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Paleontology and diagenesis of Upper Jurassic siliceous sponges from the Mazagan Escarpment

Siliceous sponges
Jurassic
Paleontology
Diagenesis
Continental margins

Éponges silicieuses
Jurassique
Paléontologie
Diagenèse
Marges continentales

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ABSTRACT

During the CYAMAZ deep diving project, two well preserved Upper Jurassic siliceous sponges were recovered from columnar stromatolitic peloidal packstones which constitute the main lithology at the Mazagan Escarpment. These sponges belong to the genera *Thyroidium leptophyllum* (Quenstedt) and *Paracraticularia* sp. *Thyroidium leptophyllum* is known to be not younger than Kimmeridgian. This sponge is thus an important fossil for dating the massive core of the Mazagan platform margin. Thin-sections of other samples show that siliceous sponges are not limited to the stromatolitic peloidal facies, but were also found in hemipelagic calpionellid limestones. Diagenesis of the siliceous sponges is characterized by the dissolution of the skeletal lattice at different stages of lithification of interskeletal sediment. Well lithified interskeletal sediment conserves the solution cavities of the skeleton. The molds are refilled by calcite and the skeletal lattice is preserved. Unlithified sediment collapses after dissolution of the skeletal opal. As the sponge body is maintained by bacterial lithification of the surrounding sediment, the resulting solution cavities show geopetal fabrics. Water turbulence and sediment transport are responsible for the very rapid decay of the organic matter and the rapid covering of the sponges before dissolution of the opaline skeleton.

Oceanol. Acta, **1984.** Submersible Cyana studies of the Mazagan Escarpment (Moroccan continental margin), CYAMAZ cruise 1982, 93-100.

RÉSUMÉ

La paléontologie et la diagenèse des éponges silicieuses jurassiques de l'escarpement de Mazagan

Pendant le projet submersible CYAMAZ, on a trouvé deux éponges silicieuses de l'âge jurassique supérieur dans des sédiments péloïdaux stromatolithiques. Ce sédiment représente la lithologie la plus importante de l'escarpement de Mazagan. Les éponges sont de l'espèce *Thyroidium* (?) *cf. leptophyllum* (Quenstedt) et *Paracraticularia* sp. Le *Thyroidium leptophyllum* caractérise le Kimmeridgien et des couches plus vieilles et constitue un fossile très utile pour dater le sédiment central de la marge de la plate-forme carbonatée de Mazagan. La diagenèse de ces éponges silicieuses est contrôlée à différents degrés de lithification du sédiment dans le réseau spiculaire. Quand le sédiment interne est bien lithifié, les spicules sont épigénisés par calcite. Quand le sédiment interne n'est pas lithifié, des structures de collapse se forment après la dissolution de l'opale. Ces éponges contiennent des cavités à remplissage géopétal. Ces phénomènes sont le résultat de la lithification rapide du sédiment péloïdal autour des éponges avant la dissolution du réseau spiculaire, dans un régime sédimentaire bien agité et oxygéné.

Oceanol. Acta, **1984.** Études par le submersible Cyana de l'escarpement de Mazagan (marge continentale marocaine), campagne CYAMAZ 1982, 93-100.

INTRODUCTION

The seaward margin of the Mazagan Plateau (NW African continental margin) is largely composed of Upper Jurassic massive limestones. During the CYAMAZ deep diving project, well preserved calcitized siliceous sponges of Jurassic are were found. In sample no. 7 (2 207 m) from dive 91, two specimens of hexactinellid sponges were recovered. They grew in a light-coloured peloidal stromatolitic limestone (Steiger, Cousin, this volume). Other samples also contain calcitized hexactinellid and lithistid siliceous sponges. All along the slope of the Mazagan Plateau, Upper Jurassic sediments containing remains of siliceous sponges were observed. They were found in coarse-grained calcareous breccias of a periplatform talus in front of the *in situ* laminated stromatolitic massive limestones (site 547B, DSDP Leg 79, Steiger, Jansa, 1984). Miocene gravity flow deposits recovered at a distance of 2 km in front of the slope and mostly composed of Jurassic material (site 545) also contain calcitized siliceous sponges. Here, the sponges are embedded in a calpionellid limestone facies. The most seaward location of Upper Jurassic siliceous sponges was found on a very slowly subsiding block 6 km off the margin of the Mazagan shallow-water platform. In this area the sponges were associated with shells of pelagic bivalves and cyanobacterial oncoids.

THE SEDIMENT

The Jurassic siliceous sponges were deposited in two different lithological facies types : firstly, in a calpionellid-bearing hemipelagic, lithoclastic to bioclastic packstone (microfacies 4, *sensu* Steiger and Cousin = microfacies 1, *sensu* von Rad *et al.*, all this volume) ; secondly, in a columnar stromatolitic peloidal packstone (microfacies 1 *sensu* Steiger and Cousin, this volume). This sediment is largely composed of peloids (Plate 2 : Fig. 1), small intraclasts, irregularly contoured ooids (Plate 2 : Fig. 2), small foraminifera and small bioclasts. The sedimentary particles are deposited in laminated domal and columnar structures cemented by micrite. These structures develop from massive bioclastic and intraclastic grainstones with the same constituents, but cemented by sparite.

The columnar stromatolitic peloidal packstones are strongly interlayered by high-energy lagoonal bioclastic grainstones, containing debris of corals and dasycladacean algae.

The columnar structures of the peloidal packstone are most probably the result of biological lithification, possibly by cyanobacterians. Early diagenetic lithification is also indicated by the fact that the stromatolitic laminae are overgrown by sessile foraminifera and that they were overgrown by terebratulid brachiopods. The structure of the rock (convex peloidal stromatolites and detrital sediment lapping on the stromatolitic structures) suggests rapid growth of the stromatolites. Their random distribution implies formation as a knobby sedimentary surface. The rigid stromatolitic domes and columns could have acted as a substrate for the settlement of siliceous sponges.

THE SPONGES

In this chapter the sponges found in sample CZ 91-7 will be described systematically (for the location of samples *see* Auzende *et al.*, this volume).

Occurrence and preservation

The two cup-shaped siliceous sponges were easily recognized on the rock specimen. In part, their outer surfaces were well prepared by unknown processes. All ostia of the sponge paragaster were visible on the external side of the body. Technical preparation was necessary to observe the internal wall of the paragaster and to determine whether the smaller sponge budded from the larger one.

Most of the rock sample was covered by a series of two calcite crusts, interlayered by pale yellowish brown nannofossil ooze. The youngest calcite crust is covered by manganese oxides. The two siliceous sponges were not encrusted by calcite. Large open spaces below the crusts can be assumed, where the calcitized sponge skeletons were possibly affected by selective dissolution.

The oscular area of the larger sponge was partly filled with peloidal sediment. Thin-sections of the oscular areas of other siliceous sponges show that it was open in the Cretaceous and then partly filled with glauconite-rich phosphates during late Cretaceous phosphatization events (von Rad, this volume).

Description and taxonomy

The determination of the sponges was made after the monograph of Schrammen (1936).

Sponge A

Class	Hysalospongea Vosmaer, 1886.
Order	Dictyida Zittel, 1877.
Family	Craticulariadae Rauff, 1894.
Genus	Thyroidium de Laubenfels, 1955.

Thyroidium (?) *cf. leptophyllum* (Quenstedt)
(Pl. 1, Fig. 1, 3, 4).

Synonymie :

1878 : *Spongites leptophyllus gigas* Quenstedt. [Quenstedt, p. 61, Pl. 117, Fig. 1-2 (Kimmeridge : Böllert, Hossingen, Swabian Alb, Germany)].

1897 : *Craticularia leptophylla* Quenst. sp. [Oppliger, p. 24-25 (Oxford, Crenularis-Schichten : Baden, Swiss Jura)].

1910 : *Craticularia cf. leptophyllus gigas* Quenst. [Kolb, p. 163 (Kimmeridge : Heuberg (Hossingen, Böllert), Swabian Alb, Germany)].

1913 : *Craticularia propinqua* Gf. [Siemiradzki, p. 21 (Kimmeridge, Zone of Oppelia tenuilobata : Podgórze, Poland)].

1915 : *Craticularia leptophyllus gigas* Quenstedt sp. [Oppliger, p. 17 (Oxford, Birmensdorfer Schichten : Hersberg, Birmensdorf, Balstal, Fretreules, Swiss Jura)].

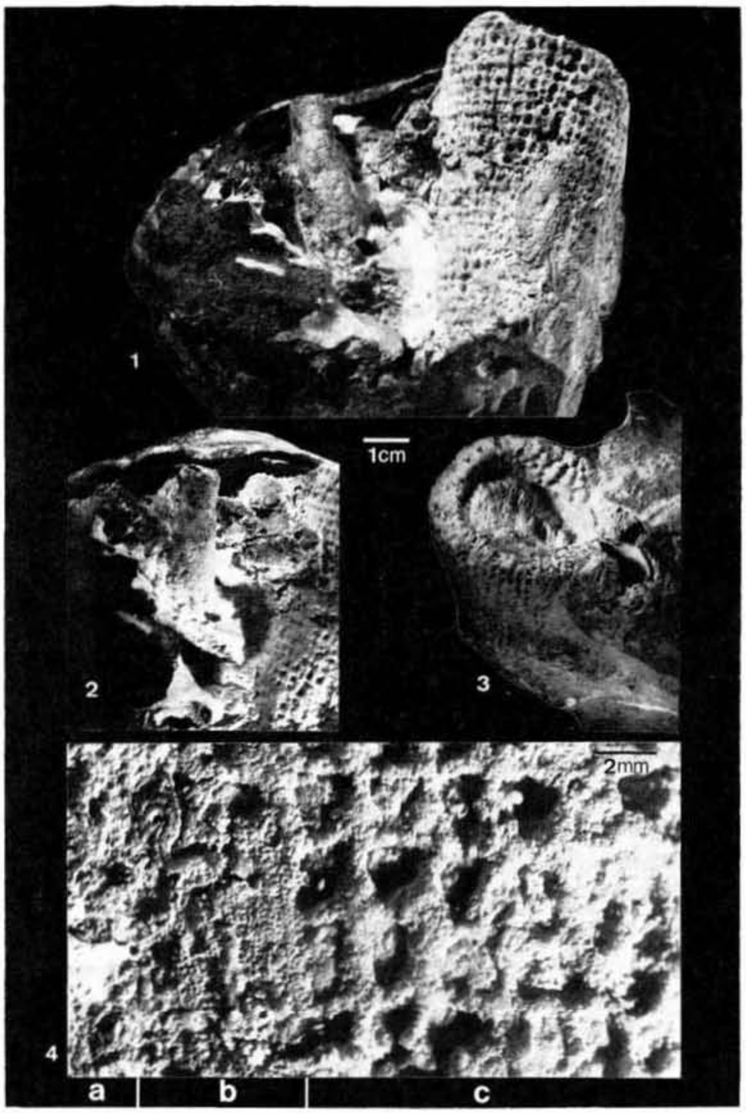


Plate 1

Figure 1

Sample CZ 91/2. Calcitized siliceous sponges from the central Mazagan Escarpment. The large sponge to the right (sponge A, see description chapter 3) is Thyroidium (?) *cf.* leptophyllum *(Quenstedt). The small sponge to the left (sponge B) is* Paracraticularia (?) *sp. The base of* Thyroidium leptophyllum *is cut and the open central cavity is visible. The left portion and the upper side of the rock specimen is covered by manganese and calcite crusts, which are interbedded with soft nannofossil ooze (washed out). Scale : 1 : 1,2.*

Figure 2

Paracraticularia (?) *sp. This cylindrical sponge in* in situ *position, attached to a peloidal crust of the columnar stromatolitic peloidal packstone (Microfacies 1). Note the rectangular arrangement of the very small ostia. Scale : 1 : 1,2.*

Figure 3

Thyroidium (?) *cf.* leptophyllum *(Quenstedt). The oscular space is filled with hard, crustose peloidal sediment. The postica appearing on the inner surface of the paragaster are tentatively arranged in vertical rows. Scale : 1 : 1.*

Figure 4

Thyroidium (?) *cf.* leptophyllum *(Quenstedt). The « etched » outer surface of the sponge. From left to right : a) peloidal crustose sediment ; b) sessile foraminifer attached to the marginal layer of the sponge skeleton ; c) vertically and horizontally arranged ostia, separated by the framework of the inner skeletal zones of the sponge and filled with peloidal sediment. The skeleton of the sponge is calcitized. Due to recrystallization, the spicula are deformed and undeterminable. Scale : 1 : 8.*

1926 : *Craticularia gigas* Quenst. sp. [Oppligeer, p. 8 (Oxfordian, Birmensdorfer Schichten : Hersberg, Birmensdorf, Balstal, Fretreules, Vallorbes, Swiss Jura ; Oxford, Wangener Schichten : Baden, Swiss Jura ; Kimmeridge, Badener Schichten : Baden, Swiss Jura)].

1936 : *Thyridium leptophyllum* Quenst. sp. [Schrammen, p. 32 (Kimmeridge, Tieringen, Hossingen, Waldhausen, Swabian Alb, Germany)].

Material

Sample CZ 91/7, one calcitized specimen, basal portion not preserved.

Description

The sponge has the shape of a very slender cone. The round ostia are arranged in regular horizontal and vertical rows, the vertical distance between the ostia is slightly greater than the horizontal distance.

As the diameter of the sponge increases upward, new vertical rows of ostia are intercalated between the existing ones. Only the first two or three ostia of each new row have a smaller diameter (Plate 1, Fig. 1).

The postica are round to elongate. Like the ostia, they are arranged in regular rows. In a few spots, the postica appear to be arranged in vertical furrows (Plate 1, Fig. 3).

The aporhyses and epirhyses (inhalant and exhalant canals) are straight, and each end beyonds the opposite surface of the sponge. The central cavity is wide and expands continuously upward through the total length of the sponge ; the wall does not become thinner towards the base of the sponge body.

Remainders of the skeletal meshwork can be seen between the ostia (Pl. 1, Fig. 4), but due to recrystallization individual spicules are not discernible.

Dimensions

Length : 78 mm. Diameter at the upper end : 40 × 47 mm. Diameter at the basal end : 29 mm. Diameter of the ostia : 1-2 mm (1,5 mm, average). Density of the ostia : 18/cm^2, average. Diameter of the postica : 1,3 × 1,3 mm up to 1,3 × 2,0 mm. Density of the postica : 16-20/cm^2. Thickness of the wall : 7-8,5 mm.

Remarks

The sponge has been assigned to the species *Leptophyllum* because of the dimension, shape, and arrangement of the ostia and postica, and because of the wall thickness, although Schrammen (1936 : 32) gives a slightly different density of the ostia (20-25 ostia/cm^2).

However, Schrammen (1.c.) does not describe any other sponge of this family with a skeletal construction *and* a distribution of the ostia similar to this specimen.

Thyroidium leptophyllum is generally described from platy fragments, thus indicating a large growth form of the species (Kolb, 1910 : 163 ; Oppliger, 1897 : 24 ; 1915 : 17 ; 1926 : 8 ; Siemiradzki, 1913 : 21). Yet a large size is not considered to be an important species criterion.

According to Schrammen (1.c.), the characteristic of the genus is the arrangement of the postica in vertical furrows. Unfortunately, this is not clearly discernible in the specimen, because the central cavity and the canals are filled with a hard carbonate sediment, which cannot be removed.

Sponge B

Genus Paracraticularia Schrammen, 1936

Paracraticularia (?) sp.

(Pl. 1, Fig. 2).

Material

Sample CZ 91/7, one calcitized specimen.

Description

The sponge is approximately cylindrical with a rounded upper termination. The lower part of the body is tapered with the base hidden in the carbonate sediment. The tiny ostia are arranged in regular horizontal and vertical rows. The vertical distance between the ostia is slightly greater than the horizontal distance.

The postica appear very undistinctly, only at one point on the inner wall is their distributional pattern visible. They seem to be arranged like the ostia.

The central cavity extends through the whole length of the sponge. From base to top the wall does not increase in diameter.

Because of the calcitization of the sponge skeleton, no spicules nor canals are discernible.

Dimensions

Length : 40 mm. Diameter at the upper end : 10 × 16 mm. Density of the ostia : 110-130/cm^2. Thickness of the wall near the upper end : 2 mm.

Remarks

Schrammen (1936 : 28) defined the genus *Paracraticularia* as the branched growth form of *Craticularia* Zittel (1877). Ziegler (1962 : 575-576) considered *Paracraticularia* invalid, because branched specimens of *Craticularia parallela* (Goldfuss) also occur, and the general characteristics of the skeleton of both genera were the same.

However, the genus *Paracraticularia* has not been revised, and the specimen recovered in sample CZ 91/7 can be referred to this genus because it is only comparable to the following three species :

— *Paracraticularia striato-punctata* Schrammen, 1936 (Early Oxfordian of the Franconian Alb, Germany).

This species has only up to 100 ostia/cm^2.

— *Paracraticularia tubifera* Schrammen, 1936 (Middle Kimmeridgian of the Swabian Alb and the Franconian Alb, Germany).

This species has colonial growth form and has only up to 100 ostia/cm^2.

— *Paracraticularia radiciformis* Schrammen, 1936 (Upper Kimmeridgian of the Swabian Alb).

The species is branched and has 150-160 ostia/cm^2.

Sponge diagenesis

Diagenesis of siliceous sponges is characterized by the calcitization of the opaline skeleton and by a good preservation of the entire sponge body. But fossil siliceous sponges may also have a complete shape without having a preserved skeletal lattice. Thin-sections of the siliceous sponges found at the Mazagan Plateau show that the skeleton :

— may be entirely calcitized (Pl. 2 : Fig. 3),

— may be partly removed and replaced by sediment (Pl. 2 : Fig. 4),

— may be totally removed and replaced by sediment.

In all cases the sponge body is preserved.

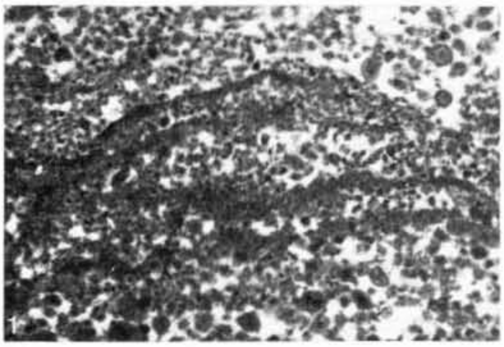
Entirely calcitized fossil sponges contain fine-grained peloidal sediment. The skeleton obviously acted as a baffle after the decay of the organic matter. The most interesting question is, how the shape of the sponge could be preserved when the skeleton was completely dissolved. The character of the surrounding sediment helps us to understand the very complex history of this type of sponge diagenesis. As argued above, the peloidal sediment was probably actively accumulated by bacterial crustose lithification. This suggests rapid cementation of the sediment. Crusts do not occur within the skeletal lattice. This means that the internal sediment must have been lithified by other processes.

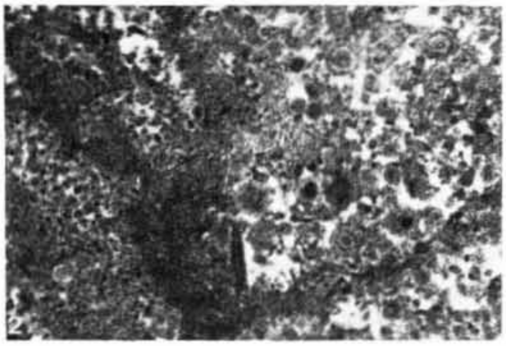
One of the recovered sponges has an almost dissolved skeleton. In the area of the paragaster a particular type of vugs occurs, arranged in three and four rows from top to bottom. The vugs are geopetally filled and fixed to the areas of the former skeletal lattice (Pl. 3).

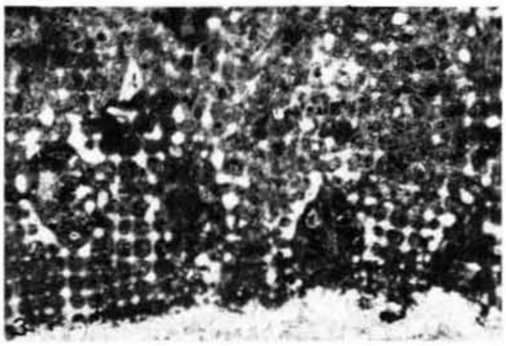
The skeletons of the other sponges recovered from the Mazagan platform limestones and hemipelagic calpionellid limestones show completely preserved calcitized skeletons (Pl. 2 : Fig. 3). According to thin-section observations, we present the following model (Fig.) :

1) Death of the sponge and complete decay of the organic matter.

2) The siliceous skeleton is completely or partly uncovered and exposed to sea water. The skeleton is partially overgrown by sessile organisms (serpulids, miliolid foraminifera, Pl. 1 : Fig. 4 and Pl. 3).







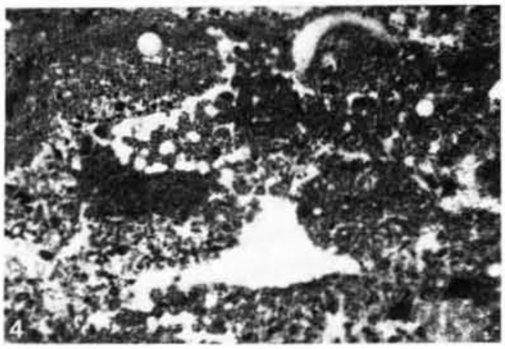


Plate 2

Figure 1

Crustose domal stromatolitic peloidal packstone (microfacies 1) from the seaward Upper Jurassic margin of the Mazagan carbonate platform. Most of the components are peloids. The micritic layers are microhardgrounds, probably cemented by cyanobacterians. In this sediment siliceous sponges occur with scattered distribution. Sample : CZ 91-7, 40 x.

Figure 3

Calcitized hexactinellid siliceous sponge. Most of the skeleton is calcitized and preserved. Detrital sediment composed of peloids has been deposited between the spicula. Sample : CZ 87-3, 40 x.

Figure 2

Crustose peloidal packstone (microfacies 1). Note the occurrence of ooids, which contain peloids as a nucleus. The development of the ooids ranges from superficial ooids to normal ooids with many rims of carbonate crystals. The surfaces of the rims are irregular. Sample : CZ 91-7, 40 x.

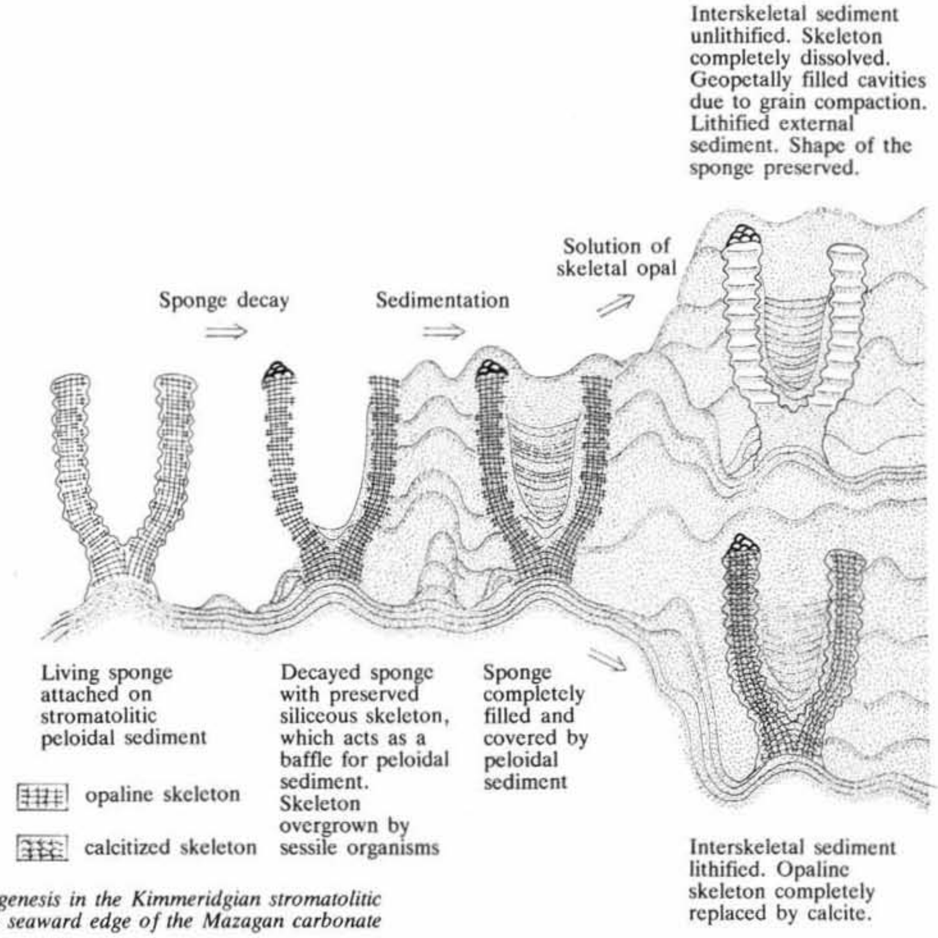
Figure 4

Marginal section of a fossil siliceous sponge. In the upper part the sponge skeleton is preserved and calcitized. In the lower part the siliceous skeleton was dissolved before lithification of the internal sediment of the meshwork. Collapse and graincompaction led to geopetally filled cavities. Sample : CZ 88-5, 40 x.

Plate 3

Figure

Siliceous sponge fossilized in the columnar stromatolitic peloidal limestone (microfacies 1). The sponge paragaster is preserved in situ, *and surrounded by peloidal and bioclastic sediment (1). Crustose laminated peloidal material (2) fills the oscular cavity. A hole (possibly a bore hole) in the center of the oscular sediment is also filled with laterally onlapping sediment. The inner surface of the left part of the paragaster is covered by a micritic peloidal crust (3). The top of the left part is overgrown by sessile foraminifera (4). The entire section of the sponge contains geopetally filled cavities (5), which indicate dissolution of the siliceous skeleton before lithification of the intraskeletal sediment. The shape of the sponge is well preserved, probably as a consequence of early bacterial lithification of the surrounding sediment. The epi- and aporhysal infill was also lithified at an early stage and hard enough to support the internal fabric. This is responsible for the distributional pattern of the geopetally filled cavities. Sample : CZ 88-5, 6x.*



Figure

Model of sponge diagenesis in the Kimmeridgian stromatolitic peloidal facies of the seaward edge of the Mazagan carbonate platform.

3) Peloidal sediment starts to be deposited in and around the sponge. The internal sediment is fine-grained due to the limited size of the skeletal meshwork. The surrounding sediment is coarser and consolidated during early bacterial lithification.

4) When the sponge is covered with sediment (lithified), recrystallization of the siliceous skeleton begins. At first, opaline silica is completely dissolved. Second, the resulting moldic porosity is refilled by calcite.

Two types of moldic porosity occur which depend on the time of lithification of the interskeletal sediment :

1) If the interskeletal sediment is lithified before dissolution of the siliceous skeleton, the cavities will be refilled by calcite and the original lattice will be preserved. 2) If the interskeletal sediment is unlithified before dissolution, the depositional fabric of the internal sediment will become unstable and collapses.

The bacterially lithified peloidal sediment around the sponge conserves the shape of the sponge. Due to the solution and collapse processes in the sponge paragaster, geopetally filled vugs develop. The distributional pattern of the vugs is probably caused by the arrangement of the exhalant and inhalant canals (aporhyses and epirhyses) which contain early-lithified bacterial sediment. This pattern therefore depends on the individual skeletal construction of the different sponge families.

At the Mazagan Escarpment the " vuggy sponges " were only observed in the stromatolotic peloidal sediment and were restricted to he Hexactinellid group.

The diagenesis of the siliceous sponges of the Mazagan Plateau is quite different from the diagenetic alterations of the Central European Upper Jurassic siliceous sponges. In the epicontinental seas north of the Tethys ocean, siliceous sponges can make up massive sponge-algal buildups (Roll, 1934, Fritz, 1958). In these buildups, sponge growth and fossilization are associated with the development of bacterial crusts (Gaillard, 1971 ; 1983 ; Nitzopoulos, 1974). These crusts " calcify " decaying sponges (Flügel, Steiger, 1982). The crusts consist of pelmicrite (Fritz, 1958 ; Hiller, 1964). The sponge body is entirely or partly protected against mechanical destruction and dissolution by these crusts. Unencrusted decaying and mazerating sponges produce " tuberoids ", which are also composed of pelmicrite (Fritz, 1958) and accumulate in tuberolitic packstones and tuberolitic wackestones around the buildups (Flügel, Steiger, 1981). In the stromatolitic peloidal sediments, as well as in the hemipelagic limestones of the Mazagan Escarpment we never observed particles which could be related to tuberoids.

In the Northern Tethyan epicontinental seas sponges growing in sparry peloidal sediment (Meyer, 1977) and the formation of dome-like sponge buildups are associated with the production of bacterial calcareous crusts which intensely encrust fossilized sponges. This is different to the situation at the Mazagan Escarpment, where it seems that the existence of bacterial crusts does not depend on the presence of decaying sponges. The crusts develop upon the peloidal sediment and generate hard domal and columnar stromatolitic structures. Although appropriate substrates for vertical sponge growth were present (Müller, 1978), massive sponge buildups could possibly not develop because of the lack of a sponge-algal community. The described diagenetic model assumes that the siliceous sponges lived in a well aerated environment, exposed to circulation. In this environment the sponge skeletons are chemically unstable and subject to dissolution. According to many authors, seawater is undersaturated in silicon (Calvert, 1974 ; von Rad *et al.*, 1977 ; Riech, von Rad, 1979). Especially in the upper 1 000 m a very high solution rate can be recognized (" silica corrosion zone ", Berger *et al.*, 1975). Higher solubility of opaline silica appears with increasing temperature, pressure pH-value (greater than 8.5), water turbulence, water content of silica phases, surface area of silica phases, salinity, decreasing CO_2-content, crystallinity, and adsorption of impurities on silica phases (Laschet, 1984). If this is the case in the Upper Jurassic shallow Atlantic in front of the Mazagan carbonate platform, the factors : relatively high temperature, decreased CO_2-content, large surface area of the skeletons and water turbulence can be deduced from the sediment. They suggest rapid dissolution of exposed siliceous material. It is thus probable that most of the siliceous sponges growing on the platform slope were totally dissolved. Only a few sponges could fossilize under special conditions, which were controlled by mechanical factors : water agitation and sediment transport. First, the organic matter must have been removed by water turbulence to expose the skeleton for internal sedimentation. Second, the sponges must have been completely covered by sediment to preserve the sponge body. To prevent dissolution of the exposed opaline skeleton, sedimentation must follow immediately the decay of the sponge.

CONCLUSIONS

The results of the paleontological and sedimentological analysis of the siliceous sponges found at the Mazagan Escarpment are :

1) The siliceous sponges belong to the species *Thyroidium* (?) cf. *leptophyllum* (Quenstedt) and *Paracraticularia* (?) sp. They never occur later than Kimmeridgian. These sponges are therefore important fossils for dating the columnar stromatolitic peloidal limestone (MF 1, Steiger, Cousin, this volume, MF 3, von Rad *et al.*, this volume). It represents the Oxfordian to Kimmeridgian core of the Mazagan platform margin, which is overlain by hemipelagic sediments of Tithonian to Berriasian age in the west, and by platform sediments of Upper Jurassic to Early Cretaceous age in the east.

2) The ecological and chemical conditions at the Mazagan platform margin lead to diagenetic processes, which are different from those observed in true sponge buildups. Those sponge buildups consist of siliceous sponges and thick bacterial crusts, which overgrow the sponges and represent a substrate for new sponge growth. At the Mazagan platform margin, sponge growth is not bound to the development of thick bacterial crusts, which calcify the sponges. Here, the peloidal sediment itself is subject to bacterial lithification showing a high sedimentation rate by rapidly growing domal and columnar structures. Before bacterial lithification the sediment probably could not act as a substrate for sponge growth. The unhomogenous lateral sequence of lithified surfaces and unconsolidated sediment would generate a knobby seafloor and a widely scattered distribution of the sponges. In this case no sponge framework can develop. It indicates, that the sponges are unimportant for the accumulation of the sediment pile, and that they do not support the stabilization of the platform margin. Sponge buildups are therefore not expected to exist in this area.

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