

A POSSIBLE HORNY SPONGE (DEMOSPONGIA, KERATOSIDA) FROM THE EASTERN CARPATHIAN OUTER FLYSCH (ROMANIA)

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Abstract. A fossil body was discovered in the Kliwa Sandstone Formation from the Marginal Fold Nappe (= the Vrancea Nappe), in the Tazlău area (Fig. 1). The morphology of this fossil (Fig. 2) and the cuticle ultrastructure (Fig. 3, Plate I) suggest that it belongs to the horny sponges group (Keratosida), leucoid type, with a wide open osculum (Fig. 4). The presence of the horny sponge in the Kliwa Sandstone Formation (Oligocene) indicates an open marine environment, with a moderate depth and a compact sandy substratum, probably situated below the limit of the storm waves.

Key words. Porifera, Demospongia (Keratosida), Eastern Carpathian Outer Flysch, Romania

INTRODUCTION

Aquatic metazoans, mostly marine, the sponges (*Porifera*), represent a primitively organized invertebrate group, which could be fixed, solitary or colonials. Sponges have variable morphology and sizes ranging between 1 cm and 2 m (Turculeț, 1994). So far, the Phylum *Porifera* contained the three *Calcispongia*, *Hexactinellida* and *Demospongia* Classes, the latest including the *Tetractinellida*, *Monaxoidea* and *Keratosida* Subclasses. The Subclass *Keratosida* incorporates horny sponges, with a skeleton composed of sponging fibres without siliceous spicules (Hyman, 1940).

Recently, living sponge specimens, with a solid calcareous skeleton, were discovered. If these specimens would be fossilized, they could be considered chaetetids, stromatopora or sphinctozoars. The histological, cytological and larval investigations indicated, without any doubt, that the above-mentioned living taxa are Porifera. This discovery determined a new organization of the Phylum *Porifera*, as well as of its phylogenetical relationships. Some authors proposed a new class for this kind of Phylum *Porifera* – *Sclerospongia* (Enay, 1990, p. 36-38). Other scientists believed that the new discov-

ered taxa may be included in the already existent classes, *Calcispongia* and *Demospongia*, respectively. Additionally, in the Phylum *Porifera* were included, as a distinct subphylum, the arheociatids.

In Romania, fossil sponges were described from different lithostratigraphical units, rarely preserved as whole bodies; they are usually found as siliceous spicules (*Cylindrophyma*, *Melonella*, *Craticularia*, *Cypellia* etc., - Simionescu, 1909; Antonescu, 1929) or calcareous spicules (*Corynella*, *Eudea*, *Sphaerospongia* - Bărbulescu, 1968). These are organized in bioherms, forming sponge facies (Bărbulescu, 1974), as the one described from the Casimcea Formation by Drăgănescu (1976). Recently, Dragastan *et al.* (1998) cited 13 demosponge species from the above-mentioned formation. Calcareous sponges were reported from many deposits from Romania, such as the Triassic from Brașov (*Colospongia* - Jekelius, 1935) and Rarău (*Discoelia*, *Stellispongia*, *Colospongia* - Turculeț, 1971), and the upper Jurassic from Bucegi (*Rauffia*, *Talmo-phora* - Patruleț, 1969) and Hăghimaș. From the later, Dragastan (1975) listed the *Barroisia* genus, identified also in the lower Cretaceous deposits from the southern Dobrogea (Dragastan *et al.*, 1998). Spongolites and spongolitic biosparites

were reported from the middle and upper Jurassic deposits of Hăghimaș (Grasu *et al.*, 1995), while isolated spicules were discovered in the Callovian-Oxfordian sediments of the Hațeg region (Mamulea, 1953), as well as in the Neocomian deposits of the Drocea Mts. (Papiu, 1953).

In the lithostratigraphical units of the Eastern Carpathian Outer Flysch, the sponges are exclusively represented by solitary spicules, mono- and poliaxons, described from the Audia (Băncilă & Papiu, 1962; Grigorescu, 1970; Grasu *et al.*, 1988), Tisaru (Filipescu, 1935), Lepșa (Durand-Delga & Micu, 1983), and Kliwa Sandstone (Filipescu, 1931; 1935a) formations. Isolated spicules or more frequently associated in gaized-spongolites and spongolites were encountered in the Hangu, Putna, Straja, Pietra Uscată, Sucevița, Jghiabu Mare, and Doamna Limestone formations (Joja, 1952; Dumitrescu, 1952; Băncilă & Papiu, 1960; Grasu *et al.*, 1988), as well as in the Vinețișu and Podu Morii formations (Grigoraș, 1955).

As for the chaetetids, these were noticed in over 20 Romanian sites from Dobrogea, Eastern Carpathians, Metaliferi Mts., Moesian Platform and the Transylvanian Basin. The inventory and the description of some unknown taxa from Romania belong to Baltres (1973). Cretaceous species of stro-

matopors and chaetetids were described by Dragastan *et al.* (1998) from the South Dobrogea.

Bioerosional traces due to the boring sponge *Cliona* were found on the Jurassic belemnites from Topalu (Bărbulescu, 1974) and on the *Ostrea* coquilles from the Miocene of the South Dobrogea (Rado, 1983), and from the Petroșani basin (Culda, 1984).

GEOLOGICAL SETTING

The region between the Tazlău Mare Valley and the Brusturatu Stream is situated at around 3.5 km west from the Tazlău locality (Fig. 1). The Paleogene deposits which crop out in this area belong, from a tectonical point of view, to the Horațița-Doamna Digitation of Marginal Fold Nappe (= the Vrancea Nappe). In this region, the following lithostratigraphical entities occur, according to Micu, 1983: the Jghiabu Mare Formation (Ypresian), the Doamna Limestone and the green clays (Lutetian), as well as the Bisericani, the Globigerina Marls and the Lucăcești Sandstone formations (Priabonian). During the Oligocene, the Lower Menilite, the Bituminous Marls, the "Ardeziform" Shales with the Fierăstrău Sandstone at the base, the Lower Disodile, and the Kliwa Sandstone for-

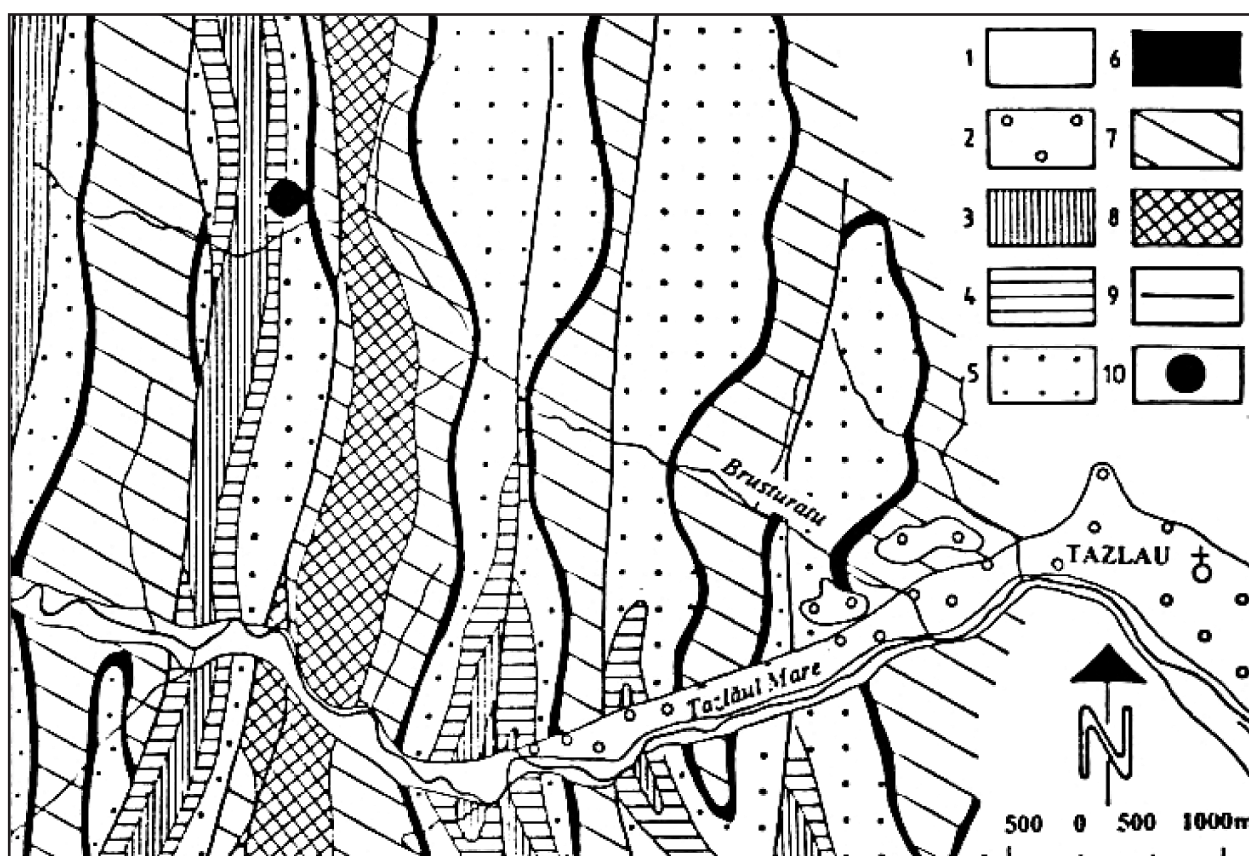


Fig. 1 Geological map of the Tazlău-Brusturatu region (simplified after the Geological map of Romania, scale 1:50 000, Sheet 48d Tazlău). 1. Holocene (alluvia); 2. Pleistocene (terraces); 3-4. Oligocene–Lower Miocene (3, Gura Șoimului Formation; 4, Upper Dysodiles and Upper Menilites); 5-6. Oligocene (5, Lower Dysodiles and the Kliwa Sandstone Formation; 6, Lower Menilites, Bituminous Marls); 7. Priabonian (Bisericani Formation, Globigerina Marls and the Lucăcești Sandstone); 8. Ypresian–Lutetian (Jghiabu Mare Formation, Doamna Limestone, green clays); 9, Fault; 10, Fossiliferous site

mations were sedimented. The Oligocene-Lower Miocene is characterized by the presence of the Upper Dysodiles, Upper Menilites and Gura Țoimului formations. The age of the later above-mentioned formation, Early Burdigalian, was assigned at its stratotype by Ionesi și Bogatu (1986). Notably, towards the upper part of the Upper Dysodiles Formation, the Falcău Tuff occurs, having in Brusturatu Stream section over 6 m in thickness (Alexandrescu *et al.*, 1984). Structurally, the Tazlău-Brusturatu region is characterized by the presence of the scale-folds, displaying an inclination of the flanks to the west more than 50°.

OCCURRENCE

The study sample was collected by one of us (P. Ț.) from a little right tributary of the Brusturatu Stream, just at the north from a coast gallery made by the former IPEG (presently GEOMOLD) Suceava, at around 6 km upstream from its confluence with the Tazlău Valley (Fig. 1). The fossil was gathered from the alluvia of the stream and yielded a reduced degree of rolling, which indicates a relatively short distance of transport. The filling, an arenite Kliwa type material, suggests that the sample comes from the Kliwa Sandstone Formation, which crops out on the eastern flank of the Geamăna-Jilabău Syncline, with the axial part made of the Gura Țoimului Formation (Micu, 1983).

PALEONTOLOGICAL DESCRIPTION

The analyzed sample is a flattened tronconic body having a number of 12 segments, which come over one another (Fig. 2). Numerous slightly deep dermal semicircular folds (Fig. 3a) are perpendicularly disposed on each segment. The obvious deformation of the studied fossil body, entirely filled with Kliwa sand type, is easily recognizable due to the variable length of the segments (Fig. 2a), which could yield a "flow" aspect (Fig. 2b), as well as to the longitudinal fissures (Figs. 2a, b).

The above-mentioned morphological details, conserved due to the reduced degree of rolling, but especially the dermal ultrastructure suggest that this fossil body belongs to the horny sponge group (*Keratosida*).

Phylum *Porifera* Grant, 1872
Class *Demospongia* Sollas, 1875
Order *Keratosida* Grant, 1861
Family and genus *Incertae sedis*

Material. A single sample, preserved in the Collection of the Paleontological Laboratory of the University "Alexandru Ioan Cuza" from Iassy.

Description. A fossil body, in the shape of a segmented tronconic bag (Figs. 2a, b), with a circular base and osculum, strongly flattened (Fig. 2c), due to the deformation produced by the late burial. The outer wall of the bag (the ectosom) is

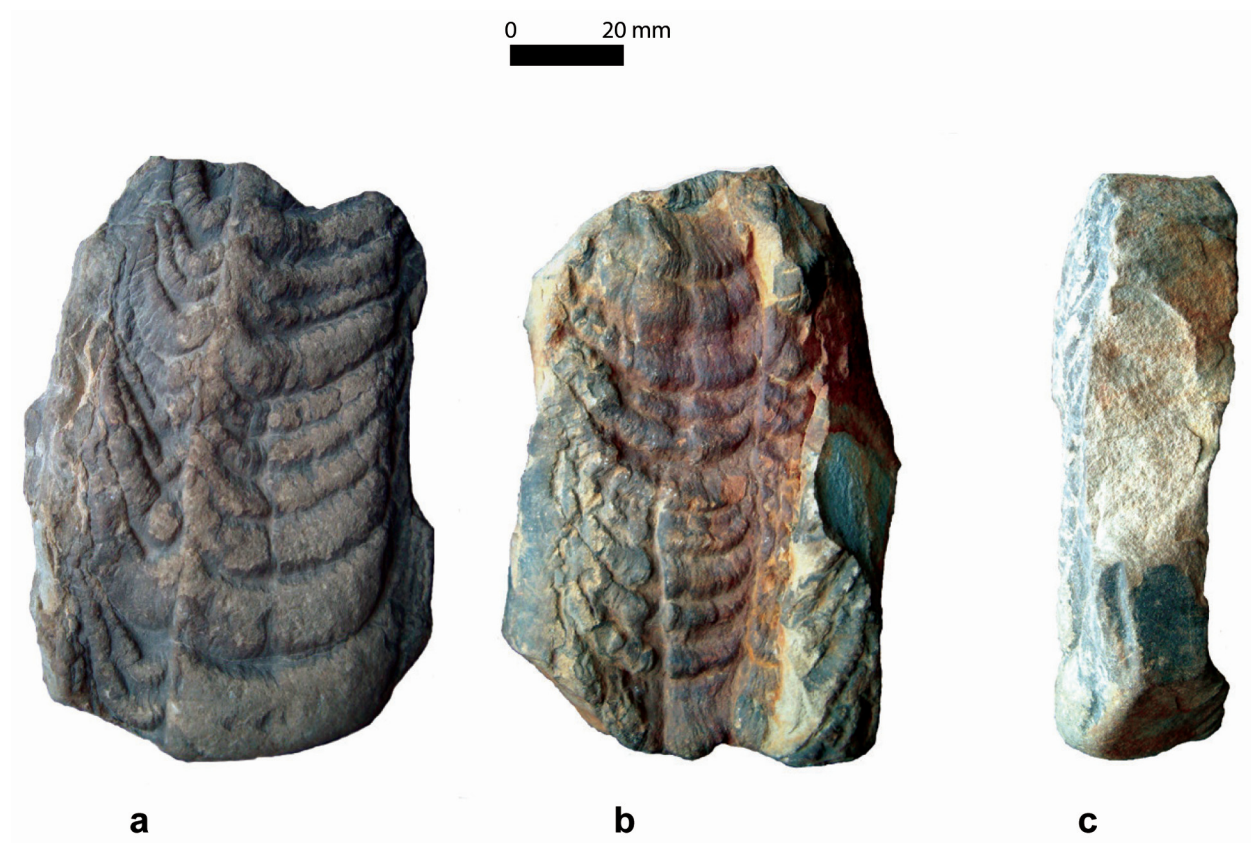


Fig. 2 Strongly deformed horny sponge

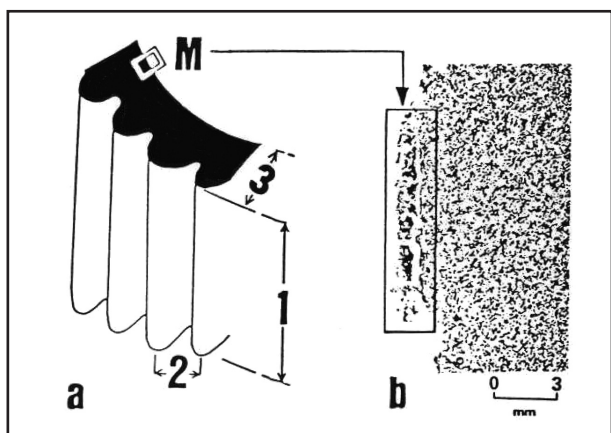


Fig. 3 Dermal membrane (a) with the location of the piece analyzed under the light microscope and under the scanning electron microscope (M), and a detail from the contact between the derma and the filling sand (b)

represented by a thin brown-blackish folded cuticle (= derma) (Fig. 3a). On 1 cm segment length, 6 semicircular folds, around 15 mm high (Fig. 3a, 1), having a distance between two successive crests of 1,6 mm (Figs. 3a, 2), could be observed. The dermal thickness does not usually exceed 1 mm (Figs. 3a, 3). The dermal folds are perpendicularly placed on each segment which borders the tronconic body. The 12 segments are confined by depression zones, with a slightly deep profile.

The examination of a dermal piece and of the sandy content under the light-polarizing microscope (Fig. 3b) revealed that the derma reacted as an isotropic body. It is well known that this optical property is common for the bodies which crystallized under the cubic system, as well as for the amorphous ones, which include numerous organic substances. Taking into account this observation, the dermal investigation carried out under the scanning electron microscope (Fig. 3a, M) indicated the doubtless presence of a fibrous mass of organic origin (Plate I, Figs. 1, 2). The net of the fibres, probably of sponging type, yielded an obvious amorphous aspect (Plate I, Figs. 3, 4). Rarely, formations similar to the monoaxon spicules, with a central channel, occur (Plate I, fig. 5), with the base (?) exhibiting ramifications as the one from Plate I, Fig. 6. Pores with an irregular contour (Plate I, Fig. 7), as well as circular (Plate I, Fig. 8) could be observed. Several micas flakes and detritic quartz grains are present.

The spongine, which is secreted by the scleroblasts, belongs to the group of insoluble proteins (scleroproteins), chemically inert and resistant at the proteolytic enzymes. The scleroproteins could be found in the animal body in a solid form, having the function to sustain the internal organs (= the skeleton proteins) or to protect against external aggression. The most important scleroproteins are represented by keratin, collagen, fibroin, elastin and spongine (Nenişescu, 1958). After Block and Bolling (*in* Hyman, 1940), the spongine contains iodines and different aminoacids (lysine, arginine,

cistine, fenilalanine, glicine and, subordinately, histidine and tyrosine). Remarkably, the spongine has a big amount of iodine, up to 14%. The iodine is also present in big proportions, together with the sulphur, in the keratine (yielding a percent of 3% in the hair and in the wool).

Dimensions. The deformed sample is 190 mm high and has a median width of 120 mm. The dimensions of the reconstructed body (Fig. 4): the base diameter = ? 66 mm; the osculum diameter = ? 106 mm; the height = ? 180 mm; the volume = around 1062 cm³.

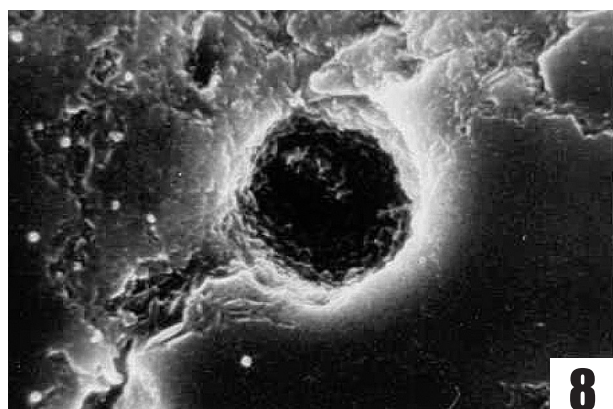
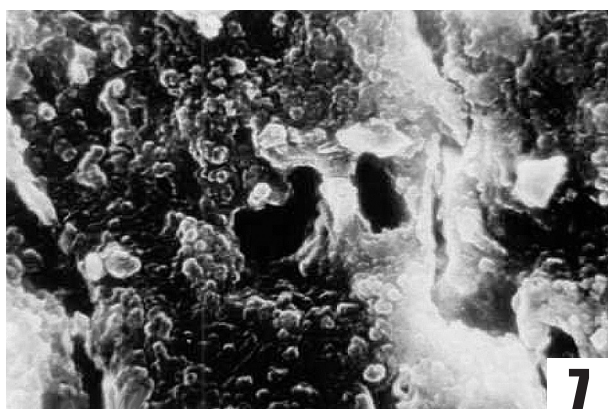
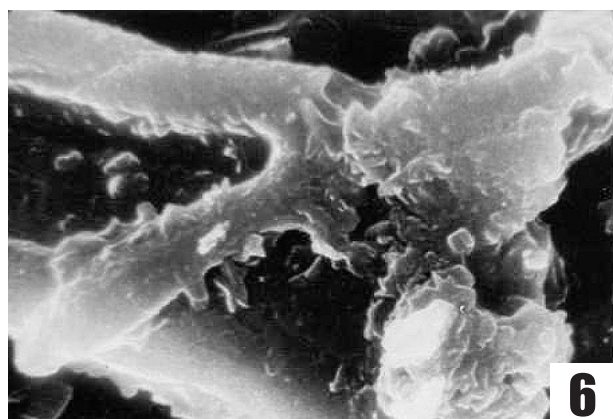
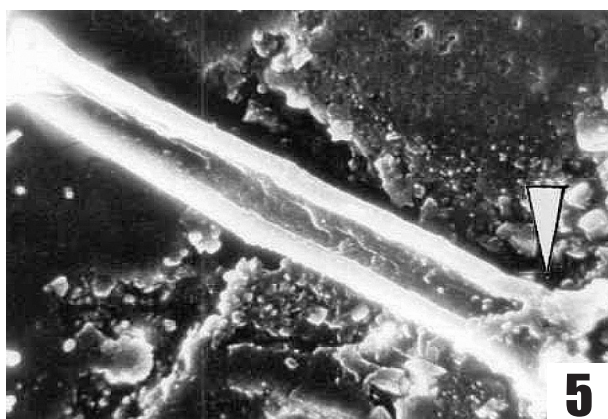
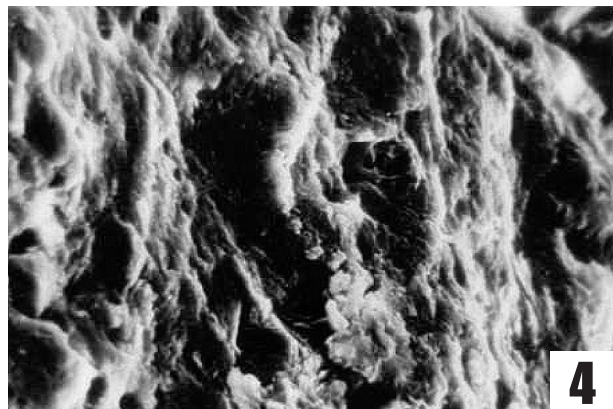
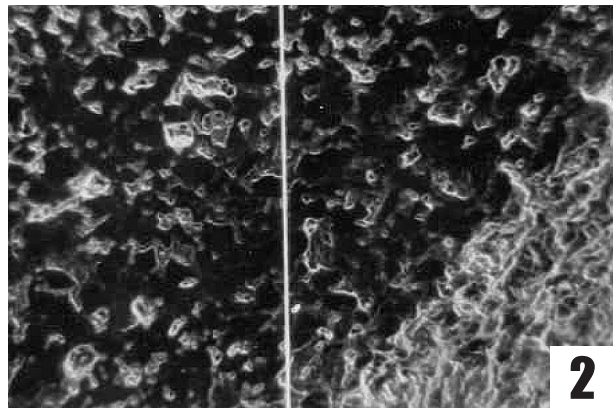
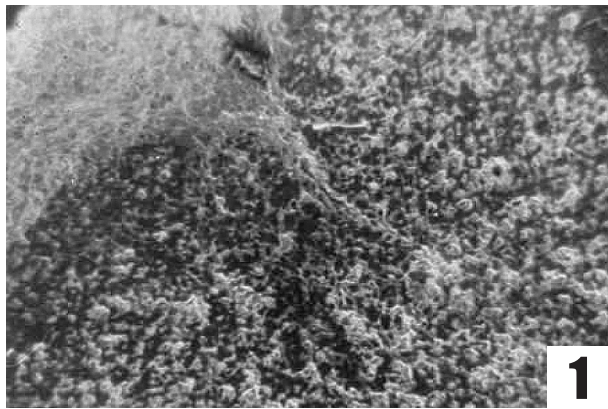
Observations. Laubenfels (1963) include three families in the *Keratosida* Order: two (*Spongilidae, Dysideidae*) certain and one uncertain. The fossil taxa of the former above-mentioned family (*Spongia, Verongia, Aplysinofibria, and Scyphia*) are totally made by spongine. Those of the *Dysideidae* Family (*Dysidea, Spongelites, and Spongelmorpha*) have the spongine fibres connected by fragment and debris. The uncertain family contains a single genus, *Felixium*, with a cylindrical curved body and an elaborate sculpture (Laubenfels, 1963).

A metazoan group with a high instability and variability inside the phylum (Levi, 1957), the actual sponges in general and especially the fossil ones are sometimes difficult to determine and classify. In both cases, the investigation of the skeleton is useful, as well as the study of the spicules (Levi, 1957). Former studies indicated that the spicule list is representative for the family diagnosis, the placement of the spicules for the family assignment, that of the spicules in the skeleton and their modification for the genus, while the exterior form and the placement of the spicules for the species (Burton, 1932 *in* Levi, 1957). As regards the fossil sponges, the chance to identify them for certain decreases from the class to the species whenever there are only isolated spicules left of the sponge specimen (Laubenfels, 1957).

Recent research indicate the fact that the fossil sponge microstructure, as well as that of the present-day sponges (especially of calcareous sponges) accurately reflect the organic control role in the skeleton mineralization. Wood (1991; *in* Mastandrea & Russo, 1995) indicated that the type of the mineralization has a great significance even for the lower taxonomical categories (*i.e.*, genus, family), while the placement of the spicules is important for those belonging to upper taxonomical categories. The biological control of the skeleton mineralization is essentially involved in the flowing of the diagenetical fluid flux into the spaces defined by the macro-molecular compounds, insoluble in water. The biomineralization processes are reflected in a certain type of microstructure, which presents certain features concerning the mineralogy, the shape, the dimensions, the spatial distribution, as well as the way of the microstructure growth (Mastandrea & Russo, 1995).

The analyzed specimen has in general similitudes, concerning the shape and the segmentation, with the *Casearia reticulata* species (Moret, 1952, fig. 11d). The derma, very plicated, yielded obvious resemblances with the folded wall of the siliceous sponge *Ventriculites striatus* (Davitaşvili, 1956, fig. 46).

PLATE I



* All the figures x 3200

The match between the fibre aspect of the studied specimen (Pl. I, Fig. 2) and that belonging to the *Aplysiofibrina carbonicola* species, found in the Carboniferous deposits of the Podolsk region, is also remarkable (Rezvoi *et al.*, 1962, pl. VIII, Fig. 5). At a first prospect, the studied specimen is very similar with the fossil coral *Laterophyllia* (*Scleractinia*), whose species - *L. turri-formis* și *L. minima* -, described by Kühn (1933) and by Brants (1972) proceeded from the Oligocene-Lower Miocene deposits of the Central Iran. Notably, at the *Laterophyllia* taxa, the septa and the thin columela have a leaf shape. The coral body has a characteristic shape, with two parts which are simetrically scalariform and opposite (Brants, 1972, pl. I-III).

Supposedly the structure type to which the studied specimen belongs, is of a leucon type, otherwise characteristic for most of the sponges from the *Demospongia* class. In our case, this structure type was probably necessary for stability reasons. Because it was relatively high, with a widely open osculum and with thin dermal membrane (?ectosom), this solitary horny sponge could stay in a vertical position only due to a developed endosom (Fig. 4).

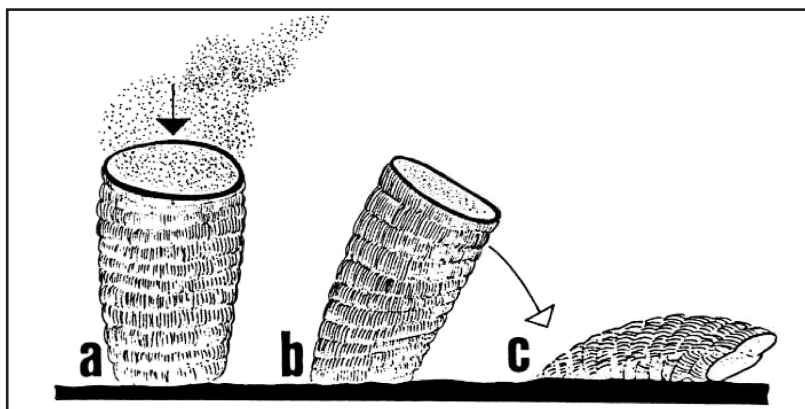


Fig. 4 Reconstruction of the horny sponge: (a) position during life and the filling with sand of the central cavity; (b) tilt and deformation of the sponge, due to its weight, after the filling with sand; (c) sponge position before burial

DISCUSSION AND CONCLUSIONS

The horny sponges (*Keratosida*) are exclusively composed of spongine fibres, with the skeleton made by two collagen types: spongine A and spongine B. The spongine A is represented by the fibres spread in the fundamental substance, while the spongine B forms the thick fibres, which consolidate and connect the mineral skeleton without spicules of the horny sponges (Vacelet, 1971a).

Displaying different shapes, from the sphere shaped to the palmate-tabulars, the horny sponges are covered by a membrane as a skin, very resistant, with either numerous pores or just a few, in the latest situation being diffusely spread (Hyman, 1940). Many of the present-day horny sponges have a superficial hyaline-elastic pellicle, which forms the cuticle. This cover proceeds from the fortifying of the mucus secreted by the ectosomatic specialized cells. Some studies indicate that it is not possible to appreciate if the cuticle membrane and the fibre spongine are identical (Vacelet, 1971b).

The sponges are organisms typical of shallow water environment, directly attached from a hard substratum through-

out the spongine secretion. They prefer warm tropical and subtropical waters, but the small species could reach Polar Regions (Hyman, 1940). Like many marine organisms, the sponges could offer indications concerning the depth of the basin water. In the Strakhov's scheme (1958, Fig. 102), the sponges are found at the following depths: between 0-15 m there are the calcareous sponges; between 20-75 m there are siliceous and horny sponges; between 100-400 m there are the lithistids; below the depth of 400 up to the abyssal zone the hexactinellids are prevailing. Consequently, the horny sponges are populating the shallow marine environment, which corresponds to the upper part of the neritic zone.

Notably, the sponge morphology indicates accurately enough the environment. Where strong flows are acting, the sponge morphology is of amorphous or crust type, while in the intensively populated zones the sponge exhibits an irregular shape, being adapted to the reduced spaces. In relatively calm waters, tubular sponges could be encountered, the most yielding their own symmetry, with different shapes from a cup up to a sphere (Laubenfels, 1957).

The presence of the horny sponges in the Oligocene deposits of the Eastern Carpathian Outer Flysch (the Kliwa Sandstone Formation), calls into question the origin of this formation, still under debate. Concerning the origin of this formation, two main hypotheses were advanced. One hypothesis assumed that the accumulation of the detritic material happened in a deep basin, where the turbidity currents acted. In its whole areal occurrence, *i.e.*, in the eastern part of the Tarcău Nappe and in most of the regions of Marginal Fold Nappe (= the Vrancea Nappe) development, the Kliwa Sandstone Formation yielded a remarkable lithological and petrographical constancy.

The authors who considered that the Oligocene deposits (*i.e.*, menilites, dysodiles, and Kliwa Sandstones) were deposited in a shallow marine environment, took into account some sedimentological aspects, such as waves ripples, conglomeratic intercalations, and also paleontological ones (the presence of molluscs and of isopods, littoral fishes). These features suggest a deposition of the above-mentioned formations "in the littoral zone or in the neritic zone" (Preda, 1917), "probably in the near shore" (Grozescu, 1918). The absence of the crossed stratification in the Kliwa Sandstone deposits re-

jects, according to Grozescu (1918), the hypothesis that this formation originated in the littoral dunes, as it was supposed by Mrazec and Teisseyre (1907).

The hypothesis of the deposition of the Kliwa Sandstone Formation due to the turbidity currents is supported by absence of any clayey fraction and by the advanced sorting of the sandstones (Papiu, 1960). The presence of the mecanoglyphs (indicating that the longitudinal currents which transported the arenitic material from the East-European Platform - Panin & Mihăilescu, 1967 - predominantly acted) supports the same theory. Recently, Anastasiu *et al.* (1994), which focused only on the lithofacial analysis of several bituminous sequences from the Eastern Carpathians, adopted the Reading-Richards model in order to explain the deposition of the Oligocene turbidites. Regarding the source (the sources) of the arenitic material from the Kliwa Sandstone Formation, there are some opinions in favour of the extrabasinal provenance (Panin & Mihăilescu, 1967; Anastasiu *et al.*, 1994) and other which supposed the intrabasinal provenance. The latest assumption is based on the supposition that the Cimmerian Dobrogean cordillera (Filipescu, 1935), placed between the Tarcău Nappe and the Marginal Fold Nappe (Ionesi *et al.*, 1988) acted those times.

New data acquired demonstrated that during the Paleogene times the sedimentary basin configuration of the Outer Flysch indicated several structural complications, which affected the depositional processes. In some areas of the Marginal Fold Nappe, submarine slumping took place, which led to the formation of olistolites. Olistolites which contain bituminous marls were identified in the Lower Dysodiles Formation (Ionesi & Grasu, 1993). Some olistolites with bituminous rocks were observed also in the Gura Țoimului Formation (Ionesi *et al.*, 1994). The emplacement of the olistolites caused the folding processes leading to the formation of some embryonic anticlines (Ionesi & Grasu, 1993). The tectonical instability acted also on the Kliwa Sandstone Formation, in which brecciate sandstones and deformed ones (probably due to the seismic activity which determined submarine slumping, according to Dicea, 1974) were noticed. Older fingerprints of such structural-genetical processes were identified in the Eocene Biserican Formation, in which clastic dykes are present (Humă, 1971; Grasu, 1996). This sedimentogenetical aspect suggests, at least locally, the emersion of the anticline crests, on which the waves acted. This is a possible explanation for the occurrence of the amber in a primary ore within the Lucăcești Sandstone from the Iapa Valley section (Brustur *et al.*, in prep.).

The shallow marine environment was also preserved during the debut of the Oligocene, both in the inner part, where the Pucioasa Formation contain diatoms, fructifications, small coleopters and tetractinelid sponge spicules, indicating depths up to 100 m (Voicu, 1953), as well as in the outer regions (at least in the area between Bălățești and Piatra Neamț), where in the bituminous facies of the Kliwa Sandstone the presence of isopods, bivalves and fossil fish

indicate "the deposition in a shallow marine water of the melinites and dysodiles" (Cosmovici, 1922).

Concerning the Kliwa Sandstone Formation, the presence of the wave traces indicated that its sedimentation took place in a not very deep basin (Preda, 1917; Dicea, 1974). The presence of the *Ostrea coquinas* (Bogatu, 1982), together with the *Rhizocorallium irregulare* population identified in the Vrancea half-window, led to a similar supposition. The latest forms suggest a near shore-line, making possible the activity of the benthic organisms (?crustaceans, ?annelids) under good oxygenated conditions of the substratum, in the shallow infralittoral waters, characterized by the *Cruziana* ichnofacies (Brustur *et al.*, 1995).

The presence of the horny sponge in the Tazlău basin support, in our opinion, a similar paleoenvironment setting as mentioned above. The reason is that this kind of animal are mostly related to shallow waters, with a depth of maximum 100 m. The tronconic form, with a large open osculum, indicates a shallow marine environment, probably situated below the storm waves limit, in a compact sandy substratum. The chance of the preservation of the studied specimen was due to the fact that the horny skeleton elements, as well as the phosphate ones are much more resistant in the acid environments, in comparison with the calcareous parts, which are destroyed (Müller, 1991).

As the Oligocene faunas from the Eastern Carpathian Flysch (Paucă and Ciobanu, 1986; Constantin, 1999) contain more than 200 taxa, we would expect that these faunal assemblages could clarify the paleoenvironmental aspects. As this impressive number of taxa could not bring so far the data to support paleoenvironmental reconstructions, we challenged with a "paleontological paradox", which probably will be solved by future detailed investigations. For this reason, the revision of the fossil fish faunas of the Romanian Carpathians, already started the last years (Baciu & Florea, 1998; Baciu & Tylor, 2001; Baciu & Chanet, 2002; Baciu & Bannikov, 2003, 2004; Baciu *et al.*, 2005a; Baciu *et al.*, 2005b; Santini *et al.*, 2006), could bring significant data for the Oligocene paleoecological reconstructions and for the biostratigraphy of this interval.

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