SILICEOUS SPONGE SPICULES FROM THE MIOCENE MEM MONIZ MARLS (PORTUGAL) AND THEIR ENVIRONMENTAL SIGNIFICANCE

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Received: May 2nd, 2005; accepted: January 18, 2006

Key words: Siliceous sponges, Hexactinellida, Demospongiae, spicules, Mioocene, Portugal, paleoenvironment.

Abstract. The Miocene (middle Serravalian) Mem Moniz marls from Algarve (Portugal) contain a rich and well preserved assemblage of siliceous sponge spicules, which is described here for the first time. The assemblage indicates that the sponge fauna was dominated by Astrophoridae, and in particular by Geodiidae. The presence of Eurylus sp. and probably Geodia sp. (both Astrophoridae), Samnus sp. (Spirophorida) and Alecsona wallachii (Hadromeridae) is also reported. Samnus sp. and Alecsona wallachii are reported from the fossil record for the first time. Additionally, the occurrence of litothid demosponges (represented by Thoeneidae and rhizomorinidi), Hadromerida, Spirophorida and Hexactinellida is also found. Anicornidae, Pachastrellidae (and/or Cathopellicidae), both Astrophoridae, were also clearly recognized. Less certain is the occurrence, in the Mem Moniz marls, of Tethyidae (Hadromeridae). Bathymetric reconstructions based on sponges are imprecise due to the fact that these organisms often have very wide bathymetric ranges. However, the studied sponge assemblage is clearly neither characteristic of very shallow nor very deep marine environments. The dominance of astrophorids and the presence of litothids and hexactinellids suggest a depth of at least several tens to one hundred metres, or even more.

Riassunto. Le marne mioeeniche di Mem Moniz (Serravalian medio) dell’Algarve (Portogallo) contengono una associazione a spicole di spugne silicee, ricca e ben conservata. Esso viene qui descritta per la prima volta. L’associazione è dominata dagli Astrophoridae, in particolare dalle Geodiidae. Viene pure ricordata la presenza di Eurylus sp. e probabilmente di Geodia sp. (entrambi appartenenti agli Astrophoridae), Samnus sp. (Spirophoridae) e Alecsona wallachii (Hadromeridae). Queste ultime due forme sono descritte per la prima volta allo stato fossile. Viene pure indicata la presenza di demosponge litothidi (rappresentate da Thoeneidae e rhizomorinidi), di Hadromerida, Spirophorida e Hexactinellida. Ugualmente viene riconosciuta la presenza di Anicornidae, Pachastrellidae (e/o Cathopellicidae), entrambe appartenenti agli Astrophoridae. È invece meno certa la presenza nelle marne di Mem Moniz delle Tethyidae (Hadromeridae). Le ricostruzioni bathimetriche basate sulle spugne sono solitamente imprecise a causa della grande estensione bathimetrica della maggior parte dei taxa. Tuttavia, l’associazione studiata è chiaramente né poco, né molto profonda. Il prevalere degli astrophoridi e la presenza di litothidi e hexactinellidi suggerisce una profondità compresa tra alcune decine di metri sino a circa 100 metri di profondità, se non di più.

Introduction

The whitish marls of Mem Moniz are a sedimentary unit of Miocene age outcropping in a restricted area north of the locality of Albufeira, in Algarve, Southern Portugal (Fig. 1). These marls are almost completely devoid of macrofossils. On the other hand it has a rich microfossil content, in which siliceous sponge spicules are plentiful and one of the most common biogenic elements present. Apart from them, calcareous nanofossils, diatoms, benthic and planktic foraminifera and rare ostracods occur.

Ever since their discovery, the spicule-rich Mem Moniz deposits have been involved in sizzling controversy. Their stratigraphic positioning, first, and palaeoenvironmental significance, later, fueled a seemingly never ending debate (see, eg. Romarin et al. 1979; Cachão 1995; Antunes et al. 1997; Cachão et al. 1998).

The abundant and well preserved siliceous sponge spicules of Mem Moniz therefore are of considerably palaeontological and palaeoenvironmental interest. Their study is crucial for the interpretation of the environmental setting in which these deposits were formed.

The excellent preservation of these fossil spicules should enable their clear identification and assignment.

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to sponge taxa at a family level and hopefully even to specific level. This would represent an important contribution to the history of the siliceous sponges, especially to the as yet poorly known Caenozoic history of nonlithistid demosponges.

Geological setting and stratigraphy

The whitish marls of Mem Moniz crop out in the central sector of Algarve (Southern Portugal), approximately 9 km to the North-Northeast of Albufeira. The Mem Moniz outcrop is limited to a relatively small elliptical area of about 1 km² at the present day altitude of 70-80 m above mean sea level (Fig. 1). The marls lay generally subhorizontal. Nontheless, a section of the outcrop located between faults, tilted approximately 20° SE, displays a 17 m continuous sequence that was sampled for the present study (Fig. 2). They overlie, with unconformity, Lower Cretaceous marls and sandstones.

Formerly considered a Cretaceous outcrop, the Mem Moniz marls were recognised as a Miocene marine deposit only in the early 1970's (Romariz et al. 1979). Since its Miocene assignment, this outcrop has attracted considerable interest due to its litho- and biofacies uniqueness, namely the almost complete absence of macrofossils (both body fossils and ichnofossils) so abundantly found in its surrounding Miocene marine sedimentary units of Algarve. On the other hand, its fine marly texture seems paradoxical due to its inland position relative to the majority of the other Southern Portuguese shallow marine Miocene deposits, typically clustered along the present day coastal area (Cachão 1995).

Lithostratigraphically, the marls of Mem Moniz are part of the Middle Member of the Lagos-Portimão Formation commonly represented, in the coastal area of Algarve, by macrofossiliferous biocalcareites (Cachão 1995; Cachão et al. 1998). The Lagos-Portimão Formation makes up part of the first main sedimentary carbonate Portuguese Neogene sequence (Cachão & Silva 2000), represented in the entire Algarve region, but having a larger cartographic expression on the coastal region west of Albufeira (Cachão 1995). This formation is separated from an upper siliciclastic sequence (Carcela and Ludo Formations; Cachão et al. 1998) by an important regional unconformity (Cachão & Silva 2000).
The calcareous nannofossils assemblage in the Mem Moniz marls indicates their placement in the Okada & Bukry's (1982) subzone CN5a, being compatible with a Middle Serravalian age (Cachão 1995). $^{87}$Sr/$^{86}$Sr isotopic dating performed on planktic foraminifera tests from this unit indicates an age of 12.5 (+0.7-1.7) Ma (Antunes et al. 1997).

The Mem Moniz marls are interpreted as a deposit formed during a relatively rapid transgressive episode, over a polygenic surface, cut by coastal encroachment on top of a Mesozoic basement (Cachão 1995). The existence of important tectonic deformation (the Algibe flexure of Kullberg et al. 1992) in this area may have pre-adapted it to be preferentially eroded into a more or less depressed and restricted sub-basin defined on a generally open shallow marine platform.

A significant part of the 40% of carbonate content of the white marls of Mem Moniz is biogenic (calcareous nannofossils, benthic and planktic foraminifers and rare ostracods) associated with a less important siliceous biogenic component (around 10%) mainly constituted by diatoms and sponge spicules (Romariz et al. 1979; Cachão 1992). Rare fish remains, mainly scales and isolated bones, can also be found.

Material and methods

Previous sampling for calcareous nanoplankton research scanned the entire sequence and determined that diagenesis increases upwards while diatom and spicule content decreases in that same direction. Thus three samples from the lowermost sector were selected for the present study (Fig. 2). Rock bulk samples were dissolved in weak hydrochloric acid and siliceous spicules picked-up under binocular microscope. The spicules were mounted on a stub and investigated under SEM. No significant difference in spicule composition was found between the various samples. The identification of the sponges was performed by comparison with characteristic spicules of Recent sponges. Terminology of spicules can be found in Boury-Esnault & Rützler (1997) and Hooper & Van Soest (2002).

All the investigated material of sponge spicules is housed in the Institute of Paleobiology, Polish Academy of Sciences, Warszawa, under the collection number ZPAL Pl.19.

The sponge spicules of Mem Moniz

Hexactinellid spicules

Hexactinellida, Schmidt, 1870 (for basic taxonomy of Recent and fossil hexactinellid sponges see Reiswig 2002 and Krautter 2002) are characterized by triaxial spicules (= hexactines) or their derivatives. Hexactinellid spicules are very rare in our samples. They are represented only by loose hexactines and pentactines. The pentactines (Fig. 3A-D) are ectosomal spicules (outer surface or spongocel surface), while hexactines (Fig. 3E-G) are most probably choanosomal spicules, but may in part belong to the ectosome as well. None of these spicules are characteristic of any particular group of hexactinellids, but absence of fragments of fused choanosomal skeleton, suggest that we are dealing, most probably, with Lyssacinosia Schulze, 1886 (Hexasterophora Schulze, 1886). Similar spicules occur in Amphidiscophora, but this is a benthal/abyssal group today and most probably it was in the Miocene, its presence being rather improbable in the Mem Moniz deposits.

Today, all hexactinellid sponges inhabit deep water environments (Reid 1968; Vacelet 1988), with the exception of such specific habitats as submarine caves (Vacelet et al. 1994) and fjords (Vacelet 1988; Leys et al. 2004) where they may be found in shallow water, what is associated with their preference of stable environments and low and turbulence (Mehl 1992). There are no data specific to the Miocene, but there is no indication that this situation was different than today.

Fig. 3 - Hexactinellid spicules (most probably Lyssacinosia); A-D : ectosomal pentactines; E-G : hexactines, Scale bars 100 μm.
Fig. 4 - Geodiid (Astrophorida) spicules. A-F. Aspidasters of *Eurylus* sp.; A-E: scale bar 50 μm; F: scale bar 20 μm; G-O. Sterasters of *Geodia*. G. scale bar 100 μm. L. details of, scale bar 20 μm; O. scale bar 20 μm.
Demospicule spongals

Demospicules are characterised by spicules (loose or articulated, in the case of lithistids), which may be tetraxial and/or monaxial, but are never triaxial (see Hooper & Van Soest 2002). Demospicule spongals are the most common in the investigated deposits. Some of the more morphologically complex spicules are very characteristic, allowing a more or less precise taxonomic assignment. Others, usually morphologically simpler, have no diagnostic value, and may belong to various groups of soft demospicules. They are described and illustrated here without attribution to lower taxonomic groups.

Geodiid spicules. The family Geodiidae Gray, 1867 (Astrophorida Sollas, 1888) is characterised by the presence of large oxeas and triaenes among megascleres; microscleres are spherasters, eustasters or microrhbds (Uriz 2002a). Spicules undoubtedly assigned to the family Geodiidae are represented in the examined material by various spherasters, and their variant called aspidaster. These spicules occur in the outermost layer of a sponge, forming a very dense layer. They are the most common demospinceule spicules in our samples. Aspidasters (Fig. 4A–F), which are a flattened version of spheraster, are characteristic of the Recent genus Euryalys Gray, 1867 (Uriz 2002a). Typical spherasters are represented in our material by three morphological types, which differ in size and, particularly, in surface sculpture: type 1 (Fig. 4G, M–O), type 2 (Fig. 4H–I) and type 3 (Fig. 4J–L). The type 3, however, may as well simply be an early developmental stage of the other spheraster types. The observed differences exceed, however, those observed today in one species, suggesting we most probably are dealing with several different species in our material.

Unfortunately, the taxonomy of Recent geodiid spongals is based on the sponge structure and on the assemblage of spicules (one sponge contains several different types of spicules) (Uriz 2002a), not on the morphology of spherasters. In Recent forms spherasters with various sculptures may be assigned to the same genus, whereas spicules with similar spheraster sculpture may occur in different genera. This is clearly a matter in need of further investigation based on Recent material. Thus, in the case of disassociated fossil spicules, it is impossible to determine with certainty the genus they belong to. However, in this case, it most probably was Geodia Lamarck, 1815, as suggested by its shape.

Geodiid demospicules have also various styles, oxeas and triaenes, but in the isolated form they are not characteristic enough to be recognized as belonging to geodiids. Thus, one cannot exclude that some oxeas and styles and triaenes from the investigated material may indeed belong to geodiid spongals. Similar spicules occur in other astrophorid spongals as well. Geodiid spongals occur world-wide and have wide bathymetric ranges, but are typical of bathyal depths and soft bottoms (Uriz 2002a). The species Euryalys eustrum (Schmidt, 1868), known from the Atlantic and the Mediterranean was reported, for example, from a depth between 3 m and 1384 m (Boury-Esnault et al. 1994). The genus Geodia has an intertidal to bathyal (~2840 m) distribution (Vacelet 1988). Therefore spherasters cannot be used as reliable bathymetric indicators.

Questionable fossil spherasters of Geodiidae have been reported, in thin sections, from rocks as old as Cambrian (Reitner & Mehl 1995), but well preserved spherasters are known only since the Jurassic (Reiff 1967; Wiedenmayer 1994). A Miocene geodiid sponge, bodily preserved, was described from Spain by Brimaud & Vachard (1986). Isolated geodiid spherasters were described from the Paleocene of the Alabama by Rigby & Smith (1992), from th Lévi e Eocene of Australia (Hinde 1910) and New Zealand (Hinde & Holmes 1892), from the Miocene of Italy (Bonci et al. 1990, 1997; Queirolo et al. 2002), and Moravia (Riha 1982; Pysora & Hladilova 2003). In paleontological papers, spicules morphologically similar to spherasters, but monaxial (spherasters are polyactinal), the selenasters, typical of Recent Placospongiidae Gray, 1867, are often erroneously ascribed to Geodiideae. Selenasters are very common, for example, in the Upper Jurassic sponge facies in Europe (see e.g., Pysora 1997). The oldest known aspidasters of Euryalys are known from the Upper Cretaceous of Germany (Wiedenmayer 1994). Eocene aspidasters were reported by Hinde & Holmes (1892) from New Zealand.

Lithistid spicules. Lithistid spongals are a polyphyletic group of demospicules sharing one common character: they have a choanosomal skeleton composed of articulated, more or less irregular spicules called desmas (Pysora & Lévi 2002a). Lithistid spongals, however, differ in the type of desmas as well as the type of ectosomal spicules and associated microscleres. Both choanosomal desmas and ectosomal spicules occur in the investigated material. The most common are ectosomal phyllo- triaenes (Fig. 5A–H). Discoceratia are very rare (Fig. 5I). Both are characteristic of lithistid spongals of the family Theonellidae Lendenfeld, 1903 (Pysora & Lévi 2002a, b). Morphological variability of phylloceratia is rather low and probably they belong to one species; discoceratia may belong to a second, different species. Tetracline desmas are rare (Fig. 5J–K). They occur, among others, in the Theonellidae (Pysora & Lévi 2002a, b), thus they probably are conspecific with the ectosomal phylloceratia. The most common choanosomal desmas in our material are the rhizoclines (Fig. 5L–O), which occur in various Recent families (Pysora & Lévi 2002a). In the paleontological literature they usually are assigned to Rhizomorina (Pysora 2002).
loose phyllotrianes are already present in Triassic sediments (Mostler 1978; Widenmayer 1994).

Samid spicules. Samidae Sollas, 1888 are a monotypic demosponge group assigned on the basis of sigmaspore microscleres to Spirophorida Bergquist & Hogg, 1969 (Van Soest & Hooper 2002). In our material amphiatrienes are common (Fig. 6), closely resembling the only known recent species Samia ambiguus Gray, 1867. The first undoubted fossil occurrence of the genus Samia was reported from the upper Aquitanian-Burdigalian of Italy, and erroneously described as ‘dichotraenae spicule’ by Bonci et al. (1990, pl. 8, fig. 12). However, Widenmayer (1994) suggested that the Eocene spicules assigned by Hinde & Holmes (1892) to Ditriella, from the Eocene Oamaru Diatomite (New Zealand), should also be ascribed to this genus. S. ambiguus is a neritic sponge with excavating habit, reported from various regions of the world (Widenmayer 1994; Van Soest & Hooper 2002), including the Mediterranean where it occurs in shallow submarine caves (Pulitzer Finali 1983). The palaeoenvironment associated with the fossil occurrence from Italy was interpreted, based on forams, diatoms, and facies analysis, as an outer shelf to upper slope open marine environment (Bonci et al. 1990).

Alecid spicules. The family Alecostaeidae Rosell, 1996 (Hadromerida Topsent, 1894) is represented among the studied spicules by rare acanthoaxes (Fig. 7N), and another characteristically tuberculated oxeas (Fig. 7O-R). The acanthoaxes closely resemble the ones from the Recent species Alectona miliares Carter, 1879 (Rützler 2002), whereas the tuberculated oxeas are identical to the spicules of the Recent species A. wallichii (Carter, 1874) (Bavastrello et al. 1998; Rützler 2002). Noteworthy is the case of this last species. So far, A. wallichii had been reported only from the Indo-Pacific, but recently it was also discovered in a submarine cave.
on the Lebanese coast (J. Vacelet, 2004, pers. comm.). A
such distribution, fossil and Recent, may be another
example of the Tethyan relict (cf. Boury-Esnault et al.

The predominantly circumtropical genus Aleato-
na Carter, 1879 is excavating in habit and known from
the Indo-Pacific, Atlantic and the Mediterranean, from
very shallow water down to depths of 664 m (Bavestrel-
lo et al. 1998).

Other "soft" demosponge spicules. By "soft" de-
mospoites we understand those sponges which have no
articulated choanosomal spicules, i.e., all non-lithistid
demospines with siliceous spicules.

The family Anconiniidae Schmidt, 1870 (Astro-
phorida Sollas, 1888) is characterised by the presence
of various triaenes with long rhombide and oxeas.
Characteristic microscleres are oxeas, sanidases
and microcrabs. Some of the plagiotriaenes (Fig. 8A-
D, J) and orthotriaenes (Fig. 81) present in our material
belong, most probably, to Anconiniidae. Some of the
oxyasters (Pl. 9E-F) and dichotriaenes (Fig. 10H-I) are
very similar to those known from some Stellata species
(e.g., Lévi & Lévi 1983, figs. 23-25). Anthasters (Fig. 9J-
K) also occur among anconinid sponges (e.g., Lévi 1958,
fig. 3), but their attribution is less certain, because simi-
lar spicules may be found in other demosponge groups.

Wiedenmayer (1994) attributed fossil anthasters to spir-
astellid (Hadoromerida, Spirastellidae Ridley & Dendy,
1886) and/or chondrillid demosponges (Chondrosida
Boury-Esnault & Lopes, 1985; Chondrillidae Gray,
1872). Anthasters were described from the Eocene of
New Zealand by Hinde & Holmes (1892). Some large
oxeas, already mentioned when discussing geodiid
sponges, may in part belong to anconinids as well. To-
day Anconiniidae are known from soft to hard bottom
and from shallow to bathyal depths (Uriz 2002b).

Triaenes of calthrop type (Fig. 10A-F), or their
modifications, are also very common in the investi-
gated deposits. They characterize two Recent families:
Pachastrelinidae Carter, 1875, and Calthropellidae Len-
denfeld, 1907 (both Astrophorida) (see Maldonado
2002; Van Soest & Hooper 2002). Unfortunately, the
difference between representatives of these families lies
in other spicule elements, thus it is impossible to tell
to which group they belong for sure. Some of the
ectosomal dichotriaenes (Fig. 10G-I) found in the same
samples may also belong to pachastrellid and/or cal-
thropellid sponges. However, similar spicules also oc-
cur in anconinids (especially Fig. 10H-I) or lithistids
(Fig. 10G).

Very common in the investigated material are pro-
triaenes, short shafted triaenes (Fig. 8E-G) which
may occur in various astrophorid demosponges.

Large oxyasters (Fig. 9E-F) and spherasteres (Fig.
9G-H) resemble megasters known from the family
Tethyidae (Hadoromerida Topsent, 1894) (Sara & Bavas-
trello 1996), but similar spicules may occur also in An-
coniniidae (see Stelleta hyperoxea in Lévi & Lévi 1983).
Other spherasteres (Fig. 9A-D, I) common in the studied
material may also belong to hadromerid sponges.

Oxeas (Fig. 7A-C, G-H, J-K) are a very general-
ised type of spicules and, as such, are not characteris-
tic of any particular demosponge, occurring as main and/
or accessory spicules in nearly all demosponge groups.
Bearing in mind the undoubted presence (see above) of
goedid and anconinid demosponges in the investigated
material, the large oxeas (Fig. 7A-C) present in the stu-
died assemblage belong, most probably, to these
sponges. A similar problem is posed by strongyloxeas
(Fig. 7D-E), styles (Fig. 7F, I), and diaenes (Fig. 7L) which
are too generalized to be attributed to any particular
demosponge group. Nonetheless, some sculptured ox-
eote spicules may be very characteristic and even allow a rather precise attribution. The acanthoxea illustrated in the Fig. 7: M is identical to those occurring in sponges of Recent genus *Acanthotetilla* Burton, 1959 (see fig. 1 and pl. 2c-d in Van Soest 1977 and Van Soest & Rützler 2002).

**The paleoenvironment of the Mem Moniz marls**

The almost complete absence of macrofossils, namely of benthic organisms, quite common in almost all other Southern Portuguese Miocene shallow marine facies, together with the absence of bioturbation may be
interpreted as reflecting anoxic or suboxic bottom conditions. This interpretation is sustained by the occurrence of benthic Foraminifera of the families Buliminidae, Bolivinidae and Uvigerinidae (Antunes et al. 1990). These taxa are typical of environments rich in organic matter that accumulated in more or less restricted bottom conditions, thus generating oxygen poor bottom environment conditions and their presence in these deposits suggest that similar conditions prevailed in the Mem Moniz palaeoenvironment. The high ratio of benthic versus planktic Foraminifera, and the dominance of the coastal genera Nonion, Ammonia and Gibicides (Romariz et al. 1979) suggest a shallow marine environment for this sector of the Algarve platform during Middle Miocene times.

The siliceous flora is dominated by Chaetoceros RS, Paralia sulcata and Thalassionema nitzschoides, meroplanktonic and planktic species commonly occurring in coastal upwelling areas. The calcareous nanoplankton assemblage is dominated by Noelaerhabdaceae (mainly Reticulofenestrids) followed by Coccolithaceae (mainly Coccolithus pelagicus s.l.) and Helicosphaeraceae. The presence of these groups, together with the absence of asteroliths, are indicative of shallow marine productive environmental conditions (Cachão 1995).

It seems that many sponge spicules found in the investigated rocks came from animals living outside the area of their final deposition. The studied assemblage shows evidences of some sorting (lack of larger spicules which occur in the same sponges as here recognized), suggesting that at least some spicules were washed in from the surrounding environments. This interpretation is also supported by the fact that lithistid sponges usually colonize hard substrata, which are lacking in the Mem Moniz marls outcrop. The presence of Samus sp., sponges, which bore into hard carbonate substrata, equally supports this interpretation. The soft demosponge spicules attributable to Alectona (a boring sponge), again, tell a similar story: no calcareous hard substrate which could be bored was found in this outcrop. Moreover, lithistid sponges, due to their articulated choanosomal skeleton, have a relatively high preservation potential. Therefore, if such sponges inhabited the Mem Moniz marls area during its deposition (which clearly occurred under low hydrodynamic conditions), then we should find at least some body fragments of these sponges, not only isolated spicules.

Taking into account the excellent preservation shown by all the examined material, the spicules, most probably, were subjected to a transport over a short distance. At least part of the spicules were washed in from surrounding environments which had the hard

Fig. 8 - Various "soft" demosponge triaenes (Astrophorida): A-D, orthotriaenes (probably Anconitidae); E-F, protriaenes; H, anatriaene; I, orthotriaene; K-M, plagiodiotriaenes. A-G, I-N, scale bars 200 μm; H, scale bars 100 μm.
carbonate substrate (shells of molluscs, for example) necessary for some of the identified sponges. This idea is supported by the common presence of sponge borings in the molluscan bioclasts in other correlative Miocene units that surround the Mem Moniz marls.

The bathymetric situation of the Mem Moniz marls palaeoenvironment is difficult to estimate based solely on sponge spicules, because most of the identified sponges show very wide bathymetric ranges (see above). However, due to the presence of lithistid and (although rare) of hexactinellid sponges we can be sure that it was not an infralittoral assemblage. Hexactinellid sponges are characteristic of depths of at least several tens of meters. Furthermore, lithistid sponges, if we exclude the special case of submarine caves and/or fjords, are typical of depths of at least several tens, if not hundreds of meters or more. This bathymetric interpretation is also supported by the astrophorid dominance which in recent oceans characterize deeper water environments (Maldonado 1992; Maldonado & Young 1996). Taking into consideration all the available data a depth below the storm wave base can be envisaged for the palaeoenvironment of deposition of the Mem Moniz marls.

Conclusions

The Middle Serravalian Mem Moniz marls (Algarve, Portugal) contain a rich and diversified siliceous sponge spicules assemblage, indicating the existence of a diverse sponge fauna, mainly of demosponges, that were dominated by astrophorids and including lithistids. Hexactinellids are relatively rare and represented by Lyssacinosia.

Among the sponges identified, the most common are geodiids, including Eurylus sp. and probably Geoidea sp. (Astrophorida). Samus sp. (Spirophorida) and Allocellaria wallischi (Hadromerida) were also identified, both until now unknown in the fossil record. Less certain is the identification of A. milliari. Among the lithistids, the theonellids and thizomorinids were present. Other demosponges are represented by anconinids (Astrophorida) and, hadromerids (among them probably
Tethyidae), as well as pachastrellids (and/or calthropellids) (Astrophorida). The sponge assemblage of the type occurring in the Mem Moniz marls is characteristic neither of very shallow nor very deep environment and most indicates a depth of below the storm wave base (probably 100 meters or more).

Acknowledgments. Contribution of the Portuguese FCT Project POCI/32724/PAL/2000 ("Comparative (paleo)environmental analysis of oceanic and coastal domains, over the last 20 Ms, based on calcareous nannoplankton", CANAL), co-financed by FEDER. The authors thank Bernard Landau for linguistic improvements of the manuscript.

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