfuss, 1826. The piriform shape appears in different lithistid families e.g. *Scytalia curta* Moret 1926 (desmas as rhizoclones), *Melonella radiata* (Quensted) (dydimoclones). Our specimens resemble also in shape to another tetracladine, *Phyllodermia* Schrammen 1924. *Siphonia* and *Phyllodermia* differ in the ectosomal spicules which are not preserved in our material. As a consequence, assignment is tentative. Menin (1972) and Visentin (1994) already reported the presence of *Siphonia* sp. in Lovara and Cengio dell'Orbo quarries. Catullo (1856) reported *Siphonia* from the Cretaceous and Eocene of NE Italy but recently Matteucci & Russo (2011) demonstrated that none of the specimen described by Catullo belongs to siliceous sponges. Manzoni (1882) reported a doubtful *Siphonia* from the Miocene of N Italy.

Genus **Rhoptrum** Schrammen, 1910

Type species. *Rhoptrum scytaliforme* Schrammen, 1910 p. 104

Rhoptrum? sp.
(Fig. 22A–D)

Material. 2 fragments (MCZ-I 3732, MCZ-I 3742) from Cengio dell'Orbo quarry.

Description. Subcylindrical to cylindrical fragments (Fig. 22A, B) of 4.2–4.5 cm in diameter, wall thickness 1.3–2 cm, central spongocoel 1.5–2.5 cm in diameter. On the external surface irregularly distributed rounded canal openings 700–2000 µm in diameter. The choanosomal skeleton shows radial and longitudinal canals 500–1000 µm large (Fig. 22C). Choanosomal skeleton composed of tetraclones desmas (Fig. 22D) probably smooth that are up to 450–569 µm in size.

Remarks. The material strongly resemble in shape the cretaceous tetracladine genus *Rhoptrum*. It also shows affinities to another cretaceous tetracladine, *Phymatella* Zittel, 1878. The 2 genera are very similar

in general shape, canalization, canal openings pattern. The main difference is in ectosomal spicules which are not preserved in our material. As a consequence the assignment is uncertain.

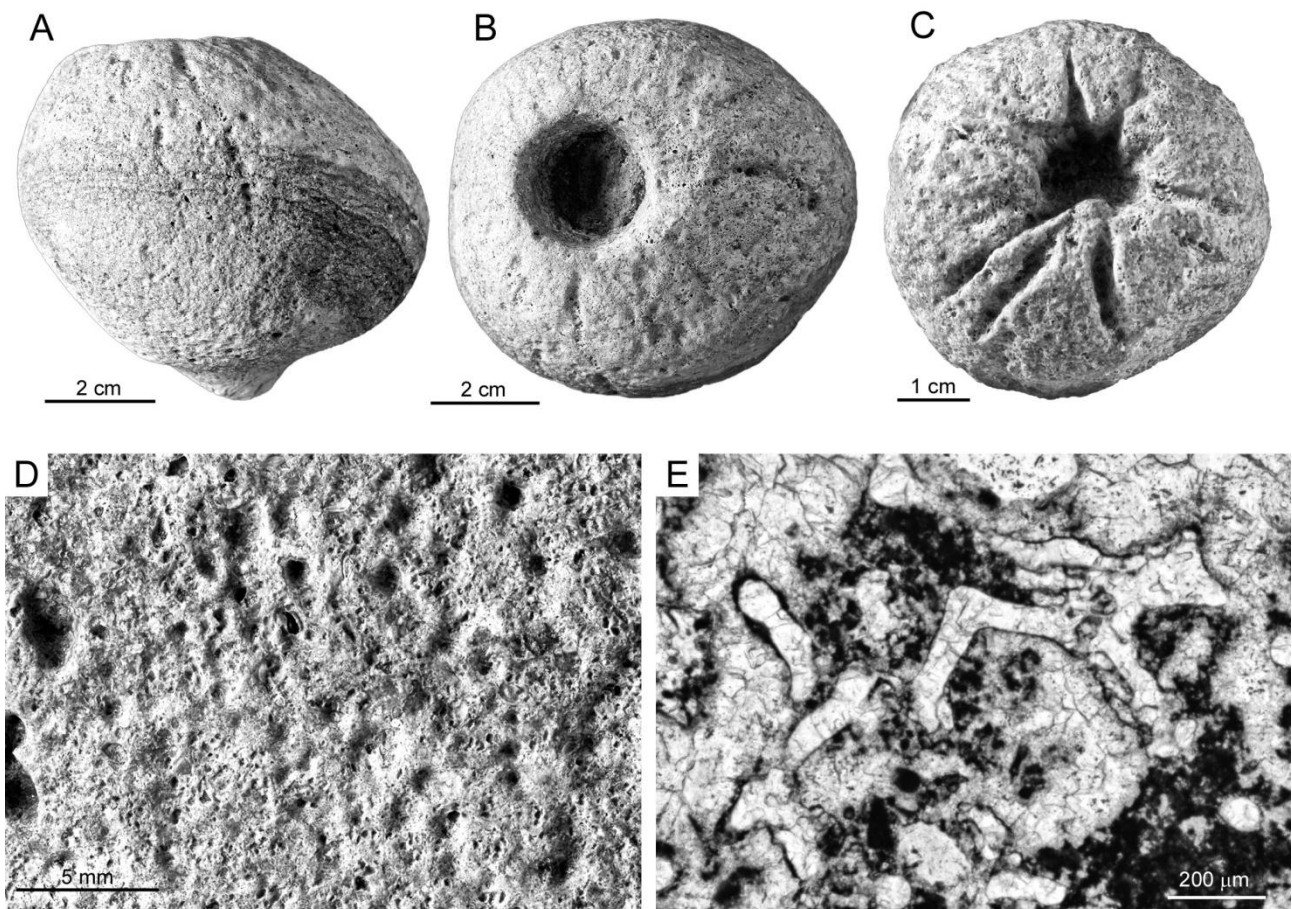


Figure 21. *Siphonia?* sp. **A, B, D, E** MCZ-I 3738; **C**, MSNVE-22810 (photo: B. Favaretto). **A**, lateral view, note subglobular shape and small stalk; **B, C**, upper view, radial canals around large rounded terminal osculum; **D**, detail of outer surface with badly preserved rounded canal openings; **E**, detail of longitudinal thin section, poorly preserved tetraclones.

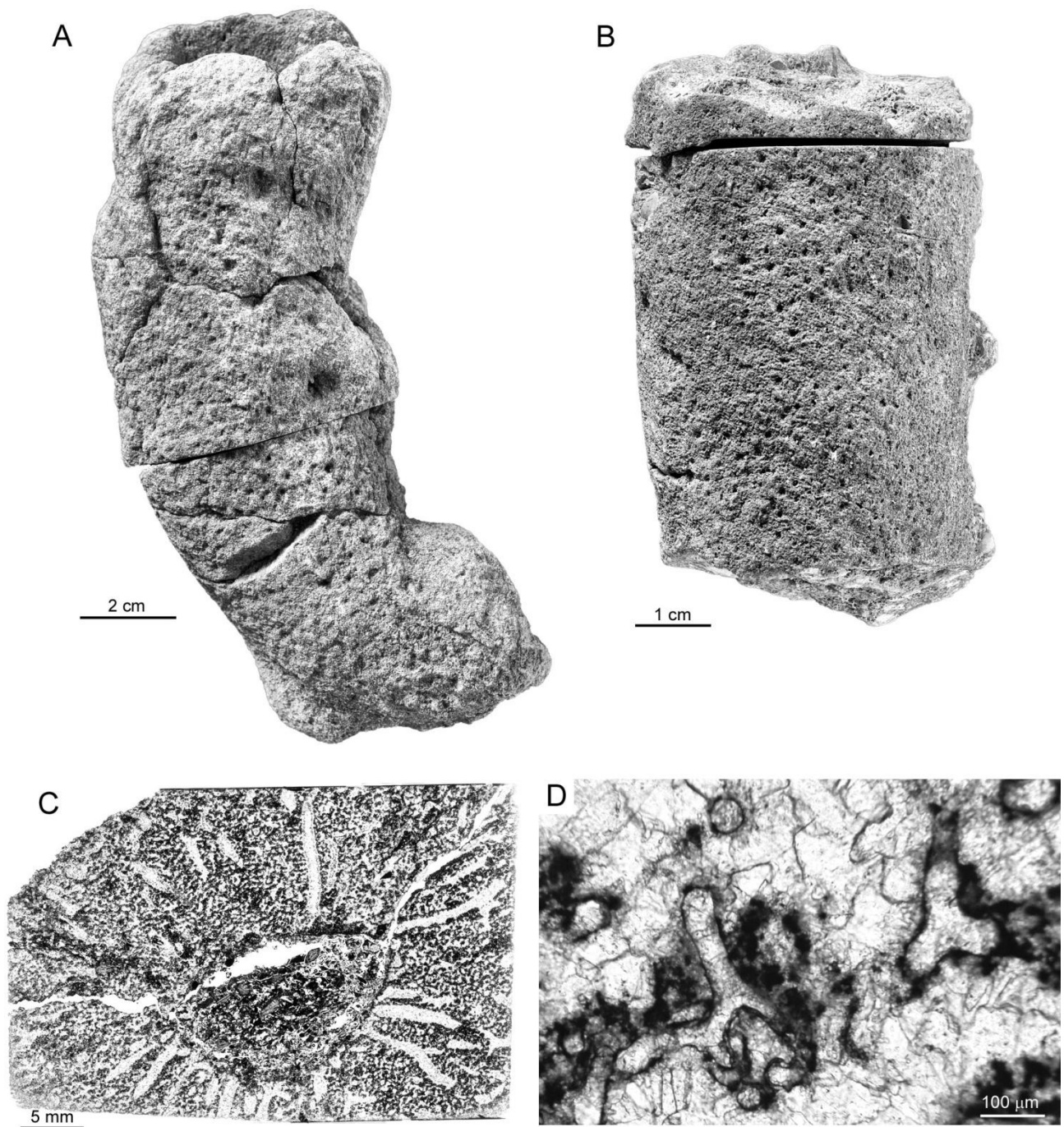


Figure 22. *Rhoptrum?* sp. **A, C, D**, MCZ-I 3742; **B**, MCZ-I 3732. **A, B**, lateral view, cylindrical fragments with irregularly distributed rounded canal openings on external surfaces; **C**, transversal thin section, thick wall and large radial canals; **D**, detail of (C) with badly preserved tetraclones.

Suborder Dicranocladina Schrammen, 1924

Family Corallistidae Sollas, 1888

Genus *Corallistes* Schmidt, 1870

Type species. *Corallistes typus* Schmidt, 1870 p. 22

Corallistes multiosculata sp. nov.

(Fig. 23A–F)

Diagnosis. Club or double club shaped sponge. Numerous small circular oscula on the flat or slightly convex top; lateral surface finely porous. Base as encrusting disk. Desmas strongly arched and tuberculated, dicranoclones.

Derivation of the name. For many oscula (in latin) on the top of the sponge

Material. 12 specimens. MCZ-I 3705, MCZ-I 3755, MCZ-I 3756, MCZ-I 3762, MSNVE-22911, MSNVE-22912, MSNVE-22913, MSNVE-22914, MSNVE-22991, MSNVE-22994, MGPD 1069, MGPD 1070

Type specimens. Holotype: MSNVE-22912. Paratypes: MCZ-I 3705, MCZ-I 3755.

Type locality and horizon: Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Small club (Fig. 23A) or double club (Fig. 23C) sponge 2.3–5 cm height, 1.1–4.3 large, and 1.2–1.8 long. On the top, circular oscula (Fig. 23B, D) of 1–1.5 mm in diameter separated by a distance of 1–2 mm. Lateral surface finely porous with rounded canal openings measuring 300 μ m in diameter (Fig. 23C). If present, basal encrusting disk up to 2 cm in diameter (Fig. 23A). In cross section, vertical canals of 800–1000 μ m in diameter leading to the openings visible on the top surface (Fig. 23E). Dicranoclones 120–200 μ m in length (Fig. 23F). Some fragments of monaxial spicules (Fig. 23G) of 200–400 μ m in length, 20 μ m wide were also observed. Because these spicules were observed in thin section only, they could be genuine monaxial - oxeas, strongyles or styles (tips are not clearly visible)- or fragments of triaenes's rhabdomes.

Remarks. This sponge is very close in shape and oscula organisation to *Meta* spp. (Pomel, 1872), synonymised - without figures - by Moret (1924) with *Stichophyma ovoidea*. Pomel did not illustrate spicules but *Stichophyma* has rhizoclones not dicranoclones. Shape and canals openings on the top are comparable with Recent corallistid species *Neophrissospongia microstylifera* (Lévi & Lévi, 1983) from New Caledonia (from the depth of 355–360 m). Isolated dichotriaenes, interpreted as ectosomal spicules of *Corallistes* sp., were reported from the Eocene of New Zealand (Hinde & Holmes, 1892) and W Australia (Hinde, 1910).

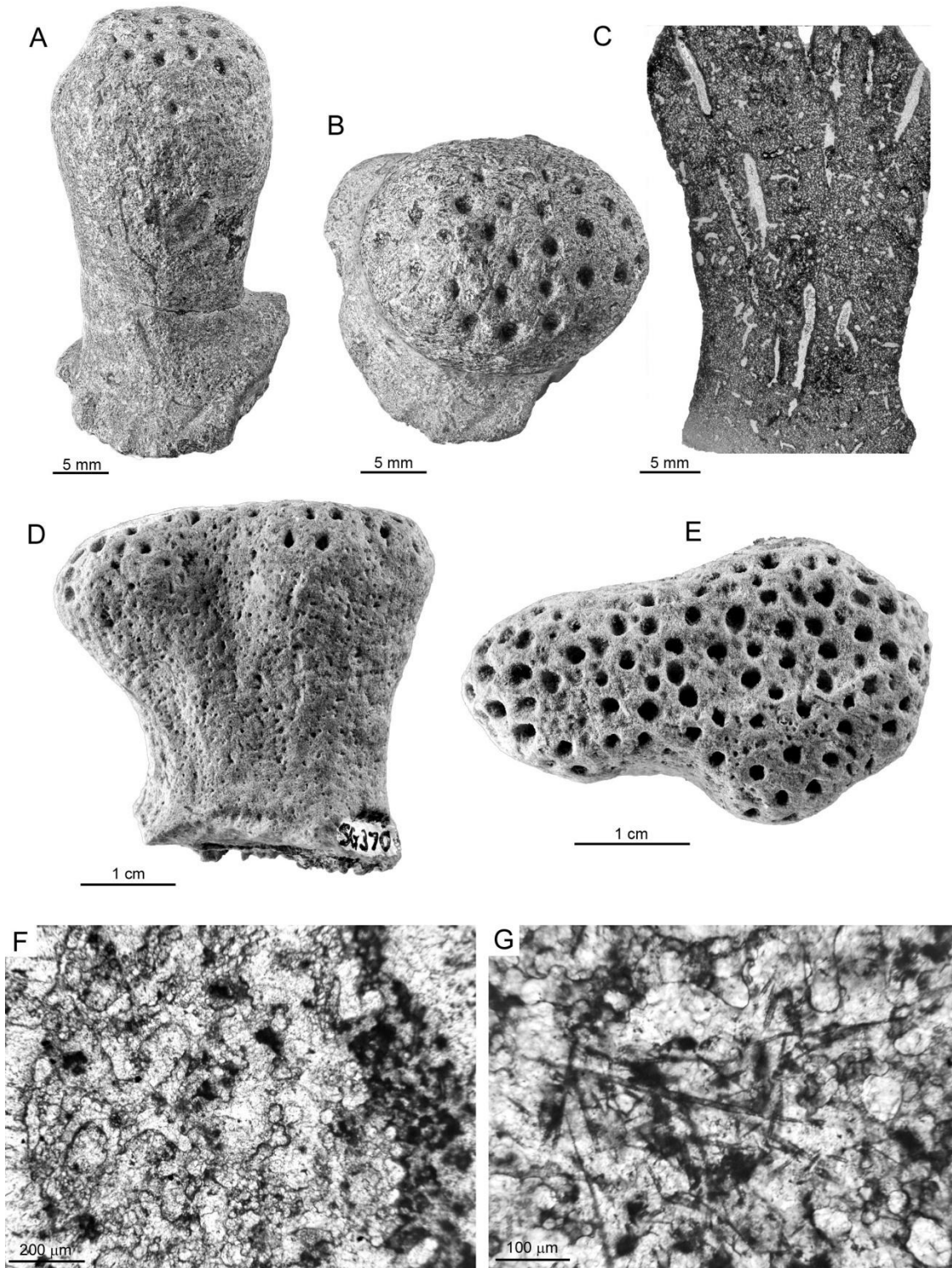


Figure 23. A, B MSNVE-22912 holotype; C, D, E, G MCZ-I 3705 paratype; F, MCZ-I 3755 paratype. A, club-shape sponge with encrusting base; C, double club shaped sponge with slightly convex top and finely porous dermal membrane; B, D, on the top of the sponges numerous small rounded oscula are present; E, longitudinal thin section with vertical canals; F, detail of longitudinal thin section with dicranoclones desmas; G, detail of (E), desmas and monaxial fragments on the top dermal part of the specimen.

Type species. *Corallistes typus* Schmidt, 1870 p. 22

***Corallistes?* sp.**
(Fig. 24A–C)

Material. 1 specimen, MCZ-I 3707 from Cengio dell'Orbo quarry.

Description. Subglobular sponge 2.8 cm high, 4.9 large, and 3.1 long. Body composed of 2 subglobular parts (Fig. 24A), with 3 and 5 oscula on the top. Oscula rounded (2 mm in diameter) or elliptical (2-3 x 4-5 mm) separated by the distance of 2.5-3 mm (Fig. 24B). In cross section, vertical canals of 2- 2- 2,4 mm in diameter opening on top surface. Desmas badly preserved, tuberculate 40-60 μ m thick, resembling dicranoclones (Fig. 24C).

Remarks. Desmas are too badly preserved to go farther on assignment. Desma length measure was impossible due to bad preservation: junction between desmas was not clearly visible . The specimen is similar to *Corallistes multiosculata* sp. nov. but it differs in general shape and has larger, less numerous, oscula. The specimen is also similar in general shape and oscula organization to *Meta gregaria* Pomel, 1872. Nevertheless, Pomel's species is more elongate while our material has a subglobular shape.

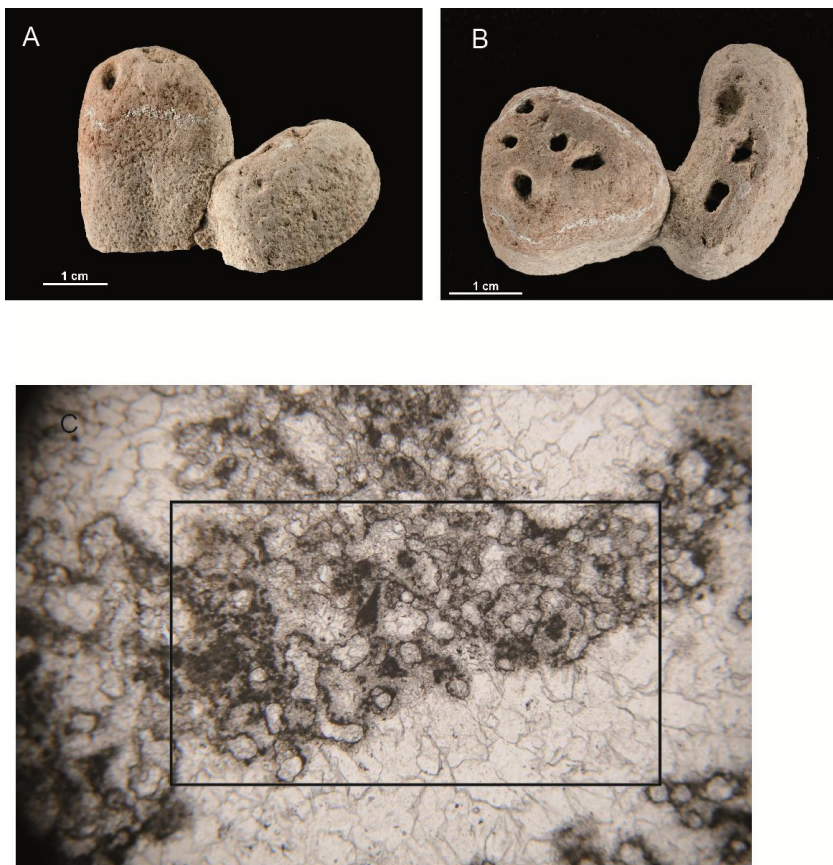


Figure 24. *Corallistes?* sp. A–C MCZ-I 3707. **A**, lateral view of the sponge composed of 2 subglobular parts; **B**, top view with rounded to elliptical oscula; **C**, detail of longitudinal thin section, poorly preserved tuberculate desmas.

Suborder Sphaerocladina Schrammen, 1924

Family Vetulinidae von Lendenfeld, 1904

Genus *Ozotrachelus* De Laubenfels, 1955

Type species. *Pachytrachelus expectatus* Schrammen, 1910 p. 174

Ozotrachelus conica (Roemer, 1841)

(Fig. 25

1841 *Cnemidium conicum* Roemer : 4, pl. 1, fig. 10.

1864 *Eudea tuberosa* Roemer: 25, pl. 10, fig. 3.

1864 *Stellispongia? conica* Roemer : 49.

1878 *Spongites conicus* Quenstedt: 374, pl. 133, fig. 3.

1910 *Pachytrachelus conicus* Schrammen: 171, pl. 24, fig. 1.

2004 *Ozotrachelus conica* in Reid 2004: 272, pl. 173, fig. 2i-j.

Material. 16 specimens: MCZ-I 3761, MSNVE-22932, MSNVE-22982, , MGP-PD 1045, MGP-PD 31431, MMC 1–8, MMC 17–18, IG-VI 272202 from Cengio dell’Orbo and Lovara quarries.

Description. Conical to cylindrical shape with rounded (rarely flat) top 1-7.4 cm height, 1.5-3.5 in diameter (Fig. XA). When present, base encrusting (Fig. XC). Rounded terminal osculum 2-5 mm in diameter, wall 6-19 mm thick. On the top surface, canals radiate from the osculum margin (Fig. XB, D). Narrow, deep, cylindrical spongocoel (Fig. XE) . External surface with small (200-300 μm in diameter), rounded canal openings. Canals running from the openings on the surface (300-700 μm large) oriented horizontally or obliquely downward. Desmas are sphaeroclones (Fig.XF), with 3-5 arms, approx 200 μm in length (arm to arm).

Remarks. The species was reported so far for the Upper Cretaceous of Germany only. Our specimens are identical with *Pachytrachelus conicus* Roemer, illustrated in Schrammen, 1910. Some larger specimens that may belong to the same species show a flat top and cylindrical shape but the desma type is not unrecognizable. They are more similar to *Phyllodermia houzeti* Ott d’Estevou et al. that belongs to Theonellida (1981: 67 pl. 5, fig. 1-4: pl.6 fig. 1-3) from the Miocene of S Spain and thus have tetracloones. Another morphologically similar species is *Cucumaltina placocephalus* Brimaud & Vachard 1986 from Miocene of S Spain but it belongs to rhizomorne lithistids that have rhizoclone desmas. All the studied specimens are conical/cylindrical in shapes, display radiating furrows on the top with central rounded osculum, and a deep narrow spongocoel. Nevertheless, as long as we do not find well preserved desmas, we cannot reject the idea that our material could belongs to different taxon. This is particularly true for the larger, cylindrical specimens.

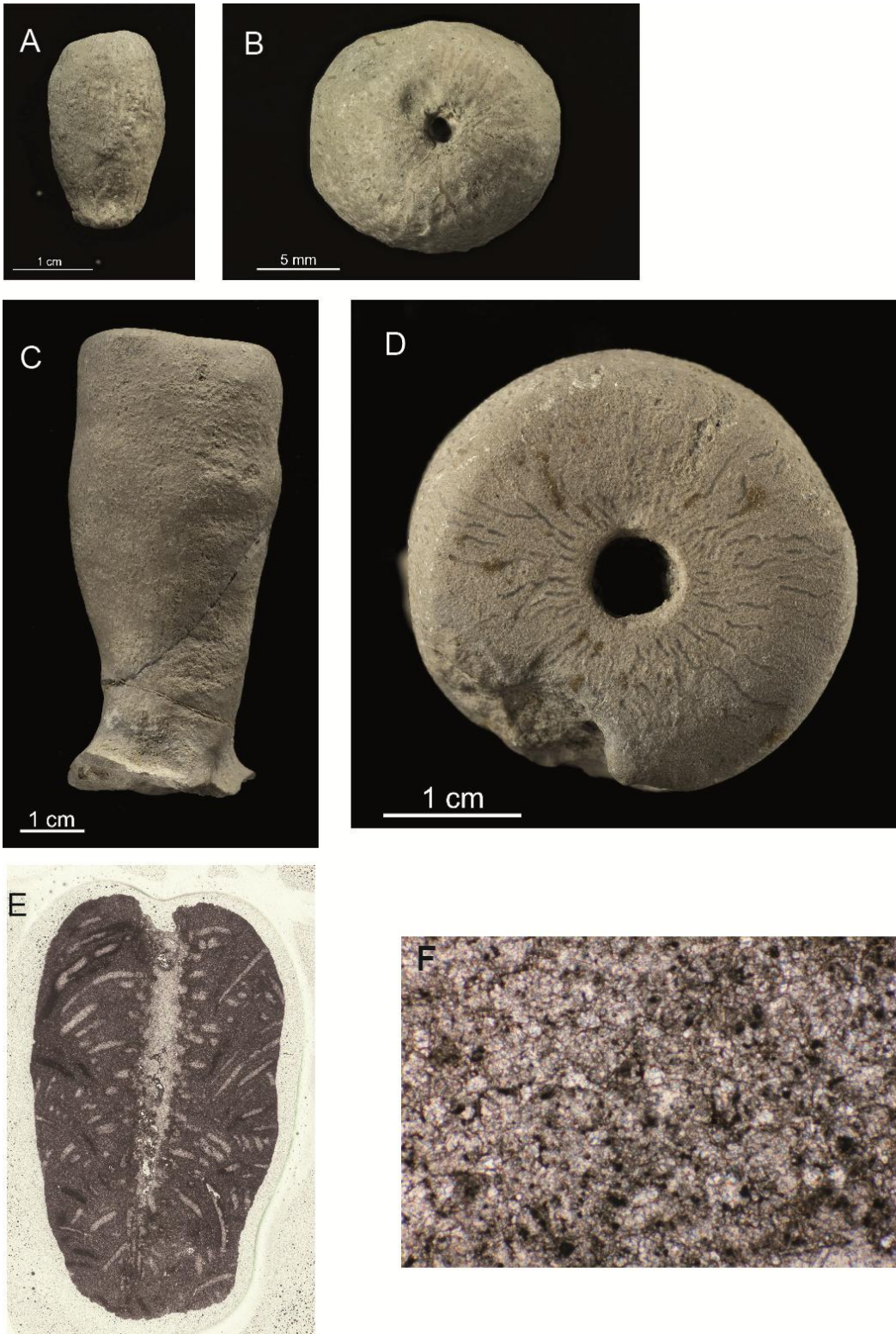


Figure 25. *Ozotrachelus conica* (Roemer, 1841). **A, B, E, F**, MCZ-I 3761; **C, D**, MSNVE-22982. **A**, lateral view, conical shape, rounded top, small canal openings on outer surface; **B, D**, top views, canals radiate from the margins of rounded terminal oscula; **C** lateral view, conical shape, flat top, encrusting base; **E**, longitudinal thin section, cylindrical spongocoel, canals oriented obliquely downward; **F**, detail of (**E**) with spheroclones desmas.

Suborder Rhizomorina Zittel, 1895

Family Azoricidae Sollas, 1888

Genus *Bolidium* Zittel, 1878

Type species. *Amorphospongia palmata* Roemer, 1864 p. 55

Bolidium bertii sp. nov.

(Fig. 26 A–F)

Derivation of the name. From Bruno Berti, venetian amateur paleontologist

Type locality and horizon: Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Ypresian/Lutetian

Diagnosis. Massive compound sponge, with lobated branches arising from a common, encrusting base. Various small rounded oscula at the top of each branch. Two systems of canals: one vertical and larger; one subhorizontal, finer and more meandriform. Desmas are rhizoclones with rounded lumps.

Material. 3 specimens: MSNVE-22815 (holotype), MCZ-3769 (paratype), MSNVE-23001

Type locality and horizon: Chiampo (Vicenza), Cengio dell'Orbo quarry, volcanoclastics, Lutetian.

Description. Massive, large sponge 7–8.3 cm high, 10.9–16.2 large, and 8–15 long composed of lobated branches (Fig. 26 A, B) 2–3.4 cm thick, 2.5–6 cm long. On top, various small rounded oscula (Fig. 26C) 2–3 mm in diameter. Distance between oscula 2–5 mm. In cross section, two systems of canals: one vertical 1400–1600 μm in diameter; one subhorizontal and more meandriform, 240–800 μm (Fig. 26D). Rhizoclones desmas with rounded lumps (Fig. 26E, F) 200–250 μm in length.

Remarks. Although general morphology and desmas shape, and the small oscula at the top of each branch fit with *Bolidium* descriptions, in our material we could not observe the small pores on the external surface. The holotype's surface was so smoothed during preparation that surface was abraded and internal canals are visible. We could than blame the lack of surface pores to an artifact of preparation.

Compound shape -with *Jerea*-like branches arising from a common base and numerous small oscula on the top- is similar to *Polyjerea dichotoma* Roemer 1864 (p. 36 Tab. XIV, fig.1), from Late Cretaceous of NW Germany but this species has tetracclone desmas. Nevertheless, the exhalant system is very similar to *Jereica*, but our material is different because oscula are quite spaced while in *Jereica* sp. they are very close and numerous.

Rhizoclones of Cretaceous *B. arbustum* Hurcevicz 1968 are similar to those of *Jereica polystoma* (Roemer, 1864). Similar is also their arrangement in strands and exhalant part. For these common features, Hurcevicz 1968 suggested a close relationship between the two genera *Bolidium* and *Jereica*. Schrammen 1910 reported *B. palmatum* (Roemer, 1864) for the Cretaceous of Germany but did not illustrate any specimen. The genus was described for Cretaceous of Europe only: Germany (Roemer, 1864; Zittel, 1878; Schrammen 1910), Poland (Hurcevicz, 1968), Greece (Mermighis & Marcopoulou-Diacantoni. 2004). This is the first record of the genus *Bolidium* for the Eocene. As a consequence Lutetian becomes the last appearance of the genus.

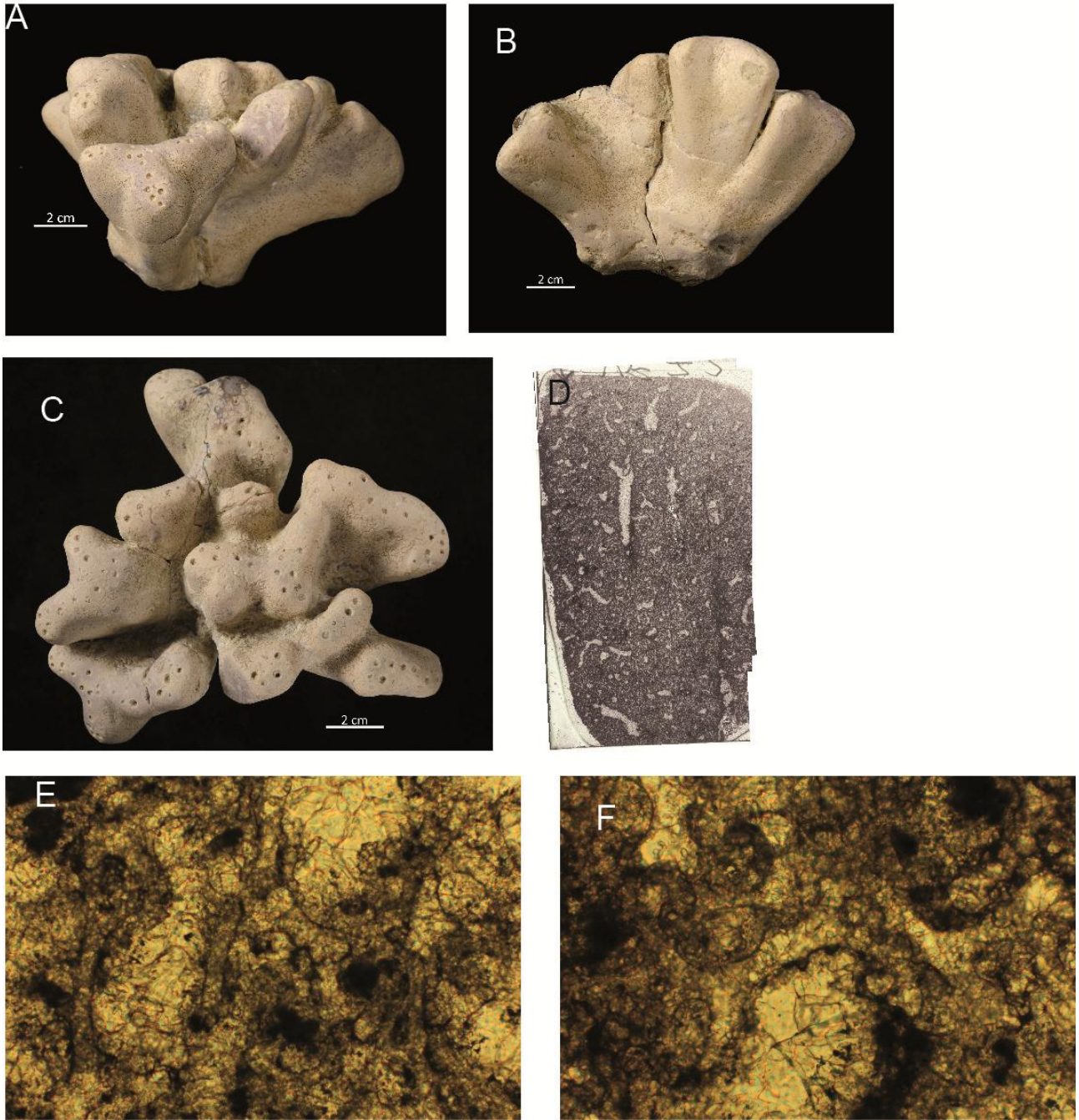


Figure 26. *Bolidium berti* sp. nov. **A–C** MSNVE-22815, holotype; **D, E, F**, MCZ-I 3769 paratype. **A, B** sides views, massive sponge composed of lobated branches, encrusting base; **C**, top view, lobated branches, various small rounded oscula; **D**, longitudinal thin section, larger vertical canals and smaller subhorizontal meandriform canals; **E, F**, detail of (**D**), rhizoclonal with rounded lumps.

Genus *Stachyspongia* Zittel, 1878

Type species. *Siphonocoelia spica* F.A. Roemer, 1864, p. 30

Stachyspongia sp.

Fig. 27(A–C)

Material. 4 specimens MCZ-I 3733, MSNVE-23022, MSNVE-22806, MMC 19 from “Cengio dell’Orbo” and “Lovara” quarries.

Description. Conical to sub-cylindrical (Fig. 27A, D) 6.0–15.0 cm height, 6.0–8.4 cm in diameter. Spongocoel is deep, tubular or slightly conical, running throughout the sponge. Circular osculum (Fig. 27B), 3–4 cm in diameter. Wall thickness 1.7–2.0 cm. The majority of the specimens bear, on the dermal surface, irregular to cylindrical outgrowths (Fig. 27B, C) 0.6–1.2 cm height, 0.9–1.4 cm large. Irregular distributed, canal openings (400–500 µm in diameter) on the outer surface. Compact skeletal framework with radial canals (300–400 µm in diameter) composed of rhizoclone desmas (Fig. 27D).

Remarks. Due to the poorly preserved desmas we attribute the specimens not farther than the genus level. The studied material show thinner wall, generally fewer and less developed dermal outgrowths than the other *Stachyspongia* species. The genus is reported, with 3 species *S. tuberculosa* (Roemer, 1864), *S. ramosa* (Quenstedt, 1878) and *S. spica* (Roemer, 1864), from the Cretaceous of Europe: Germany (Quenstedt, 1878; Roemer 1864; Zittel 1878, Schrammen, 1910), S England (Hinde, 1883), France (Moret, 1925), Spain (Lagneau-Hérenger, 1962) and Poland (Huercewicz, 1968). There is only one, dubious, record for the Eocene, from W Australia, *Stachyspongia neoclavellata* (Chapman & Crespin, 1934). This species is considerably smaller (5 cm in length, 2 cm in maximum wide) than our material. Moreover, the specimens illustrated by Chapman & Crespin (1934) and De Laubenfeld (1953) are have a ramose (one is “H shaped”) and elongated habitus that is not observed in our material. Pickett (1983) synonymized the species with the tetracladine “*Discodermia*” *retepora* which have the priority. So, if we agree that *S. neoclavellata* is not valid, this is the first record of genus *Stachyspongia* for the Eocene.

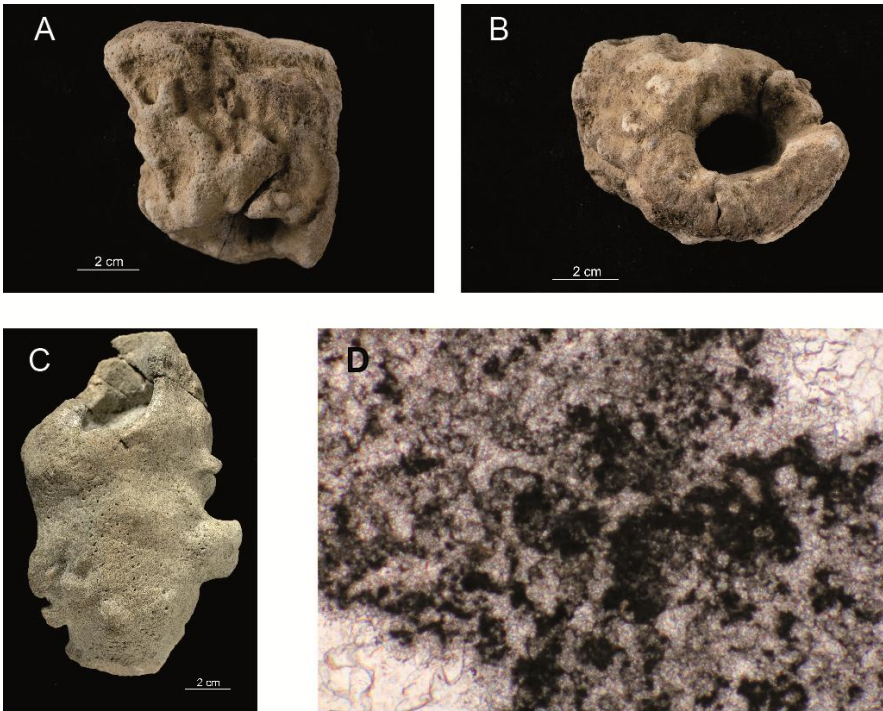


Figure 27. *Stachyspongia* sp. **A, B, D** MCZ-I 3733; **C**, MSNVE-23022. **A, C**, lateral view, conical to subcylindrical shape, irregular outgrowths, irregularly distributed canal openings; **B**, top view, circular osculum, thick sponge wall; **D**, detail of longitudinal thin section with rhizoclone desmas.

Genus *Jereopsis* Pomel, 1872 p. 177

Type species. *J. inaequalis*; subsequent designation De Laubenfelds 1955 p. 48.

Jereopsis clavaeformis (Pomel, 1872)
(Fig. 28 A–D)

- 1872 *Jerea clavaeformis* Pomel, p. 162-164, pl.4, fig. 2
1872 *Jerea gibbera* Pomel, p.164, pl.4, fig.1
1872 *Jerea obsita* Pomel, p.168, pl.4, fig.3; pl. 4 bis fig. 3
1872 *Jerea rhopaloides* Pomel, p.171, pl.4, fig.4-5; pl.18, fig. 6
1872 *Jerea fossulata* Pomel, p.164, pl.4, fig.1
1872 *Jerea curta* Pomel, p.167, pl.4 bis, fig.2
1872 *Jerea latipes* Pomel, p.172, pl.4 bis, fig.4
1872 *Jerea tuberiformis* Pomel, p.170, pl.4 ter, fig.3, pl.4 bis, fig. 5
1872 *Jerea obesa* Pomel, p.165, pl.4 bis, fig.7
1872 *Jerea inflata* Pomel, p.168, pl.4 bis, fig.8
1872 *Jerea lateralis* Pomel, p.173, pl.4 ter, fig.1
1872 *Jerea feda* Pomel, p.169, pl.4 ter, fig.2
1872 *Jerea meta* Pomel, p.171, pl.18, fig.5
1872 *Jerea uber* Pomel, p.166, pl.18, fig.4
1872 *Jerea acerra* Pomel, p.167, pl.18, fig.3
1872 *Jerea tuberosa* Pomel, p.182, pl.18, fig.1
1924 *Jereica clavaeformis*: Moret, p. 12, pl.1 fig. 5; pl. 2, fig.2-3; fig. 1 p. 12 (in text)
1986 *Jereopsis inaequalis clavaeformis*: Brimaud & Vachard, pl. 7 fig. 7; pl. 8, fig. 4
? 2005 *Jereopsis* (?) *clavaeformis*: Matteucci & Russo, pl. 1, fig. 9a-b

Material. 1 specimen: MSNVE-22981 from Cengio dell'Orbo quarry.

Description. Short cylindrical sponge 4.5 cm height and 4 cm in diameter. Shallow, bowl-like terminal depression 1 cm in diameter. No central spongocoel but a bunch of vertical canals which open in the terminal depression as small rounded openings (diameter 0.5 mm). There is another system of irregularly radial canals that open on the dermal surface with rounded, irregularly distributed, openings. Desmas are rhizoclones.

Remarks. The genus *Jereopsis* has a complicated history. As reported by Brimaud & Vachard (1986) Pomel (1872), described similar Miocene sponges from Algeria with various generic names: 3 already erected (*Jerea*, *Dichojerea*, *Polyjerea*) and 2 new (*Jereopsis* and *Jereopsidea*). Various Authors consider all the species described by Pomel as belonging to the same genus *Jereica* Zittel, 1878 (Zittel, 1878; Zeise, 1906; Moret, 1921, 1924). In particular, Moret (1924) synonymised 16 species of *Jerea* -erected by Pomel on the basis of general and oscula shapes- with *Jereica clavaeformis*. On top of that *Jereopsis* was used by Schmidt (1879) to describe a Recent lithistid genus. Due to this homonymy case, Lévi & Lévi (1983) suggested that the use of *Jereopsis* should be abandoned. Nevertheless De Laubenfeld (1955) synonymised *Jereica* and *Jereopsis* (which have the priority). Brimaud & Vachard (1986) then, taking into account priority, reconsidered Moret's taxonomy and used the name *Jereopsis inaequalis clavaeformis* (Pomel, 1872) for Miocene sponges from S Spain. Reid (2004) considered valid both genera *Jereopsis* and *Jereica*. Moreover

he synonymized the type specie of genus *Jereopsis* (*J. inaequalis*) with *Jerea claeiformis* leading to the recombination of the name in *Jereopsis clavaeformis*. Our specimen is identical in shape and terminal depression to *Jerea acerra* Pomel 1872. The specimen illustrated by Matteucci & Russo (2005) shows on the external surface elongated outgrowths not observed in our material. Moreover, the side canal openings have an irregular shape in their material while they are rounded in our. General shape of our specimen is also similar to *Moretispongia micropora* LAGNEAU-HÉRENGER, 1962 from Aptian of Spain but our specimen lacks the typical margined ostia on sides. General structure and especially exhalant system are very similar to a Recent rhizomarine from New Caledonia *Jereicopsis graphicophora* Lévi & Lévi, 1983 (410-415 m deep). Finally, Moret (1921) revising *Jereica*, pointed out that this genus was extremely abundant, both in number of specimens than in species, during Upper Cretaceous transgression.

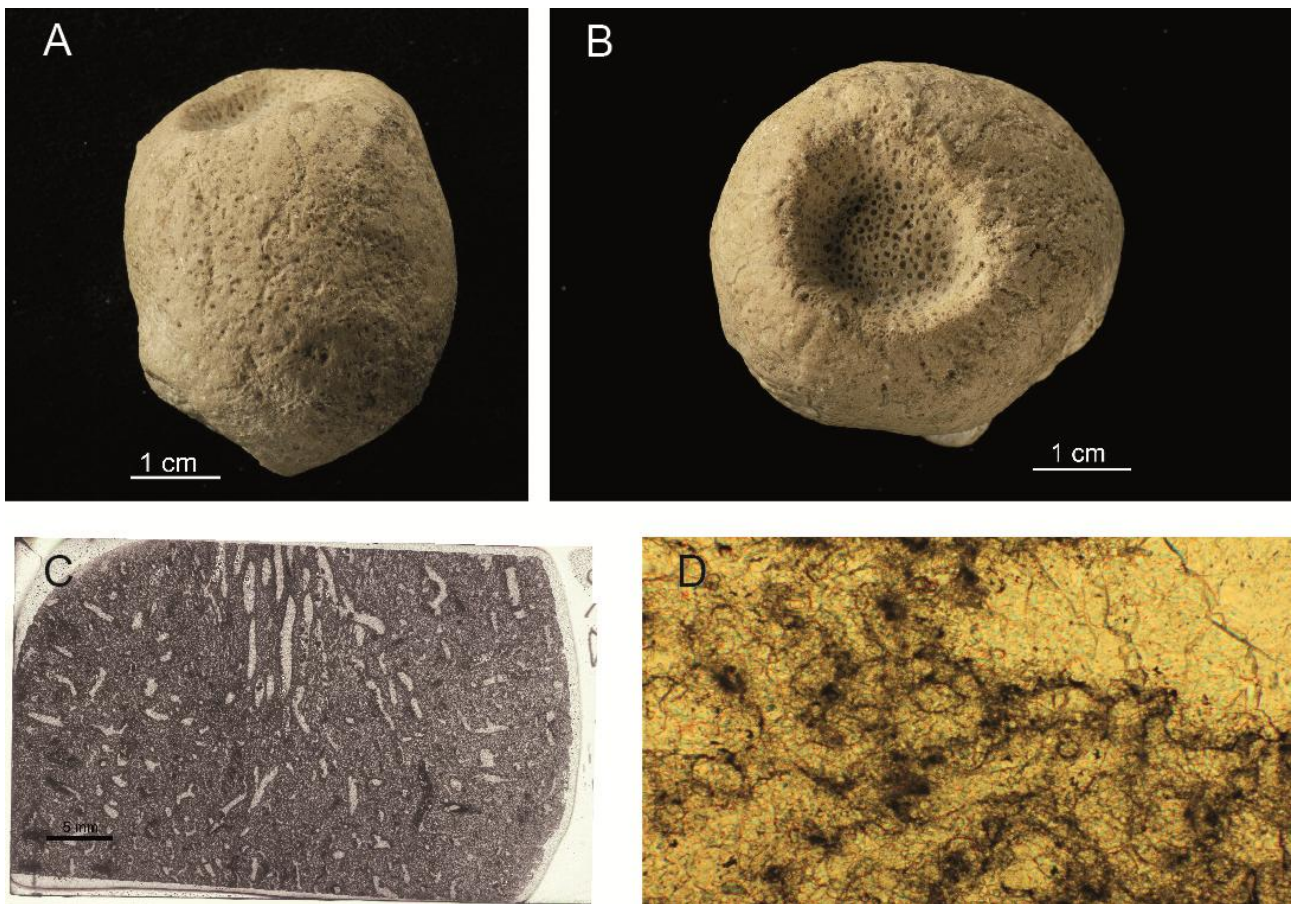


Figure 28. *Jereopsis clavaeformis* (Pomel, 1872). **A–D**, MSNVE-22981. **A**, lateral view, short cylindrical shape; **B**, top view, shallow, bowl-like terminal depression with rounded canal openings; **C**, longitudinal thin section, larger vertical canals, smaller and shorter radial canals; **D**, detail of (C) with rhizoclone desmas.

Family Scleritodermatidae Sollas, 1888
Genus *Verruculina* Zittel, 1878

Type species. *Chenendopora aurita* F.A. Roemer, 1864, p. 43; subsequent designation Schrammen 1924, p. 124

Verruculina ambigua (Pomel, 1872)
(Fig. 29 A–C)

1872 *Pleurophyma ambigua* Pomel, p. 137, pl 5 ter, fig. 2-3

1924 *Verruculina ambigua* Moret, p. 15, pl. 2, fig 4-4'

1981 *Verruculina ambigua* Ott d'Estevou et al. p. 69, pl. 7, fig. 4-5, fig.6-7?,

1986 *Verruculina ambigua* Brimaud & Vachard, p. 309, pl. 5, fig.1-3

Material. 7 specimens, MCZ-I 3802, MSNVE-22922, MSNVE-22908, MMC 12–15, from “Cengio dell’Orbo” and “Lovara” quarries

Description. Discoidal to cup-like (Fig. 29A) sponge 3.2–7.0 cm in diameter. Wall thickness 0.5–0.7 cm. Upper surface, irregularly distributed, numerous raised rounded canal openings (Fig. 29B), 500–700 µm in diameter. Distance between canal openings: 2–3 mm. In thin section dense skeleton of heavily calcified desmas (Fig. 29C) were observed, but their shape was unrecognizable.

Remarks . All the studied specimens appears to have been smooth. Although typical rhizoclones were not observed and characteristic raised canal openings were visible in MCZ3802 only; we attribute the specimens to *Verruculina ambigua* (Pomel 1872) for the general shape, the dense desma skeleton, and the pattern of canal openings on the upper surfaces. The smaller specimens are discoidal while the larger ones are vase-shaped. This feature was observed by Ott d'Estevou (1981) as well. The species was recorded in the Miocene of Algeria (Pomel, 1872; Moret, 1924) and S Spain (Ott d'Estevou et al. 1981, Brimaud & Vachard 1986). This is the first record of the species for the Eocene. Another *Verruculina* Eocene species, *V. albanyensis* Chapman & Crespin, 1934, was recorded for W Australia (see also Pickett, 1983). The latter specie differs from the studied material in having thicker wall (0.8–0.9 cm), larger (1.75 mm in diameter) and less numerous canal openings on the upper surface.

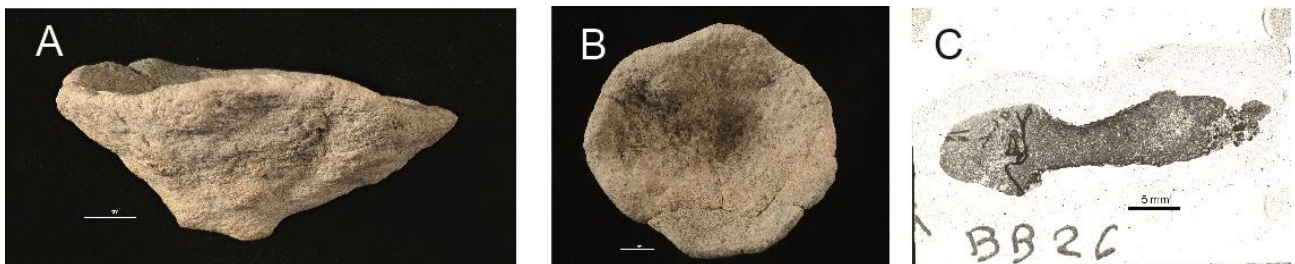


Figure 29. *Verruculina ambigua* (Pomel, 1872). A–C, MCZ-I 3802. A, side view, cup-like shape. B, top view with raised rounded canal openings. C, detail of longitudinal thin section with dense, desma-bearing skeleton.

Platychonia sp.

Fig. 30(A–E)

Material. 2 fragmentary specimens, IG-PD 366222, MCZ-I 3770 from Cengio dell’Orbo quarry.

Description. Plate-like to leaf-like (Fig. 30A, B) sponge fragments 8.2 cm high, 4.1–6.8 large, 2.7–4.7 long. Surfaces of specimens covered with delicate pores (Fig. XC). Thick wall (1.2 cm) with small radial canals in diameter (Fig. 30D). Thorny rhizoclonal (Fig. 30E) 150-250 µm in length, forming a dense skeleton.

Remarks. The presence of rhizoclonal, small canal opening on both surfaces, small radial canals and a leaf-like habitus supports the attribution to genus *Platychonia* Zittel, 1878. This is a typical Jurassic genus but it was reported in the Eocene of Australia too, *Platychonia tertiaria* Chapman & Cressin 1934 p. 117 Pl. 11, fig. 22. Unfortunately the species is poorly illustrated and preserved, only one picture on the entire specimen. Moreover, the attribution to a rhizomorine genus is dubious as the desmas are described as globular and having “4 to 7 or more radiating arms” and then they could be possibly spheroclonal. Leaf-like habitus is very similar to other rhizomorine sponges *Phlyctia expansa* and *Histiodia undulata* from the Miocene of Algeria described by Pomel (1872) and revised by Moret (1924) (=Histodia Moret, 1924 p. 16 *nom. null.*). Our material is different from *Phlyctia* in lacking fibrous divergent skeletal structure and from *Histiodia* in lacking external longitudinal furrows. Moreover, in both miocenic genera radial canals are missing. Another rhizomorine genus, *Chonellopsis* has very similar morphologically too, but it has canals opening only in upper surface only while the studied specimens show them in both sides of the wall (Schrammen 1937, p. 96). Our material is very similar to Cretaceous *Chonella tenuis* Roemer, 1864 but it lacks the concentric growth lines. Moreover the wall is thicker (12 mm in our material, 4–6 mm in Schrammen 1910–1912 description p.161).

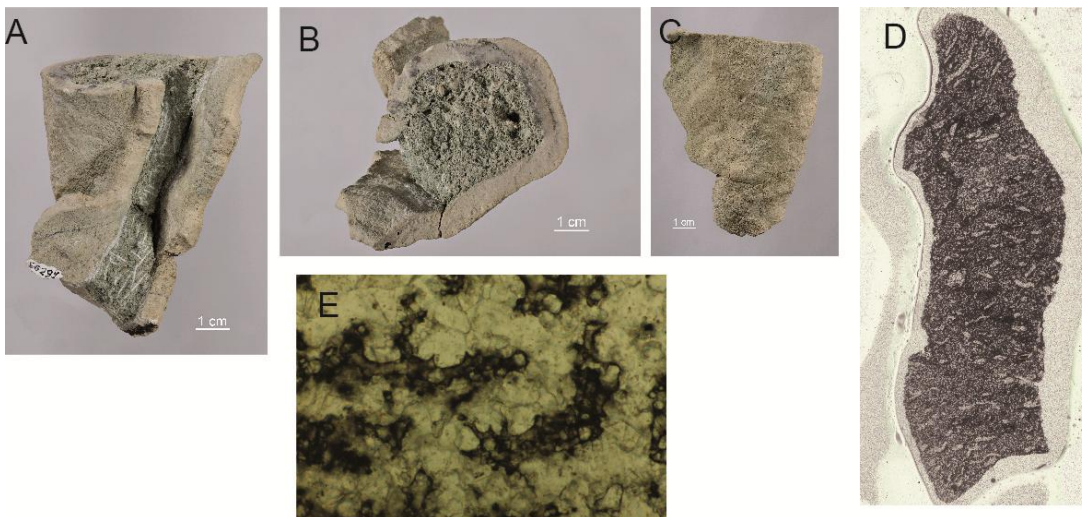


Figure 30. A–C, MCZ-I 3770; D, E, IG-PD 366222. Lateral (A) and top (B) views of leaf-like specimen; C, detail of upper surface with delicate pores; D, transversal thin section of the wall with dense skeleton and small radial canal; E, detail of (D) with thorny rhizoclonal.

Family Uncertain

Indeterminate rhizomorine sp. A

Fig. 31(A–C)

Material. 3 specimens: MCZ-I 3723, MCZ-I 3731, MSNVE-22992 from Cengio dell'Orbo quarry.

Description. Thick-walled (0.8–1.4 cm) vase shaped (Fig. 31A) sponge 3–9 cm height and 3.7–7.7 cm in larger diameter. Smooth surface without canal openings. Deep spongocoel. There are two systems of canals: one radial and larger, the other from the top (spongocoel) finer and meandriform (Fig. 31B). Desmas, possibly rhizoclonal (Fig. 31C).

Remarks. left in open nomenclature because the specimen is too poorly preserved. The habitus resembles the Jurassic rhizomorine genus *Hyalotragus* but the studied specimen lack vertical canals which are diagnostic for that genus.

Indeterminate rhizomorine sp. B

(Fig. 31D–F)

Material. One specimen MCZ-I 3736 from Cengio dell'Orbo quarry.

Description. Cylindrical fragment 7 cm high and 4.4 in diameter. One large circular oscula on the top. Rounded canal openings visible in some part of the surface. Thick wall. Fibrous skeleton framework. Desmas possibly rhizoclone.

Remarks. Desmas are faintly visible in thin section. The skeleton framework is similar to *Phlyctia expansa* from Spain (Pisera & Busquets, 2002) but the latter is flat.

Indeterminate rhizomorine sp. C

(Fig. 31G–I)

Material. 3 specimens MCZ-I 3759, MCZ-I 3760, MSNV-22928 from Cengio dell'Orbo quarry.

Description. Subglobular sponge (Fig. XG) 1.2–2.2 cm high, 2–3 in diameter. Circular and shallow terminal osculum (Fig. XH). No spongocoel. On the external surface, rounded canal opening of 300–400 μm in diameter. Desmas possibly rhizoclonal (Fig. XI)

Remarks. Due to the poor preservation of the material, attribution cannot be carried any further.

Indeterminate rhizomarine sp. D

(Fig. 31J, K)

Material. 8 specimens: MSNVE-23032, MSNVE-22918, MSNVE-22919, MSNVE-22930, MSNVE-22943, MSNVE-22961, MGP-PD 1051, MGP-PD 1057 from Cengio dell'Orbo quarry.

Description. Ear-like small sponge (Fig. 31J) 1.1-1.9 cm high, 1.4-2.5 in larger diameter. Encrusting base, central circular osculum of 3-6 mm in diameter (Fig. 31K), wall thickness 6-10 mm. Small radial canals. Tuberculated rhizoclones?

Remarks. Due to the poor preservation of the spicules, attribution cannot be carried any further.

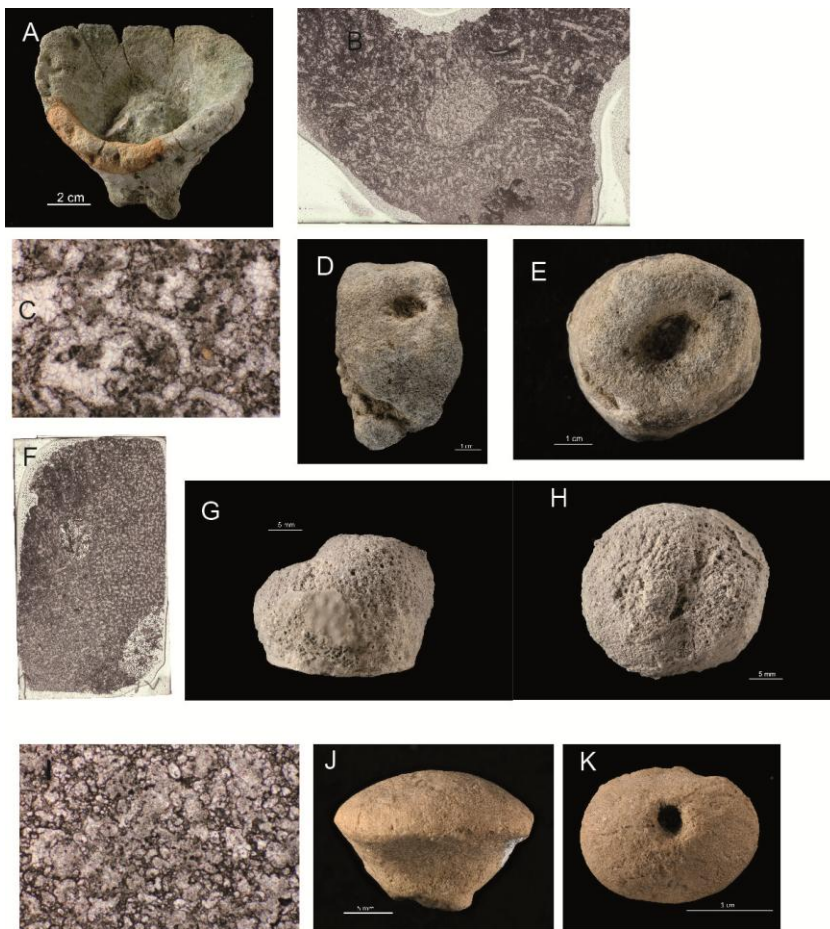


Figure 31. *Indeterminate rhizomarine sp.* A: **A, B, D**, MCZ-I 3731; **C**, MCZ-I 3723. **A**, lateral-top view of vase shape sponge with a deep spongocoel; **B**, longitudinal thin section, two systems of canals: one radial and larger, the other from the spongocoel finer and meandriform; **C**, rhizoclone desmas; *Indeterminate rhizomarine sp.* B: **D-F**, MCZ-I 3736. **D**, lateral view cylindrical shaped fragment; **E**, top view, thick wall and circular terminal osculum; **F**, longitudinal thin section, Fibrous skeleton framework. *Indeterminate rhizomarine sp.* C: **G-I**, MCZ-I 3759. **G**, lateral view, subglobular shape, rounded canal opening on the external surface; **H**, top with, faintly visible terminal circular osculum; **I**, detail of longitudinal thin section, rhizoclone desmas; . *Indeterminate rhizomarine sp.* D, **J, K**, MSNVE-23032; **J**, lateral view, ear-like shape, encrusting base; **K**, top view, rounded terminal osculum.

Family Uncertain

Genus *Pliobolia* Pomel, 1872

Type Species. *P. vermiculata* Pomel, 1872 p. 212

Pliobolia? sp.

(Fig. 32A-D)

?2005 *Pliobolia* (?) *vermiculata* Pomel 1872; Matteucci & Russo: 59, pl. 3, figs 1a, 1b.

Material. 3 specimens: MCZ-I 3774, MSNVE-22893, MSNVE-22805 from Cengio dell'Orbo quarry.

Description. Subglobular, cup-shaped sponge (Fig. 32A, B) 2.1-8.8 cm high, 4.5-11.2 cm in diameter. On the external surface small canal openings together with rare larger openings surrounded by radial furrows (Fig. 32C). Wall thickness 1.2-1.6 cm. Internal spherulitic stratified structure (Fig. 32D), no desmas visible.

Remarks. The upper surface is very similar to the specimen described by Pomel for the Miocene of Algeria. Nevertheless, the main canal openings are less evident in our material as well as radial furrows.

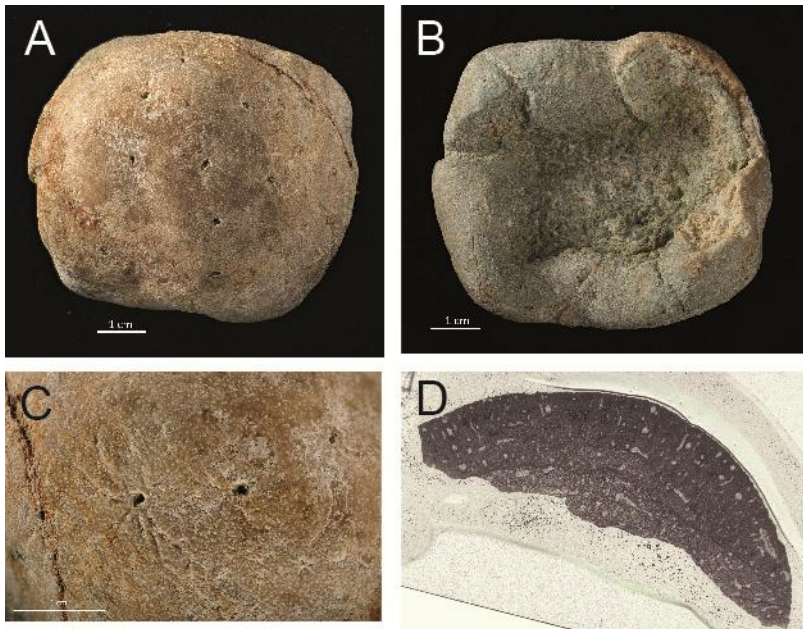


Figure 32. *Pliobolia?* sp. **A, B**, MSNVE-22893; **C**, MCZ-I 3774. **A**, top view with small canal openings together with rare larger openings surrounded by radial furrows; **B**, bottom view, cup-shaped thick-walled sponge; **C**, detail of external top surface with larger openings surrounded by radial furrows; **D**, longitudinal thin section with spherulitic stratified structure.

Family Uncertain
Genus Uncertain

Indeterminate lithistid sp. A

Material. 1 specimen MCZ-I 3798 from Cengio dell'Orbo quarry.

Description. Subglobular, massive sponge 3.8 cm height, 6 large, 5.2 long. On the whole surface many circular to elliptical oscula 0.5-2.0 cm in maximum diameter. Oscula have a 3-4 mm high rim. Cylindrical or conical spongocoel. In cross section a dense structure is visible with completely calcified (peloidal micrite) desmas ghosts. Short canals 480-960 large μm , 1600-4800 μm long.

Remarks. Our specimen is morphologically identical to the Upper Cretaceous *Discodermia gleba* Schrammen, 1910 (p. 98 tab. 15 fig. 2). Schrammen indicated a "chestnut" dimension while our specimen is larger. As it was not possible, due to bad preservation, to recognize desmas type, thus the assignment is dubitative. Moreover, the diagnostic ectosomal spicules, phyllostriaenes, are not preserved. *Discodermia* sp. phyllostriaenes are reported for the Eocene of SW Australia (Hinde, 1910), New Zealand (Hinde and Holmes 1892) and the Miocene of Spain (Ott d'Estevou et al., 1981). Another Miocene record for the genus is for Algeria (Moret, 1924). Unfortunately just the spicules are illustrated.

"Sphinctozoa"

Class Demospongiae Sollas, 1885
Order Dictyoceratida Minchin, 1900
Family Verticillitidae Steinmann, 1882
Genus *Vaceletia* Pickett, 1982 p. 241

Type species. *Neocoelia crypta* Vacelet, 1977 p. 509

Vaceletia progenitor Pickett, 1982
(Fig. 33A-D)

1982 *Vaceletia progenitor*; Pickett: 242, figs 2-6.

Material. 2 fragments, MCZ-I 3763, MDGP1056 from Cengio dell'Orbo quarry.

Description. Cylindrical, externally segmented (Fig. 33A) fragments 1.5-1.7 cm height, 0.7-1.3 cm in diameter. Domical upper surface bearing a circular terminal osculum of 1.8-2 mm in diameter (Fig. 33B). Spongocoel cylindrical 1.8 mm in diameter. The sides of spongocoel have a continuous wall (endowall: 150-200 thick) running for the full length of the specimen MCZ-I 3763. Sponge walls 2-3 mm in thickness. Internally the sponge consists of a series of annular, crescent shaped chambers. Chambers extend the full width of the sponge wall (Fig. 33C). They are 400-600 μm height and traversed normally by pillars (50-100 μm thick). Subpolygonal canal openings (100 μm in diameter) on the external surface (Fig. 33D).

Remarks. Our material is morphologically identical to the specimens from Pallinup Siltstone, upper formation of the Plantagenet Group (Upper Eocene-Priabonian- SW Australia) described by Pickett (1982). As a matter of fact most of the morphological features are comparable. Chambers are smaller in our specimens, and, curiously, more similar to living species *Vaceletia crypta* (Vacelet, 1977) (Table 2). In our

material, pillars have a thickness measure between *V.crypta* and *V.progenitor* from Australia. In MCZ 3763, it was possible to measure the endowall only as the external surface was strongly eroded by preparation. The Western Australian specimens are branched while we interpret our material as fragments of branches. This is thus the second record of this sphinctozoan sponge from the Cenozoic that extends geographical range of the specie. The Australian record and the present one bridged the gap between the previously youngest known fossil sphinctozoans of the Cretaceous (e.g. *Vaceletia crustans* Reitner & Engeser 1989 from Spain) and the extant forms.

The extant genus *Vaceletia* is the only Recent representative of the polyphyletic group “Sphinctozoa” or chambered calcareous sponges. It has a chambered skeleton of aragonite and is devoid of spicules. The genus is distributed in Indo-Pacific area, in semi-closed cavities of coral reefs, front reef caves and bathyal environments, 10-530 m depth (among others Vacelet, 2002; Wörheide G., Reitner, J., 1996). Wörheide (2008), on the base of rDNA sequences analyses of living *Vaceletia* sp. specimens, found high affinity to the extant order Dictyoceratida Minchin, 1900.

	branch diameter	Chamber height	Spongocoel diameter	Canal openings diameter	Pillar thickness	Endowall thickness
<i>crypta</i>	4	0.6	0.5-0.8	0.1	0.04-0.05	0.05
<i>progenitor</i> (Australia)	5.9-11.9	0.9-1.2	2.0	0.1	0.1-0.17	0.15
<i>progenitor</i> (Chiampo)	7-13	0.4-0.6	1.8	0.1	0.05-0.1	0.15-0.20

Table 2. Comparison of various parameters of *Vaceletia crypta*, *V. progenitor* from Australia and *V. progenitor* from Chiampo. Measurements in mm (data from Pickett, 1982 and this study)

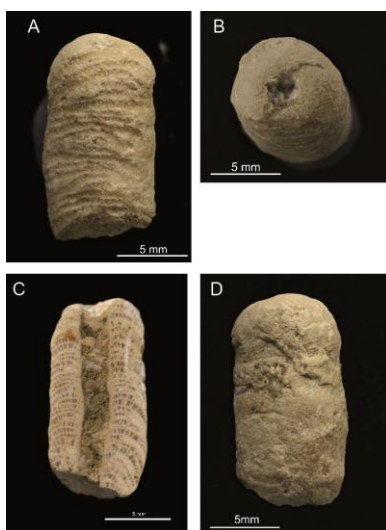


Figure 33. *Vaceletia progenitor* Pickett, 1982. **A-D**, MCZ-I 3763 **A**, lateral view, cylindrical shape, domical upper face, body externally segmented; **B**, top view, circular terminal osculum; **C**, longitudinal section with cylindrical spongocoel running for the full length of the specimen, sponge wall composed of series of annular, crescent shaped chambers. Chambers are traversed normally by pillars; **D**, detail of the subpolygonal canal openings on the external surface.

Paleoecology

Functional morphology: mode of attachment

Some specimens of *Ozotrachelus conica* and *Corallistes multiosculata* nov. sp. (lithistids) show a basal disc of 2–3 cm in diameter (Fig. 36 A, B). These discs are subcircular and generally broken at their edges. Most specimens, however, are broken at the base of the stalk. In Recent sponges, basal disks are attached on a hard substrate.

There is more direct evidence that sponges were attached to hard substrate at least in their initial life stages. Some specimens of hexactinellids and lithistids are still attached to larger foraminifera (Fig. 36 F, G). Moreover, red algae and larger foraminifera (*Nummulites* sp.) were found incorporated in the skeleton of sponges (Fig. 36 H, I). In one case, a hexactinellid sponge of the genus *Hexactinella* was found to encrust a rhodolith (Fig. J). In other cases, small cavities (0.8–1.6 cm high, 0.7–1.6 in diameter) (Fig. 36K) are found at the base of complete sponges that are interpreted as originally hard objects that dissolved during diagenesis or were organic in nature.

Specimens of some hexactinellids show instead tuber-like or root-like basal structures. Three *Laocoetis patula* specimens, for example, show a tuber-like basal part that is 2.5–4.6 cm in diameter and 3.6–5.8 long (Fig. 37 C, D). Delicate root-like structures of 4–4.5 mm in diameter were observed in a specimen of *Guettardiscyphia/Pleurogettardia*, although their delicate tips are always broken (Fig. 37 E). These basal structures differ from those of *Laocoetis*, because they are more delicate and smaller in proportion to the complete sponge body. As for the basal disk, also these structures are often lost by fracturation of the specimen during deposition.

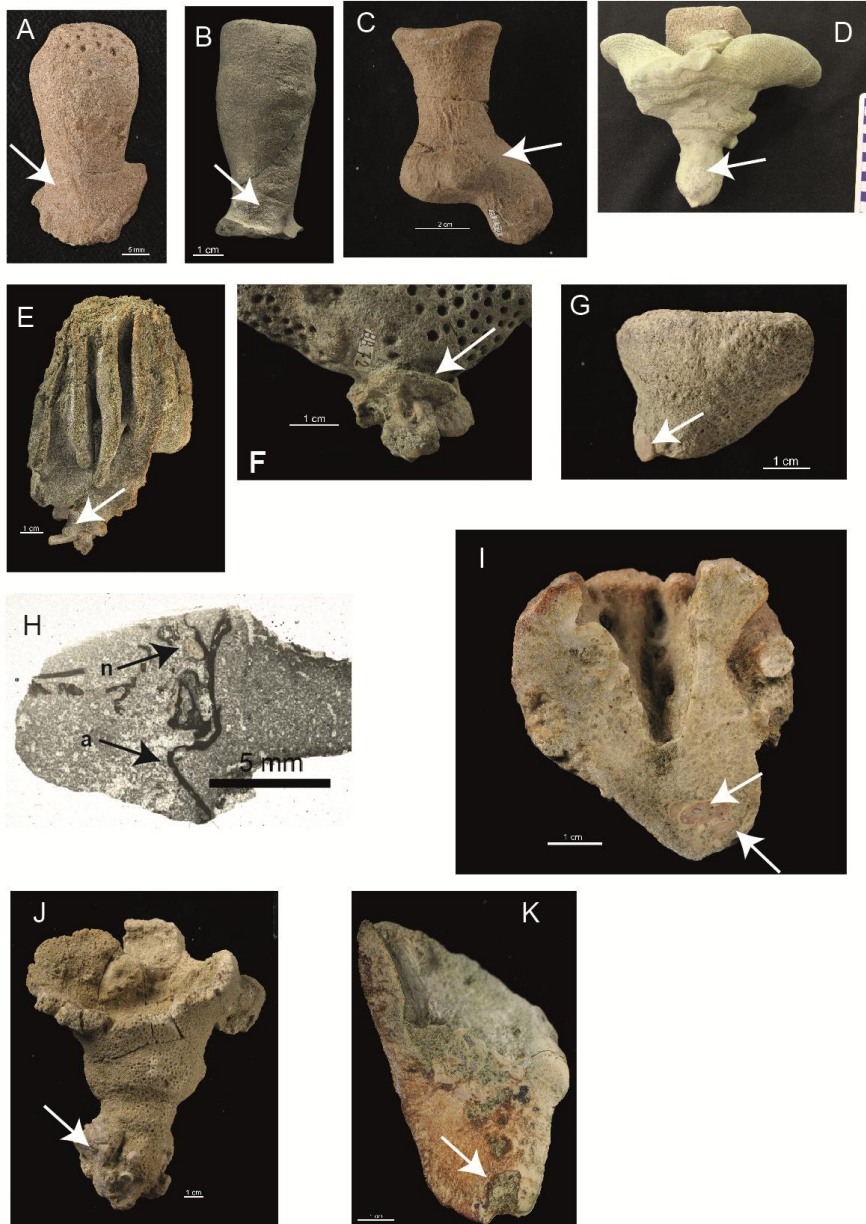


Figure 37. **A**, MSNVE-22912 *Corallistes multiosculata* sp. nov. showing encrusting basal disk (arrowed). **B**, MSNVE-22982 *Ozotrachelus conica* with basal disk (arrowed). **C**, MSNVE-22891 *Laocoetis patula* with tuberosity base (arrowed). **D**, MMC 22 *L. patula* with tuberosity base (arrowed). **E**, MSNVE-22891 Rootlike structures (arrowed) at the base of *Pleuroguettardia iberica*. **F**, MSNVE-22977 hexactinellid encrusting a cluster of larger foraminifera (arrowed). **G**, MCZ-I 3723 lithistid encrusting a larger foraminifera (arrowed). **H**, MSNVE-22908 thin section of lithistid sponge showing a red algae (a) and small nummulite (n) inside the body. **I**, MSNVE-22979 cross section of lychniscosan sponge *Coronispongia confossa* sp. nov., showing nummulites (arrowed) at the base of the body. **J**, MCZ-I 3804 *Hexactinella clampi* sp. nov. encrusting red algae nodules (arrowed). **K**, MCZ-I 3731 lithistid sponge with a hole at the base (arrowed) suggesting that the sponge encrusted an object that disappeared during diagenesis.

Sponge clusters

During this study six slabs bearing numerous sponge specimens were found. They are 5.9–12.5 cm high, 12.9–27 large and 8.2–21 long. The slabs are mainly composed of hexactinellid (hexactinosan and lychniscosan) sponges. From a preliminary qualitative analysis of the slabs surfaces, the more abundant species is the lychniscosan *Callicylix eocenicus* Pisera and Busquets, 2002. Other Hexactinellids *Camerospongia canalata.*, *Guettardiscyphia/Pleurogettardia* and *Laocoetis patula* were also found. The specimens seem in life position and apparently growing one on each other . We interpreted these structures as natural sponge clusters.

Juvenile specimens

More than 150 specimens among more than 900 investigated are less than 3 cm high. Some are 1.5 cm or less .For the majority of these specimens taxonomic attribution was impossible due to paucity of diagnostic features. Nevertheless, few of them were assigned to described taxa with reasonable confidence e.g. *Laocoetis patula*, *Stauractinella eocenica*, *Callicylix eocenicus*, *Toulminia italica* . These taxa show a broad dimension range. Considering entire specimens only, *Toulminia* smallest specimen is half the size of largest one, *Callicylix* smallest one is one sixth, *Stauractinella* is one tenth. We cannot exclude the idea that many of small specimens could be genuinely adult. Yet, we consider the ones for which assignment was possible, as juvenile.

Discussion

Taphonomy of Chiampo sponge fauna: a proposal

From these observations, some preliminary conclusions can be drafted. The precipitation of pyrite and peloidal micrite could be induced by the presence of sulfate reducing bacteria. As fluorescence is induced mostly by unsaturated organic compounds, the evidence that the clotted peloidal micrite was fluorescent implies it precipitated incorporating organic matter, which supports the idea that it was produced by bacteria (i.e., it is a microbial carbonate). Bacteria could have also contributed to volcanic glass alteration. Palagonite is the first stable product of aquatic mafic glass alteration. Stroncik & Schminke (2002) reported that microbial activity enhances the rate of dissolution of volcanic glass by creating a local microenvironment as a result of the fluids of their metabolic products.

The idea that, in sponges, micrite formation may be induced by microbial communities is quite widespread in literature (e.g. Narbonne and Dixon 1985; Brachet et al. 1987; Reitner 1993; Warkne 1995, Buckeridge et al. 2013). Calcification occurs within those portions of the sponge that are buried in the sediment and it is a *syn-vivo* to early *post-mortem* process (Brachert 1987; Neuweilwer et al. 2007). Gaillard (1983) gave a flow scheme of diagenetic process with different preservational stages . A case study are European Late Jurassic “calcareous mummies”, where the original siliceous skeleton was replaced by calcite sparite in a very early cementation process (among others Keupp et al. 1990; Brachet 1991; Pisera 1997; Leinfelder 2001). Chiampo sponges seem to be different from “calcareous mummies”. First of all, the space between spicules in Chiampo sponge bodies is not a micrite but mostly a sparite. Then, clotted peloidal micrite is present in

Chiampo but not so abundant as in Jurassic sponges. However, the microbial metabolization of soft tissues of sponges seems to have been important for preservation in the studied case: spicules, which are constituted by calcite sparite as well as the cement around them, are recognizable in thin section only because they are coated by a thin veil of fluorescent micrite. This micrite is locally in continuity with patches of fluorescent clotted peloidal micrite, and is thus most probably the product of microbial anaerobic metabolization of the sponge soft tissue.

Local water chemistry due to high alkalinity linked to volcanism could be an important factor in preservation as well. High alkalinity could have enhanced opal spicules' dissolution and calcite precipitation. Preservations similar to that of Chiampo sponges, with original siliceous skeleton wholly dissolved and empty voids filled with calcite or other minerals (e.g. pyrite, celestite), is widely reported, along with Jurassic "calcareous mummies". Some other examples come from the Late Cretaceous: hexactinellids of Ukraine (Świerczewska-Gładysz and Danuta Olszewska-Nejbert, 2013) and demosponges from Denmark (Madsen&Stemerick, 2012).

We explain the scarce pyrite in hexactinellids due to the low amount of soft tissue in comparison with lithistid demosponges (Leys 1999). The scarcity of organic matter could have limited sulfate reduction reactions that lead to pyrite formation.

The fact that generally no sediment was found inside the sponge canals could suggest that the sponges were still alive when buried, with their organic tissue still covering them. The preservation of delicate, easily-disrupted structure such as external membrane could indicate that sponges were buried by a gentle turbidite? flow. On top of that, the presence of organisms from different depths (e.g. planktic and larger foraminifera), is an evidence of re-sedimentation and confirm Beccaro et al. (1999) facies analysis.

Based on the above observations a model of the taphonomic/diagenetic sequence can be proposed as follows: (Fig. 34):

A. The sponge was in situ (evidences: delicate encrusting base, various ontogenetic stages, sponge clusters, no record of sponges in other sites).

B. The sponge was buried very quickly by pyroclastic sediments (possibly turbidites/debris flows) (evidences: volcanic glass, no sediment in the interspicular space and canals, mixed associate microfauna, siliceous membrane preserved in some specimens).

Partial calcification of decaying tissue by sulfate-reducing bacteria (clotted peloidal micrite, pyrite)

C. Complete solution of opaline skeleton, filling of interspicular and spicular voids by calcite sparite.

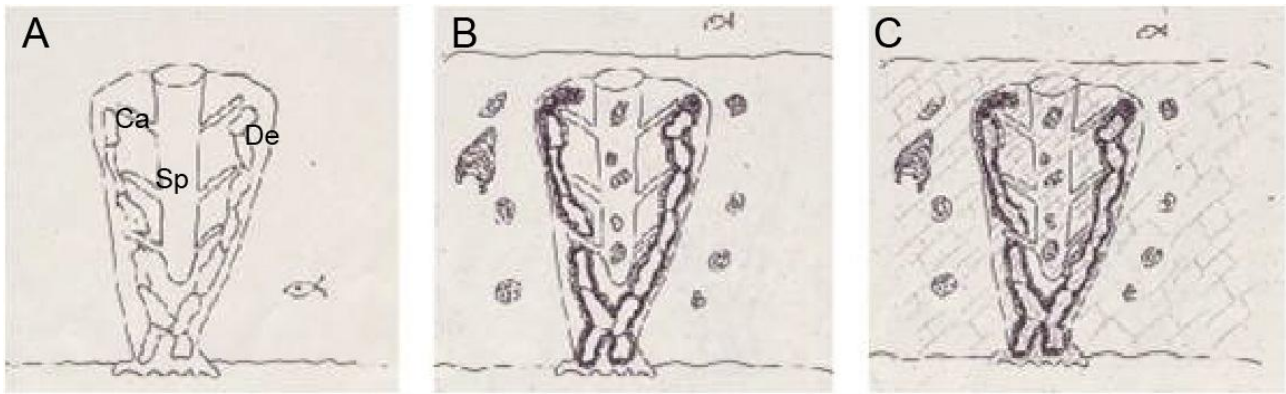


Figure 34. Drawing about taphonomic and diagenetic events. **A**, the sponge was in situ (evidences: delicate encrusting base, various ontogenetic stages, small bioherms). Ca= canals, Sp= spongocoel, De= siliceous desma; **B**, the sponge was buried very quickly by pyroclastic sediments (possibly turbidites/debris flows) (evidences: volcanic glass, no sediment in the interspicular space and canals). Partial calcification of decaying tissue by sulfate-reducing bacteria (clotted peloidal micrite, pyrite) **C**, complete solution of opaline skeleton, filling of interspicular and spicular voids by calcite sparite.

Taxonomy of Chiampo sponge fauna

This study led to the description and illustration of 32 siliceous sponge species (Tab. 3).

Among these species, we propose the institution of 10 new species: *Stauractinella eocenica*, *Rigonia plicata*, *Hexactinella clampi*, *Camerospongia tuberculata*, *Camerospongia visentini*, *Toulminia italica*, *Coronispongia confossa*, *Cavispongia scarpae*, *Corallistes multiosculata*, *Bolidium bertii*. 24 genera were described, 2 of which new (*Rigonia* and *Coronispongia*).

Of the 32 siliceous sponges species 15 belongs to class Hexactinellida (with 1 species belonging to order Lyssacinosa, 7 Hexactinosida, 7 Lychniscosida) and 17 to class Demospongia (with 16 lithistids and 1 Agelasidae). This can be expressed in terms of percentage with 47% of species belonging to class Hexactinellida (22% to order Lyssacinosa, 22% Hexactinosida, 3% Lychniscosida) and 53% to class Demospongia (50% lithistids and 3% Agelasidae) (Fig. 35).

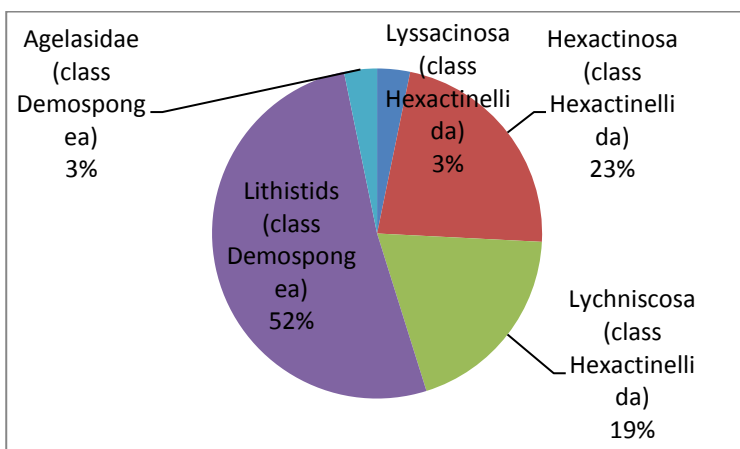


Figure 35. Percentage of species belonging to various siliceous sponges genera (class in brackets).

Even if more than 900 specimens housed in Museum collections were studied only 259 were useful for taxonomic assignments. The other ones were either too badly preserved or still surrounded by the sediment. This was particularly the case of University of Padova Museum collection (IG-PD) for which, for 447 specimens only 7 were useful for assignment.

If we take into account the specimens for which the assignment was possible (n. 259) we can have attempt some abundance data (Fig. 36).

The more abundant species is *Callicylix eocenicus* Pisera & Busquets, 2002, followed by *Laocoetis patula* Pomel, 1872, *Stauractinella eocenica* sp. nov, *Pleuroguettardia* aff. *iberica* Pisera & Busquets, 2002/*Guettardiscyphia thiolati* (d'Archiac, 1846) and *Camerospongia visentini* sp. nov.

74% of the specimens belong to class Hexactinellida, 24 % to class Demospongia.

Of course we should bear in mind that we are dealing with Museum collections so there is a strong sampling bias. For this reason no diversity statistic can be done on this material.

Nevertheless, from a first study of sponge clusters (see paleoecology paragraph) the predominance of hexactinellids versus lithistid appear to be genuine. This aspect could be developed with field sampling and a detailed study of sponge clusters.

A comparison of Chiampo fossil genera with other localities in time and space was made (Tab.3). As literature about fossil sponges often bear taxonomic mistakes, we performed the comparison with selected papers. Nevertheless we should consider that the our taxonomic data are approximate too. Data quality in paleospongiology is a serious problem. Difficulties in taxonomic assignments, discontinuous fossil record together with preservation and collection bias; (Hartman et al 1980; Pisera 2004) make sponges not the best organisms for paleobiological analysis.

Taking these aspects in mind some observations on faunal composition at generic level can be done.

The cretaceous character of Chiampo sponge fauna is clear (Tab. 3). In fact, excluding the 2 new genera here proposed, of 22 genera described , 14 are in common with a typical Cretaceous fauna.

There are 3 genera that have root in the Jurassic: *Stauractinella*, *Laocoetis* (Kaesler 2004) and *Ventriculites* (Hérengrer 1942).

5 genera are present the Eocene and Miocene of Spain, 4 in the Miocene of Algeria.

5 genera are still extant: Today *Laocoetis*, *Anomochone*, *Vaceletia* are recorded in the Indo-Pacific Ocean. *Hexactinella* is also present in the Pacific Ocean (off S Carolina, USA) while *Corallistes* is cosmopolitan and it is present in the Mediterranean Sea too (Van Soest et al. 2014).

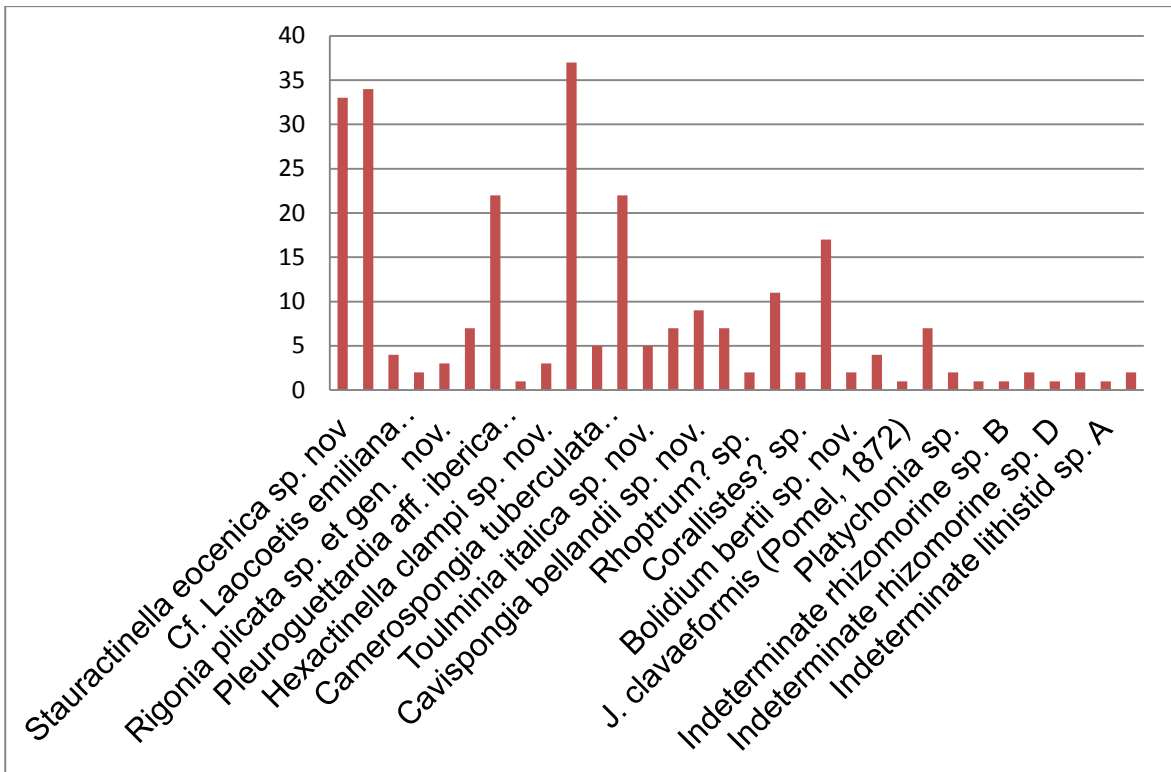


Figure 36. Number of specimens per taxa (abundance). Total number of specimens: 259.

GENUS	CRETACEO US	EOCENE					MIOCE NE		PLIOCE NE	RECE NT
	NW GERMANY	SPAI N	US A	NEW ZEALAND	W AUSTRALI A	SPAI N	ALGERI A	ITAL Y	ITALY	
<i>Stauractinella</i>	1	0	0	0	0	0	0	0	0	0
<i>Laocoetis</i>	1	1	1	0	0	1	1	1	1	1
<i>Pleuroguettardia</i>	1	1	0	0	0	0	0	0	0	0
<i>Guettardiscyphia</i>	1	1	0	0	0	0	0	0	0	0
<i>Anomochone</i> sp.	0	0	0	1	0	0	0	0	0	1
<i>Hexactinella</i>	1	1	0	0	0	1	0	0	0	1
<i>Callicylix</i>	1	1	0	0	0	0	0	0	0	0
<i>Ventriculites</i>	1	0	0	0	0	0	0	0	0	0
<i>Camerospongia</i>	1	0	0	0	0	0	0	0	0	0
<i>Toulminia</i>	1	0	0	0	0	0	0	0	0	0
<i>Cavispongia</i>	0	0	0	0	0	0	0	0	0	0
<i>Siphonia</i> sp.	1	0	0	0	0	0	0	1	0	0
<i>Rhoptrum?</i>	1	0	0	0	0	0	0	0	0	0
<i>Corallistes</i>	0	0	0	1	1	0	1	0	0	1
<i>Ozotrachelus</i>	1	0	0	0	0	0	0	0	0	0
<i>Bolidium</i>	0	0	0	0	0	0	0	0	0	0
<i>Stachyspongia</i> sp.	1	0	0	0	0	0	0	0	0	0
<i>Jereopsis</i> Pomel, 1872	1	0	0	0	0	1	1	1	0	0
<i>Verruculina</i>	1	0	0	0	0	1	1	0	0	1
<i>Platychnonia</i>	0	0	0	0	1	0	0	0	0	0
<i>Pliobolia</i>	0	0	0	0	0	1	0	0	0	0
<i>Vaceletia</i>	0	0	0	0	1	0	0	0	0	1
TOTAL	15	5	1	2	3	5	4	3	1	6

Table 3. List of Chiampo fossil genera described in this study. Presence (1) or absence (0) of the genera in other localities in time and space. Sources: NW Germany (Schrammen 1910, 1912), Eocene Spain (Pisera and Busquets 2002), Eocene USA N Carolina (Rigby, 1981; Finks, 2011), Eocene SW Australia (Chapman and Crespin; de Laubenfelds 1953; Pickett 1982,1983). Eocene New Zealand Chatman Island (Buckeridge et al. 2013; Kelly et al. 2003; Kelly & Buckeridge 2003, 2005; Consoli et al. 2009), Miocene Algeria (Pomel 1872; Moret 1924). Miocene Italy (Malfatti, 1900; Matteucci and Russo 2011), Miocene Spain (Moret, 1925; Brimaud & Vachard 1986 a,b), Pliocene Italy (Matteucci & Russo 2011). For the Algerian sponges, the genera revised by Moret (1924) are listed. Recent sponges records from World Porifera Database (Van Soest et al. 2014). The 2 new genera described in this study are obviously excluded.

Table 3. Systematic list of Chiampo sponges described in this study.

Phylum Porifera Grant 1836

Class Hexactinellida Schmidt, 1870

Subclass Hexasterophora Schulze, 1887

Order Lyssacinosida Zittel, 1877

Family Stauractinellidae De Laubenfels, 1955

Stauractinella Zittel, 1877

Stauractinella eocenica sp. nov.

Order Hexactinosida Schrammen, 1903

Family Craticulariidae Rauff, 1893

Laocoetis Pomel, 1872

Laocoetis patula Pomel, 1872

Cf. *Laocoetis emiliana* (Malfatti, 1900)

Pleuroguettardia Reid, 1963

Pleuroguettardia iberica Pisera & Busquets, 2002

Family Cribrospongiidae Roemer, 1864

Rigonia gen. nov.

R. plicata sp. nov.

Guettardiscyphia de Fromentel, 1860

Guettardiscyphia thiolati (d'Archiac, 1846)

Family Tretodictyidae Schulze, 1887

Anomochone Ijima, 1927

Cf. *Anomochone* sp.

Hexactinella Carter, 1885

Hexactinella clampi sp. nov.

Order Lychniscosida Schrammen, 1903

Family Callodictyonidae Zittel, 1877

Callicylix Schrammen, 1912

Callicylix eocenicus Pisera & Busquets, 2002

Family Ventriculitidae Smith, 1848

Ventriculites sp.

Family Camerospongiidae Schrammen, 1912

Camerospongia d'Orbigny, 1849

Camerospongia tuberculata sp. nov.

Camerospongia visentini sp. nov.

Toulminia Zittel, 1877

Toulminia italica sp. nov.

Family Diapleuridae Ijima, 1927

Coronispongia gen. nov.

Coronispongia confossa sp. et gen. nov.

Family Neoaulicystidae Zhuraleva, 1962

Cavispongia Quenstedt, 1877

Cavispongia scarpae sp. nov.

Class Demospongea Sollas 1875

"Lithistida"

Suborder Tetracladina Zittel, 1878

Family Siphoniidae d'Orbigny, 1851

Siphonia Goldfuss, 1826

Siphonia sp.

Family Theonellidae von Ledenfeld, 1904

Rhoptrum Schrammen, 1910

Rhoptrum? sp.

Suborder Dicranocladina Schrammen, 1924

Family Corallistidae Sollas, 1888

Corallistes Schmidt, 1870

Corallistes multiosculata sp. nov.
Corallistes? sp.
 Suborder *Sphaerocladina* Schrammen, 1924
 Family Vetulinidae von Lendenfeld, 1904
Ozotrachelus de Laubenfels, 1955
Ozotrachelus conica (Roemer, 1841)
 Suborder Rhizomorina Zittel, 1895
 Family Azoricidae Sollas, 1888
Bolidium Zittel, 1878
Bolidium bertii sp. nov.
Stachyspongia Zittel, 1878
Stachyspongia sp.
Jereopsis Pomel, 1872
J. clavaeformis (Pomel, 1872)
Verruculina Zittel, 1878
Verruculina ambigua (Pomel, 1872)
 Family Platychoniidae Schrammen, 1924
Platychonia Zittel, 1878
Platychonia sp.
 Family Uncertain
 Indeterminate rhizomorphine sp. A
 Indeterminate rhizomorphine sp. B (E)
 Indeterminate rhizomorphine sp. C
 Indeterminate rhizomorphine sp. D
 Genus *Pliobolia* Pomel, 1872
Pliobolia? sp.
 Suborder Uncertain
Indeterminate lithistid sp. A
 Order Agelasidae Verrill, 1907
 Family Verticillitidae Steinmann, 1882
Vaceletia Pickett, 1982
Vaceletia progenitor Pickett, 1982

Sponge autoecology

The ecology of Eocene sponges of the Chiampo Valley was never clarified. According to Matteucci & Russo (2005) these sponges were living in relatively shallow and warm water. Beccaro et al. (2001) found that the sponge-bearing sediment of Cengio dell'Orbo quarry exhibits sedimentary structures indicative of mass transport, but could not observe the sponges in situ.

In this study, it wasn't possible to collect in situ complete sponge specimens as well, but the systematic examination of a large collection (more than 900 specimens) allows some considerations on the autoecology of sponges on the base of their functional morphology.

Some lithistid sponges of Chiampo Valley were colonizing an hard bottom substrate. This is indicated by the presence of a basal disk, which in Recent lithistids occurs in sponges of hard bottoms or attached to hard objects on muddy substrate (Pisera 1997; Pomponi et al 2001). The basal disk is absent in many specimens only because the stalk is perhaps the most fragile part of the sponge, and thus the basal disk is very often lost.

Instead, the tuber-like basal structures of some hexactinellids indicate anchoring in soft sediment, similarly to the tuber-like basal part of Jurassic hexactinellid *Cribrospongia radicata* (Quensted) that was interpreted

as a structure that prevents the sponge to sink into mud creating a buoyancy. At the same time the mass of the basal root structure keeps the sponge in an upright position (Krautter 1998).

Rootlike structures in hexactinellids are seldom reported in literature (among others, Reid 1958a). Krautter et al. (2006) described similar basal structures in *Aphrocallistes vastus* and *Heterochone calyx*, in the only recent hexactinellid reef, off British Columbia. In these two species it was observed that with increasing size they produce rootlike outgrowths. They can attach to hard surfaces such as rocks or sponge skeletons. Krautter et al. (2006) interpreted this as an intrinsic mechanism to optimize stability as these basal outgrowths help to keep the growing sponge in an optimal life position. Thus, we interpreted the delicate root-like basal structure of *Guettardiscyphia/Pleurogettardia* as an evidence of attachment to a hard substrate.

Summarizing, there is compelling evidence that most of the Eocene sponges of Chiampo Valley were colonising a hard substrate, at least in their early growth stages. Generally, sponge larvae need to settle on hard objects (rocks, mollusks shells, rhodoliths, etc.) to begin their metamorphosis (Berquist 1978). In this process, an envelope around hard objects could develop (Krautter et al. 2006), and in a later stage sponges can incorporate sediment and living organisms like foraminifera (Cerrano et al. 2007; Guilbault et al. 2006). This explains the occurrence of small bioclasts completely enclosed in some sponges at Chiampo. However, also mature specimens on the higher end of the size distribution among the fauna of Chiampo retain structures indicative of a hard substrate. The presence of different modes of attachment in Chiampo sponge fauna suggest heterogeneous bottom surface conditions. This feature was well documented in Miocenic sponge fauna from S Spain (Brimaud & Vachard 1985) in resedimented deposits.

Today, in the unique hexactinellid reef on the continental shelf of West Canada, at around 200 m depth, probably sponges first colonized a hard substrate (iceberg furrows) (Conway et al. 2001; Krautter et al.; Leys et al. 2007 and literature therein). The reef is formed by sponge generations growing on older generation of sponges. The sponges act as baffles, trapping sediments in suspension, which quickly fill up any spaces between individual sponges, and thus stimulate the growth of the bioherm.

Hexactinosida and the Lychniscosida have a high reef building potential (Mehl 1992). During Phanerozoic, siliceous sponges were recurrently important reef-building organisms (Brunton & Dixton 1994). Maximum expansion was recorded for the Late Jurassic when siliceous sponges formed a discontinuous deep-water reef belt over 7000-km long spanning the northern margin of the Tethys Sea (Krautter 1997; Pisera 1997 and references therein).

In Chiampo sponge horizon various ontogenetic stages are present: juvenile specimen together with fully grown ones. The abundance of small specimens indicates that reproduction must have been a frequent event (Klitgaard & Tendal, 2001).

Conclusions

1. The bodily preserved fauna from Chiampo Valley show a high diversity (32 species), dominated by siliceous sponges with solid skeleton (Hexactinellida, Demosponge lithistid,). The fauna has a cretaceous character. 10 new species and 2 new genera are proposed.
2. The original siliceous skeleton of sponges was dissolved and replaced by molds in calcite sparite. A constant presence of (possibly microbial) peloidal micrite was observed.
3. Sponges colonized a mixed substrate, eventually forming small bioherms/sponge cluster. The sponge fauna is essentially *in situ*.

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