

Holothurian sclerites from the Triassic of Jordan and their stratigraphic importance

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ABSTRACT - Holothurian sclerites are some of the most stratigraphically important microfossils of the middle Triassic of Jordan. Stratigraphically and palaeogeographically important faunas have been obtained by dissolving Triassic carbonate rocks with a dilute acetic acid. The oldest forms, *Acanthotheelia jordanica* Sadeddin, *Priscopodatus quadratus* Kozur & Mostler, and *Tetravirga perforata* Mostler, occur in the Hisban Formation (Anisian) in the area of the northeast corner of the Dead Sea and Wadi Abu Oneiz. North of this area in Wadi Salit, Ladinian holothurian faunas are especially characterized by the mass occurrence of *Schizothelidia jordanica* and *Schizothelidia multiporata* Kozur & Sadeddin in the lower part of the section (Fassanian) and *Theelia tubercula* Kristan-Tollmann in the upper part (Longobardian). In spite of some differences, the Jordanian Middle Triassic holothurian faunas are similar to those from the Northern Alps and Germanic Basin, and the Himalayas. As yet, no holothurian sclerites have been recovered from Jordanian Lower or Upper Triassic deposits. *J. Micropalaeontol.* 15(1): 87–95, April 1996.

INTRODUCTION

Holothurians are a significant group of echinoderms in the modern fauna but have a limited fossil record. They are represented only by sclerites – small calcareous spicules formed in the body wall of the organism. Holothurian sclerites are widespread in micropalaeontological residues but have only been the subject of limited study, e.g. Frizzell & Exline (1955a,b), Gilliland (1993).

Holothurian sclerites from Jordan were unknown until Kozur & Sadeddin (1990) described the first holothurian sclerites from Middle Jurassic carbonate rocks. Later, Sadeddin (1991) described the new holothurian species *Acanthotheelia jordanica* from early Middle Triassic rocks of the Pelsonian (middle Anisian). Sadeddin & Kozur (1992) discussed the geographic distribution of *Theelia tubercula* Kristan-Tollmann and its Triassic distribution. Kozur & Sadeddin (1992) described the new family Schizothelidae and two new species; *Schizothelidia jordanica* and *S. multiporata* and the new genus *Schizoacanthotheelia* from the Fassanian (early Ladinian). Further investigations by dissolving Triassic carbonate rocks from different localities using dilute acetic acid solutions indicate that Triassic sediments in Jordan frequently contain holothurian sclerites (see Fig. 2). Upper Cretaceous carbonate rocks (Cenomanian–Turonian) have also been found to be rich in holothurian sclerites (Sadeddin, in preparation).

In this paper, Triassic rock sequences from various localities in which holothurian sclerites occur are briefly discussed; holothurian sclerites are described from strata of the Anisian (Hisban Formation) and Ladinian. To date, no holothurian sclerites have been obtained from the lower Triassic (Skythian) of Jordan. Holothurian sclerites from the late Triassic (Carnian) outcrops have not yet been documented (although the lower part of the rock sequences at Wadi Huni could be placed into Cordevolian (lower Carnian)).

All studied specimens are deposited in the Department of Earth and Environmental Sciences, Yarmouk University, Irbid, Jordan.

HOLOTHURIAN-BEARING SAMPLES – LITHOLOGY AND PALAEOLOGY

Northeast corner of the Dead Sea (Area 1 of Fig. 1)

Samples S1, 7b, 8b, TJ1, TJ6, TJ7, TJ17 and TJ19 were taken from the Hisban Formation (Hisban Limestone Member) and the Salit Formation from Wadi Hisban and south of Jalda (Fig. 1a).

The Hisban Limestone Member consists of massive thick grey limestone beds in the base (S1), followed by wavy bedded grey limestone ‘Wellenkalk’ (7b), fossiliferous marly, grey to yellowish limestone (8b) with frequent bivalves (*Placunopsis* sp.), brachiopods (*Coenothyris vulgaris*, *Aulacothyris* cf. *A. agnosta*) and cephalopods (*Beneckeia* spp., *Germanonautilus bidorsatus*) and thin layers of yellowish (subordinate reddish) marl.

Sample S1 which was taken from the lower part of the Hisban Limestone Member (massive limestone) at Wadi Siyala contains the holothurian sclerites: *Theelia patinaformis* Mostler, *Calclamna germanica* Frizzell and Exline, *Calclamna trettoensis* Mostler, *Theelia zapfei* Kozur & Mostler.

Sample 7b from the grey wavy limestone beds (in Wadi Hisban) contains a rich assemblage of holothurian sclerites comprising mostly the genus *Calclamna*: *Calclamna* sp., *C. nuda* Mostler, *C. trettoensis* Mostler and few *Theelia* (*Theelia* cf. *muelleri* Kozur & Mostler).

Sample 8b was taken from the fossiliferous marly limestone 10 m above sample 7b. It contained a rich sclerite fauna dominated by species of *Theelia* such as *Theelia germanica* Kozur, *Theelia planorbicula* Mostler, *Theelia* sp., *Achistrum monochordata* Hodson et al., *Calcancora* sp.

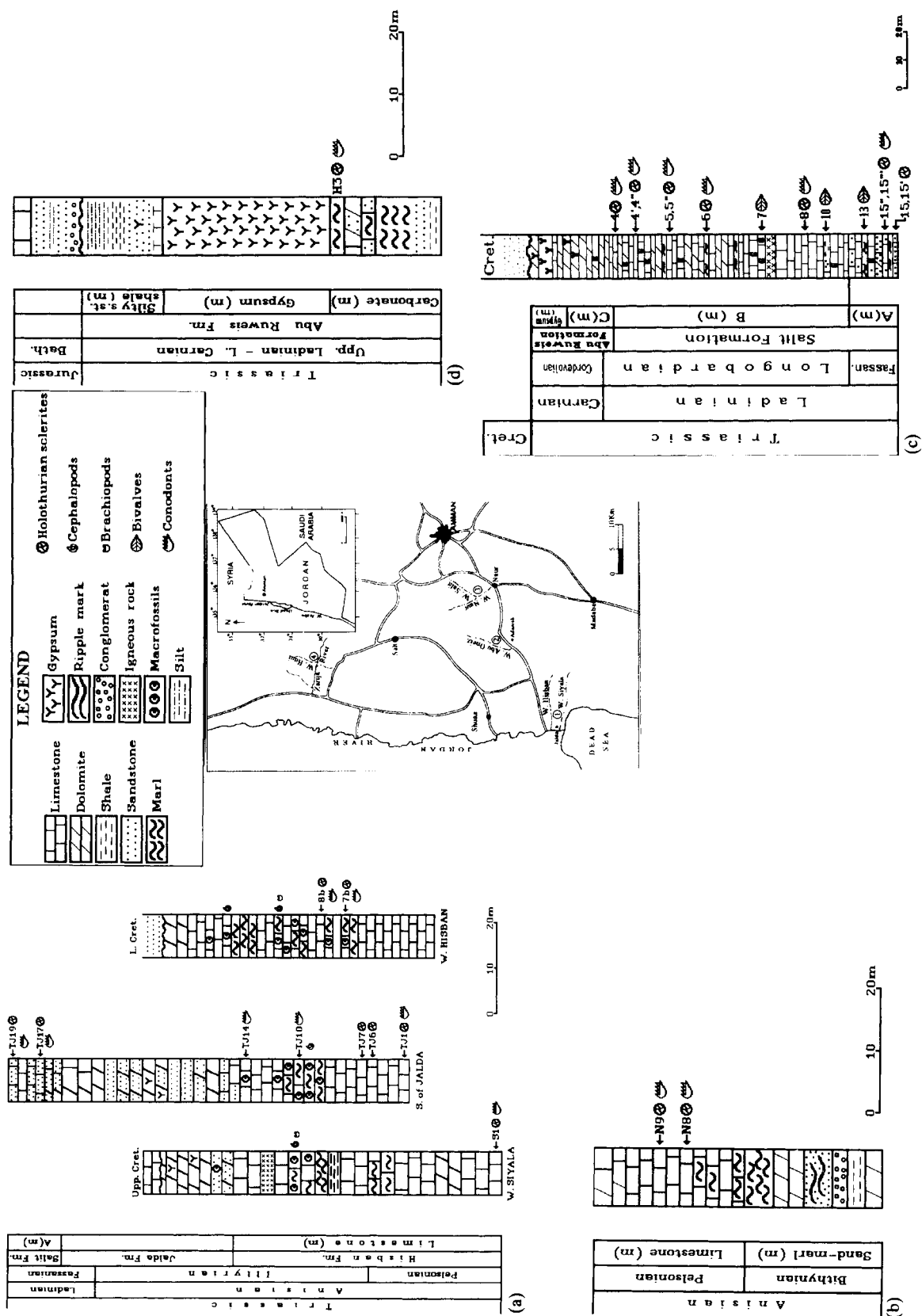


Fig. 1. Location map. Numbered areas: 1, NE corner of the Dead Sea; 2, Adasiah; 3, Naur; 4, Zarqa River. **(a)** Columnar sections of the Triassic deposits in Area 1. **(b)** Investigated section in Wadi Abu Oneiz in Area 2. **(c)** Generalized section from Wadi Salt in Area 3. **(d)** Lithology of the Triassic deposits from Wadi Huni in Area 4.

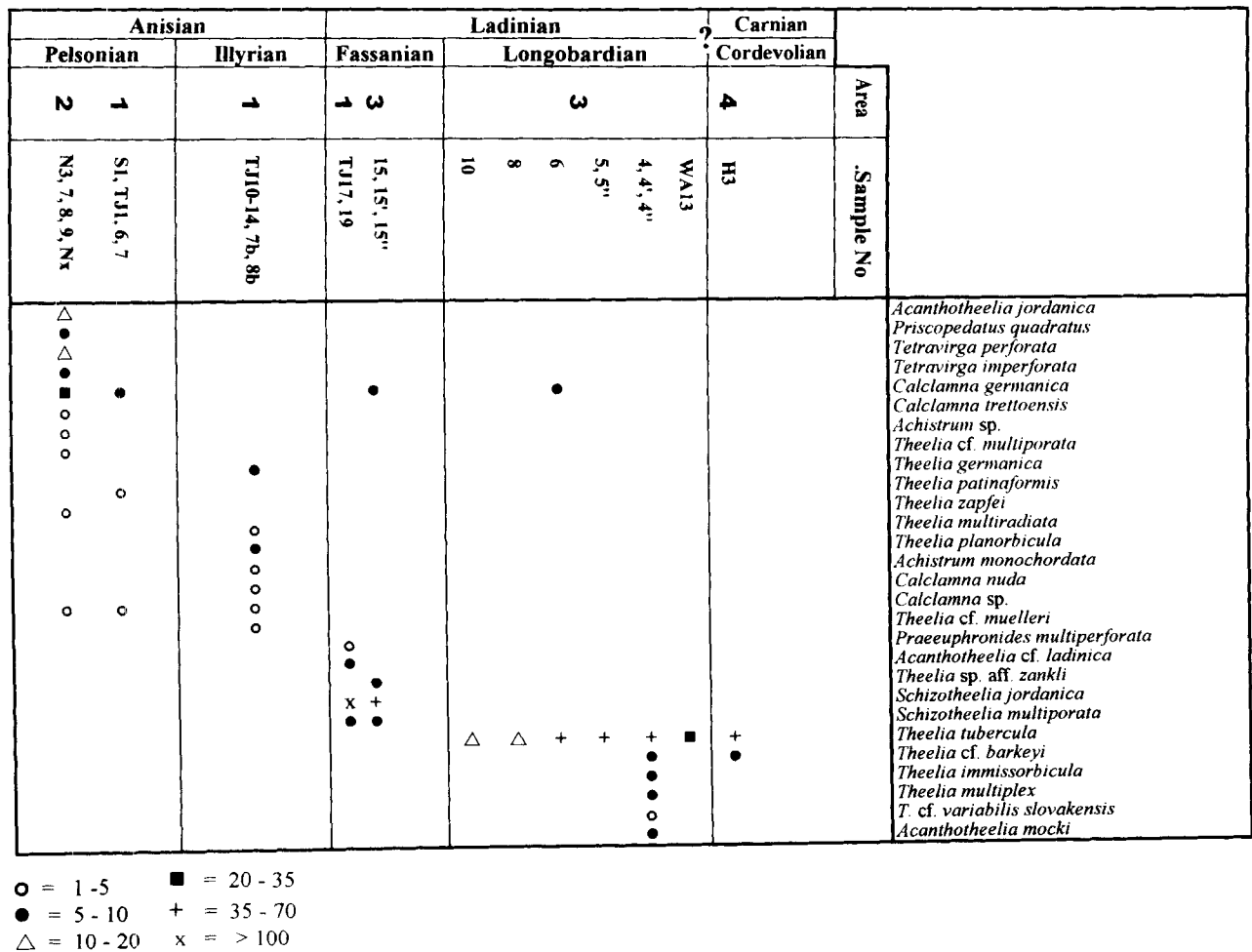


Fig. 2. Stratigraphic distribution of the holothurian sclerites found in the present study.

Samples TJ17 and TJ19 were collected from the upper portion of the Jalda section which belongs to the lower part of Salit Formation (lower part of member A) which consists of sandy limestone beds with *Trigonodus*, dolomitic limestone and sandy dolomitic limestone. These samples yield the following holothurian sclerites: *Schizothelia jordanica* Kozur & Sadeddin, *Schizothelia multiporata* Kozur & Sadeddin (dominant), *Priscopodatus* sp. (few), *Theelia* sp. (solitary).

Adasiah (Area 2 of Fig. 1)

Samples N8 (NT5) and N9 were collected from the Hisban Formation (lower part of the Hisban Limestone Member) at Wadi Abu Oneiz 2.5 km SW of Adasiah (Fig. 1b). Both samples were taken from the massive, thick bedded grey limestone (N9 is 5 m above N8). They yielded rich holothurian sclerite faunas containing *Tetravirga perforata* Mostler, *Calclamna germanica* Frizzell & Exline, *Calclamna* sp., *Achistrum* sp., *Priscopedatus quadratus* Kozur & Mostler, *Acanthotheelia jordanica* Sadeddin, *Theelia* sp., *Theelia zapfei*. Kozur & Mostler.

Naur (Area 3 of Fig. 1)

Samples 15, 15', 8, 4" and 4, were collected from the Salit Formation at Wadi Salit west of Naur (Fig. 1c). Samples 15 and 15" were taken from the sandy limestones (lower part of member A). In these samples abundant holothurian sclerite faunas have been found that are dominated by the genus *Schizothelia*, and include *Schizothelia jordanica* Kozur & Sadeddin, *Schizothelia multiporata* Kozur & Sadeddin. Also present are *Acanthothelia* cf. *A. ladinica* Kozur & Mostler, *Theelia* sp. aff. *T. zankli* Kozur & Simon, a few unidentified sclerites (poorly preserved *Priscopodatus*) and a rich conodont assemblage containing among other forms frequent *Pseudofurnishiuss priscus* Sadeddin.

The holothurian-bearing samples 8, 4', and 4 were taken from member B of the Salit Formation which consists of limestones, dolomites, dolomitic limestone, marls and shales in the form of streaks and lenticular deposits. Sample 8, collected from limestone beds with *Trigonodus* and *Posidonia* that are overlain by a 4 m volcanic intrusion (tracyandesite sill), contains the holothurian sclerite *Theelia tubercula* Kristan-Tollmann and also yields frequent conodonts (*Pseudofurnishius sosioensis* Gullo & Kozur).

Samples 4" and 4 were collected from the upper portion of the Salit Formation (upper part of member B) which consists of 30 m limestone with nodular, fossiliferous layers and dolomites containing some banded, platy fossiliferous layers. Sample 4" contains a rich assemblage of holothurians belonging to *Theelia* cf. *T. barkeyi* Kozur & Simon, *T. immisorbicula* Mostler, *T. multiplex* Speckmann, *Theelia* cf. *T. multiplex* Speckmann, *Theelia* cf. *T. variabilis slovakensis* Kozur and Mock, and *Theelia* sp. Sample 4, collected from the same beds (10 m above 4"), contains exclusively *Theelia tubercula* Kristan-Tollmann. Sample 4" also contained frequent conodonts including *Pseudofurnishius murcianus* Van Den Boogaard (exclusively monoplatform type) and *Budurovignathus mungoensis* (Diebel).

Zarqa River (Area 4 of Fig. 1)

Sample H3 belongs to the Abu Ruweis Formation (Fig.1d) from Wadi Huni (basal part, carbonate member) which comprises dolomites, dolomitic limestone, marly limestone, marl, sandy marl and cellular dolomite. This sample, which was collected from the marly limestone contains holothurian sclerites belonging to *Theelia tubercula* Kristan-Tollmann, *Theelia* cf. *T. barkeyi* Kozur & Simon and frequent conodonts comprising exclusively *Budurovignathus mungoensis* (Diebel) and *B. mostleri* Kozur. The lower part of this sequence (sandy marl) contains ostracods: *Lutkevichinella egerleri* Kozur.

AGE OF THE ROCK SEQUENCES WHERE HOLOTHURIAN SCLERITES HAVE BEEN FOUND

The age of the Triassic rock sequences in Jordan were determined primarily by the use of conodonts (e.g. Kozur, 1968, 1974, 1980, 1989; Gullo & Kozur, 1989; Sadeddin, 1990; Sadeddin & Kozur, 1992), partly by cephalopods, brachiopods and pelecypods (e.g. Cox, 1924; Wagner, 1934; Parnes, 1975). Conodonts from the study area have been investigated in detail and documented by Sadeddin (in press, Paläontographica abt. A)

Wadi Hisban section (Fig. 1a)

Based on conodonts (belonging to *Neogondolella bulgarica*), a middle Anisian (Pelsonian) age is warranted for the lower part of this section. The presence of *Paragondolella hanbulogi* in sample 7b, *Gondolella constricta* in sample 8b, and accompanying macrofossils such as ammonites (*Beneckeia levantina*) and brachiopods (*Coenothyris vulgaris*) indicate an upper Anisian (Illyrian) age for the middle and upper part of this succession.

Jalda section (Fig. 1a)

The holothurian-bearing samples TJ1, TJ6 and TJ7 from the basal part of Jalda section yielded conodonts referred to *Neogondolella bulgarica* indicating a middle Anisian age (Kozur, 1989). Samples TJ10–TJ14 from the middle part of the Jalda section contain poorly preserved holothurian sclerites (*Theelia* spp.). The accompanying conodonts belonging to *Paragondolella hanbulogi*, *Gondolella bifurcata*, *Gondolella constricta* and macrofossils comprising ammonites (*Beneckeia* sp.), brachiopods (*Coenothyris vulgaris*) and bivalves (*Placunopsis* sp.) indicate an upper

Anisian age. The basal portion of the upper part of the Jalda section consists of fossil-free, brownish weathered, hypersaline dolomites, cellular dolomites, sandstones and dolomitic sandstones. These sediments correspond in facies to the higher upper part of the hypersaline Germanic middle Muschelkalk (Kozur, 1974). They are also overlain by the basal beds of the upper Muschelkalk, which consist of sandy limestones, dolomites, dolomitic limestones, often with mass occurrences of *Trigonodus* (samples TJ17–TJ19) and containing conodonts (*Pseudofurnishius priscus*, *P. siyalaensis*) of Fassanian (early Ladinian) age (Sadeddin, 1990; Sadeddin & Kozur, 1992). These fossil-free sediments could be placed into the Illyrian (uppermost Anisian).

The lower and middle part of the Jalda section can be correlated with the section of Wadi Hisban, whereas strata referred to the upper part of the Jalda section are not exposed in Wadi Hisban.

Abu Oneiz section (Fig. 1b)

No age diagnostic microfossils have been found in the basal part of this section. Based on lithostratigraphic correlation with analogous sequences in area 1, a lower Anisian age is justified for this part. In the middle and upper part of this section which represents the Hisban Limestone Member, holothurian faunas have been found (samples N3, N7, N8, N9, and Nx) that are especially characterized by the oldest *Acanthotheelia* (*Acanthotheelia jordanica* Sadeddin, 1991). A Pelsonian (middle Anisian) age (well dated by a conodont fauna collected by the author with *Nicoraella germanica*, *Nicoraella kockeli* and *Neogondolella bulgarica*) is warranted for the middle and upper part of Abu Oneiz sequence.

Wadi Salit section (Fig. 1c)

The basal portion of this and the uppermost portion of the Jalda section are very similar. Samples 15, 15', 15" and 15''' contain abundant holothurians that are also especially characterized by *Schizotheelia jordanica* and *Schizotheelia multiporata*. The accompanying conodonts collected by the author (*Pseudofurnishius priscus*) are analogous to those of the upper portion of Jalda section, indicating a Fassanian (early Ladinian) age. No holothurian sclerites have been found in the samples directly above samples 14, 13, 12, 11, from the lower part of this section. The presence of *Budurovignathus truempyi* Hirsch in sample 12 indicates an uppermost Fassanian (Fassanian/ Longobardian) age for this part of the section. In samples 10, 8, 7, 7", 6, 6", 5, 5", 4, 4' and 4" holothurian sclerites have been recorded that are characterized by the frequent occurrence of *Theelia tubercula* which appears in all samples except sample 7 and 7". Samples 10 and 8 contain conodonts belonging to *Pseudofurnishius sosioensis* which Gullo & Kozur (1989) placed in the lower Longobardian; macrofossils have also been reported comprising *Trigonodus* sp. (sample 10), and *Posidonia wengensis* (sample 8). *Placunopsis flabellum* has been found in the horizon from which samples 7 and 7" were collected. These samples and samples 6, 6', 6", 5 and 5" have yielded highly evolved representatives of *Pseudofurnishius murcianus* (biplatform type) and a middle Longobardian

age is indicated for this part of the succession. In samples 4, 4' and 4'' which contain frequent *Theelia tubercula*, conodonts comprising *Pseudofurnishius murcianus* (exclusively monoplatform type) and *Budurovignathus mungoensis*, partly transitional to *Budurovignathus diebeli*, have been found. This level (4, 4', 4'') belongs to the higher Longobardian–Ladinian/Carnian boundary. The next higher beds which consist of dolomite, gypsum, cellular dolomite are analogous to the Germanic lower 'Gipskeuper' and the adjacent areas. Based on lithostratigraphic correlation with these sequences, an early Carnian age is indicated for these beds.

Wadi Huni section (Fig. 1d)

Based on the conodonts *Budurovignathus mungoensis* and *B. mostleri* an uppermost Longobardian–lowest Cordevolian age (Ladinian/Carnian boundary) is indicated for the holothurian-bearing lower part of this section.

The middle and upper part of this section (gypsum and shale members of Abu Ruweis Formation) overlaying the carbonate member, is correlatable with the top part of the Salit section (shale member is missing) and analogous to the lower 'Gipskeuper' of the Germanic Basin and the adjacent areas (lower member of Mohilla Formation, Israel). On the basis of the lithostratigraphic correlation with the aforementioned sequences, an early Carnian age is warranted for the middle and upper part of Wadi Huni section.

DISCUSSION

The Triassic of Jordan belonged to a marginal sea south of the southern Tethys. In Skythian sediments which are exposed at the eastern rim of the Dead Sea (twenty samples have been studied), no holothurian sclerites have been found as yet. The first association appears in Anisian carbonate rocks from Wadi Siyala (area 1, Fig. 1, NE corner of the Dead Sea) and Wadi Abu Oneiz (area 2, Fig. 1, Adasiah) consisting of *Calclamna germanica* Frizzell and Exline, *Calclamna trettoensis* Mostler, *Calclamna* sp., *Priscopodatus quadratus* Kozur & Mostler, *Theelia* cf. *T. multiporata* Kozur, *Theelia zapfei* Kozur & Mostler, *Tetravirga imperforata* Frizzell and Exline and *Tetravirga perforata* Mostler.

These associations are characterized by the frequent occurrence of *Acanthotheelia jordanica* Sadeddin which appears in the Pelsonian of Jordan. According to Mostler (1970, 1973) *Acanthotheelia* Frizzell & Exline appears in the Illyrian (Upper Anisian) of the northern calcareous Alps, Hungary and western Carpathians. Kozur (1969) and Kozur & Mostler (1970) did not report *Acanthotheelia* in the holothurian sclerite associations from the Pelsonian (Middle Anisian) of the Germanic Basin.

The early Middle Triassic (Anisian) holothurians from Jordan are, with some differences, similar to those of North Tethyan faunas known from the northern Alps, western Carpathians and the Germanic Basin (Sadeddin, 1991)

In the Illyrian (Upper Anisian) from Wadi Hisban and Wadi Siyala (Fig.1a) *Calclamna* sp., *Calclamna nuda*

Mostler, *Calclamna trettoensis* Mostler, *Theelia germanica* Kozur, *Theelia* cf. *T. muelleri* Kozur & Mostler, *Theelia planorbicula* Mostler, *Theelia multiradiata* Kozur, *Theelia* sp., *Achistrum monochordata* Hodson, Harris and Lawson are present.

The Fassanian (early Ladinian) holothurian sclerite associations from Wadi Siyala (top of Jalda section, Fig.1a) and from Wadi Salit section (Fig.1c) are characterized by the mass occurrence of *Schizotheelia jordanica* Kozur & Sadeddin and *Schizotheelia multiporata* Kozur & Sadeddin. In addition to *Schizotheelia*, *Acanthotheelia* cf. *A. ladinica* Kozur & Mostler are also present. Forms without stratigraphic value such as *Calclamna germanica* Frizzell & Exline, *Praeophronides multiperforata* Mostler and poorly preserved *Priscopodatus* occur (see Kozur & Sadeddin, 1992).

The Longobardian (Upper Ladinian)–Lower Cordevolian (Lower Carnian) holothurian associations from Jordan which consist of: *Achistrum* sp., *Calclamna germanica* Frizzell & Exline, *Theelia* cf. *T. barkeyi* Kozur & Simon, *Theelia* sp., *Theelia* cf. *T. variabilis slovakensis* Kozur & Mock, *Theelia immisorbicula* Mostler and *Theelia multiplex* Speckmann are characterized by the frequent occurrence of *Theelia tubercula* Kristan-Tollmann. In Jordan, which belongs to the West Mediterranean–Arabian faunal province of the southern Tethys (*sensu* Kozur & Mostler, 1971) late Middle Triassic (Ladinian) rocks yield the same holothurian species that occur in other regions of this province (Kozur & Sadeddin, 1992).

Theelia tubercula which has been regarded so far as an index species for the Cordevolian (early Carnian) was found in the early Longobardian (early late Ladinian) of Jordan together with the conodont species *Pseudofurnishius sosioensis* Gullo & Kozur. It occurs in shallow-water sediments as well as in pelagic sediments, is regarded as a palaeogeographic indicator for the southern Tethys and its marginal seas, and has the same distribution as the conodont genus *Pseudofurnishius* Sadeddin & Kozur (1992), see also Kozur & Simon (1972), Kozur *et al.* (1974), Kozur *et al.* (1985). In the higher sediments (Wadi Salit and Wadi Huni, Fig.1c, d) which belong most probably to the early Carnian, no holothurian sclerites have been found.

In addition to holothurian sclerites crinoid debris, echinoids, conodonts, ostracods, foraminiferans, microbivalves, microgastropods and fish remains are present in most studied samples. No relationship could be discerned between the presence or abundance of holothurians with any of these fossil groups.

SYSTEMATIC PALAEONTOLOGY

The classification followed is that of Frizzell & Exline (1955b), which is based on the morphology of the sclerites, and has an artificial character.

Family **Stichopitidae** Frizzell & Exline, 1955b

Genus ***Tetravirga*** Frizzell & Exline, 1955b

Tetravirga perforata Mostler, 1968
(Pl. 1, fig. 1)

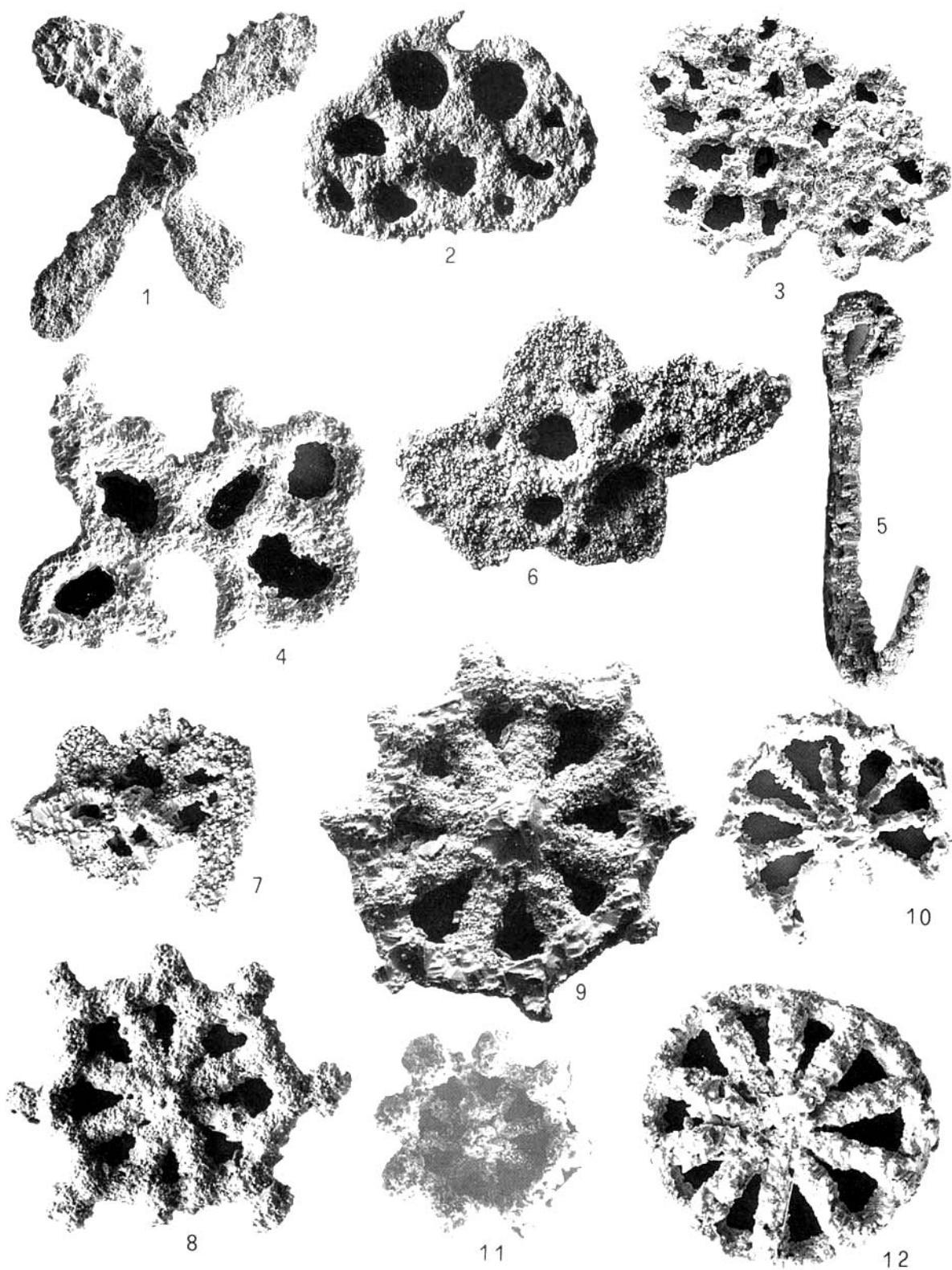


Plate 1

1968c *Tetravirga perforata* n. sp. Mostler: 10, pl. 1, figs 6–7.
Material. 15 specimens.

Occurrence. Pelsonian of Jordan. Anisian; Germanic and Alpine Triassic (Pelsonian-Illyrian).

Family **Calclamnidae** Frizzell & Exline, 1955b

Genus **Calclamna** Frizzell & Exline, 1955b

Calclamna germanica Frizzell & Exline, 1955b
 (Pl. 1, figs 2, 4)

1955b *Calclamna germanica* n. sp. Frizzell & Exline: 76–77, pl. 2, figs 1–5.

Material. 28 specimens.

Occurrence. Pelsonian, Illyrian of Jordan (Hisban Limestone); Anisian–Liassic.

Remarks. *C. germanica* is very much like *C. norica* Kozur & Mock, 1972 from lower Norian of Slovakia, differing in the smaller size, fewer perforations (15–38 in *C. norica*). The central holes of *C. germanica* are essentially larger than the surrounding holes, while those of *C. norica* are of same size or slightly larger.

Calclamna trettoensis Mostler, 1979
 (Pl. 1, fig. 3)

1979 *Calclamna trettoensis* n. sp. Mostler: 337–338, pl. 3, figs. 1–11, 13.

Material. 3 specimens.

Occurrence. Pelsonian of Jordan; Pelsonian of Tretto (Vicentin, Italy).

Remarks. *Calclamna trettoensis* shows some similarities to *C. germanica* Frizzell & Exline, 1955, differing in having many more holes, irregular outline and smaller central holes. *C. norica* Kozur & Mock, 1972 is larger and has rounded to oval, larger holes (especially the central holes).

Family **Achistridae** Frizzell & Exline, 1955

Genus **Achistrum** Etheridge, 1881 emend Frizzell & Exline, 1955

Achistrum monochordata Hodson, Harris & Lawson, 1956
 (Pl. 1, fig. 5)

1955 *Calcligula hucki* n. sp. Frizzell & Exline: 70–71, pl. 1, fig. 28.

1956 *Achistrum monochordata* n. sp. Hodson, Harris & Lawson: 340–341, text-figs 10–11.

1978 *Achistrum triassicum* Gadzicki, Kozur, Mock & Trammer: 360, pl. 49, figs 4–6.

1987 *Achistrum bichordata* Soodan & Whatley: 186, pl. 1, fig. F.

1992 *Achistrum monochordata* Gilliland: 194–196, pl. 4, figs 1–8 (with synonyms).

Occurrence. Illyrian (middle Triassic) of Jordan; early Carboniferous to early Cretaceous worldwide.

Remarks. The single specimen present, recorded from the Middle Triassic (fossiliferous marly limestone) differs from all other forms of the genus by commonly having a single bar across the eye. The reporting of this species from early Carboniferous to early Cretaceous by many authors, contradicts the statement of Frizzell & Exline (1966) that the eye of *Achistrum* is simple in earlier forms, but becomes cross-barred in later forms.

Family **Priscopedatidae** Frizzell & Exline, 1955

Genus **Priscopedatus** Schlumberger, 1890, emend. Frizzell & Exline

Priscopedatus quadratus Kozur & Mostler, 1970
 (Pl. 1, fig. 6–7)

1970 *Priscopedatus quadratus* n. sp. Kozur & Mostler: 371–372, pl. 3, figs 2–3.

Material. 4 specimens.

Occurrence. Pelsonian of Jordan; Pelsonian of Germanic basin; Pelsonian of Tethyan Triassic.

Family **Theeliidae** Frizzell & Exline, 1955b

Genus **Acanthotheelia** Frizzell & Exline, 1955b

Acanthotheelia jordanica Sadeddin, 1991
 (Pl. 1, fig. 1–3)

1991 *Acanthotheelia jordanica* n. sp. Sadeddin: 234–235; pl. 1, figs. 1–5.

Material. 14 specimens.

Occurrence. Pelsonian of Jordan (in the lower part of Hisban Limestone) 25 m below the ‘Terebratul beds’ with *Beneckeia* spp.

Description. Wheel-like large sclerite with 7–9 spokes and subcircular to polygonal outline. Periphery always with one large spine opposite to every interspoke space. Distal ends of spines often expanded knob-like. Rim moderately broad, its inner margin not or only slightly bent inward. Spokes moderately long, straight, mostly broad but some times narrow, of equal width throughout. Hub small to medium-sized. Upper surface of hub convex and sometimes higher than upper margin of rim. Lower surface slightly convex to plane.

Explanation of Plate 1

Fig. 1. *Tetravirga perforata* Mostler, sample N8, Pelsonian, Repository number S1/8/71/88, Wadi Abu Oneiz, ×155. **Fig. 2.** *Calclamna germanica* Frizzell & Exline, sample N8, Pelsonian, Rep. no. S1/8/66/88, Wadi Abu Oneiz, ×225. **Fig. 3.** *Calclamna trettoensis* Mostler, sample 7b, Illyrian, Rep. no. S1/14/168/88, Wadi Hisban, ×165. **Fig. 4.** *Calclamna germanica* Frizzell & Exline, sample 7b, Illyrian, Rep. no. S1/14/183/88, Wadi Hisban, ×165. **Fig. 5.** *Achistrum monochordata* Hodson, Harris & Lawson, sample 8b, Illyrian, Rep. no. S1/11/129/88, Wadi Hisban, ×155. **Figs 6–7.** *Priscopedatus quadratus* Kozur & Mostler, Fig. 6: sample N9, Pelsonian, Rep. no. S1/8/64/88, Wadi Abu Oneiz, ×220; Fig. 7: sample N9, Pelsonian, Rep. no. S1/18/293/88, Wadi Abu Oneiz, ×230. **Figs 8–9.** *Acanthotheelia jordanica* Sadeddin, sample N8, Pelsonian, Rep. no. S1/9/77.82/88, Wadi Abu Oneiz, ×135. **Fig. 10.** *Acanthotheelia* cf. *A. ladinica* Kozur & Mostler, sample 15, Fassinian (early Ladinian), Rep. no. S1/1/17/88, upper view Wadi Salit, ×280. **Fig. 11.** *Acanthotheelia mocki* Kozur, sample WA 13, Longobardian (late Ladinian), Rep. no. 42/93, Naur area, ×150. **Fig. 12.** *Theelia zapfei* Kozur & Mostler, sample TJ6, Pelsonian, Rep. no. S1/10/113/88, lower view, 2 km south of Jalda, ×200.

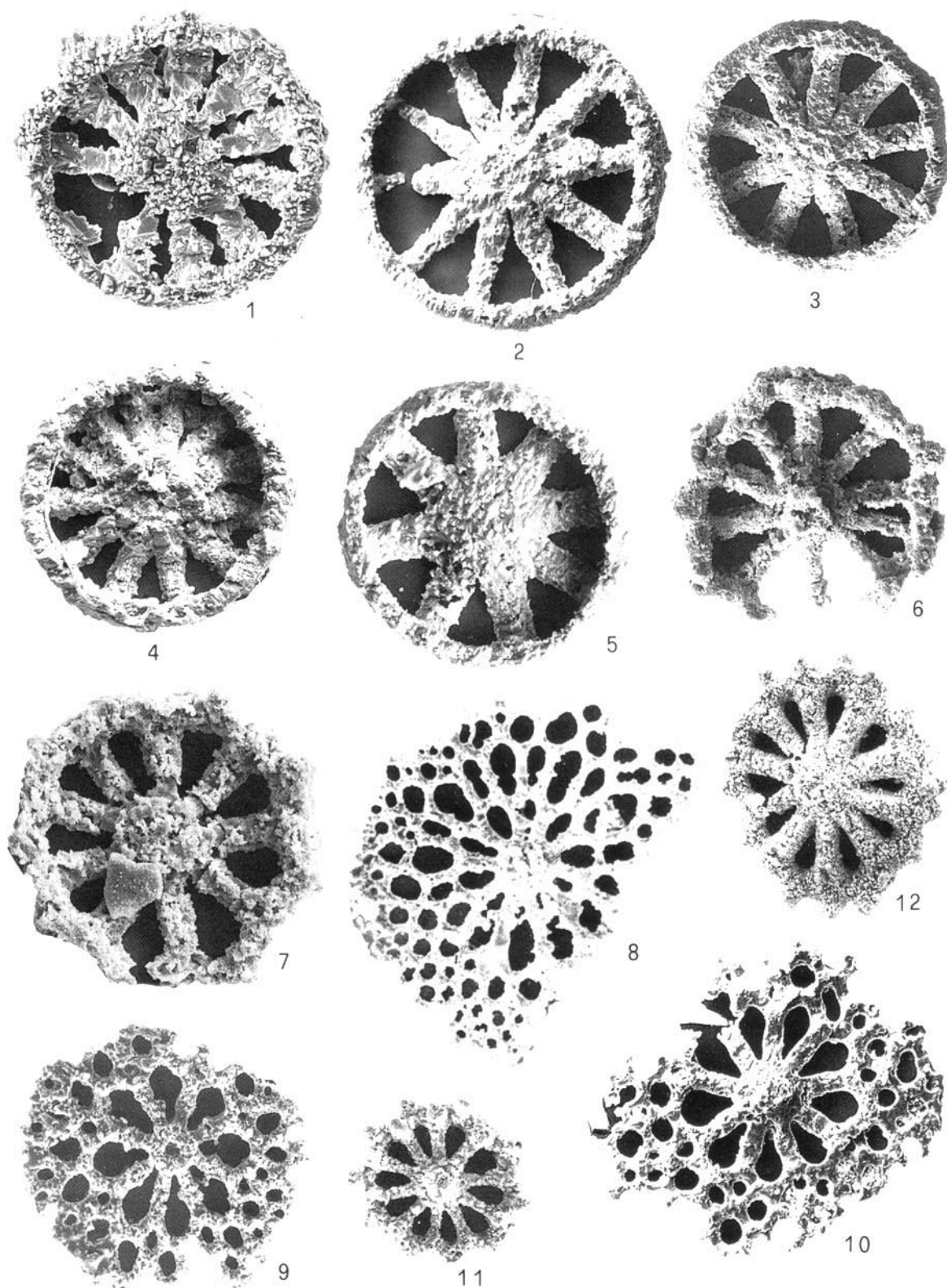


Plate 2

Remarks. *Acanthotheelia jordanica* is very similar to *Acanthotheelia mocki* Kozur, 1985 and *A. virgiliae* Kozur, 1985 (from the Cordevolian of Spain), but both are smaller (for measurements, see Sadeddin, 1991) than *A. jordanica*. The rim of *A. mocki* is broader than the rim of *A. jordanica* and the rim of *A. jordanica* is broader than the rim of *A. virgiliae*.

Acanthotheelia* cf. *A. ladinica Kozur & Mostler, 1971
(Pl. 1, fig. 10)

Occurrence. Fassinian (Lower Ladinian) of Jordan, together with *Pseudofurnishius priscus*, *P. siyalaensis* (Conodonts) and *Schizothelidia multiporata*, *Schizothelidia jordanica* (Holothuroidea).

Remarks. This form (only one specimen is present) differs from *A. ladinica* Kozur & Mostler by its smaller size, shorter spokes. Both the lower and upper surface of the hub in *A. ladinica* Kozur & Mostler are flat.

Acanthotheelia mocki Kozur, 1985
(Pl. 1, fig. 11)

1985 *Acanthotheelia mocki* Kozur Kozur *et al.*: 106, pl. 1, figs 1–4.

Material. 9 specimens.

Occurrence. Cordevolian (early Carnian) of Spain; Longobardian (late Ladinian) of Jordan.

Remarks. See *A. jordanica*.

Theelia* cf. *T. barkeyi Kozur & Simon, 1972
(Pl. 3, figs 3–4)

Occurrence. Uppermost Longobardian (late Ladinian) of Jordan.

Remarks. This form differs from *T. barkeyi* Kozur & Simon by its shorter, wider spokes.

Theelia germanica Kozur, 1969
(Pl. 2, fig. 4)

1969 *Theelia germanica* n. sp. Kozur: 148–152, pl. 1, figs 1, 3, 6; pl. 2, figs 1–2, 5–8.

1970 *Theelia germanica* Kozur & Mostler: 377–378, pl. 2, figs 1–8.

Material. 7 specimens.

Occurrence. Illyrian of Jordan (middle Triassic) from the fossiliferous marly limestone beds 'Terebratel beds' with *Beneckeia levantina* (Hisban Formation); Lower Anisian–Pelsonian (middle Anisian) of Germanic basin; from the Triassic of Spiti (Himalaya, India).

Remarks. *Theelia immissorbicula* Mostler, 1968b which is known from late Anisian–late Norian, a probable synonym of *T. germanica*. However, *T. immissorbicula* has a very high hub (considerably higher than the plane of the rim). *T. subcirculata* Mostler, 1968b is also similar to *T. germanica* but it differs in having predominantly subcircular, undulating outline and a smaller hub. *T. synapta* Gilliland, 1992, shows some similarity, but it is distinguished by the number of spokes (7–15, predominantly 10–13), the toothed inner margin of the rim and the median ridge on the spokes. The illustrated specimen on plate, 3, fig. 9, may be a synonym of *T. germanica*. *T. zapfei* Kozur & Mostler, 1970 is very much like *T. germanica* and may be identical to it. However, it has fewer spokes and a less inwardly bent margin.

Theelia immissorbicula Mostler, 1968b emend. Kozur & Mock, 1972
(Pl. 3, figs. 6, 8)

1968b *Theelia immissorbicula* n. sp. Mostler: 26–27, pl. 5, fig. 1.

Occurrence. Uppermost Longobardian (late Ladinian) of Jordan, Pelsonian, early Norian of Alps; late Anisian and Carnian of Bulgaria.

Theelia* cf. *T. muelleri Kozur & Mostler, 1970
(Pl. 2, fig. 1)

Occurrence. Illyrian of Jordan.

Remarks. This form (only one specimen is present) differs from *T. muelleri* Kozur & Mostler; the hub of *T. muelleri* is smaller and lies obviously below the upper plane of the rim and the lower surface of the hub is plane to slightly concave.

Theelia multiplex Speckmann, 1968
(Pl. 3, figs 9–10)

1968 *Theelia multiplex* n. sp. Speckmann: 4, figs 1–3.

Occurrence. Uppermost Longobardian (late Ladinian) of Jordan, together with *Pseudofurnishius murcianus*, Wadi Salit section; it is also reported from Cassian beds of eastern Alps (late Ladinian).

Theelia* cf. *T. multiplex Speckmann, 1968
(Pl. 3, figs 11–14)

Occurrence. Uppermost Longobardian (late Ladinian) of Jordan.

Remarks. This form differs from *T. multiplex* by having wider spokes with the same width throughout.

Theelia planorbicula Mostler, 1968
(Pl. 2, figs 2–3)

Explanation of Plate 2

Fig. 1. *Theelia* cf. *T. muelleri* Kozur & Mostler, sample 7b, Illyrian, Rep. no. S1/14/167/88, Wadi Hisban, $\times 165$. **Figs 2–3.** *Theelia planorbicula* Mostler, Fig. 2: sample 8b, Illyrian, Rep. no. S1/10/112/88, $\times 200$; Fig. 3: Sample 8b, Illyrian, Rep. no. S1/11/118/88, $\times 165$, Wadi Hisban. **Fig. 4.** *Theelia germanica* Kozur, sample 8b, Illyrian, Rep. no. S1/11/116/88, Wadi Hisban, $\times 165$. **Fig. 5.** *Theelia* cf. *T. zawidzkae* Kozur & Mock, sample 8b, Illyrian, Rep. no. S1/10/98/88, Wadi Hisban, $\times 220$. **Figs 6–7.** *Theelia* n. sp. aff. *zankli* Kozur & Simon, sample 15, Fassinian, Rep. no. S1/1/4.1/88, Fig. 6: $\times 220$; Fig. 7: $\times 380$, Wadi Salit. **Fig. 8.** *Schizothelidia multiporata* Kozur & Sadeddin, sample TJ17, Fassinian, Rep. no. S3/26/5/88, 2 km south of Jalda, $\times 200$. **Figs 9–10.** *Schizothelidia jordanica* Kozur & Sadeddin, sample 15, Fassinian, Rep. no. W2/5/24.13/89; Fig. 9: $\times 130$; Fig. 10: $\times 200$, Wadi Salit. **Figs 11–12.** *Theelia tubercula* Kristan-Tollmann, sample 8, lower Longobardian (early middle Ladinian), Rep. no. W2/7/16.19/90, upper view, $\times 180$, Wadi Salit.

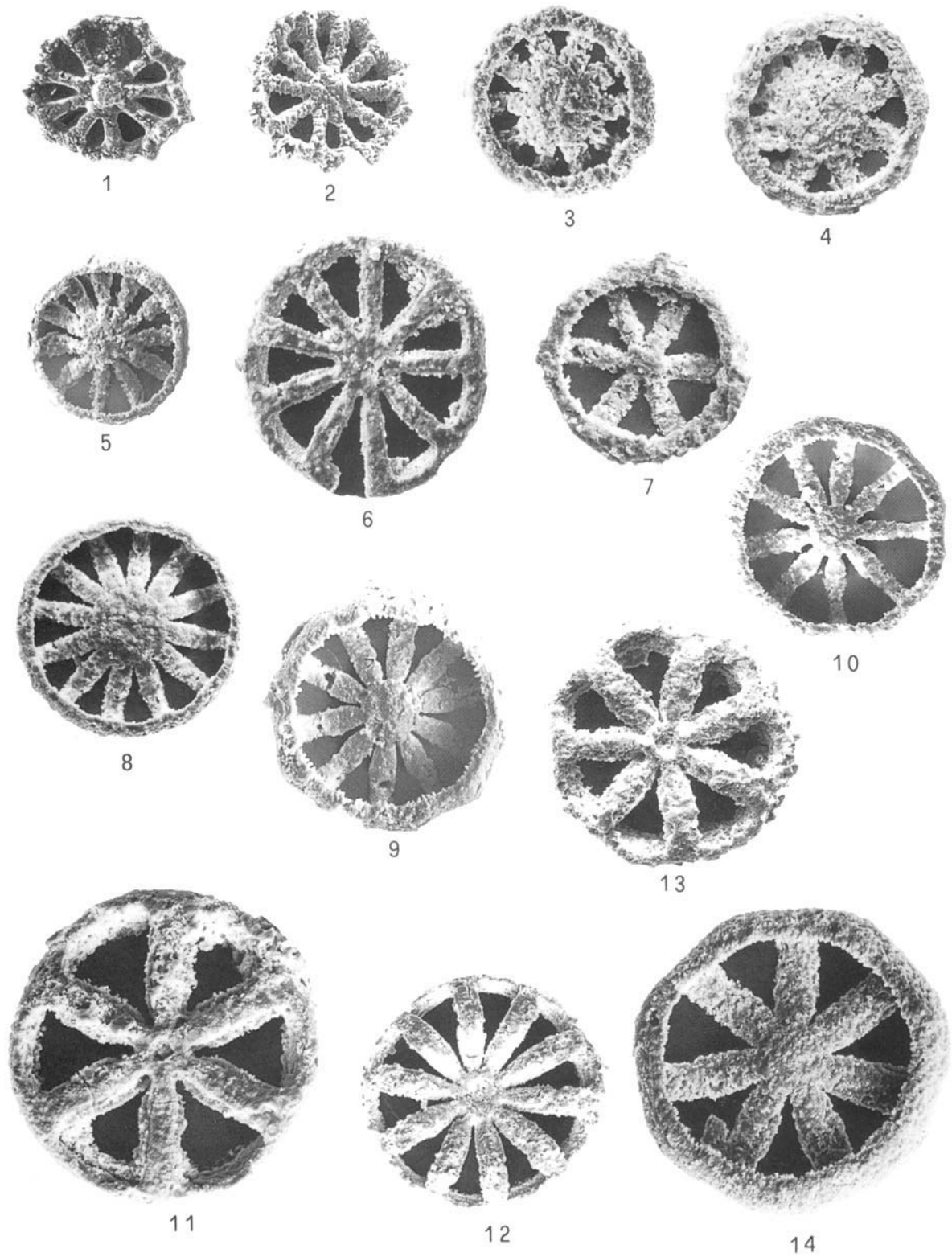


Plate 3

1968b *Theelia planorbicula* n. sp. Mostler: 28, pl. 5, fig. 3

1968 *Theelia alta* n. sp. Speckmann: 208, pl. 3, fig. 1.

Occurrence. Illyrian (late Anisian) of Jordan, from the fossiliferous marly limestone 'Terebratel beds' with *Beneckeia* spp., Anisian–Norian of Europe, Middle Triassic of India (Himalaya).

Theelia tubercula Kristan-Tollmann, 1963

(Pl. 2, figs 11–12; Pl. 3, figs 1–2)

1963 *Theelia tubercula* Kristan-Tollmann: 396–370, pl. 8, figs 1–6.

Material. 50 specimens.

Occurrence. Longobardian and Cordevolian of southern Tethys and its marginal seas.

Remarks. *Theelia pralongiae* Kristan-Tollmann, 1963 also possesses tubercles arranged like that of *T. tubercula*, but only on the upper surface of the rim. *Theelia zankli* Kozur & Simon, 1972 possesses at the outer margin of its rim vertical sharp-ending edges opposite the interspoke spaces. In both the upper and lower view, these edges have the appearance of short spines. Occasionally the edges are divided in the middle into two short spines that are located facing one another at the upper and lower part of the outer margin of the rim. These forms have some similarity with *T. tubercula* but without rounded or truncated tubercles and the rim is unsculptured opposite the spokes.

Theelia cf. *T. variabilis slovakensis* Kozur & Mock, 1972
(Pl. 3, fig. 7)

1966 *Theelia variabilis* n. sp. Zankl: 83, pl. 6, fig. 5a–c, 6–8; 8; pl. 7, figs. 1–5.

1972 *Theelia variabilis slovakensis* n. subsp. Kozur & Mock: 23–24, pl. XII, figs. 7–13, pl. XIII, figs 1–7.

Occurrence. Uppermost Longobardian of Jordan.

Remarks. The only specimen present is closely related to *T. variabilis slovakensis*, but it is smaller and the spokes are of the same width throughout.

Theelia sp. aff. *T. zankli* Kozur & Simon, 1972
(Pl. 2, figs 6–7)

Material. 7 specimens.

Occurrence. Fassanian (early Ladinian) lowerpart of Salit Formation, together with *Pseudofurnishius priscus* (Conodonta) and *Schizothelidia jordanica* from Wadi Naur (*P. priscus* zone).

Remarks. The specimens can be compared with *T. zankli* Kozur & Simon, 1972, (p. 149, pl. 1, fig. 10, pl. 2, figs. 14, 20, 21) from Cordevolian (early Carnian) of southern Spain, but the latter species is larger.

Theelia zapfei Kozur & Mostler, 1970
(Pl. 1, fig. 12)

1968 *Theelia* sp. Speckmann: 212–213, pl. 3, fig. 6.

1970 *Theelia zapfei* n. sp. Kozur & Mostler: 382, pl. 4, figs 21, 23, 25.

Material. 3 specimens.

Occurrence. Pelsonian of Jordan, Pelsonian of germanic basin and Tethyan Triassic.

Remarks. *Theelia zapfei* is very closely related to *T. subcirculata* Mostler, 1968b but the latter is larger and has a subcircular outline. *Theelia germanica* Kozur, 1969 is also very similar, but differs by its larger number of spokes.

Theelia cf. *T. zawidzkae* Kozur & Mock, 1972
(Pl. 2, fig. 5)

Occurrence. Illyrian (late Anisian) of Jordan.

Remarks. The only specimen present is very much like *T. zawidzkae* Kozur & Mock, 1972 from the lower Norian of Slovakia, differing by its smaller size and by having spokes of the same width throughout. *Theelia norica* Mostler, 1969 from Norian of Steinbergkogel, Austria, which was also recorded by Kozur & Mock (1972) from the lower Norian of Slovakia is also similar, but differs in having three spokes tapering strongly near the hub and smaller hub.

Family **Schizothelidae** Kozur & Sadeddin, 1992

Genus **Schizothelidia** Kristan-Tollmann, 1972

Schizothelidia jordanica Kozur & Sadeddin, 1992
(Pl. 2, figs 9–10)

1992 *Schizothelidia jordanica* n. sp. Kozur & Sadeddin: 10–14, figs 4, 5a–c, 6a–f, 7b–d.

Material. Several hundred specimens.

Occurrence. Fassanian (early Ladinian) of Jordan, together with *Pseudofurnishius priscus* Sadeddin, *Pseudofurnishius siyalaensis* Sadeddin & Kozur, from Wadi Naur and Wadi Siyala (*P. priscus* zone).

Description. Hub round, small, lies slightly elevated above the plane of the sclerite on both sides or at the same level, with flat or slightly concave centre. From the hub emanate 7–11, predominantly 9–10 narrow spokes of the same width throughout. Interspoke spaces drop-like, pointing inwards, always larger than outer pores. Spokes are multi-furcated whereby the adjoining branches produce different-sized pores, which generally become smaller outwards. The pores are irregularly shaped; rounded, oval, or drop-like and may be elongated either parallel or perpendicular to the periphery.

Explanation of Plate 3

Fig. 1. *Theelia tubercula* Kristan-Tollmann, sample 4, upper Longobardian, Rep. no. W2/7/7/90, upper view, $\times 180$, Wadi Salit. **Fig. 2.** *Theelia tubercula* Kristan-Tollmann, sample H3, uppermost Longobardian Cordevolian (late Ladinian early Carnian), Rep. no. W2/7/20/90, lower view, $\times 180$, Wadi Huni. **Figs 3–4.** *Theelia* cf. *T. barkeyi* Kozur & Simon, sample 4", uppermost Longobardian, Rep. no. S1/19/305, 312/88, $\times 280$, Wadi Salit. **Fig. 5.** *Theelia* cf. *T. immissorbicula* Mostler, sample 4, uppermost Longobardian, Rep. no. S1/19/323/88, $\times 230$, Wadi Salit. **Figs 6, 8.** *Theelia immissorbicula* Mostler, sample 4", uppermost Longobardian, Rep. no. S1/19/322, 315/88: Fig. 6: lower view; Fig. 8: upper view, $\times 280$, Wadi Salit. **Fig. 7.** *Theelia* cf. *T. variabilis slovakensis* sample 4", uppermost Longobardian, Rep. no. S1/19/330/88, upper view, $\times 280$, Wadi Salit. **Figs 9–10.** *Theelia multiplex* Speckmann, sample 4", uppermost Longobardian, Rep. no. S1/19/310, 321/88, upper view, Fig. 9: $\times 250$; Fig. 10: $\times 200$. **Figs 11–14.** *Theelia* cf. *T. multiplex* Speckmann, sample 4", uppermost Longobardian, Rep. no. S1/19/319, 313, 309, 307/88, Fig. 11: $\times 280$; Fig. 12: $\times 190$; Fig. 13: $\times 195$; Fig. 14: $\times 280$, Wadi Salit.

Remarks. *Schizoacanthocheelia spiniperforata* Zawidzka, 1971 from the upper Anisian of west Carpathian and from Cordevolian of Spain, differs from *Schizothelidia jordanica* by having distally uni- or bi-furcated spokes. *Schizothelidia schizomata* Kristan-Tollmann, 1973 from Carnian of the southern Alps, has lancet shaped, proximally and distally pointed interspoke spaces and pores. *Schizothelidia multiporata* Kozur & Sadeddin has small or unequally sized interspoke spaces.

Schizothelidia multiporata Kozur & Sadeddin, 1992
(Pl. 2, fig. 8)

1992 *Schizothelidia multiporata* n. sp. Kozur & Sadeddin: 14–15, fig. 8a–b.

Material. 7 Specimens.

Occurrence. Fasnian (early Landinian) of Jordan, together with *Pseudofurnishius priscus* Sadeddin and *P. siyalaensis* Sadeddin & Kozur from Wadi Naur and Wadi Siyala (*P. priscus* zone).

Description. Hub relatively large, flat or very slightly arched. Spokes 10–13, short, narrow. The interspoke spaces are long oval-drop shaped, distally rounded. The adjoining pores are large, generally elongate, rarely irregularly shaped. Some of the adjoining pores are larger than the interspoke spaces. These pores are followed distally by different sized but clearly smaller pores. The outer pores are rounded (rarely oval) drop shaped or irregular.

Remarks. *Schizothelidia multiporata* Kozur & Sadeddin differs from *Schizothelidia schizomata* Kristan-Tollmann, 1973 and *S. jordanica* Kozur & Sadeddin by its unusual short spokes and small interspoke spaces.

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