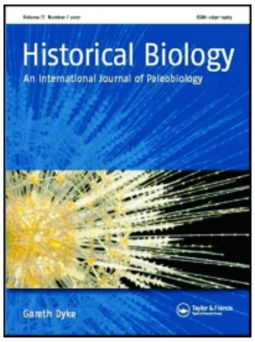

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A Callovian (Middle Jurassic) poriferan fauna from northwestern Jordan: taxonomy, palaeoecology and palaeobiogeography

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ABSTRACT

The present work describes the first fossil sponge assemblage from Jordan, belonging to Demospongiae and Calcarea; hexactinellid sponges are absent from the collections. *Mughanniyyum hanium* gen nov., sp. nov. is described, and a new subfamily, Jordaniinae, is proposed, belonging to Scleritodermatidae (Demospongiae). Another new demosponge species, *Geoditesia jordaniensis* sp. nov., is described on the basis of well-preserved specimens. The genus *Geoditesia* is previously known only from loose *Geodia*-type spicules. It is the first description of an articulated sponge bearing this kind of spicule. The assemblage is compared with similar occurrences in the Negev Desert (Israel) and Kachchh Basin (India). While the sponge fauna and the facies represented by the Negev Desert assemblage are very different, in the Kachchh Basin there are sponges present with similar external morphology belonging to related taxonomic groups. The palaeobathymetry of the studied sections from Jordan indicates slightly shallower water than in the Kachchh Basin. There is also slight stratigraphic difference between Jordan and the Indian Basin, in that the Jordanian assemblage is of Callovian age, while in Kachchh it is Bathonian.

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Sponges; Callovian; Mughanniyya Formation; Jordan

Introduction

The present paper is a further contribution to a series of recent studies on the Middle Jurassic invertebrate faunas of northwestern Jordan (Ahmad 1998, 1999, 2000, 2002a, 2002b, 2003; Pandey et al. 2000; Feldman et al. 2012). Since the end of the last century, a number of palaeontological studies have dealt with Callovian deposits in Jordan. The most important of these described new faunas of brachiopods (Ahmad 2000, 2002b, 2003; Feldman et al. 2012), echinoids, bivalves and gastropods (Ahmad 1999), and corals (Pandey et al. 2000).

A number of sponge specimens were collected during field work at the Tal el Dhahab section, representing a well-defined community with particular features and composition, but with similarities with other sponge faunas found on the Gondwanan Tethys shelf. They are the first fossil sponges found in Jordan, and are compared here with other Middle Jurassic sponges known from other areas.

During the Jurassic, the Levant was part of the Tethys shelf of Gondwana, which extended from Morocco in the west, to the Arabian Peninsula in the east, and southward to the Horn of Africa. It is represented by a mixed carbonate-siliciclastic ramp setting of large width (Abu El-Ata et al. 2013; Ahmad et al. 2013). The study area is part of the elevated platform terrain of the Arabian Nubian Shield, which is covered by intermittent Palaeozoic to Cenozoic sedimentary successions consisting mainly of clastic units with marine carbonates increasing upward (Figure 1; Rybakov & Segev 2005).

Cox (1925) and Muir-Wood's (1925) studies of brachiopods and mollusks identified for the first time the fossils in these Jordanian formations as being of Jurassic age. Ahmad (1999) studied the bivalve and brachiopod faunas of the Jordanian Middle Jurassic strata, and he assigned these faunas to a narrow age range, between the Bajocian and Callovian. Recently, Feldman et al. (2012) revised and described new taxa of Middle Jurassic rhynchonellids from northwestern Jordan.

In northwestern Jordan, Jurassic outcrops (Figure 1) can be found along the western part of Wadi Zarqa, beginning near the old Jerash Bridge and extending westward to Deir-Alla, a distance of about 20 km; toward the south, the outcrop belt passes through Ain-Khuneizir, Subeihi, and Arda Road (Ahmad 2002b). Two further outcrops, where dolomite and limestone are present, can be found in the Baqa Depression near the intersection of Wadi Mahis and Wadi Shueib.

The Jurassic sequence of Jordan has been subdivided into seven formations (Table 1): Hihi, Nimr, Silal, Dhahab, Ramla, Hamam, and Mughanniyya (Khalil & Muneizel 1992). The Mughanniyya Formation belongs to the Callovian, the Hamam and Ramla formations belong to the Bathonian and the Dhahab and Silal formations belong to Bajocian. Blake (1935, 1940) was the first to construct a geological cross section midway between the 'Zerqa Mouth' and the Jerash Crossing, showing the general

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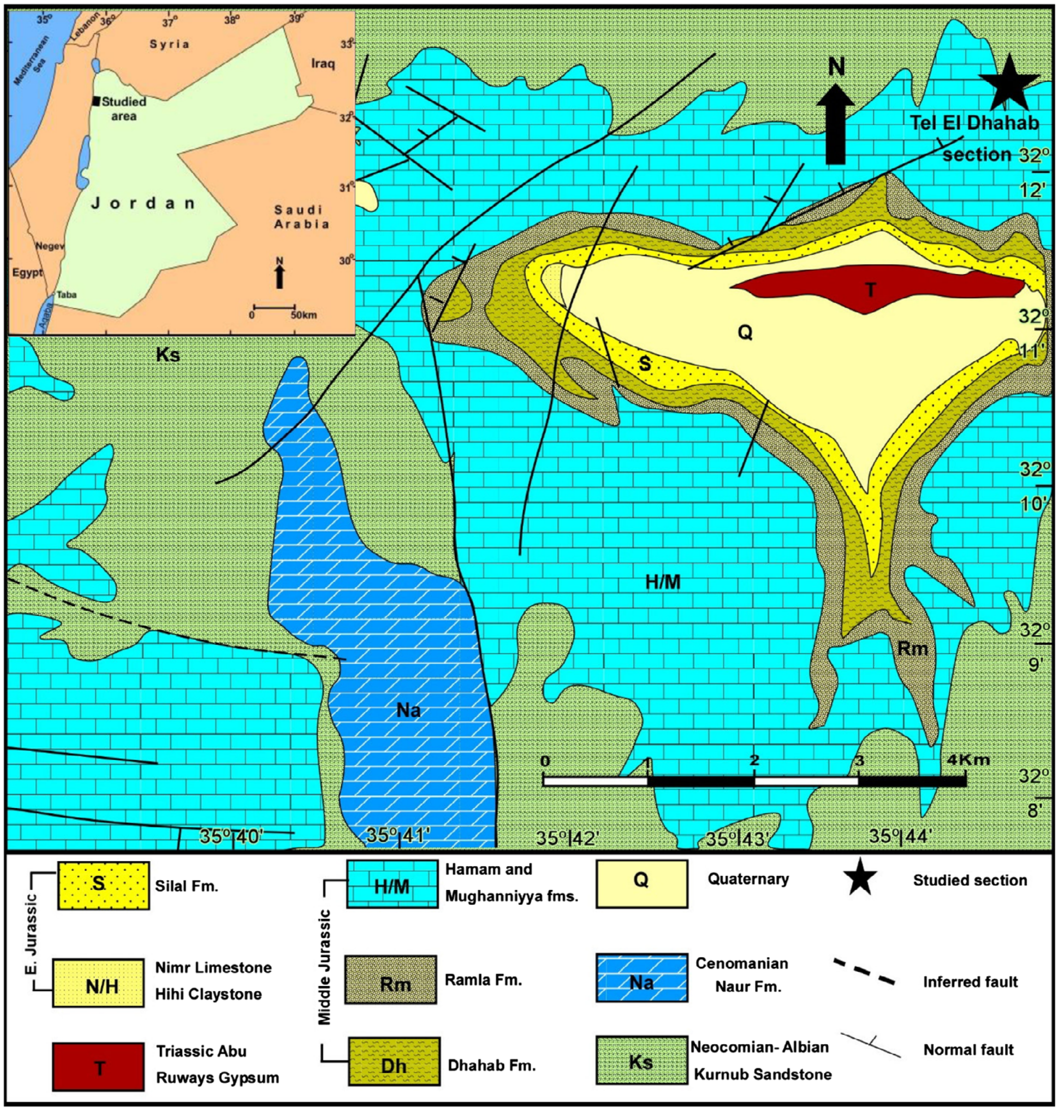

Figure 1. Geological map of the study area (modified after Muneizel & Khalil 1993; Swarieh & Barjous 1993).

Table 1. Stratigraphic framework of the Middle Jurassic rocks in northwestern Jordan.

Group	Stage	Formation
	Callovian	Mughanniyya
Azab	Bathonian	Hamam
		Ramla
	Bajocian	Dhahab
	Hettangian – Aalenian	Silal
		Nimr Limestone
		Hihi

structure of the area. However, detailed stratigraphic sections were only provided in 1959 by Wetzel and Morton (Picard & Hirsch 1987).

The poriferan fauna in the present study was collected from the Mughanniyya Formation at the Tal el Dhahab section. The Mughanniyya Formation (Figure 2) represents the upper part of the Jurassic sequence in Jordan and crops out consistently below the Kurnub Sandstone Group. It consists of limestone intercalated with marl; the limestone contains a macroinvertebrate fossil fauna and is topped by dolomitic limestone. The base of the Mughanniyya Formation represented a major transgressive phase, which has been recorded in Jordan and in many areas of the Arabian-African plates, beginning in basal Callovian time (Ahmad et al. 2013).

Material and methods

A total of 39 identifiable sponge specimens are considered here, found scattered through the investigated interval. The size of the specimens varies between 1 and 4 cm. They are more or less isometric, and show no microbial crusts; there are also epibiotic organisms present, such as serpulids. The sponges are small but robust and are associated with small solitary corals or massive colonies. The specimens are almost entirely calcitized, the silica of the preserved parts of the skeleton being completely replaced by calcite. Only in very rare cases are spicules seen to preserve their original siliceous composition. When sponge fossils are treated by controlled corrosion, such spicules occur on the specimens' surfaces, but very seldom and irregularly. Usually, in the residuum resulting from dissolution of body parts in

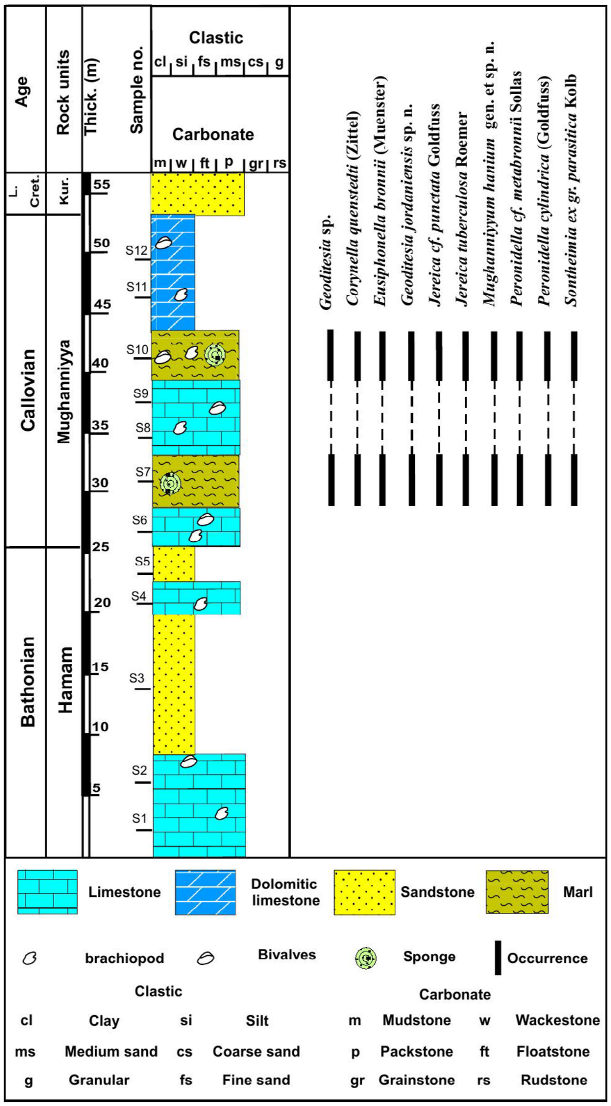

Figure 2. Stratigraphic column of the Mughanniyya Formation and its boundaries at Tal el Dhahab section.

concentrated (36%) hydrochloric acid there are no recognisable siliceous structures, but only a small quantity of clayey mud. However, much of the original spicular network, as well as some of the loose spicules, have preserved a variety of morphological features, despite the calcification. Those preserved features provide useful elements for identification.

The preparation processes differed, depending on the preservation. After thorough ultrasonic cleaning, the fossils were treated, when necessary, with 9% acetic acid for 1–24 h. Polished sections (either longitudinal or transverse) and peels were made for some specimens, followed by etching in acid. Complete dissolution in acetic or hydrochloric acid was also made for small fragments, in order to find the siliceous parts such as any siliceous spicules that might have been preserved, but with poor results.

The specimens were thoroughly examined using an optical microscope of up to 80x zoom. Finally, digital photos were taken through the microscope to illustrate fine details.

All specimens are stored in the collection of the Faculty of Natural Resources and Environment, Department of Earth and Environmental Sciences, The Hashemite University, Zarqa, Jordan.

Institutional abbreviations. ESH 2009, Earth and Environmental Science at Hashemite University, Zarqa, Jordan.

Results

Systematic palaeontology

The systematics of Porifera in Kaesler (2004) is used in the present paper, emended by later studies such as Borchiellini et al. (2004), Morrow et al. (2012), Morrow and Cárdenas (2015), Schuster et al. (2015).

Phylum Porifera Grant, 1836
Class Demospongiae Sollas, 1875
Subclass Heteroscleromorpha Cárdenas et al., 2012
Order Tetractinellida Marshall, 1876
Suborder Astrophorina Sollas, 1887
Family Geodiidae Gray, 1867
Subfamily Geodiinae Gray, 1867

Genus ***Geoditesia*** Zhuravleva in Rezvoi et al., 1962 (nom. nov. pro *Geodites* Carter, 1871)
Diagnosis. sponge and microscleres unknown; type species based on stout triaenes, dichotriaenes, and diaenes, loose in sediment, like those of various modern ancorinids and geodiids; some also resembling the dermalia of contemporaneous megamorine lithistids (Kaesler 2004). Rays of triaenes with blunt ends (Zhuravleva in Rezvoi et al., 1971).
Type species. *Geodites haldonensis* Carter, 1871

Geoditesia jordaniensis sp. nov.
Figures 3(1)–(6), 4(1)–(6), and 5(1)–(2)

Derivation of name. Refers to the country where the newly described species occurs.
Holotype. Figure 3(1) – specimen ESH 2009 I 34
Paratypes. Figure 4(5) – specimen ESH 2009 I 48, Figure 3(2),(3) – specimen ESH 2009 I 1a, Figure 3(4)–(6) – specimen ESH 2009 I 1b, Figure 4(1) – specimen ESH 2009 I 17, Figure 4(2) – specimen ESH 2009 I 36, Figure 4(3),(4) – specimen ESH 2009 I 39.
Other material. 12 specimens with mostly calcified spicules.
Type locality and horizon. Tal el Dhahab, Callovian marls of Mughanniyya Formation.
Diagnosis. Geodiid sponge consisting of a homogeneous mass of intermingled spicules, mainly oxeas and triaenes; sterrasters also present; inner structure chaotic.
Description. General shape is a flattened ball, or a thick disc. A few specimens have a spherical, flattened oval or thick ellipsoidal shape. The diameter of the studied specimens ranges between 18 and 31 mm, and the thickness between 10 and 18 mm. The thickness / diameter ratio is between 41 and 83%. The pedicle is not visible in any specimen, and osculum is rarely preserved.

Usually, longitudinal sections of the sponge body show only a homogeneous structure and no spongocel, no spicule network or aquiferous system, and no radial features. On some rare specimens, a very shallow spongocel is present, as a slight depression that is almost unnoticeable, below the osculum outline. When present, osculum is narrow (3–7 mm in diameter), slightly

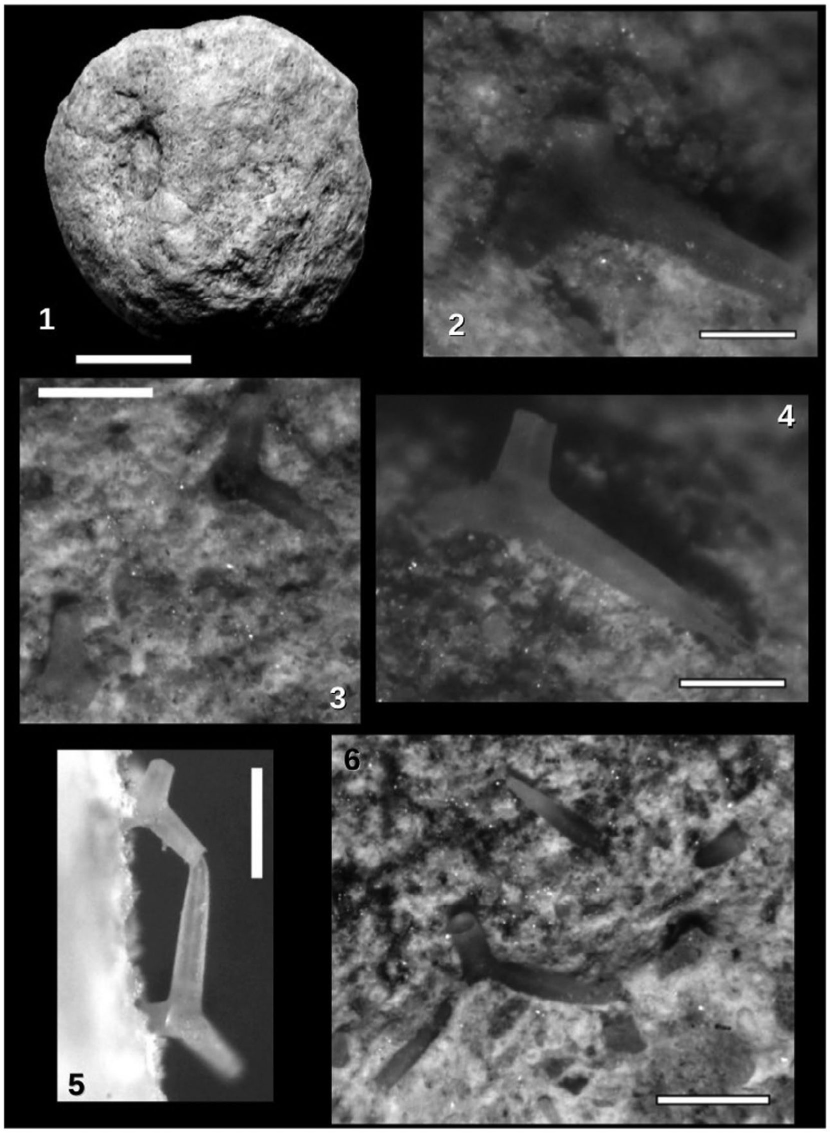

Figure 3. *Geoditesia jordaniensis* sp. nov. (1) Holotype, oscular view, specimen ESH 2009 I 34; scale bar = 7 mm. (2, 3) *Geodites* type blunt radial triaenes revealed by acid corrosion, specimen ESH 2009 I 1a; scale bar = 0.05 mm (2), 0.08 mm (3). (4–6) Smooth and slender radial protriaenes, specimen ESH 2009 I 1b; scale bar = 0.1 mm.

elliptical, always off-centred on the flat upper surface, and with rounded edges.

The skeletal architecture is mainly homogeneous, with many oxeas. Tetractine megascleres are present. Very few of them, still siliceous and corrosion resistant, protrude from the surface. The main spicule types found are as follows (ordered by general abundance): oxeas, triaenes (protriaenes with straight rays), styles (as oxea variants; this is a feature of the family, according to Kaesler 2004), prodichotriaenes. However, the proportions of the different types vary in different specimens. Usually, triaenes have blunt rays, but a prodichotriaene shows tapered ends of the deuteroclads. If completely dissolved using acetic acid, the residue contains only a few siliceous oxeas and triaenes. There is no obvious explanation for why most spicules were calcitized while some preserved their siliceous composition. Microscleres represented by reniform sterrasters. In some specimens, the intermingled spicules, mainly oxeas, sterrasters and triaenes, heavily calcitized and cemented together, are so numerous and dense, as to appear as a continuous fabric.

The sponges accreted some spicules from the surrounding environment. Long spicules of different forms attached to the sponge surface are presented in Figure 3(2),(4). One particular type of spicule with hexactinellid affinities occurred in this manner (Figure 4(3),(4)). It has a slender and long rhabd, with cladi fused together by a circular ring, instead of a single point with a round opening; this gives the appearance of a crown, with central circular cavity. From the ring, cladi are short and may be straight or slightly curved towards distal end.

Spicules dimensions: protriaenes: rhabds 1700–1800 × 65 µm, cladi 650–1800 µm; prodichotriaenes: rhabds up to 1700 × 25 µm, protocladi 43 µm, deuterocladi 23 µm; large oxeas 2300–4000 × 140–230 µm; small oxeas 450–1200 × 70–140 µm; styles up to 2000 × 360 µm; dichotriaenes: rhabds up to 1800 × 65 µm, protocladi 300 µm, deuterocladi 420 µm; sterrasters are large 140–330 µm.

The spicules are slender, and the protruding ones that can be observed most clearly are smooth. The spicules direction is

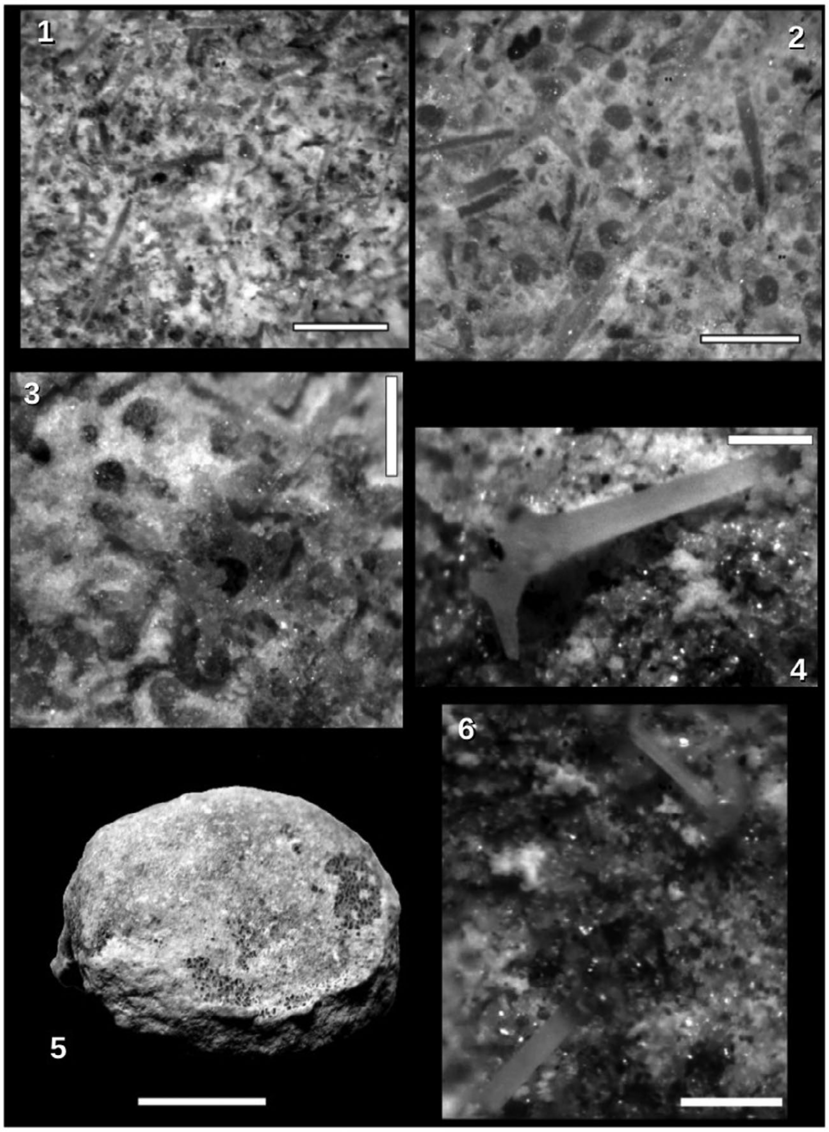

Figure 4. *Geoditesia jordaniensis* sp. nov. (1) Oxeas, monaxon microspicules, micro-spheres and sterraster chaotically intermingled, specimen ESH 2009 I 17; scale bar = 0.1 mm. (2) Dichotriaenes, micro-spheres, sterrasters and oxeas chaotically intermingled, specimen ESH 2009 I 36; scale bar = 0.5 mm. (3) Peculiar spicule, specimen ESH 2009 I 39; scale bar = 0.3 mm. (4) Unidentifiable spicule, parallel with sponge surface, specimen ESH 2009 I 39; scale bar = 0.25 mm. (5) Specimen ESH 2009 I 48; scale bar = 9 mm. (6) Thin, slender spicules, with broken tips, protruding through the sponge surface at various angles, specimen ESH 2009 I 2; scale bar = 65 µm.

chaotic everywhere. Their sections on the sponge surface are longitudinal, angled or transversal.

Remarks. The studied specimens show spicules similar to the ones in the Mesozoic species *Geodites planus* Hinde, *Geodites sp.* (Hinde, 1893) and *Geodites cornutus* Hinde. They are all trifid spicules, but the triaenes of our specimens have a strong fusion point and are more slender, blunt, and shorter, rather than thick, tapered and pointed as the ones of *Geodites sp.* The lateral rays of the latter arise from the shaft at the same or lower angles, in comparison with the spicules observed here. In the studied specimens the triaenes are also straight, without furcate lateral rays as in *Geodites planus.* Furthermore, they are not curved backwards (anchor-type) as in *Geodites cornutus*. The variations in spicule morphology are slight in the new material, and therefore they are all attributed to a single species. Specimens described here do not comply with any of the previously defined taxa and there is not enough data to attribute the studied spicules to any of the above species. All the studied specimens can best be assigned to a single species, since the only variations in spicule morphology are related to their proportions.

Tetractine megascleres are usually broken and calcitized. Some of them, still siliceous, were exposed by etching using a 9% acetic acid solution, for three hours. The spicules preserved in the body are much more numerous than in the residue, since most of them are completely calcitized and are entirely dissolved in acid.

It has been noted (Hinde 1887; Rich 1958) that the genus *Geodites* Carter (1871) has not been formally defined, and species belonging to this genus were only described on the basis of the various loose spicules in the sediments (Hinde & Holmes 1892). De Laubenfels (1963) established the criterion of identification of *Geodites* to be megasclere morphology (triaenes with blunt rays). Finally, according to Rezvoi et al. (1971) and Reid in Kaesler (2004), Zhuravleva replaced, in 1962, the invalid *Geodites* name and reconsidered the genus under a new name: *Geoditesia*.

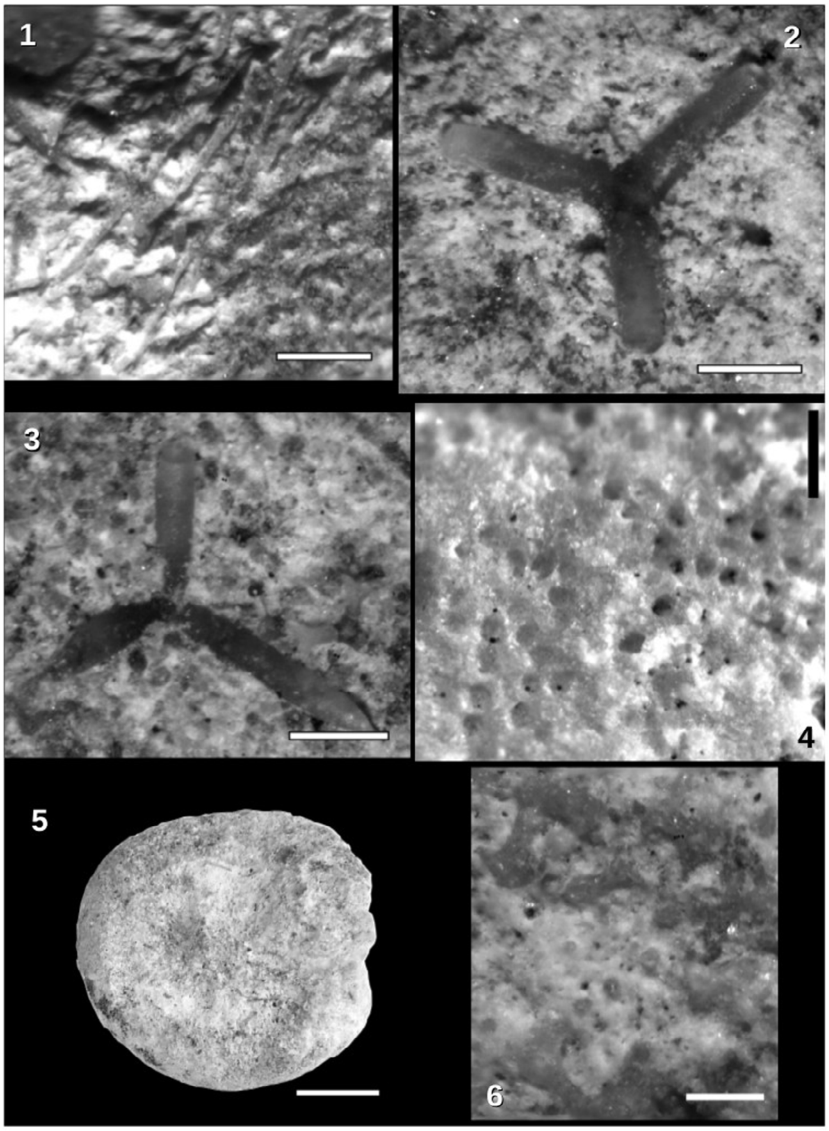

Figure 5. (1) *Geoditesia jordaniensis* sp. nov. – thin oxeas of the structure, specimen ESH 2009 I 2; scale bar = 0.1 mm. (2) *Geoditesia jordaniensis* sp. nov. – smooth and slender radial triaene, specimen ESH 2009 I 10; scale bar = 0.25 mm. (3) *Geoditesia* sp. – triaene-type megasclere, with radial orientation, specimen ESH 2009 I 26; scale bar = 0.7 mm. (4) ?*Geoditesia* sp. – small round ostia on the cortex, with irregular disposition, specimen ESH 2009 I 22; scale bar = 1 mm. (5) *Sontheimia* sp. ex gr. *S. parasitica* Kolb, specimen ESH 2009 I 24?; scale bar = 6 mm. (6) *Sontheimia* sp. ex gr. *S. parasitica* Kolb – tetraclones among micro-spheres, specimen ESH 2009 I 24?; scale bar = 0.3 mm.

It is noteworthy that until now there have been no entirely preserved fossils belonging to the genus known; only loose spicules are described. One of the reasons might be poor cohesion of the skeletal elements in the structure, so that the sponge easily disintegrated after death. The absence of fusion between the mineral skeletal elements, combined with a turbulent environment, is probably the reason that *Geodites* spicules can be abundant in sediments. In the fossils, the spicules are secondary cemented by calcitic precipitation during diagenesis.

The closest genus with living representatives to *Geoditesia* is *Geodia*, also a member of the Geodiinae. However, the living forms have a radiate inner structure like in *Geodia stellata* (Kaesler, 2004). On the contrary, *Geoditesia* has a chaotic disposition of spicules and a much smaller body size.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

Geoditesia sp.
Figure 5(3)

Material. 1 specimen (ESH 2009 I 26).

Description. Spherical sponge, 28 mm in diameter, without visible osculum or pedicle. It has a large variety of spicules: oxeas, arranged radially or parallel to the surface, triaene-type megascleres, some of which are dichotriaenes; there are also protriaenes, and microscleres: discoasters and sterrasters.

Remarks. The general appearance of the detailed surface in microscopic view is clearly different from *Geoditesia jordaniensis* sp. nov., due to relative abundance of larger oxeas and triaenes. The fossil, probably represents a new species, but the study of more than a single specimen is required.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

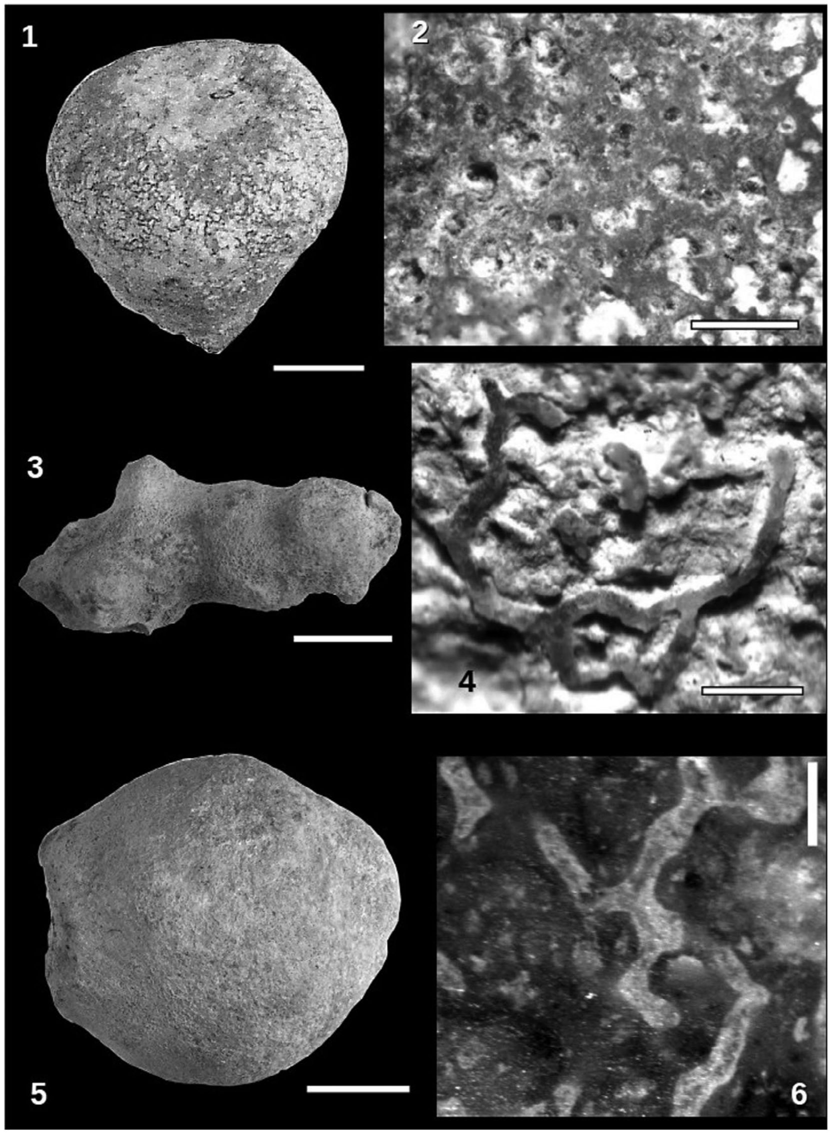

Figure 6. (1) *Jereica sp.*, specimen ESH 2009 I 24; scale bar = 3 mm. (2) *Jereica sp.* – sponge surface, exposing small irregular ostia, specimen ESH 2009 I 24; scale bar = 0.1 mm. (3) *Jereica* sp. cf. *J. tuberculosa* Roemer, specimen ESH 2009 I 6; scale bar = 1 cm. (4) *Jereica* sp. cf. *J. tuberculosa* Roemer – fused megascleres in contorted network arrangement, specimen ESH 2009 I 6; scale bar = 1.5 mm. (5) *Mughanniyyum hanium* gen. nov., sp. nov. – holotype, specimen ESH 2009 I 11a; scale bar = 1 cm. (6) *Mughanniyyum hanium* gen. nov., sp. nov. – holotype, calcitized desma in polished section, specimen ESH 2009 I 11a; scale bar = 0.5 mm.

?*Geoditesia* sp.
Figure 5(4)

Material. 1 specimen (ESH 2009 I 22).
Description. Round, sub-spherical, slightly flattened sponge. The body does not present any particular inner order, but is composed of a dense array of chaotically intermingled spicules without any visible alignment. There are no internal canals, paragaster or osculum visible. Partially calcitized fine oxeas are present. On the surface, there are also calcitized triaenes visible, and sterrasters typical of the Geodiidae. The cortex is partially preserved, showing abundant very small round ostia (0.2–0.3 mm in diameter).
Remarks. The specimen is ascribed to *Geoditesia (Geodites)*, the only Middle Jurassic genus assigned to the family. The studied sponge is similar to *Geodites* sp., sensu Hinde (1893), but it is not identical. The angles between the clads and the rhabd of the specimen are slightly more obtuse than right angles, the rhabds are much more slender and the clads are longer. The triaenes in our material are of the ancorinid type and there is no doubt about the affiliation to the tetractinellids in general.
Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

'Lithistida'
Order Tetralithistida Lagneau-Hérenger, 1962
Suborder Tetracladina Zittel, 1878
Family Protetraclisidae Schrammen, 1924
Genus *Sontheimia* Kolb, 1910

Type species. *Sontheimia parasitica* Kolb, 1910, subsequent designation by de Laubenfels, 1955

Sontheimia sp. ex gr. *S. parasitica* Kolb, 1910
Figure 5(5),(6)

Material. 1 specimen (ESH 2009 I 24?).
Description. Small, hemispherical, cup-like sponge, with small but distinct osculum. Height 15 mm, diameter 21.5 mm. The

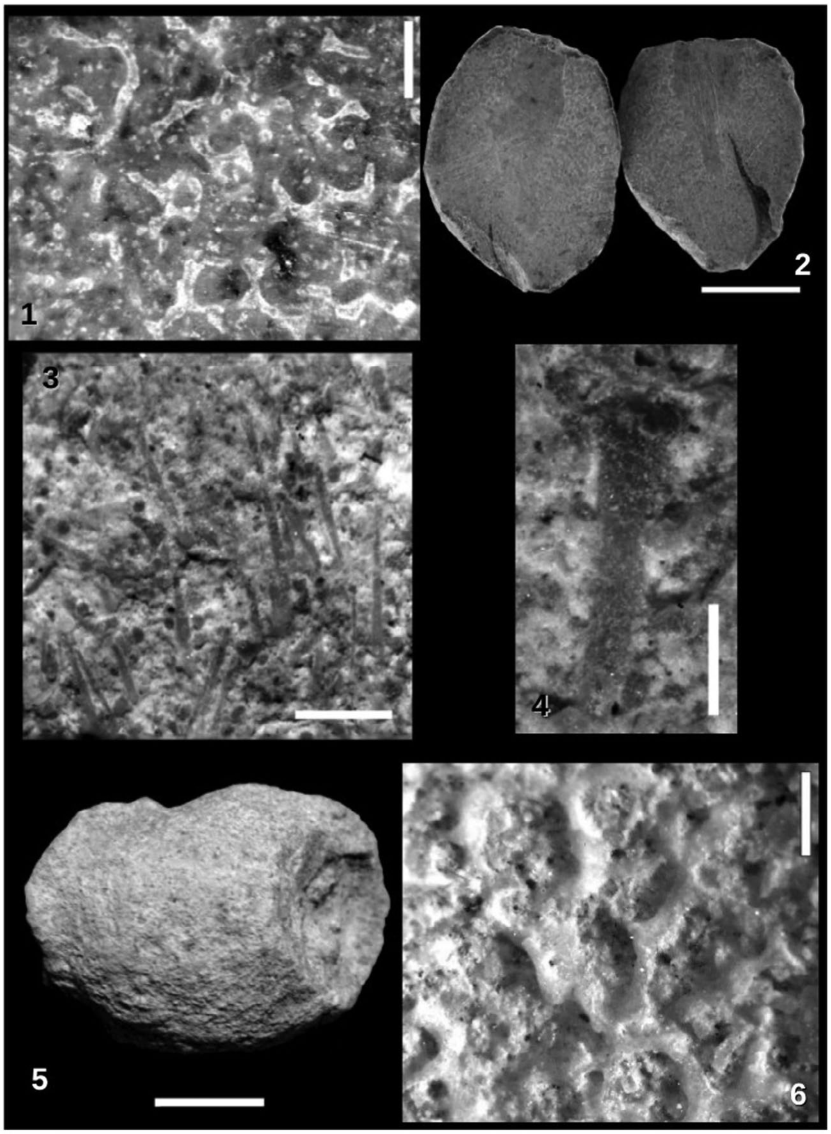

Figure 7. *Mughanniyyum hanium* gen. nov., sp. nov. (1) Holotype, various loose megaclones in polished sections, specimen ESH 2009 I 11a; scale bar = 1 mm. (2) Polished longitudinal section, specimen ESH 2009 I 4; scale bar = 1 cm. (3) Fascicular groups of oxeas, specimen ESH 2009 I 4; scale bar = 0.1 mm. (4) An atypical tylostyle within sponge body, specimen ESH 2009 I 4; scale bar = 80 µm. (5) Specimen ESH 2009 I 12; scale bar = 1 cm. (6) Desmas on corroded surface, specimen ESH 2009 I 16; scale bar = 0.1 mm.

walls are thin (3–5 mm). The pores or ostia not visible and the aquiferous system cannot be identified. Strong tetraclones and radial triaenes are present. Sometimes, there are interlocked spicules including mesotrider or trider tetraclonal desmas, as well as oxeas. Reniform microspheres, of 60–75 µm, visible on the surface. No cortex preserved.

Remarks. The specimen is similar to *Sontheimia parasitica*, but the presence of microspheres and oxeas represents a clear difference in spiculation. Skeletal meshes are also not visible.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan; upper White Jura (upper Malm) of Sontheim and Gerstetten (Swabian Alb) (Wagner 1963); Oxfordian marls (Alfa), Plettenberg; Oxfordian crumpled limestones (Alfa), Bärenthal (Pisera 1997), Germany.

Order Spirosclerophorida Reid, 1963
Suborder Rhizomorina Zittel, 1895
Superfamily Scleritodermatoidea Sollas, 1888

Family Jereicidae Schrammen, 1924
Genus ***Jereica*** Zittel, 1878

Type species. *Jereica polystoma* (Roemer, 1864), subsequent designation by Moret, 1926 (fide Kaesler 2004)

Jereica sp.
Figure 6(1),(2)

Material. One small but well preserved specimen (ESH 2009 I 24).

Description. Bulbous *Jereica*, conical at the lower end, with a general shape resembling a fig fruit. There are many small ostia densely scattered on the sides. Cortex as described by Reid in Kaesler (2004) is not preserved. The exposed surface shows typical rhizoclones. The summit is poorly preserved, so the postica can be barely characterised, but are just visible.

Specimen is small, probably juvenile: 12 mm in height and maximum diameter of 11 mm.

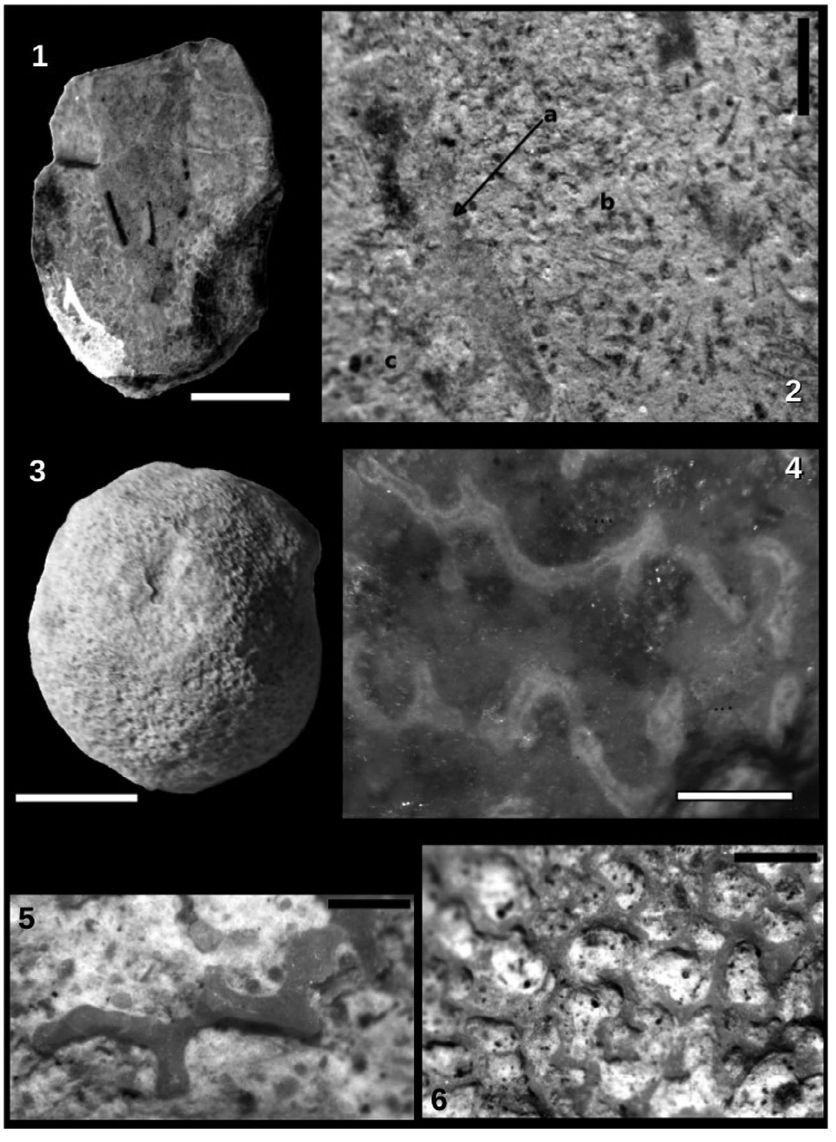

Figure 8. *Mughanniyyum hanium* gen. nov., sp. nov. (1) Longitudinal polished section showing deep, tapered paragaster and calcitized lithistid network, specimen ESH 2009 I 18; scale bar = 9 mm. (2) Corroded polished longitudinal section, showing the endosomal wall (a) separating the endosome (c) and the paragaster filling (b), specimen ESH 2009 I 18; scale bar = 1 mm. (3) Oscular view, specimen ESH 2009 I 29; scale bar = 1 cm. (4) Large megaclones in polished section, specimen ESH 2009 I 29; scale bar = 0.6 mm. (5) Branched rhizomorine desma, specimen ESH 2009 I 51; scale bar = 0.5 mm. (6) Typical reticulate pattern of the skeleton, specimen ESH 2009 I 52; scale bar = 1 mm.

Remarks. The studied fossil cannot be confused with *Coelocorypha subglobosa* Zittel, despite the sediment filled osculum, because of the visible ostia and the lack of aporhyses. It is best described as resembling *Jereica punctata* Goldfuss. However, that species is only known from the Cretaceous and it is of significantly larger size. More material would be necessary in order to ascribe the specimen to a certain species.
Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

Jereica sp. cf. *J. tuberculosa* Roemer, 1864
Figure 6(3),(4)

Material. 1 fragmented but representative specimen (ESH 2009 I 6).
Description. Knobby sponge, 42 mm long, with visible terminal osculum, tuberculate surface and small ostia. The main part of the cylindrical body is of about 15 mm in diameter, with convolute surface and irregular constrictions, with branching tapered tubercles up to 3.5 mm in height and 11 mm diameter, decreasing to 5–6 mm towards the rounded top. No osculum-like openings visible at tubercle apices. Appearance of tubercles resembles branch buds. Osculum is placed on rounded tip of the body; visible diameter about 4 mm and marginal wall thickness 2–3 mm. Cortex is not preserved. The skeleton structure is reticulate, thick, with round pores of various sizes. Most of the spicules are irregular curved rhizoclones, moderately well-defined. Where strongly interlocking, these produce a fibrous appearance to the skeleton. There are also oxeas, in small number, without particular orientation. On the body surface, the megascleres are linked in a meandering network, with no regular geometrical pattern. The sponge is completely calcitized.
Remarks. The genus is typical of the German Cretaceous, but has also been recovered from the Polish Upper Jurassic (Trammer 1982). The main difference of this specimen compared with the

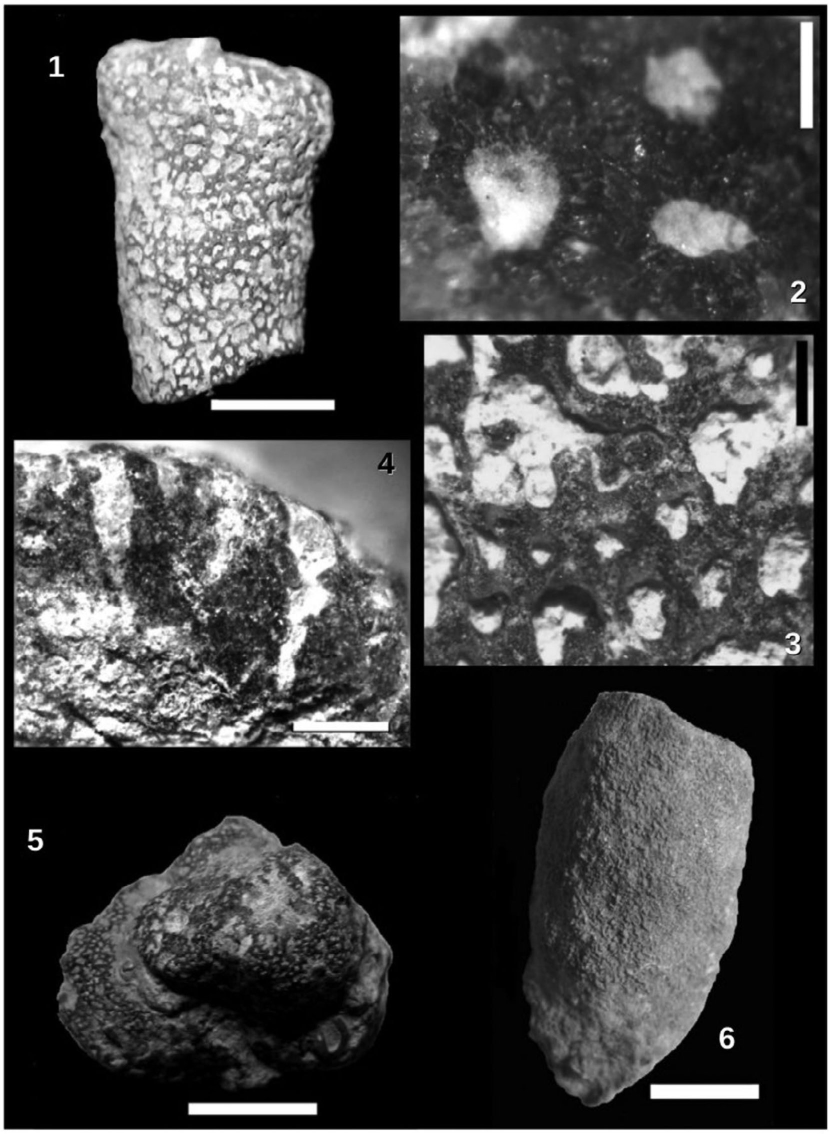

Figure 9. (1) *Pareudea bronnii* (Goldfuss) – pore pattern on the fragmentary specimen ESH 2009 I 28; scale bar = 8 mm. (2) *Pareudea bronnii* (Goldfuss) – secondary radial calcite crystals around ostia, specimen ESH 2009 I 28; scale bar = 0.5 mm. (3) *Pareudea bronnii* (Goldfuss) – thick skeletal fibres around deep incurrent channels, specimen ESH 2009 I 28; scale bar = 1 mm. (4) *Pareudea bronnii* (Goldfuss) – inhalant water channels, specimen ESH 2009 I 28; scale bar = 1.5 mm. (5) *Pareudea bronnii* (Goldfuss) – colonial specimen ESH 2009 I 44; scale bar = 1 cm. (6) *Peronidella cylindrica* (Goldfuss), specimen ESH 2009 I 45; scale bar = 1 cm.

Cretaceous specimens is the latter have the spicules completely and densely covered with numerous clearly visible, strong processes. The only other reason for the provisional identification is that the species is considered typical of the Upper Cretaceous and has not previously been reported from the Jurassic.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

Family Scleritodermatidae Sollas 1888

Remarks. The affiliation to the family is based on the skeletal features: skeletal framework clearly fibrous internally, but without conspicuous longitudinal fibres; internal structure exposed at skeletal surface, not masked by external cortex; megarhizoclones and desmas on the surface are similar to those in the interior; typical sigmaspires and oxeas are present (after Reid in Kaesler 2004). The outer shape of the specimens described here as *Mughanniyyum* gen. nov. does not comply with the regular morphology of body and osculum seen in previously-known representatives of the family. It more closely resembles the Jereicidae in overall form; however, unlike the latter, the internal structure is reticular rather than fibrous and there are no longitudinal fibres. The paragaster also has a completely different morphology. The skeletal framework of our material is far more significant for taxonomic affiliation than gross body form, and hence our assignment to the Scleritodermatinae.

A new subfamily, Jordaniinae, is here introduced to accommodate *Mughanniyyum* gen. nov.

Subfamily Jordaniinae, new subfamily

Derivation of name. Refers to the country where the type material was collected.

Diagnosis. Bulbous or cylindrical, compact, with thick walls; skeletal framework made of non-tuberculate dicranoclone desmas and un-connected oxeas. No skeletal channels or cortex are present.

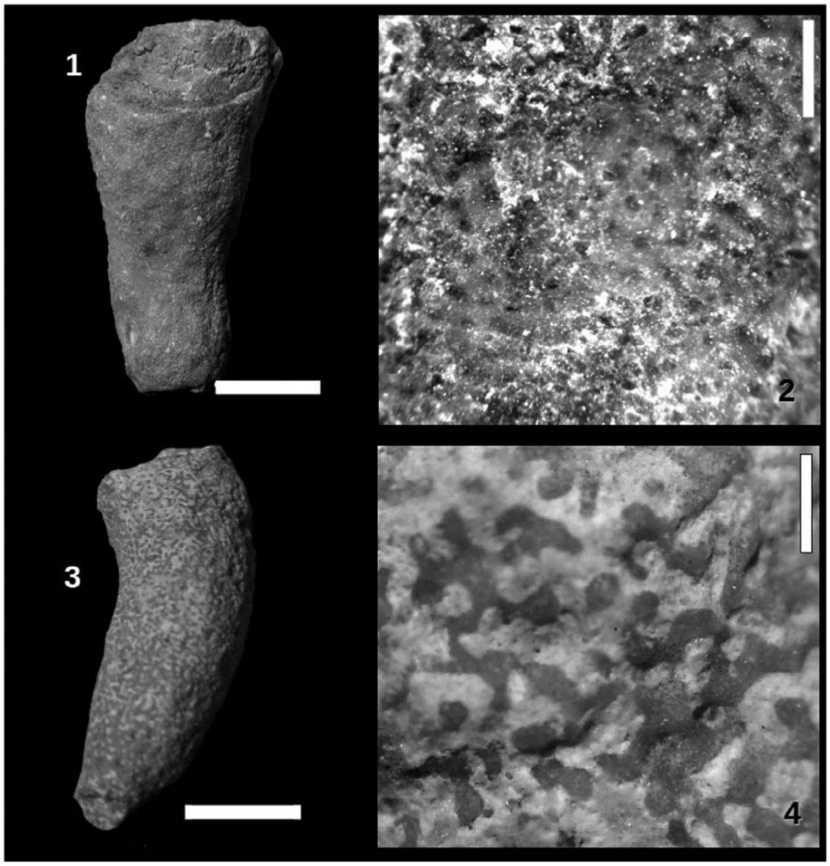

Figure 10. (1) *Peronidella* sp. cf. *P. metabronnii* Sollas – cortex covered with small pores, showing depressions, specimen ESH 2009 I 5; scale bar = 1 cm. (2) *Peronidella* sp. cf. *P. metabronnii* Sollas – arrangement of small pores, specimen ESH 2009 I 5; scale bar = 0.5 mm. (3) *Endostoma quenstedti* (Zittel), specimen ESH 2009 I 19; scale bar = 1 cm. (4) *Endostoma quenstedti* (Zittel) – surface detail, specimen ESH 2009 I 19; scale bar = 0.25 mm.

Remarks. The new taxon is differentiated from the subfamily Scleritodermatinae Sollas mainly by the bulbous, compact shape of the type material, unlike the typically funnel-like, flabellate or convolute sponges of the latter subfamily, for which the general morphology is distinctive. There are also no skeletal pores as are visible in Leiodorellinae Schrammen and there are no aporhyses or elongate postica as seen in Amphitelioninae Schrammen. The family Scleritodermatidae Sollas also includes an uncertain subfamily containing the genus *Pleurophymia* Pomel (Reid in Kaesler 2004), which shows sufficient distinct features to warrant a distinct subfamily status. These include a generally cup-like or flabellate shape, large papilliform postica, small pores, and skeletal canals. These features indicate that the genus cannot belong to the newly described subfamily.

Genus ***Mughanniyyum*** gen. nov.

Type and only species. *Mughanniyyum hanium* sp. nov.
Derivation of name. Refers to the name of the lithostratigraphic unit from which the specimens were collected.
Diagnosis. Demosponges with bulbous to cylindrical habit and the surface with a reticulate pattern. Osculum is always visible and paragaster is moderately deep, conical, single channelled, without differentiated aquiferous system internally. Skeletal network consists of connected rhizomorine monocrepidial megaclones (megarhizoclones). Large and small oxeas are usually present, straight or slightly curved. Triaenes not identified.

Mughanniyyum *hanium* sp. nov.
Figures 6(5),(6), 7(1)–(6) and 8(1)–(6)

Derivation of name. The species is named in the memory of Hani Ahmad, brother of the co-author of the present study, Fayez Ahmad.
Holotype. Figures 6(5),(6) and 7(1) – specimen ESH 2009 I 11a.
Paratypes. Figure 7(2)–(4) – specimen ESH 2009 I 4; Figure 7(5) – specimen ESH 2009 I 12; specimen ESH 2009 I 13; Figure 7(6) – specimen ESH 2009 I 16; Figure 8(1),(2) – specimen ESH 2009 I 18; Figure 8(3),(4) – specimen ESH 2009 I 29, Figure 8(5) – specimen ESH 2009 I 51.
Other material. A well-preserved fragment.
Type locality and horizon. Tal el Dhahab, Callovian marls of Mughanniyya Formation.
Diagnosis. Paragaster large, circular in cross section and without lateral channels, but with narrow vertical furrows on its interior surface. Reticulate skeletal network includes desmas. An endocortex is present adjacent to paragaster, consisting of irregular rhizoclones, as a continuous endosomal wall. The oxeas are long and thin, sometimes in un-oriented fascicular groupings, otherwise in confused arrangement within sponge body. The abundant oxeas penetrate the endocortex in region near paragaster. Loose desmas may be present.
Description. Sponges 22–41 mm in height and 15–29 mm maximum diameter. The shape may be slightly elongated. Pedicle trace may be present. Osculum narrow (4–7 mm in diameter).

Paragaster slightly larger than osculum in diameter. Furrows inside paragaster measure 1000–1080 μm in width. Paragaster grows thinner towards the base. Walls thick, with no visible ostia. All spicules are completely calcitized in our specimens. Oxeas also present in the paragaster filling; oxea dimensions are up to 3700 μm in length and 190 μm in width. There is some morphological variability between specimens in terms of proportions of the oxeas (and in some cases they are absent), and in desmas density, but the main features are constant. On some specimens, remains of a skeletal membrane may be present, partially covering the osculum.

Remarks. The external features are quite similar with those of *Jereica*, except for the paragaster, which does not consist of a set of narrow channels, with separate openings to the oscular surface, but forms a single large cavity with a clearly defined osculum. The similarity of the fibrous spicular structure is also questionable, since the reticulate or fibrous character of the structure is quite subjective and there are no longitudinal fibres.

One of the specimens is attached to a bivalve. This might indicate a preference for hard substrata.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan.

Class Calcarea Bowerbank, 1864
Subclass Calcaronea Bidder, 1898
Order Stellispongiida Finks & Rigby, 2004
Family Stellispongiidae de Laubenfels, 1955
Subfamily Stellispongiinae de Laubenfels, 1955
Genus *Pareudea* Étallon, 1859

Type species. *Scyphia bronnii* (Goldfuss, 1829), subsequent designation by de Laubefels, 1955

Pareudea bronnii (Goldfuss, 1829)
Figure 9(1)–(5)

1858 *Scyphia Bronnii* Goldfuss – Quenstedt, p. 697, pl. 84, Fig. 20.
1862 *Scyphia Bronnii* Münster – Goldfuss, pp. 86, 87, pl. XXXIII, Fig. 9.
1864 *Pareudea gracilis* Etallon – Etallon in Thurmann and Etallon, p. 421, pl. LVIII, Fig. 30.
1878 *Scyphia Bronnii* Goldfuss – Quenstedt, p. 171, 183, 184, pl. 124, Fig. 1–15.
1963 *Eusiphonella bronnii* (Goldfuss) – de Laubenfels, p. E99, text-Fig. 84,3.
1964 *Eusiphonella bronnii* (Münster) – Wagner, p. 25–28, text-Fig. 1, pl. 5, Fig. 1–3.
1968 *Eusiphonella bronnii* (Münster) – Bărbulescu, p. 1(229), 4(232), Tab. 1, pl. I, Fig. 1.
1975 *Eusiphonella bronnii* (Muenster) – Hurcewicz, pp. 226, 246, Tab. 1, pl. XXXIX, Fig. 10.
1984 *Eusiphonella bronnii* (Münster in Goldfuss) – Müller, pp. 33, 34, pl. 21, Fig. 3–10, pl. 22, Fig. 1.
1991 *Eusiphonella bronnii* (Muenster) – Bizzarini, pp. 88, 89, pl. 2, Fig. 1.

Material. One fragmentary specimen and one colony of several individuals – ESH 2009 I 28 – Figure 9(1)–(4); ESH 2009 I 44 – Figure 9(5).

Description. Small sponge, almost cylindrical, with base slightly narrower than the apical end. It has a central, narrow osculum (¼ to 1/5 of the sponge diameter). The distal end has sharp edges. The skeleton consists of fibres in typical reticulate pattern, with irregular loops. The depth of the paragaster is varied: in the fragmentary specimen it is rather large, while in the colony, the paragasters are shallower. Specimen body diameters: 8–10 mm, osculum diameter: 1.5–2 mm, wall thickness: 3–4 mm. The colony dimensions are 26 × 21 mm and it consists of four individuals in diverging positions from a single attachment point. The individuals which are entirely preserved measure 5–9 mm in height. Fine ostia are present all over the lateral surface and they have various sizes and irregular rounded shape. Ostia are uniformly distributed, but there is no geometric arrangement. The skeletal network is completely re-crystallized, with radial crystals surrounding ostia. The latter are the lateral openings of deep horizontal channels directed towards the paragaster.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan; coral strata of Upper Jurassic in Franconia and Swabia, Germany (Goldfuss 1862); Upper Jurassic of western Central Dobrogea, Romania (Bărbulescu 1968); Upper Oxfordian of Polish Jura Chain, Poland (Hurcewicz 1975); Oxfordian, England (Hurcewicz 1975); Upper Jurassic of Valdobbiadene (Venetian Prealps), Italy (Bizzarini 1991).

Genus *Peronidella* Zittel in Hinde, 1893

Type species. *Spongia pistilliformis* (Lamouroux, 1821), SD by de Laubenfels, 1955

Peronidella cylindrica (Goldfuss, 1826)
Figure 9(6)

1834.*Scyphia cylindrica?* Goldfuss – Klöden, p. 271.
1852.*Spongites (Scyphia) elegans* Goldfuss – Quenstedt, p. 673, pl. 61, Fig. 2.
1862.*Scyphia elegans* – Goldfuss, p. 5, pl. II, Fig. 5.
1862 *Scyphia cylindrica* – Goldfuss, pp. 4, 5, pl. II, Fig. 3, pl. III, Fig. 12.
1883 *Peronella cylindrica* Goldfuss – Hinde, pp. 167, 168, pl. XXXII, Fig. 4.
1885 *Spongites (Scyphia) elegans* Goldfuss – Quenstedt, p. 1039, pl. 85, Fig. 5.
1968 *Peronidella cylindrica* Goldfuss – Bărbulescu, pp. 235–237, pl. II, Fig. 29, 30, pl. III, Fig. 15–23.
1975 *Peronidella cylindrica* (Goldfuss) – Hurcewicz, pp. 269, 270, pl. XL, Fig. 14.
1984 *Peronidella cylindrica* (Goldfuss) – Müller, p. 24, pl. 19, Fig. 1, 2.

Material. One specimen (ESH 2009 I 45).

Description. Massive cylindrical sponge, 39 mm in height and with maximum diameter 20 mm, with apical osculum. The paragaster is tubular, circular in cross section, 7 mm in diameter; deep and entirely filled with sediment. The walls are thick. Inhalant water channels are visible up to 3 mm deep into the wall thickness towards the outer surface of the body. Parenchymal skeleton consists of a dense network of thick fibres of about 0.6 mm in diameter.

Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan; Uppermost Jurassic limestones of Potsdam, Germany (Klöden 1834); Nattheim, Germany (Quenstedt 1852, 1885); Upper Jurassic limestones of Streitberg, Muggendorf and Thurnau, Germany (Goldfuss 1862); Upper Jurassic of Randen, Heidenstadt, Germany (Hinde 1883); Coralline Oolite (Upper

Table 2. Sponge taxa occurrence in the Kachchh Basin, the Mughanniyya Formation (Jordan) and Negev Desert. Taxa of Kachchh are according to Mehl and Fürsich (1997). Taxa of Negev are according to Wilson et al. (2010). Taxonomical affiliations were updated, according to Kaesler (2004), emended by Borchiellini et al. (2004), Morrow et al. (2012), Morrow and Cárdenas (2015), and Schuster et al. (2015).

Sponge taxa	Kachchh sponge facies (Bathonian) no. of species	Jordan – Mughaniyya Formation (Callovian) no. of species	Negev Desert coral-sponge community (Callovian) no. of species
Class Demospongiae			
Subclass Heteroscleromorpha			
Order Tetractinellida			
Suborder Astrophorina	–	3	–
‘Lithistida’			
Order Tetralithistida			
Suborder Tetracladina	1	1	–
Suborder Didymmorina	1	–	–
Order Axinellida	–	–	5
Order Monalithistida			
Suborder Spaherocladina	2	–	–
Order Spirosclerophorida			
Suborder Rhizomorina	4	3	–
Class Hexactinellida			
Subclass Hexasterophora			
Order Hexactinosa	1	–	–
Order Lychniscosa	1	–	–
Class Calcarea			
Subclass Calcaronea			
Order Stellispongiida	–	4	–
Unrecognizable supposed sponges	1	–	–

Jurassic) at Malton, Yorkshire, England (Hinde 1883); Upper Jurassic of Western Central Dobrogea, Romania (Bărbulescu 1968); Upper Oxfordian of Polish Jura Chain, Poland (Hurcewicz 1975); Upper Jurassic of Southern Germany (Müller 1984).

Peronidella sp. cf. *P. metabronnii* Sollas, 1883
Figure 10(1),(2)

Material. One fragmentary specimen (ESH 2009 I 5).
Description. The specimen conforms with Hinde’s (1893) description. It is a simple conical sponge, straight, the summit flat, with millimetre-thick walls; up to 3 cm in height and with a relatively wide osculum; the spicular structure is very indistinctly shown. The surface of the body is covered with cortex that shows depressions in regular pattern, approximately 1 mm in diameter and separated by 1–2 mm. The cortex has small pores, of about 0.1 mm in diameter, perfectly round and equally scattered, even within the mentioned depressions.

The skeletal network is typical for the genus and it is meandering or maze-like. There are no identifiable spicule remains, either loose or fused.
Remarks. The main difference from Hinde’s (1893) description is the presence of the aforementioned depressions. However, the specimens figured in his study show an irregular surface that may be the result of natural corrosion of a primary depressed structure.
Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan; Bathonian of Dorset, England (Hinde 1893); Callovian and Upper Oxfordian of Polish Jura Mountains, Poland (Hurcewicz 1975).

Family Endostomatidae Finks, 2004
Genus *Endostoma* Roemer, 1864

Type species. *Scyphia foraminosa* Goldfuss, 1833 (by subsequent designation of de Laubenfels, 1955)

Endostoma quenstedti (Zittel, 1878)
Figure 10(3),(4)

1858 *Spongites astrophorus caloporus* Goldfuss – Quenstedt, p. 696, pl. 84, Fig. 13.
1878 *Spongites astrophorus* – Quenstedt, p. 210, pl. 124, Fig. 63, 64.
1963 *Corynella quenstedti* Zittel – de Laubenfels, pp. E98, E99, Fig. 83,4.
1964a *Corynella aff. quenstedti* Zittel – Wagner, pp. 15, 18, text-Fig. 2, 3.
1964b *Corynella aff. quenstedti* (Zittel) – Wagner, pp. 25, 26, 31, 32, 34, text-Fig. 2, pl. 6, Fig. 1, 2.
1975 *Corynella quenstedti polonica* subsp. n. – Hurcewicz, pp. 226, 232–235, Tab. 1, text Fig. 6, 7, pl. XXIX, Fig. 2, pl. XXXII, Fig. 1, pl. XXXVI, Fig. 1, XXXIX, Fig. 5, 6.
1984 *Corynella quenstedti* (Zittel) – Müller, pp. 18, 19, 28, text Fig. 4, pl. 11, Fig. 1–6, pl. 18, Fig. 1, pl. 24, Fig. 4
Material. One well preserved specimen (ESH 2009 I 19).
Description. The single specimen is slender, conical and slightly curved, 28 mm in length and 9.5 mm in diameter. It is a single individual, not a colony. The oscular surface is bordered by a precise edge and there is a distinct paragaster, and osculum. The wall thickness is 3–4 mm. Osculum is small, circular, 2 mm in diameter. Ostia barely visible on the sides. The apex is altered and the cortex is not preserved. Aquiferous system consisting of irregular channels, visibly discharging in the paragaster. Skeleton is typical for the order.
Occurrence. Callovian marls; Mughanniyya Formation, Tal el Dhahab, Jordan; Upper Jurassic of the Swabian Alb, Germany (Wagner 1964; Müller 1984); Upper Oxfordian of Polish Jura Chain, Poland (Hurcewicz 1975).

Discussion

This study describes the first recorded sponges from the Jurassic strata of Jordan. The other occurrences of Middle Jurassic sponges in the Gondwana Tethys shelf are from the Negev Desert in southern Israel (Wilson et al. 2010) and the Kachchh region in western India (Mehl & Fürsich 1997). The studied fauna shows few

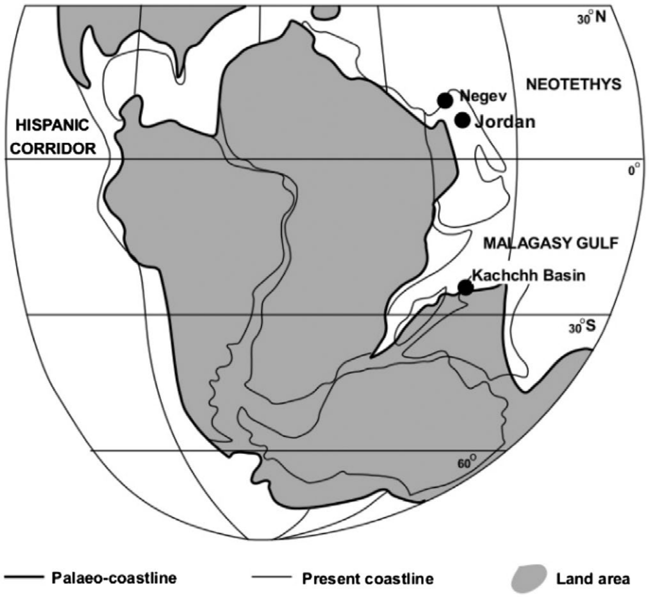

Figure 11. Palaeogeographical map of the Gondwana eastern coast (adopted from Alberti et al. 2013) showing locations of the discussed sponge faunas.

similarities with that of the Matmor Formation fauna in the Negev Desert, where sponges are mainly axinellids and the facies is different, including coral-sponge patch reefs with associated echinoderm, molluscan and sclerobiont communities, developed in shallow water along the shore, on or very near the paleoequator. In contrast, there are striking similarities between the sponge associations of the Mughanniyya Formation in Jordan and Kachchh in India.

The sponge fauna of Kachchh consists of small sized, compact sponges, associated with other invertebrates that are also present in Jordan. The non-sponge macro-invertebrates identified in both the Kachchh sponge biofacies and the Mughanniyya Formation of Jordan include the following: bivalves – *Eligmus rollandi* Douville, *Nanogyra nana* (Sowerby), *Actinostreon gregareum* (Sowerby), *Actinostreon erucum* (Defrance), *Plagiostoma* genus, *Gryphaea* genus, *Arcomytilus laitmairensis* de Loriol, *Protocardia* genus; brachiopods – rhynchonellids (but of different genera); echinoderms – cidarids of different genera; corals – *Dimorpharaea stellans* Gregory. The sponges' external morphology is remarkably similar, even though the specimens do not belong to the same taxa: centimetre sized, unbranched sponges, with rounded extremities, thick walls and small osculum. This may suggest that the environments had some common features in relation to, for example, turbulence and food supply.

The demosponge fauna is the most varied and the number of genera and species is quite similar in both locations. Furthermore, more than half of the taxa belong to the same major groups, as in the case of the lithistid sponges belonging to Tetracladina (Family Protetraclisidae) and various rhizomorine taxa. However, there are differences in the relative proportions of the sponge classes (Table 2). Class Calcarea Bowerbank is much more prevalent in Jordan, while in India, there is no identified species. Hexactinellid sponges are an important group in Kachchh, but they are completely absent in Jordan.

It is important to mention that the two sponge faunas in discussion are not precisely contemporary, but separated by between 0.1 and 2.5 Myr. In the Kachchh Basin, the Sponge Limestone Member is dated as Late Bathonian (Fürsich et al. 2005), while the Mughanniyya Formation in Jordan is of Callovian age.

In the Kachchh Basin, rare corals are associated with the sponges. The corals in the Sponge Limestone Member were not described as a separate population by Pandey and Fürsich (2001), and they comprise only 6.1% of the fauna, according to Mehl and Fürsich (1997). They consist mainly of microsolenid, solitary and cerioid colonial genera. The presumed water depth is moderate but the environment would have provided at most, only poorly illuminated conditions, as illustrated by the lack of algae and the presence of cryptic organisms that are not restricted to cryptic habitats (Mehl & Fürsich 1997). The greater number of corals in northwestern Jordan and the lack of hexactinellids suggest slightly shallower water here, in comparison with the sponge limestone of Kachchh, where the corals, although of similar types, are scarce. The sponge community in our study is associated with small sized solitary corals. One of the sponge specimens has even a juvenile corallite attached on the lateral surface as an epibiont. The presence of corals indicates a normal marine salinity.

The similar morphology of the sponges to those in India leads to the conclusion that some environmental conditions were common to both sites, as shown by the convergence of morphological features. There is also a marly facies in the Jumara Dome (Kachchh), as there is in the sponge-bearing strata in Jordan. However, in the studied sections there are no plate-like sponges, but small, broad species associated with small solitary corals or massive colonies. Their shape is an indication of strong adherence onto hard substrates (that were not identified). The compact fossil bodies appear to be adapted for offering minimal resistance against water movement, as an adaptation to the conditions of a medium energy environment, perhaps in the presence of strong sea floor currents. We estimate a depth great enough for the illumination to be faint, but water movement to be significant, resulting in moderate turbidity levels. These parameters lead to the supposition of a depth below the storm waves base, where organisms without shell could live, as in the sponge limestone facies of Kachchh (Misra & Pandey 2008). The substantial water energy resulted in a relatively low sedimentation rate that was unsuitable for bacterial growth in the form of coherent mats.

Similarly to Jordan, in Kachchh (Jumara Dome), the environment where the sponge community was developed was located on a carbonate ramp in open marine conditions, on the mid to outer part of a deep ramp. The water energy was primarily low, but increased during a transgressive phase (Misra & Pandey 2008). The similarities include the same illumination conditions, water energy and a broadly similar water depth.

Finally, the marls of the S7 and S10 levels of Tal el Dahab section indicate a greater distance to the nearest terrigenous source. This represents an open marine environment, on the proximal to mid shelf. The sponge faunas compared above are located on the shelf of Gondwana eastern coast (Figure 11). The high proportion of carbonate in the sediments is the main cause for post-burial calcitization of the siliceous spicules, and most of the sponges have had the composition of their skeleton changed after death from silica to calcite. Furthermore, according to Reolid (2007), bacteria living in sponges mesohyl (especially in geodiid demosponges), generate organic macromolecules that may encourage early mineralisation.

In the study on Middle Jurassic brachiopod faunas in Northwestern Jordan, Ahmad (2000) included some palaeoecological and palaeoenvironmental conclusions based on his observations. A marginally intertidal to shallow subtidal marine environment was considered representative for the Middle Jurassic of Jordan. That interpretation differs slightly from our conclusions based on the sponges. However, our study in Mughanniyya Formation confirms and completes his other palaeoecological conclusions: that the palaeoenvironment comprised turbid waters of low to medium energy, fine-grained muddy sediments, and a low but continuous sedimentation rate.

Sponge occurences in southern Israel and the Mughanniyya Formation in Jordan were geographically close, even though the palaeoenvironment was quite different. They both represent an equatorial climatic zone, and the development of the fauna is related to this palaeoclimate. In Jordan, the coeval coral population (Pandey et al. 2000) was a relatively shallow-water depth marker, even though it is interpreted as having been below the base of storm waves; together with the calcareous sponges, these indicate warm waters. Similar environmental conditions are also revealed by the study of bivalve and brachiopod faunas (e.g. Ahmad 2003; Feldman et al. 2012).

The northwestern Indian sponge fauna in the Kachchh Basin is of Bathonian age. In the Callovian, the Kachchh ecosystem changed significantly and sponges appear to have been absent (Fürsich et al. 2004). Corals were still present there in low abundance, but the carbonate sedimentation was replaced by a siliciclastic ramp and the faunal structure was completely changed. The climate became cooler, subtropical and humid.

The coral population did not develop significantly during the Middle Jurassic. The palaeoclimate became warmer only during the late Jurassic, according to the latitudinal belts constructed by Briggs (1995) on the basis of the terrestrial vegetation.

Conclusions

The first study of the sponge fauna from the Middle Jurassic of Jordan presents new taxa (a new subfamily, a new genus and two new species). The features of the studied sponges confirm the palaeoecological information already obtained from the study of other invertebrate groups from this sequence.

The studied association includes sponges ascribed to Demospongiae Sollas and Calcarea Bowerbank.

Sponges in the genus *Geoditesia*, such as *Geoditesia jordaniensis* sp. nov., are described for the first time as entirely preserved body fossils rather than dissociated spicules only. The type species of the genus *Geoditesia* is *Geoditesia haldonensis* Carter, 1871 described on the basis of isolated triaenes, dichotriaenes and diaenes. The genus is used for those types of spicules supposed of geodiid origin, but not identified as *Geodia* (Kaesler, 2004). A new subfamily, Jordaniinae, is introduced in the family Scleritodermatidae and the new genus *Mughanniyyum*, with a new species, *M. hanium*, is described.

A comparison with the Bathonian sponge fauna from the Kachchh Basin in Western India reveals strong similarities that reflect a similar palaeoenvironment. In contrast, the Callovian fauna of the Negev Desert, which was much closer in age and geography, shows major differences in the sponge fauna; this is interpreted as being due to a shallower water depth and other environmental differences. Overall, many aspects of the peri-Gondwanan sponge faunas appear to have been strongly constrained by palaeoenvironment, but with widespread faunal similarity when conditions were similar.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abu El-Ata AS, EI-Khafeef AA, Ghoneimi AE, Abd Alnabi, SH, Al-Badani, MAA. 2013. Applications of aeromagnetic data to detect the Basement Tectonics of Eastern Yemen region. Egypt J Petrol. 22:277–292.

Ahmad F. 1998. Taxonomy and paleoecology of the benthic macroinvertebrate fauna from the Middle Jurassic of northwestern Jordan [PhD thesis]. Wurzburg: University of Wurzburg (unpublished).

Ahmad F. 1999. Middle Jurassic macroinvertebrates from northwestern Jordan. Beringeria 23:3–46.

Ahmad F. 2000. Middle Jurassic brachiopod faunas from northwestern Jordan. Neues Jb Geol Paläontol Monat. 2000:301–313.

Ahmad F. 2002a. On the Bajocian-Callovian age of the Jurassic Rocks of Northwestern Jordan. Dirasat Pure Sci. 29:47–52.

Ahmad F. 2002b. Middle Jurassic Brachiopods Associations from Wadi Shaban, Northwestern Jordan. Abhath Al-Yarmouk Basic Sciences and Engineering Series 11:745–762.

Ahmad F. 2003. Brachiopod faunas from the Middle Jurassic Mughanniyya Formation of Wadi Shaban, Jordan. Neues Jb Geol Paläontol Abh. 228:37–59.

Ahmad F, Farouk S, Ziko A. 2013. Facies associations of the Bathonian Hamam Formation from the Northwestern Jordan. Arab J Geosci. 7:4861–4875.

Alberti M, Fürsich FT, Pandey DK. 2013. Seasonality in low latitudes during the Oxfordian (Late Jurassic) reconstructed via high-resolution stable isotope analysis of the oyster Actinostreon marshi (J. Sowerby, 1814) from the Kachchh Basin, western India. Int J Earth Sci. 102:1321–1336.

Bărbulescu A. 1968. Asupra unor spongieri calcaroși jurasici din Dobrogea. [On some Jurassic calcareous sponges in Dobrogea.] Buletinul Societății de Științe Geologice din R. S. România. 10:229–240. Romanian.

Bizzarini F. 1991. Inozoa (Porifera) del Giurassico Superiore dei Dintorni di Valdobbiadene (Prealpi Venete) [Inozoa (Porifera) from the upper Jurassic of Valdobbiadene surroundings (Venetian Prealps)]. Annali dei Musei Civici di Rovereto, Sezione: Archeologia, Storia, Scienze Naturali. 6:83–100.

Blake GS. 1935. The stratigraphy of Palestine and its building stones. Jerusalem: Printing and Stationery Office; p. 1–133.

Blake GS. 1940. Geology, soils and minerals, and hydrogeological correlation. In: Ionides MG, editor. Report on the water resources of Transjordan and their development. London: Crown Agent for the Colonies; p. 43–127.

Borchiellini C, Chombard C, Manuel M, Alivon E, Vacelet J, Boury-Esnault N. 2004. Molecular phylogeny of Demospongiae: implications for classification and scenarios of character evolution. Mol Phylogenet Evol. 32:823–837.

Briggs JC. 1995. Global biogeography. Amsterdam: Elsevier; 454 pp.

Carter HJ. 1871. On fossil sponge-spicules of the greensand compared with those of existing species. Ann Mag Nat Hist. 7, 4, 38, 14: 112–141.

Cox LR. 1925. A Bajocian-Bathonian outcrop in the Jordan-Valley and its molluscan remains: Ann Mag Nat Hist. Series 9, 15:169–181.

De Laubenfels MW. 1963. Porifera. In: Moore RC, editor. Treatise on invertebrate paleontology, part E, Archaeocyatha and Porifera. Lawrence: University of Kansas Press; p. E21–E122.
Feldman HR, Schemm-Gregory M, Ahmad F, Wilson MA. 2012. Jurassic rhynchonellide brachiopods from the Jordan Valley. Acta Palaeontol Pol 57:191–204.
Fürsich FT, Oschmann W, Pandey DK, Jaitly AK, Singh IB, Liu C. 2004. Palaeoecology of middle to lower upper Jurassic Macrofaunas of the Kachchh basin, western India: an overview. J Palaeontol Soc India. 49:1–26.
Fürsich FT, Singh IB, Joachimski M, Krumm S, Schlirf M, Schlirf S. 2005. Palaeoclimate reconstructions of the Middle Jurassic of Kachchh (western India): an integrated approach based on palaeoecological, oxygen isotopic, and clay mineralogical data. Palaeogeogr Palaeoclimatol Palaeoecol. 217:289–309.
Goldfuss A. 1862. Petrefacta Germaniae tam ea quae in Museo Universitatis Regiae Borussicae Fridericiae Wilhelmiae Rhenanae servantur quam alia quaecunque in Museis Hoeninghusiano Muensteriano aliisque extant iconibus et descriptionibus illustrata [The petrifications of Germany preserved in the Museum of the Rhenan Prussian Royal University Frideric Wilhelm others then those in the Hoeninghus Muenster Museum, illustrated with new figures and descriptions] 1, Leipzig: List & Francke. Latin and German.
Hinde GJ. 1883. Catalogue of the fossil sponges in the Geological Department of the British Museum (Natural History). London: Taylor and Francis.
Hinde GJ. 1887. A monograph of the British fossil sponges, part 1. Palaeontogr Soc. 1886:1–92.
Hinde GJ. 1893. A monograph of the British fossil sponges, part 3, sponges of Jurassic strata. Palaeontogr Soc. 1893:189–254.
Hinde GJ, Holmes WM. 1892. On the sponge-remains in the lower tertiary strata near Oamaru, Otago, New Zealand. J Linn Soc Zool. 24:177–262.
Hurcewicz H. 1975. Calcispongea from the Jurassic of Poland. Acta Palaeontol Pol 20:223–291.
Kaesler RL, editor. 2004. Treatise on invertebrate paleontology, part E (revised), Porifera. Vol. 3. Boulder, CO: The Geological Society of America & The University of Kansas.
Khalil B, Muneizel SS. 1992. Lithostratigraphy of the Jurassic outcrops of north Jordan (Azab Group). Amman: Geological Bulletin 21, Internal report for the Natural Resources Authority Amman/Jordan.
Klöden KF. 1834. Die Versteinerungen der Mark Brandenburg, insonderheit diejenigen, welche sich in den Rollsteinen und Blöcken der südbaltischen Ebene finden [The petrifications of the March of Brandenburg, especially those found in the rolling stones and blocks of the southern Baltic plain]. Berlin: C. G. Lüderitz.
Mehl D, Fürsich FT. 1997. Middle Jurassic Porifera from Kachchh, western India: Paläontologische Zeitschrift. 71:19–33.
Misra A, Pandey DK. 2008. Microfacies and depositional environment of the Bathonian Jhurio Formation of the Jumara Dome, Kachchh, western India. Asian J Exp Sci. 22:123–140.
Morrow C, Cárdenas P. 2015. Proposal for a revised classification of the Demospongiae (Porifera). Front. Zool. 12:1–27.
Morrow CC, Picton BE, Erpenbeck D, Boury-Esnault N, Maggs CA, Allcock AL. 2012. Congruence between nuclear and mitochondrial genes in Demospongiae: A new hypothesis for relationships within the G4 clade (Porifera: Demospongiae): Mol Phylogenet Evol 62:174–190.
Muir-Wood HM. 1925. Jurassic Brachiopoda from the Jordan Valley. Ann Mag Nat Hist. Ser. 9, 15:181–192.
Müller W. 1984. Die Kalkschwämme der Unterordnung Inozoa Steinmann aus dem Oberen Jura von Württemberg (SW-Deutschland) [The calcareous sponges of the suborder Inozoa Steinmann from the upper Jurassic of Württemberg (SW-Germany)]. Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie). 100:1–85.
Muneizel S, Khalil B. 1993. The geology of Al-Salt map sheet no 3154-III. Amman: NRA.
Pandey DK, Ahmad F, Fursich TF. 2000. Middle Jurassic scleractinian corals from northwestern Jordan. Beringeria 27:3–29.
Pandey DK, Fürsich FT. 2001. Environmental distribution of scleractinian corals in the Jurassic of Kachchh, western India. J Geol Soc India. 57:479–495.
Picard L, Hirsch F. 1987. The Jurassic stratigraphy in Israel and the adjacent countries. Jerusalem: The Israel Academy of Sciences and Humanities; p. 1–106.
Pisera A. 1997. Upper Jurassic siliceous sponges from the Swabian Alb: taxonomy and paleoecology. Palaeontologia Polonica 57:1–216.
Quenstedt FA. 1852. Handbuch der Petrefaktenkunde/von Fr. Aug. Quenstedt [Handbook of Petrefacts/by Fr. Aug. Quenstedt]. Tübingen: H. Laupp'schen Buchhandlung; 792 pp., 62 pl.
Quenstedt FA. 1885. Handbuch der Petrefaktenkunde [Handbook of Petrefacts]. Tübingen: H. Laupp'schen Buchhandlung; 1239 pp., 100 pl.
Reolid M. 2007. Taphonomy of the Oxfordian-Lowermost Kimmeridgian siliceous sponges of the Prebetic Zone (Southern Iberia). J Taphonomy. 5:71–90.
Rezvoi PD, Zhuravleva IT, Koltun VM. 1971. Phylum Porifera. In: Orlov YA, editor. Fundamentals of paleontology. Jerusalem: Israel Program for Scientific Translations; p. 5–97.
Rich CC. 1958. Occurrence of sterrasters of the Geodiidae (Demospongea, Choristida) in Late Cenozoic Strata of Western Wellington Province, New Zealand. New Zeal J Geol Geophy. 1:641–646.
Rybakov M, Segev A. 2005. Depth to crystalline basement in the Middle East with emphasis on Israel and Jordan. In: Hall JK, Krasheninnikov VA, Hirsch F, Benjamini C, Flexer A, editors. Geological framework of the Levant. Jerusalem: Historical Productions-Hall; p. 543–552.
Schuster A, Erpenbeck D, Pisera A, Hooper J, Bryce M, Fromont J, Wörheide G. 2015. Deceptive desmas: molecular phylogenetics suggests a new classification and uncovers convergent evolution of lithistid demosponges. PLoS ONE. 10:e116038. doi:10.1371/journal.pone.0116038.
Swarieh A, Barjous M. 1993. The geology of Suwaylih map sheet no 3154-II. Amman: NRA.
Trammer J. 1982. Lower to Middle Oxfordian sponges of the Polish Jura. Acta Geol Pol. 32:1–39.
Wagner W. 1963. Kieselschwämme und Schwam-Okologie im Korallenkalk des oberen Malm von Laisacker bei Neuburg a. d. Donau [Siliceous sponges and sponge ecology in the coral limestone of the upper Malm of Laisacker near Neuburg a. d. Danube]. Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie 3:1–20.
Wagner, W. 1964. Kalkschwämme aus dem Korallenkalk des oberen Malm von Laisacker bei Neuburg a. d. Donau [Calcareous sponges from the coral limestone of the upper Malm of Laisacker near Neuburg a. d. Danube]. Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie 3:23–36.
Wilson MA, Feldman HR, Krivicich EB. 2010. Bioerosion in an equatorial Middle Jurassic coral–sponge reef community (Callovian, Matmor Formation, southern Israel). Palaeogeogr Palaeoclimatol Palaeoecol. 289:93–101.