Rivista Italiana di Paleontologia e Stratigrafia	volume 105	numero 3	tavole 1-4	pagine 327-342	Dicembre 1999

CARNIAN REEF BIOTA FROM A MEGABRECCIA OF THE HAWASINA COMPLEX (AL AQIL, OMAN)

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Received November 16, 1998; accepted June 14, 1999

Key-words: Reef biota, brachiopods, Upper Triassic, Carnian, southern Tethys, Oman.

Riassunto. In questo articolo sono descritte associazioni di scogliera e brachiopodi raccolti nella Fm. Misfah (complesso di Hawasina) in una località presso la città di Al Aqil in Oman. Viene descritta una specie nuova di brachiopode, *Oxycolpella arabica* n. sp. La composizione della associazione di scogliera è simile a quelle conosciute nella regione alpina e mediterranea. Tuttavia esistono differenze nei popolamenti della microfauna, in particolare nei foraminiferi. Vengono infine presentati nuovi dati stratigrafici fondati sulla interpretazione di conodonti e associazioni di scogliera.

Abstract. Carnian reef biota and brachiopods of the Misfah Formation (Hawasina complex) from a locality near the town of Al Aqil in Oman are described. A new brachiopod species, *Oxycolpella arabica* n. sp. is described. The composition of the Carnian reef biota in Oman is similar to those known from the Alpine-Mediterranean region. However, differences exist in the microfauna of reef dwellers, e.g. foraminifers. New stratigraphic data based on reef organisms and conodonts are presented.

Introduction and geological setting.

The Oman Mountains are an orogenic belt composed of the Semail Ophiolite, the allochthonous Hawasina Complex, the parautochthonous Sumeini Group and the Autochthonous of the Arabian Platform (Fig. 1). The fossil specimens were collected from the Hawasina Complex, a relic of a sedimentary basin northeast of the Arabian Platform margin (Glennie et al., 1974; Bechennec et al., 1990). The Hawasina Basin, the former Southern Tethyan Ocean, yields enigmatic Upper Triassic shallow marine carbonate klippes called Oman Exotics.

Beurrier et al. (1986) defined these Exotics as a part of the Kawr Group (Misfah Formation). The Late Triassic Misfah Formation includes a volcanic basement and a very thick carbonate unit corresponding to platform sediments deposited in a proximal subtidal, locally supratidal environment. It is exposed widely in the western Oman Mountains in the area of Jabal Kawr, Misfah and Misht and interpreted to be deposited on a seamount (Beurrier et al., 1986). A sedimentary break occurs in this group, reflecting emergence during most of the Liassic period (Hutin et al., 1986; Pillevuit et al., 1997). In the map of the Birkat al Mawz area this formation is composed entirely of reefal limestone overlying the volcanic basement.

This study concentrates on paleontological investigations of a small Upper Triassic Oman Exotic exposed on a low isolated hillock near the village of Al Aqil (Fig. 2). The so-called "Aqil Exotic" comprises several isolated large-sized (max 20x10x5m), but coherent blocks within a 30 - 50m thick calcareous debris flow. The megabreccia is dipping subvertically and embedded into deepwater radiolarites of the Haliw Formation (Blendinger, 1991). The breccia contains additional smaller, decimeter-sized pebbles of basaltic lava which is commonly interpreted as the substratum of the sediments described below (Lippard et al., 1986; Hutin et al., 1986; Blendinger, 1991). Other components include "Dachstein"-type limestone of foreslope facies rich in corals and coralline sponges of Norian age. One "Dachstein" reef limestone block contains a small neptunian dyke filled with a shaly red calcareous matrix full of small ammonites (0.5 - 1cm), dated as Hettangian by Blendinger (1991). However, our own collections revealed several genera distinctive of a younger age (Pliensbachian). The megabreccia is therefore younger than Mid-Liassic and not pre-Hettangian as assumed by Blendinger (1991).

Lithology and sedimentology of the fossil-rich Aqil exotic were described in detail by Blendinger (1991). He distinguished 3 different lithozones - a basal

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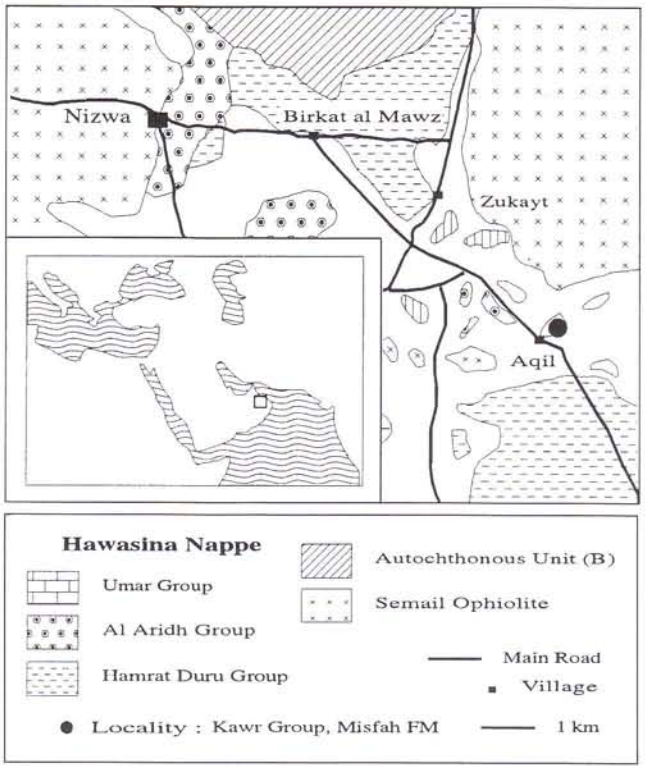


Fig. 1 - Geological map of the area around Birkat al Mawz in the central Oman Mountains: the sample locality near the village of Al Aqil is marked.

fore reef breccia (= reef limestone unit), a crinoidal-brachiopod packstone (= crinoidal limestone) and finally a cephalopod limestone unit. Due to insufficient biostratigraphic data Blendinger included all 3 units in the Norian in accordance with the stratigraphically well constrained cephalopod limestone at the top. We describe the biota of the reef and the brachiopods of the crinoidal limestone unit and report new biochronologic data for both units (Fig. 3). Based on conodonts, the reef unit and the overlying brachiopod-bearing crinoidal limestone were dated as Lower Carnian and Upper Carnian respectively. If the sequence is eventually included into the Misfah Formation of the Hawasina complex, it will mark an earlier and hitherto unknown time slice of this formation, with a geological history distinctly different than in its type-region (Pillevuit et al., 1997, p. 225).

Reef limestone.

At Al Aqil the reef limestone is normally coarse-grained with scattered packstone patches which did not yield any conodonts. Only block 4 of Blendinger (1991) contains, at its base, half a meter of bedded allodapic limestone with a finer grained, crinoid- and filament-bearing wackestone to packstone. The Lower Carnian conodonts *Metapolygnathus polygnathiformis* and *M. tethydis* were extracted from this rock. Blendinger (1991) (Fig. 2, "Block 6") mentions another locality about 4 km to the northwest of the village with an identical sedimentary sequence. There, the breccia contains reef limestone blocks of a more distal facies with small lenses of pockets of red filament-bearing packstones. The latter have produced again a rich conodont fauna consisting of a *Gladigondolella tethydis*, various ramiform elements of the *Gladigondolella multielement* (Kozur & Mostler, 1972) and *Metapolygnathus polygnathiformis* of Early Carnian age.

Reef biota.

The biota of the limestones is described briefly, based on 35 thin sections. The geographic distribution of the organisms is then discussed, and finally a comparison is made between the biota of the Al Aqil locality and other Carnian reef localities in the Tethyan realm.

Sponges.

The sponge fauna is represented by segmented sphinctozoid, non-segmented inozoid and chaetetid types. The diversity and abundance of all groups is very low. The sphinctozoid group, however, is the most abundant and represented mainly by taxa whose skeletal mineralogy was composed of Mg-calcite. The following taxa were identified:

Stylothalamia dehmi Ott (Pl. 1, Fig. 1): Only one specimen of this sponge was collected. It is composed of numerous crescent-like chambers arranged in catenulate fashion around a retrosiphonate spongocoel. Typical of this sponge is the presence of slender pillars as filling structure within the chambers interior. All the characteristics of this sponge correspond to those of the type material described by Ott (1967).

The rigid skeleton of the specimen from Oman is composed of neomorphic calcite. The rigid skeleton of the holotype of *Stylothalamia dehmi* described by Ott (1967) from the Carnian Raibl beds (Karwendel Mountains) is composed also of neomorphic calcite and was restudied by Senowbari-Daryan (1990). Some areas of the chamber walls, however, show the relic structure of primary micrite indicating an original Mg-calcite mineralogy of the rigid skeleton (see also Senowbari-Daryan, 1990; p. 48). The revision of all stylothalamid sponges of Triassic and Liassic age is necessary. Also, the affiliation of Permian species, described by Senowbari-Daryan (1990) and Rigby et al. (1994) should be checked carefully.

Subsequently, the following species of the genus were described: *Stylothalamia otti* Boiko (in Boiko et al., 1991, p. 156) from the Upper Triassic of Pamir, *Stylothalamia eleganta* (Rigby et al., 1994) from the Middle

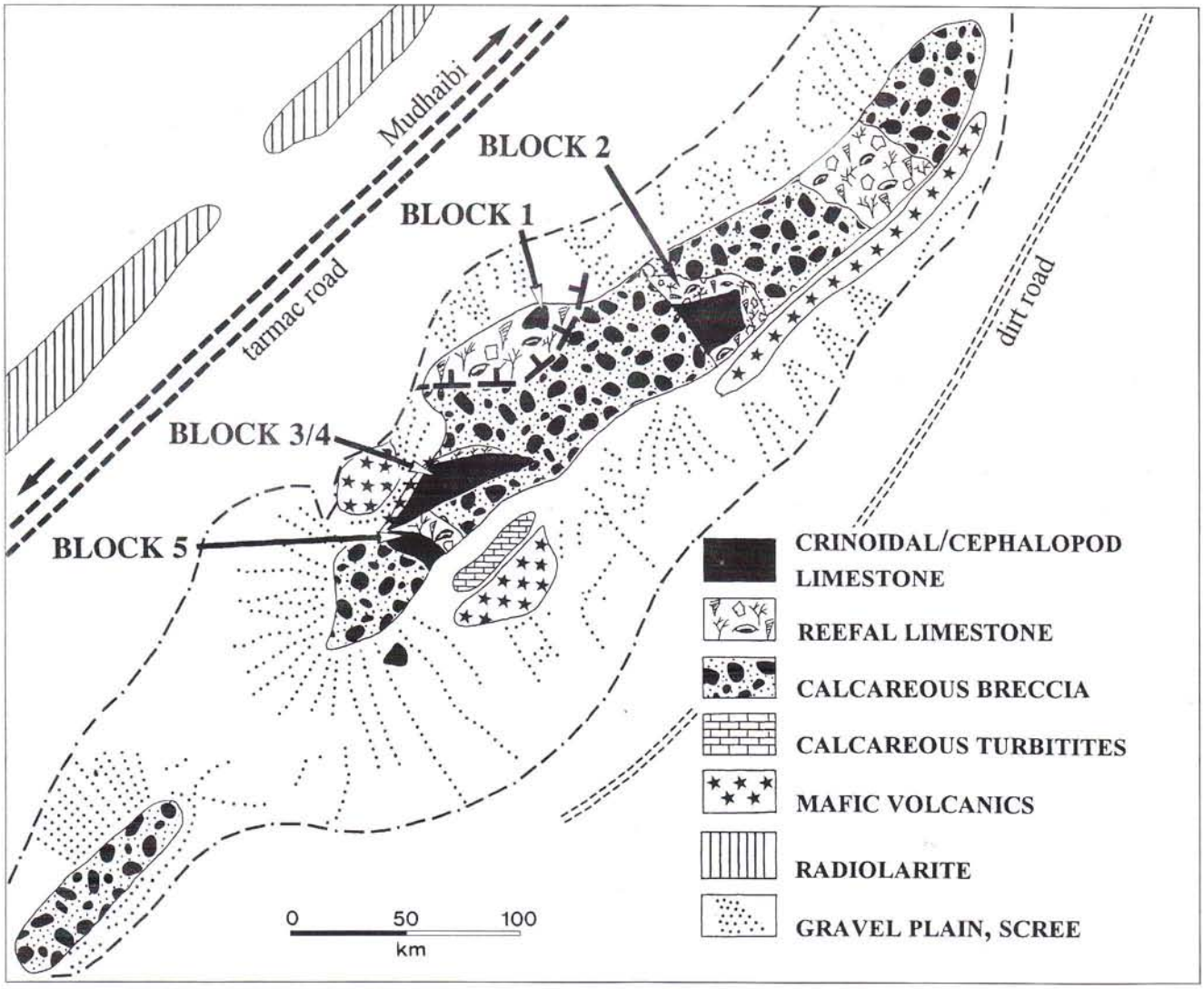


Fig. 2 - Geological sketch of the small hillock with blocks 3 and 5 modified after Blendinger (1991).

Permian of China, and *Stylothalamia polysiphonata* (Senowbari-Daryan, 1994, p. 423) from the Norian-Rhaetian of Antalya/Turkey.

The genus *Stylothalamia* has been reported from the Permian of China (Rigby et al., 1994), Sicily (Senowbari-Daryan, 1990), and from the Carnian to Liassic reef limestones of several localities in the Alpine-Mediterranean region as well as from the Pamirian Range (Senowbari-Daryan, 1990; 1994, Boiko et al., 1991). *Stylothalamia dehmi*, however, is known only from the Carnian age of several reef limestones in the Alps, Carpathians, Hydra/Greece, Slovenia, and now from Oman.

Until now *Stylothalamia* was not known from the Oman Mountains. Stylothalamid sponges occur also in Norian-Rhaetian reefs within the Nayband Formation in central Iran (Senowbari-Daryan, 1996a; Senowbari-Daryan & Hamadani,1999).

Zardinia platithalamica Dieci, Antonacci & Zardini (Pl. 1, Fig. 6) is another Mg- calcitic sphinctozoid sponge occurring in Carnian reef limestones near the town of Al Aqil. The outer segmentation of this conical sponge is poorly developed but the internal segmentaion may be well recognizable. In addition to an axial retrosiphonat spongocoel the sponge bears numerous small tubes, arranged divergently upward and to the outside. The chambers interior is filled with reticular filling structure.

Zardinia is reported from the Ladinian of the Northern Alps (Wolff, 1973), Carnian of the Southern Alps (Dieci et al., 1968), Hydra (Greece) (Senowbari-Daryan & Schäfer, 1983), and Aggtelek Karst(Hungary) (Riedel, 1990). Until now, this sponge was not known from Oman.

Zardinia cf. *retrosiphonata* Senowbari-Daryan (Pl. 1, Fig. 8) is the third species of Mg-calcite sphinctozoid sponge found in Al Aqil. The species was first described as *Zardinia* sp. 1 by Senowbari-Daryan & Schäfer (1983) and later as *Z. retrosiphonata* by Senowbari-Daryan (1990) from the Carnian reef limestones of the Island of

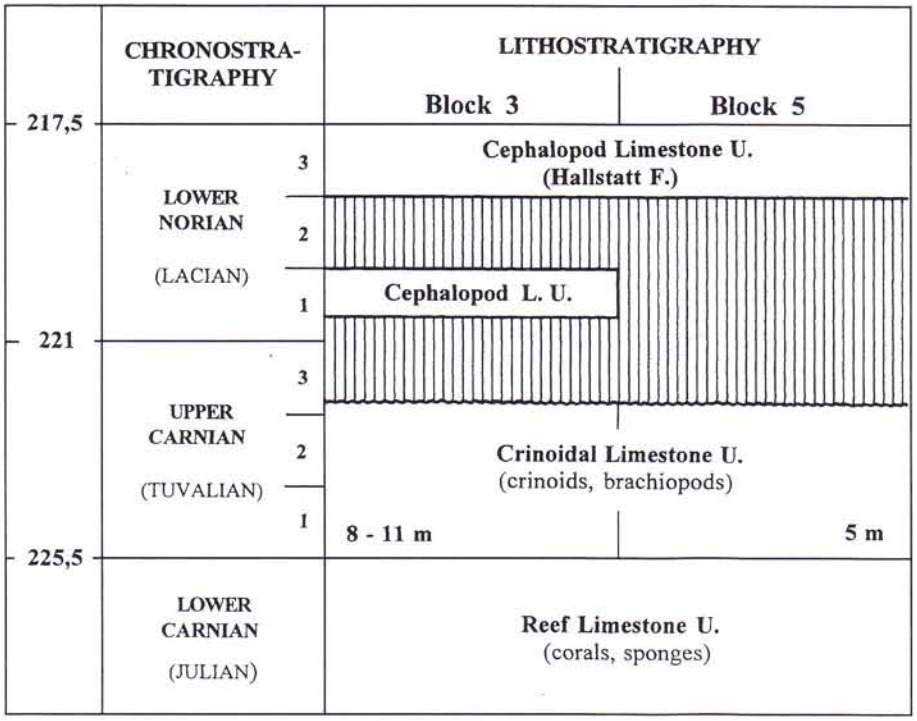


Fig. 3 - Chronostratigraphy and lithostratigraphy of the limestone units studied.

Hydra (Greece). However, we are not certain about the identity of the species from Hydra and Oman. The species from Oman is composed of several crescent-like chambers arranged around a retrosiphonate spongocoel. The chambers interior contains filling structures appearing as circles (tubes?) in cross section but reticular in longitudinal sections (Pl. 1, Fig. 8).

Cryptocoelia zitteli Steinmann is an aragonitic sphinctozoid sponge abundant in Carnian reefs in the western part of the Tethys. This sponge is known from the Carnian reef limestones of Jabal Wasa in Oman (Bernecker, 1996) and now was found also in Al Aqil (Pl. 2, Fig. 1).

Colospongia dubia Laube is another aragonitic sponge present in Carnian reefs in the western Tethys. Only one specimen of an unidentified species of the genus *Colospongia* was found in Al Aqil.

In addition to the genera described, some small unidentified sphinctozoid sponges (Pl. 2, Fig. 8), a few unidentified inozoid (Pl. 2, Fig. 3) and large colonies of chaetetid types (Pl. 1, Fig. 7) were found. At least three different species of inozoids were recognized, but a detailed description was not possible due to poor preservation. The chaetetids are represented by at least two species.

Corals.

The scleractinian coral fauna is represented by both groups of dendroid and cerioid types. The following taxa were determinated:

Proheterastrea minor Turnsek (in Turnsek & Buser, 1989) (Pl. 3, Fig. 1): The phaceloid colonies have long parallel corallites with a small diameter (2-3 mm). The thick wall is epithecal and the hexameral septa are slightly bilateral. This species was first described from the Upper Carnian (Tuvalian) of Slovenia and is known also from Hydra (Greece) (Turnsek & Senowbari-Daryan, 1994).

Rhopalodendron juliensis Turnsek (in Turnsek & Buser, 1989) (Pl. 3, Fig. 2): The dendroid/phaceloid colonies consist of many subcylindrical corallites, about 3-4 mm in diameter. They show extracalicinal budding and thin septa of equal thickness. The very small styliform columella is seldom preserved. The species is known from the Upper Carnian (Tuvalian) (Turnsek & Buser, 1989) and Lower Norian (Lacian) (Ramovs & Turnsek, 1991) of Slovenia.

Stuoresia fluegeli Turnsek & Senowbari-Daryan, 1994 (Pl. 3, Fig. 3): The cerioid colonies have corallites, roundish in cross section, produced by intracalicinal budding in many directions. The septa are compact, arranged in 3-4 cycles and the wall is septothecal. A columella is not developed. The species is known only from the Carnian to lowermost Norian of Hydra (Greece) (Turnsek & Senowbari-Daryan, 1994) and now from the Al Aqil locality of Oman.

Problematic organisms.

Problematic organisms are relatively abundant. The most abundant species *Ladinella porata* Ott (Pl. 2, Figs. 1-2, 7) grows as epifauna on other organisms, like sponges or algae. "*Tubiphytes*" is the next most abundant fossil among the microproblematic organisms. "*Tubiphytes*" *multisiphonatus* Schäfer & Senowbari-Daryan (Pl. 1, Fig. 5) has a bush-like growth form and is characterized by an axial and irregularly-shaped "cavity" produced by growing of multiple axial "cavities". "*Tubiphytes*" *gracilis* Schäfer & Senowbari-Daryan (Pl. 2, Fig. 4), a small multibranched species, is an important producer of reef detritus. *Plexoramea cerebriformis* Mello (Pl. 1, Fig. 9) is another relatively abundant problematic organism living among reef builders like sponges or corals. Other problematica are *Baccanella floriformis* Pantic (Pl. 1, Fig. 2), *Radiomura cautica* Senowbari-Daryan & Schäfer, and partly abundant tube-like organ-

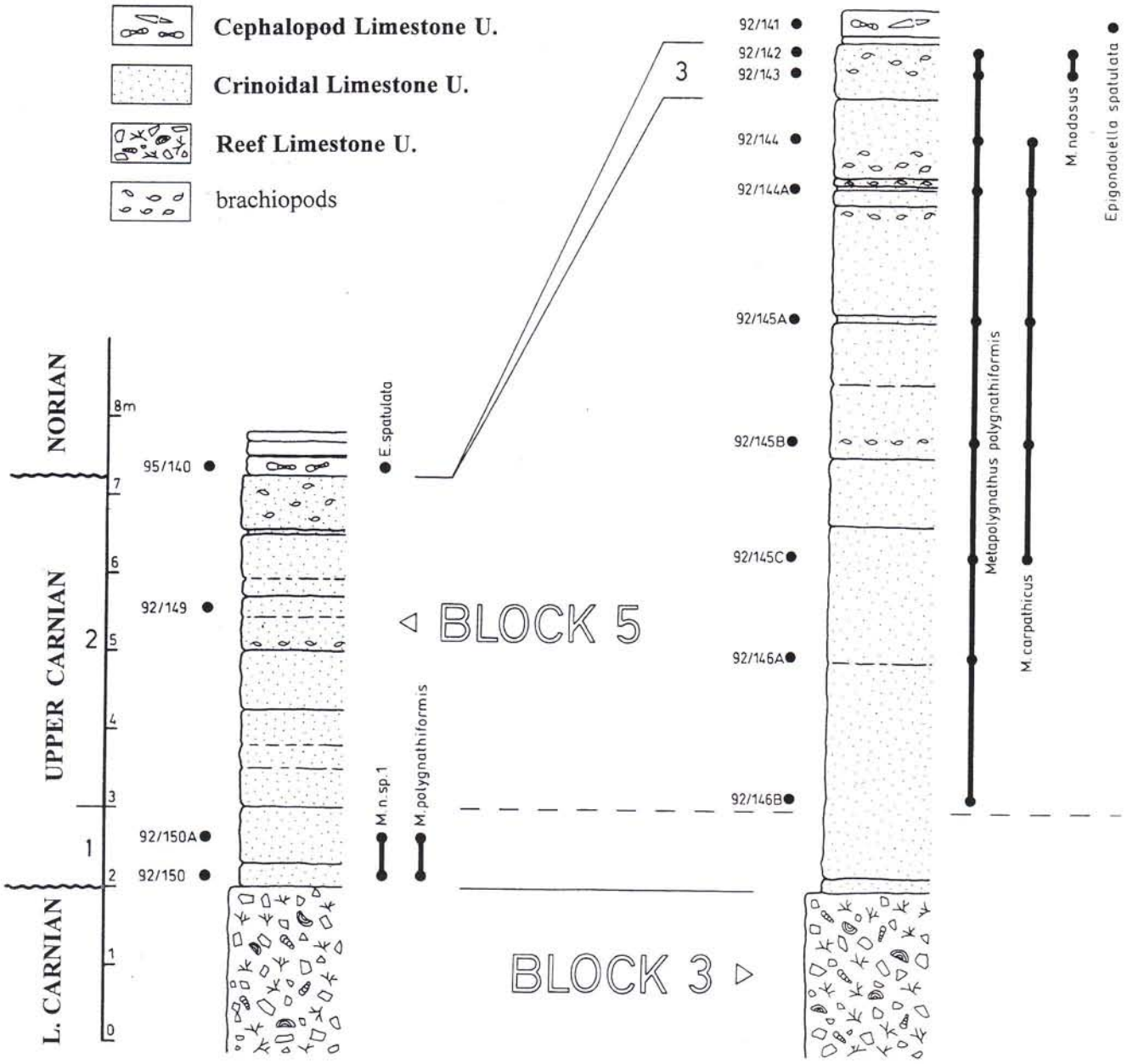


Fig. 4 - Lithological columns of blocks 3 and 5 (conodont samples are indicated).

isms similar to those described as *Macrotubus babai* by Fois (in Fois & Gaetani, 1981) from Ladinian reefs of the Dolomites, Italy. An undetermined small chambered problematic organism (foraminifer?), found in Al Aqil, is depicted on Pl. 2, Fig. 7.

Foraminifers.

Foraminifers are very rare within the limestones studied. Only some agglutinated types like *Bigenerina* (Pl. 2, Fig. 10), small *Palaeolituonella* sp., and unidentified taxa (Pl. 1, Fig. 4) were found. Miliolids are extremely rare and represented by few specimens of *Ophthalmidium*. The typical Carnian spiriamphorellid or cucurbitid foraminifers, abundant in Carnian reefs of the western Tethys and Turkey, could not be found in the Carnian limestones of this locality. Bernecker (1996) found, however, some Norian types of these kind of foraminifers in Norian/Rhaetian reefs in Oman.

Algae.

The flora is limited to solenoporacean red algae of both *Solenopora*- and *Parachaetetes-type* (Pl. 2, Figs. 4, 6). The skeleton of *Parachaetetes* sp. may reach a maximum dimension of up to 10 cm. The algae are characterized by strongly concentric dark and light zones reflecting the well- and poorly-preserved areas within the skeleton (Pl. 2, Fig. 6). In addition, some fragments tentatively identified as the udoteacean green alga *Egeri-*

codium hungaricum Flügel et al. (1991/1992), originally described from the Carnian reefs of the Bükk-Mountains near Eger in Hungary, were found in one thin section.

Other organisms.

Bryozoans are rare in Al Aqil and represented by poorly-preserved colonies, as documented in Pl. 2, Fig. 9. Hydrozoans were not found. Gastropods, bivalves, ostracods, echinoid spines, fragments of crinoids and unidentified worm tubes of different size occur.

Finally, the presence of the worm tube of *Barbafera carnica* Senowbari-Daryan should be emphasized. This organism, originally described as possibly a dasycladacean green algae, was recently interpreted as worm tubes (Senowbari-Daryan, 1996b). In some areas of Al Aqil it is extremely abundant. It occurs as a baffler, building small patch-reefs of several square meters in this locality (Senowbari-Daryan & Bernecker, 1997).

"Spongiostromata"-type crusts are the most abundant encrusting organisms around the corals, sponges or other reef builders. The bubble-like encrusters (algae?, sponges?) known from other Carnian reefs occur rarely.

Comparison.

The biotic composition of the Carnian reef limestones exposed near the town of Al Aqil corresponds to the biota known from other Carnian localities in the Tethyan realm. Compared with other Carnian reefs of the northwestern Tethys, the Al Aqil fauna is noteworthy because of its low diversity although this is most probably due to insufficient collection and sampling of the limestones. Further investigations of other Carnian localities (in preparation) will help to resolve this issue.

The only difference between the biotic composition of the Carnian of Al Aqil and other Carnian reefs of the northwestern Tethys is the relatively low diversity of foraminiferal association of the former, especially the total lack of spiriamphorellid or cucurbitid types, which are abundant foraminifers in Carnian reefs of numerous localities in the Carpathians, Italy (Sicily and Apennines), Greece, and Turkey. The cucurbitid foraminifers also occur with a low diversity and frequency in the Carnian reefs of the Northern Calcareous Alps and in the Southern Alps. These foraminifers are not known from the central or eastern part of the Tethys.

The abundant occurrence of the worm tube *Barbafera carnica* as a reef builder in Al Aqil locality is an additional difference from the Carnian reefs in the western Tethys.

Stratigraphic position.

In general, the biotic composition of Ladinian and Carnian reefs of the Tethyan realm is very similar. However, the stratigraphic age of the reef limestones investigated in Oman is based on some sponges (e. g. *Stylothalamia dehmi* Ott), problematic organisms (e. g. *Barbafera carnica* Senowbari-Daryan), and algae (*Egericodium hungaricum* Flügel et al.) which are known only from Carnian, and not Ladinian, reefs. The composition of the coral fauna supports this stratigraphic dating of the reef limestones.

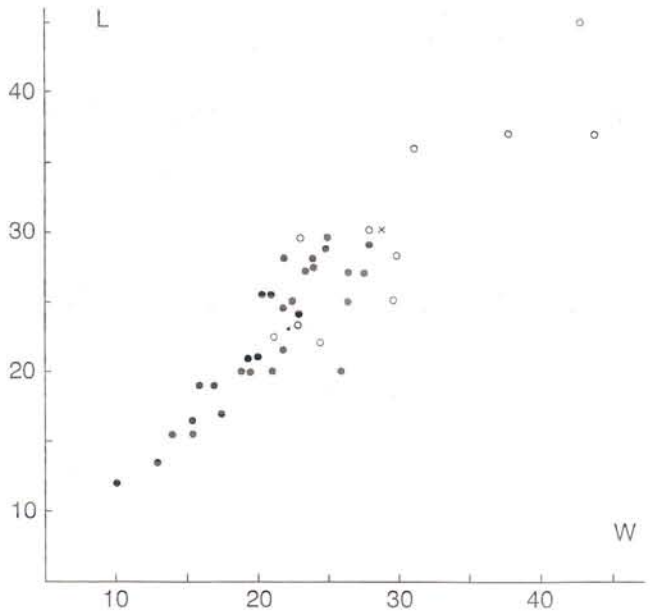


Fig. 5 - Length/width scattergram for 32 complete specimens of *Oxycolpella arabica* sp. n. (x = holotype) and 11 specimens of *Oxycolpella* aff. *arabica* sp. n. (o), in mm. Al Aqil.

Crinoidal limestone.

Originally, the unit was named as crinoidal brachiopod packstone by Blendinger (1991). The term crinoidal limestone seems more appropriate since brachiopods are restricted to certain layers with many barren intervals in between, especially in the lower part of the unit. As already mentioned, the unit starts discontinuously above the reef limestone. The sedimentary change is strongest in block 5 where the basal light-grey crinoidal packstone is replaced by a thin layer of reddish crinoid- and filament-bearing wackestones (Fig. 4). Packstones rich in disarticulated crinoid ossicles dominate the sequence. Brachiopods are almost missing in the basal part and become frequent only towards the top of the unit. At the beginning they are concentrated in thin (10 cm) and rare layers which get thicker (up to 60 cm) and more frequent up section. Disarticulated shells and shell fragments are common; complete specimens are often damaged and spar-filled, well-preserved specimens are very rare. Small-sized (2-3 cm) globular and smooth-shelled ammonites (*Arcestes*, *Megaphyllites*) appear in the upper part and may indicate a continuous deepening of the environment.

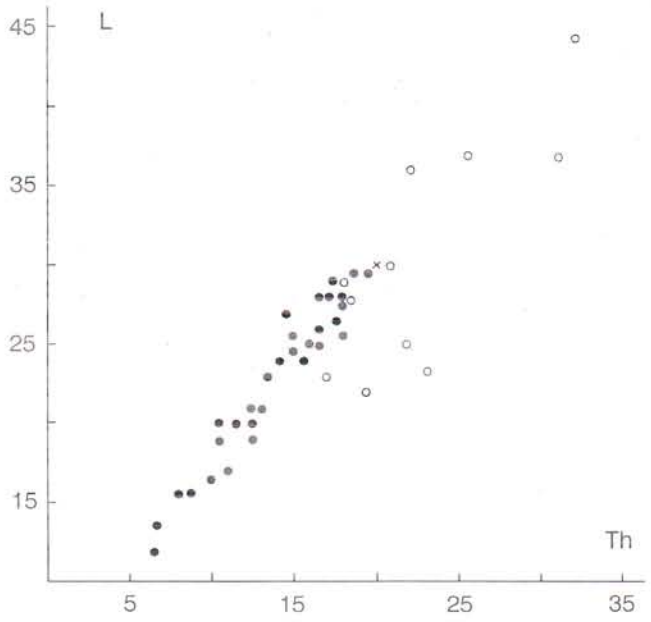


Fig. 6 - Length/thickness scattergram for *Oxycolpella arabica* sp. n. and *Oxycolpella* aff. *arabica* sp. n.. For explanation see Fig. 5.

The crinoidal limestone shows remarkable thickness variations over a short distance. Plausible explanations for this include a) local syndepositional faulting of the reef limestone during the crinoidal limestone deposition (Blendinger, 1991), or b) onlap of the crinoidal limestone above a drowning unconformity surface

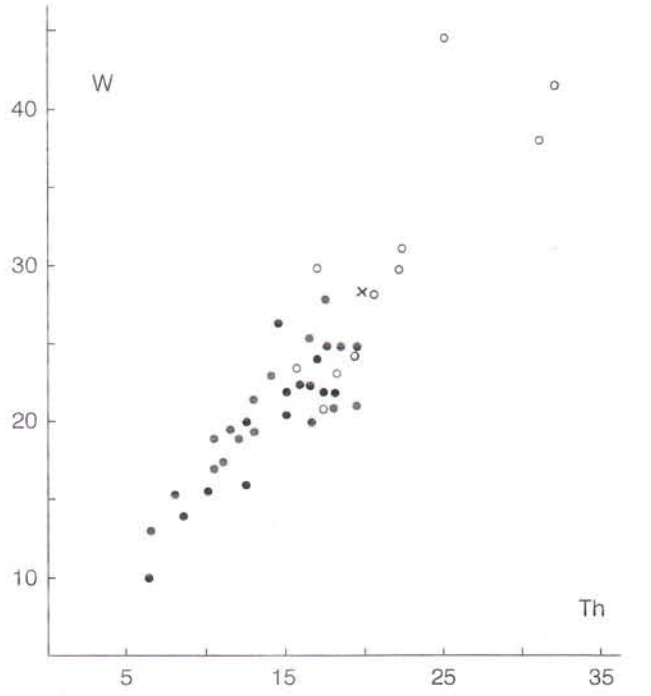


Fig. 7 - Width/thickness scattergram for *Oxycolpella arabica* sp. n. and *Oxycolpella* aff. *arabica* sp. n.. For explanations see Fig. 5.

(Schlager, 1989). The overall sequence made of reef limestone - hiatus - crinoidal lst. - condensed cephalopods, records a typical drowning succession known from many carbonate platforms through geological time (Schlager, in press). Within this depositional system the crinoidal limestone marks a distinct transgressive event which might be well recognizable along other Tethyan margins at the base of the Upper Carnian.

Stratigraphic position.

The crinoidal limestone was dated in both blocks 3 and 5 (*sensu* Blendinger, 1991) as exclusively Late Carnian. The basal 1m of block 5 contains *Metapolygnathus polygnathiformis* and *M.* n. sp. 1, together indicative of the lowermost Tuvalian (Gallet et al., 1994). The main part of the unit (up to 8 m in block 3, 5 m in block 5) contains the bulk of the brachiopod fauna. This part of the unit is also most probably the host of the specimens described and collected from an isolated block at the northern footwall of the hill below block 5 (Fig. 3). Two conodont intervals, a lower interval with exclusively *Metapolygnathus polygnathiformis* and an upper interval with the co-occurrence of *M. polygnathiformis* and *M. carpathicus* document the presence of the middle Tuvalian (Fig. 3). Rare fragmented ammonites (92/149: *Arcestes*, *Megaphyllites applanatus*) are present also but are not time-diagnostic. Conodonts of the lower Tuvalian 3 (*M. polygnathiformis* and *M. nodosus*) were found only in the topmost half meter of block 3. Summarizing the data, it is possible to attribute the brachiopods described below to a relatively narrow time interval of about 1-2 million years corresponding to the Tuvalian 2 or *Tropites subbullatus* zone in terms of Tethyan Triassic ammonoid biochronology (Krystyn, 1980).

Brachiopods (M. Siblik)

Order Athyridida Boucot, Johnson & Staton, 1964

Suborder Athyrididina Boucot, Johnson & Staton, 1964

Superfamily Athyridacea Davidson, 1881

Family Spirigerellidae Grunt, 1965

Subfamily Spirigerellinae Grunt, 1965

Genus *Oxycolpella* Dagys, 1962

Oxycolpella arabica sp. n.

(Pl. 4, Figs. 1A-1C, 2A-2C, 4, Text-Figs. 5-9)

Derivatio nominis: Arabicus, -a, -um (lat. = Arabian, coming from Arabian peninsula).

Holotype: Specimen illustrated on Pl. 4, Figs. 2A-2C.

Depository: Holotype and paratypes are deposited in the "Staatssammlung für Paläontologie und historische Geologie", Münich.

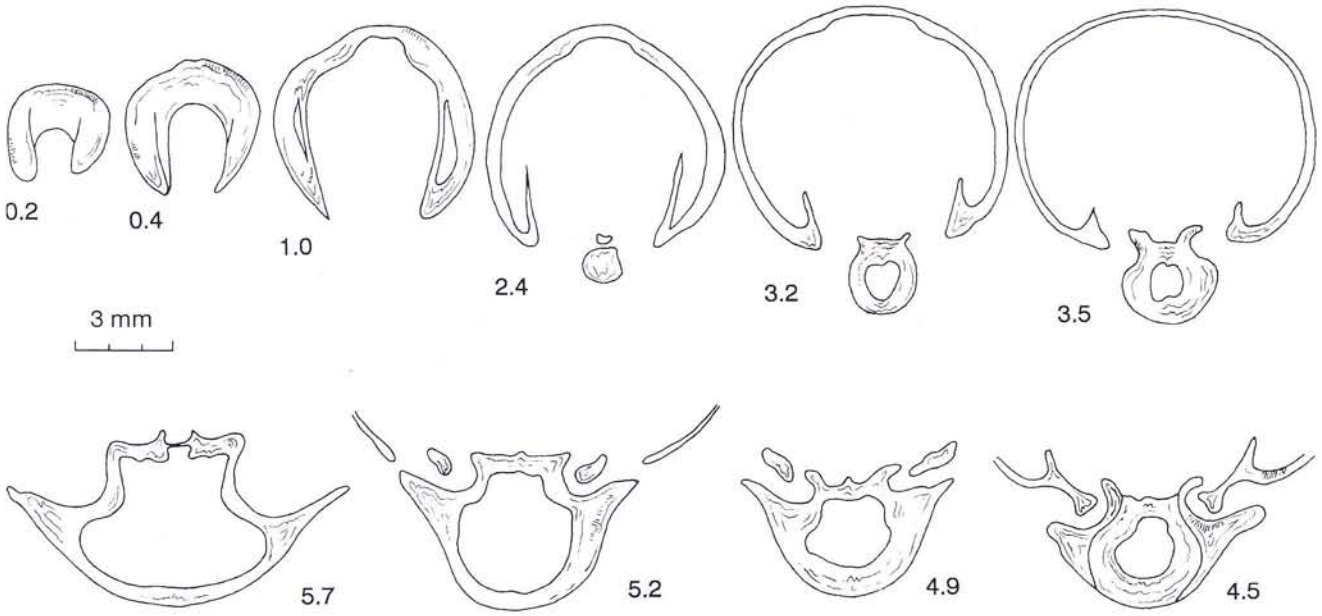


Fig. 8 - *Oxycolpella arabica* sp. n.. Serial transverse sections; cumulative spacing given in mm from pedicle to umbo. The seventh section shows unusually weak hinge teeth. Total length of specimen 25.5 mm. Al Aquil. Enlarged.

Locus typicus: See block 3 and 5 in Fig. 2, Al Aqil.
Stratum typicum: Crinoidal limestone, Carnian (Tuvalian).
Material: 52 specimens, mostly decorticated internal moulds. The specimens illustrated measure (length x width x thickness): 25.2 x 22.6 x16.2 mm (Pl. 4, Figs. 1A-1C) and 30.0 x 28.7 x 19.8 mm (Pl. 4, Figs. 2A-2C, holotype).
Diagnosis: Biconvex shells of medium to large size, subpentagonal outline with length/width ratio over 1, highly uniplicate anterior commissure. Pedicle umbo massive, incurved. Cardinal process large and bilobed, hinge plate unpierced.

Description.

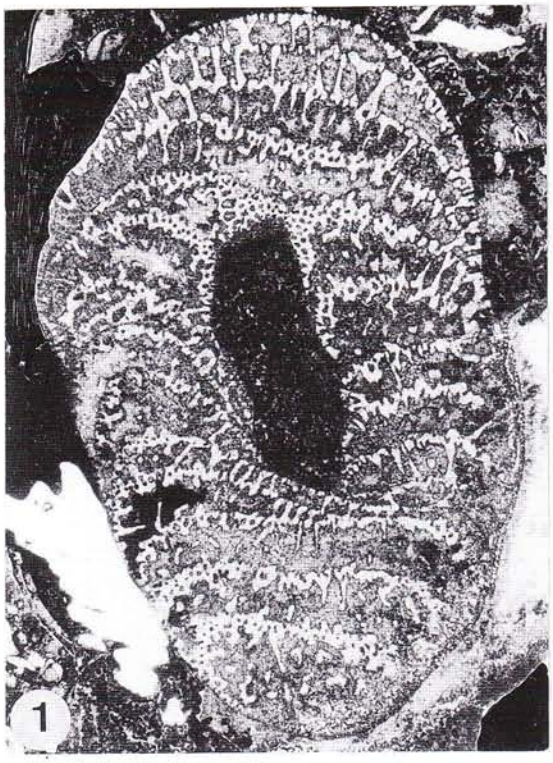
a) Morphology. Medium- to large-sized biconvex specimens of subpentagonal outline, reaching dimensions of 30.0 mm in length, 29.0 mm in width and 19.5 mm in thickness. In most specimens the shell is slightly longer than wide. The maximum width is situated at or near the shell mid-length. Pedicle umbo strong and incurved. Interarea indiscernible. Details of pedicle beak and foramen are poorly preserved or broken off in most specimens. However, very short, poorly marked blunt beak ridges are discernable. Hinge line short and subangular (angle approximately 90%). Fold of brachial valve distinct in the anterior half of valve. Pedicle valve medianly flattened, in two specimens with narrow axial sulcation, traceable anteriorly. Lateral commissure bends sharply dorsally in its anterior part, forming broad and high plication at shell anterior margin. Poorly marked concentric growth lines developed at least in marginal part of valve. Young specimens subcircular, with only low, gently curved anterior plication.

b) Internal characters (Text-Figs. 8-9). Dental plates usually very short, subparallel or slightly divergent. Well-developed pedicle collar observed in 2 speci-

PLATE 1

Sponges, foraminifers, worm tubes and problematic organisms from the Carnian reef limestones of Al Aqil, Oman.

Fig. 1 - *Stylothalamia dehmi* Ott. Oblique section of numerous chambers with perforated walls and internal filling structure of slender pillars. X4.
Fig. 2 - Section of the problematic organism *Baccanella floriformis* Pantic. X20.
Fig. 3 - Oblique longitudinal and transverse sections of the worm tube *Barbafera carnica* Senowbari-Daryan. X2.5.
Fig. 4 - Longitudinal section of an agglutinated foraminfer that is relatively abundant within the reef limestones (compare fig. 5). X40.
Fig. 5 - Longitudinal and oblique sections of *"Tubiphytes" multisiphonatus* Schäfer & Senowbari-Daryan, an abundant organism in Ladinian-Carnian reefs in the western Tethys and Oman. Two small agglutinated foraminifers are associated with *"Tubiphytes"*. X12.
Fig. 6 - *Zardinia platithalamica* Dieci, Antonacci & Zardini. Longitudinal section shows the crescent-like chambers with internal reticular structure, numerous vertically arranged tubes and the axial spongocoel. X3.
Fig. 7 - Oblique section of the skeleton of an unidentified chaetetid sponge (approximately 10 cm in diameter). X4.
Fig. 8 - *Zardinia* cf. *retrosiphonata* Senowbari-Daryan. Section of a branched (?) specimen shows the crescent-like chambers with internal filling structure and the axial spongocoel(s). X2.2.
Fig. 9 - *Plexoramea cerebriformis* Mello. Section exhibits a small cavity in the central part and some trichome-like and irregularly arranged elements in the skeleton. X20.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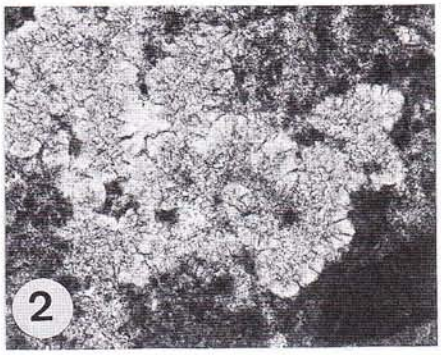
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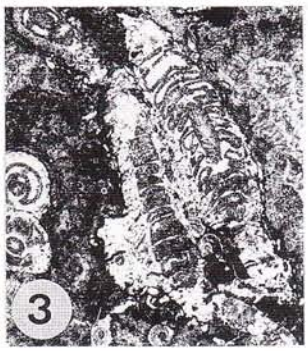
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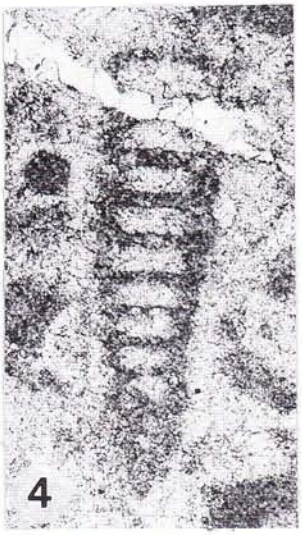
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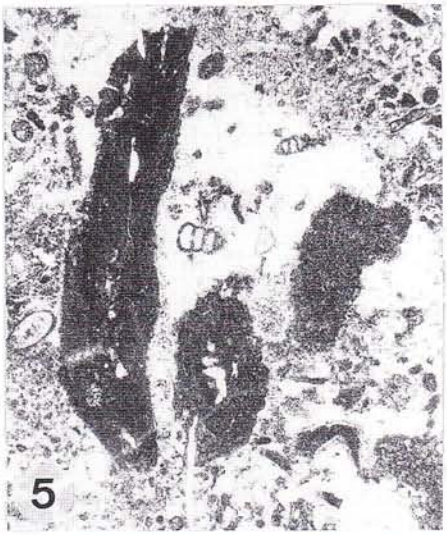
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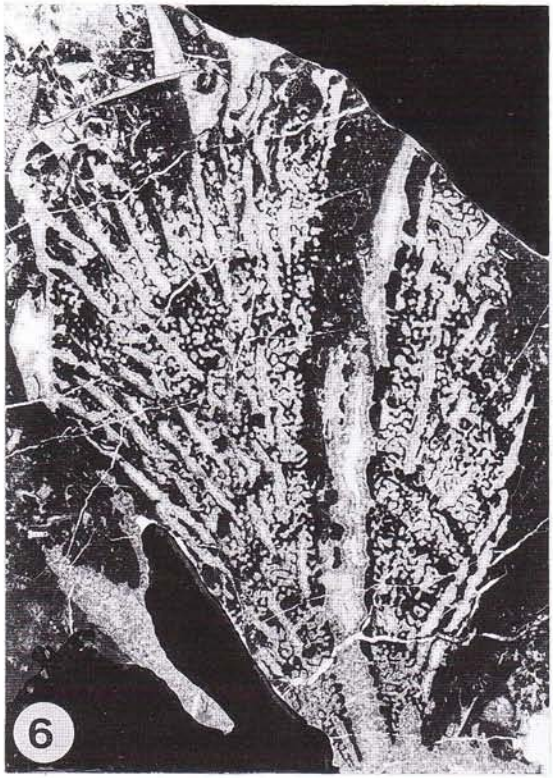
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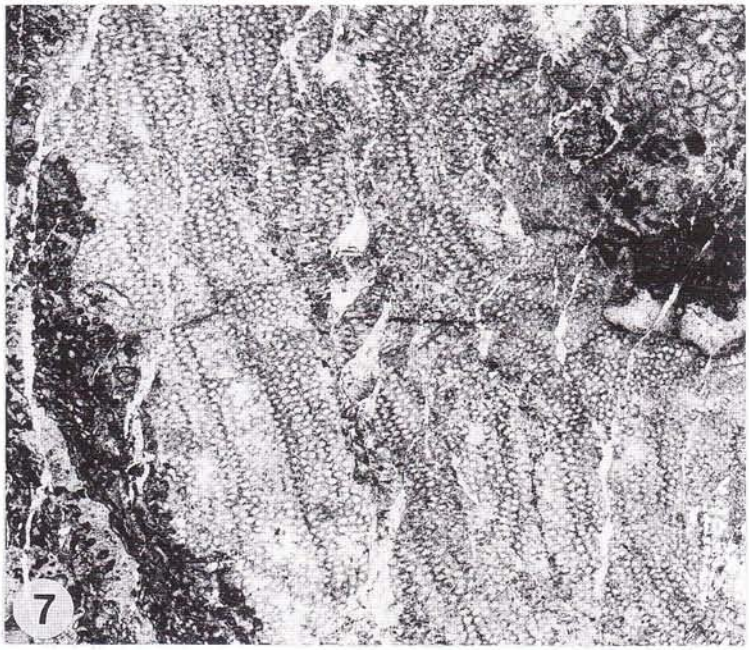
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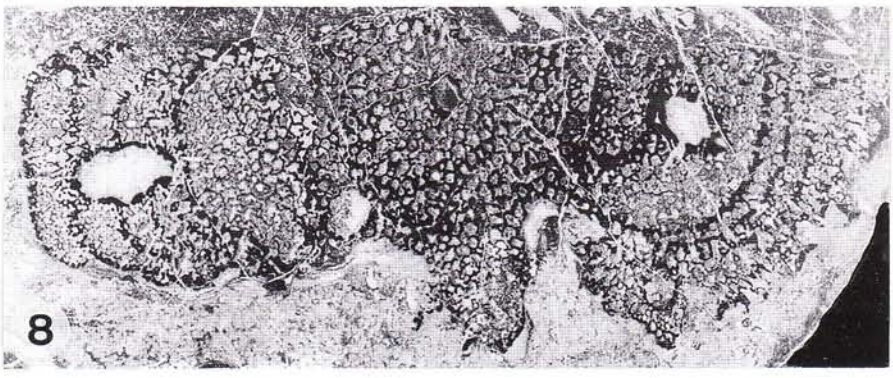
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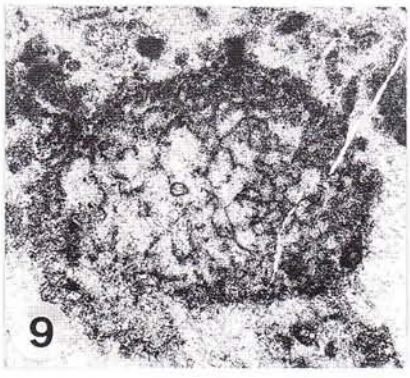
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mens (from 11 specimens sectioned). Stout hinge teeth inserted obliquely into large sockets. Cardinalia strongly developed. Large, bilobed cardinal process present. Hinge plate flat, thick and unpierced. Both outer and inner socket ridges well developed. A low dorsal myophragm may be distinguished posteriorly. Spiralia characterized by about 10-12 volutions. Secondary shell thickening present in a few specimens only. Muscle scars unknown. Other internal characteristics not ascertainable due to poor preservation.

Remarks. Even though the material is highly recrystallized and not ideally preserved for sectioning, it shows the essential features of *Oxycolpella* Dagys (1962) such as a strong bilobed cardinal process, and unpierced hinge plates. It is referred to this genus also based on external features, in accordance with the original diagnosis, given by Dagys (1962, p. 68). Internally, *Oxycolpella* resembles *Ochotathyris* Dagys (1974), except that the latter genus has undergrown dental plates and a simple, small cardinal process. Highly variable external morphology is known in oxycolpellid species and this creates difficulties in the determination. The need to consider whole populations was mentioned already by Pearson (1977) who met with difficulties in placing individuals. The outline of the shell and the shape of the anterior plication (varying from subangular, trapezoidal to subtrigonal) are the most variable features of *Oxycolpella*. The external characters of the Oman specimens are, however, distinct enough to justify a new species. Typical features are its subpentagonal outline slightly longer than wide, relatively thick shells, and high linguiform plication with its width occupying nearly the total anterior view of the shell. The new species from Oman differs remarkably from the type species of *Oxycolpella* - *Oxycolpella oxycolpos* (Suess), described first from the uppermost Triassic of the Alps, which has larger, transversally oval shells with the hinge line curved in obtuse angle, brachial valve more convex toward umbo, lower and narrower anterior plication and coarse growth lines. *Oxycolpella arabica* sp. n. has some affinities with

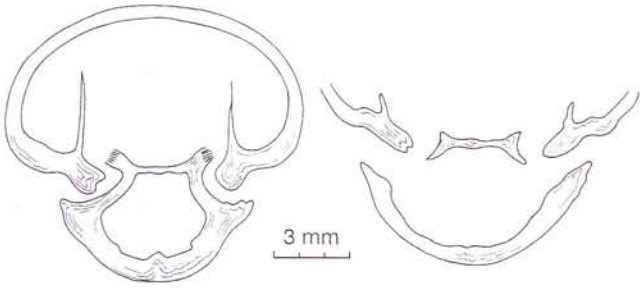


Fig. 9 - *Oxycolpella arabica* sp. n.. Left section shows strongly developed hinge teeth and relatively long dental plates of another specimen. Due to the fragmentary character of the specimen, the distance from pedicle to umbo could not be measured. Length of specimen 29.4 mm. Al Aquil. Enlarged.

Oxycolpella kunensis described by Dagys (1963) from the Norian-Rhaetian of the Caucasus. However, this species tends to have its maximum width anteriorly and its maximum thickness posteriorly if compared with *O. arabica* sp. n. It also has a large sulcation of the pedicle valve, and a less marked convexity of the shell as seen in anterior view. Different outline, well-developed sulcation of the pedicle valve and differently shaped anterior plication are features of other oxycolpellids - *O. robinsoni* and *O. guseriplica* described by Dagys (1962) from the Norian of the Caucasus. The finding of *Oxycolpella* in the southern part of the peri-Gondwanian Tethys in Oman documented in this study enriches the present knowledge of the world-wide distribution of this genus, known from the Alps, Turkey, Iran, Caucasus, Himalaya, China, New Caledonia, New Zealand, and Chile (see Kristan-Tollmann, 1987).

Oxycolpella aff. **arabica** sp. n.

(Pl. 4, Figs. 3A-3B, Text- Figs. 5-7, 10)

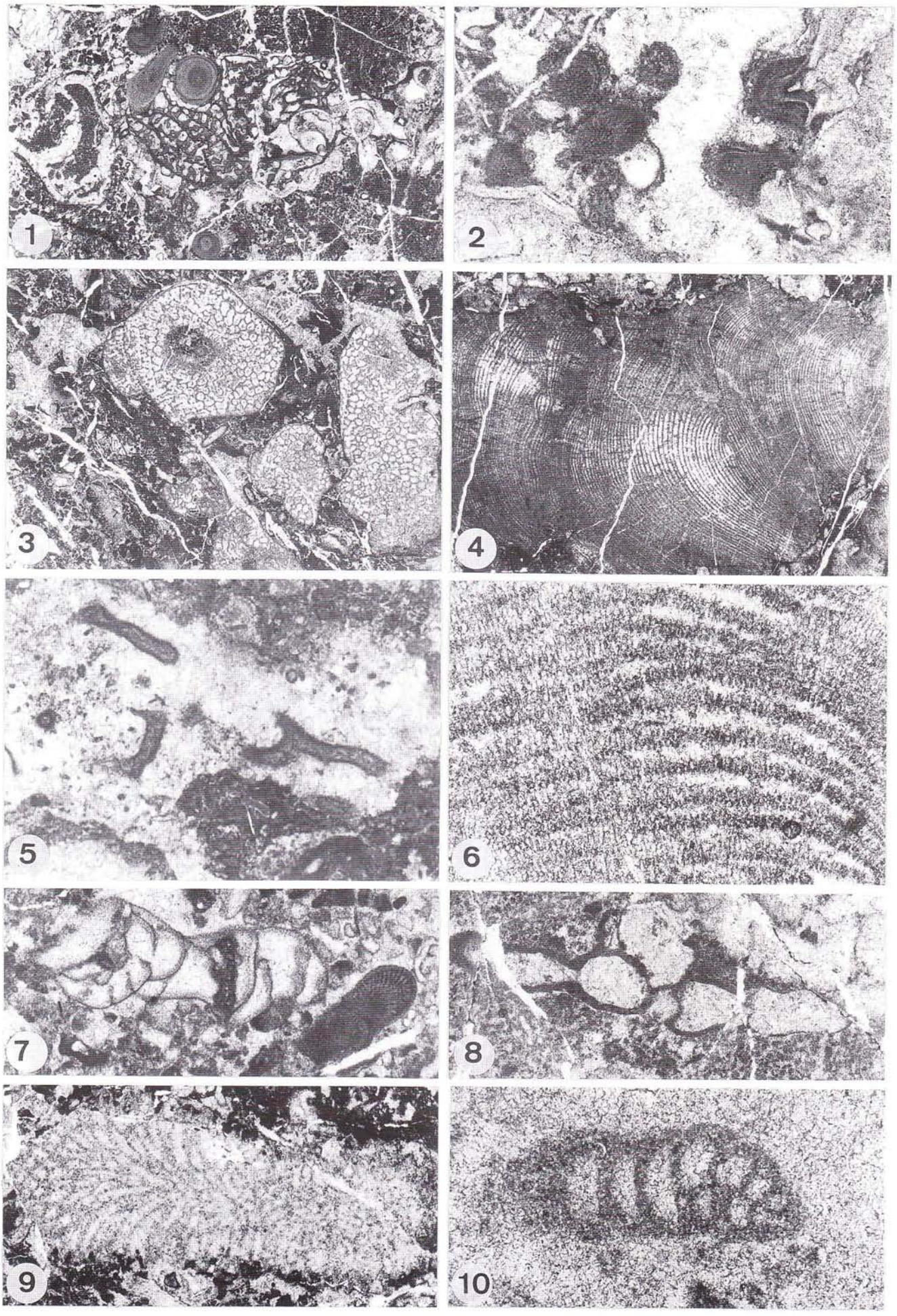
Material: 41 mostly fragmentary, damaged specimens. The specimen illustrated is 23.5 mm long, 21.0 mm wide and 16.6 mm thick.

Locality: This material was collected by L. Krystyn from the same locality as *O. arabica*. It is very probable that Krystyn's materi-

PLATE 2

Sponges, microproblematic organisms, bryozoans, foraminifers and algae from the Carnian reef limestones of Al Aqil, Oman

Fig. 1 - *Cryptocoelia zitteli* Steinmann (A), *Colosopongia* sp. (B), and *Ladinella porata* Ott (C) in a micritic-microsparitic reef limestone. X5.
Fig. 2 - Section of several specimens of *Ladinella porata* Ott, an abundant organism in Carnian reefs of Oman. X16.
Fig. 3 - Undetermined inozoid sponge. X2.5.
Fig. 4 - Longitudinal section of a red alga of *Parachaetetes*-type with distinct horizontally running elements. X3.5.
Fig. 5 - "*Tubiphytes*" gracilis Schäfer & Senowbari-Daryan, a relatively abundant organism in Carnian reefs of the Tethys and in Oman. This organism is an important contributor of reef detritus. X20.
Fig. 6 - Magnification from fig. 4 shows the vertically oriented cell structures and horizontally arranged elements of this red alga. X20.
Fig. 7 - A small chambered problematic organism (foraminifer?)(A) and a well preserved specimen of *Ladinella porata* Ott (B). X20.
Fig. 8 - Small sphinctozoid sponge. X16.
Fig. 9 - Bryozoa gen. et sp. indet. X10.
Fig. 10 - An agglutinated foraminifer (*Bigenerina* sp.) with a biserial initial stage followed by a uniserial arrangement of the chambers. X100.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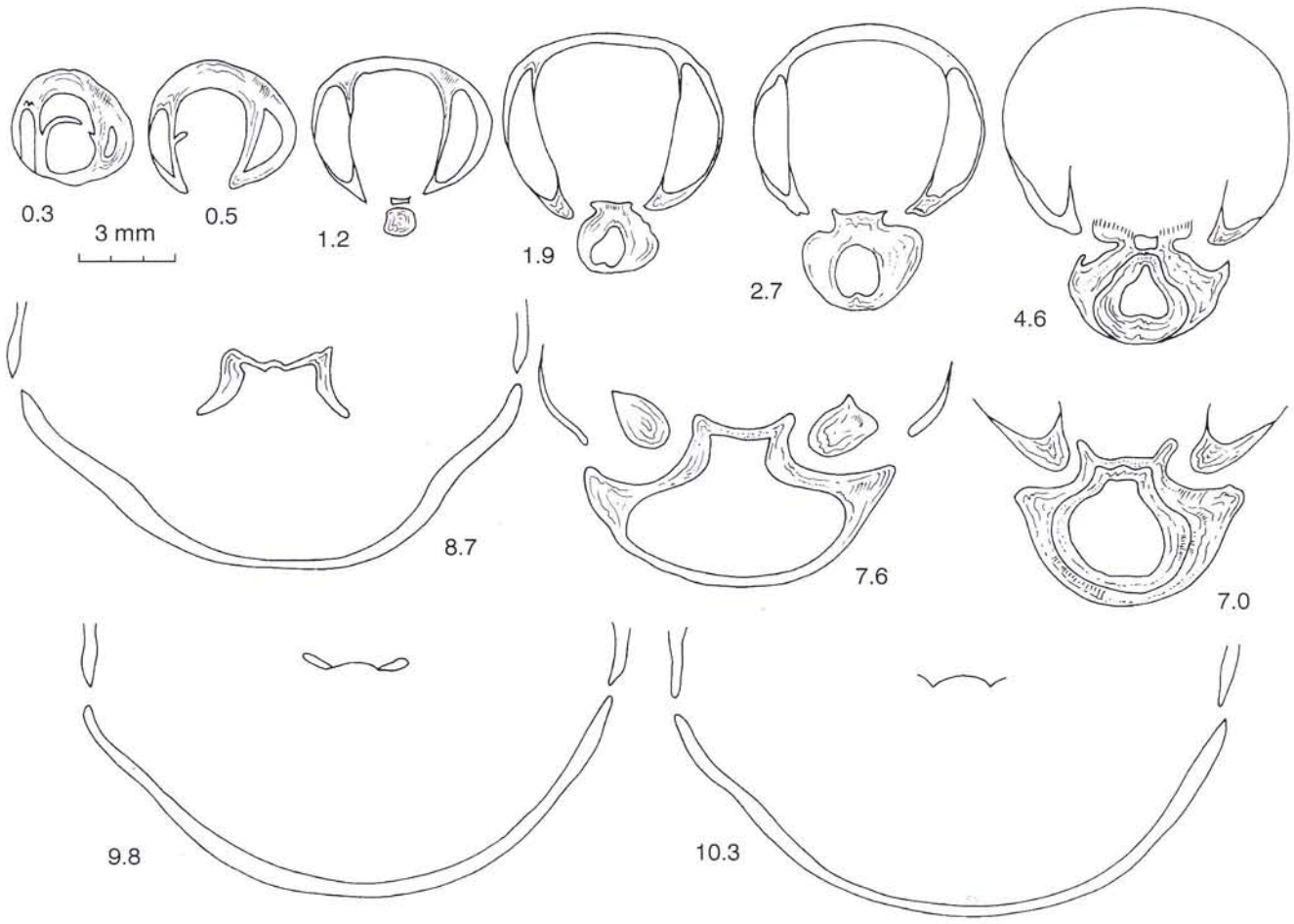


Fig. 10 - *Oxycolpella* aff. *arabica* sp. n.. Serial transverse sections measured from pedicle to umbo. Pedicle collar and longer dental plates are easily visible. Total length of specimen 31.0 mm. Al Aquil, Krystyn´s Sample 92/145B. Enlarged.

al is the same species, described above as *Oxycolpella arabica* sp. n., but proof of identity will require a subsequent study of new, more numerous and better preserved material.

Description. Broadly subpentagonal or transversely oval large specimens up to 45.0 mm long, 44.5 mm wide and 33.0 mm thick. Some specimens develop sulcation on the pedicle valve and narrower plication anteriorly, similar to *O. robinsoni* Dagys. Internal characters (Fig. 10) are essentially as described for *O. arabica* sp. n. However, infilling of crystalline calcite made it impossible to trace the complete internal structure.

Remarks. This *Oxycolpella* differs from *O. arabica* sp. n. by its larger size and relatively wider shells. The species is differentiated from *O. robinsoni* Dagys by a different outline, narrower beak and angular hinge line.

Paleoenvironment.

Based on sedimentologic evidence the crinoidal limestone was interpreted by Blendinger (1991) as deposited below the permanent current wave base, in a depth of more than 300 m. Recent articulate brachiopods which inhabit warmer climatic regions, usually live also in deeper waters (Bitner, 1996). Our comprehensive collection from Al Aqil consists of 100% *Oxycolpella*, a large athyrid genus well known from many Upper Triassic Tethyan locations. Within the Alpine Kössen formation (Upper Triassic) Golebiowski (1991) identified 4 different brachiopod biofacies, including a

PLATE 3

Scleractinian corals and incrustations from the Carnian reef limestones exposed near the village of Al Aqil, Oman

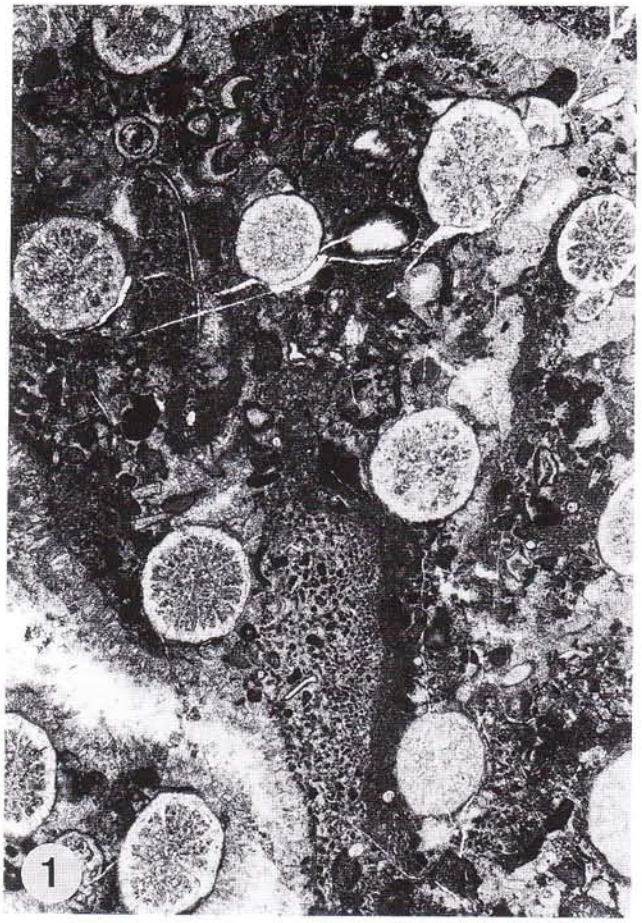
Fig. 1 - Cross section of a phaceloid colony of the small upper Carnian coral *Probeterastrea minor* Turnsek. The sediment between the calices is a wacke- - grainstone with small foraminifers and peloids. X5

Fig. 2 - Cross section through a phaceloid to dendroid scleractinian *Rhopalodendron juliensis* Turnsek. Note the intracalicinal budding. X5.

Fig. 3 - Section through a recrystallized cerioid colony of *Stuoresia fluegeli* Turnsek. This coral is known from Carnian reefs of Hydra, Greece. X4.

Fig. 4 - Strongly recrystallized scleractinian coral showing incrustations of spongiostromate and bubble-like crusts. X5.

Fig. 5 - Section through the calices of a dendroid coral surrounded by several generations of chaetetid sponges. X4.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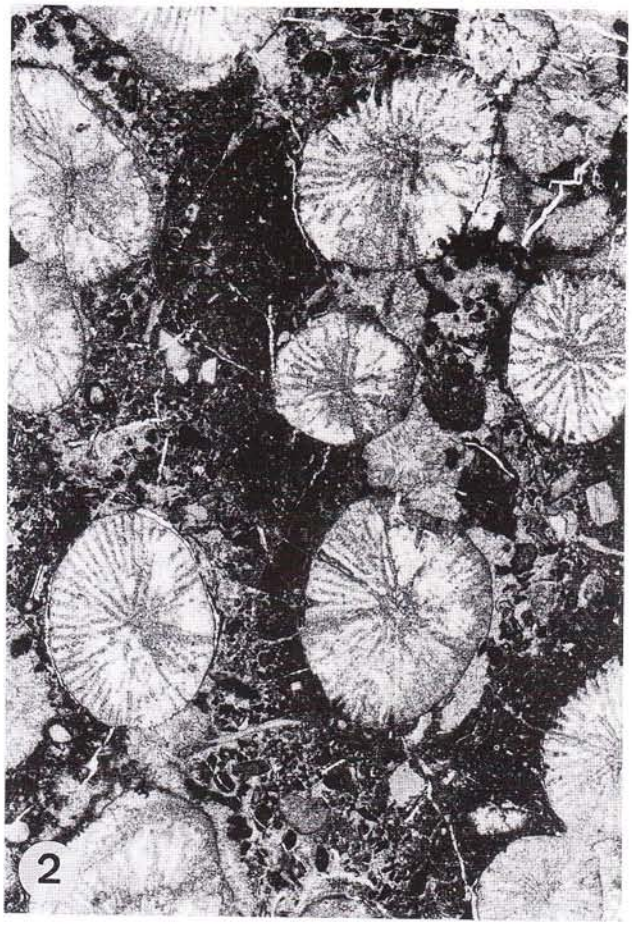
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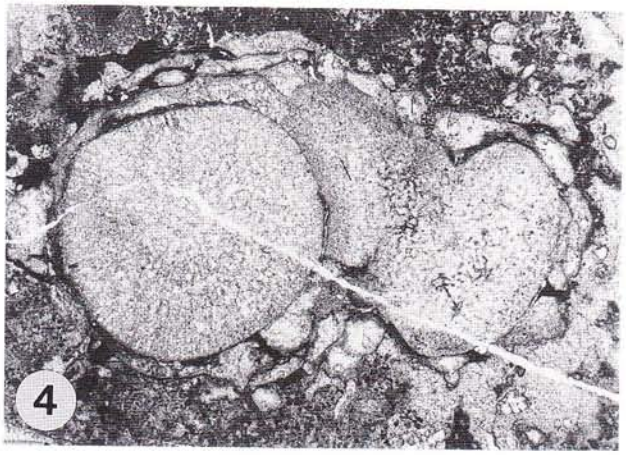
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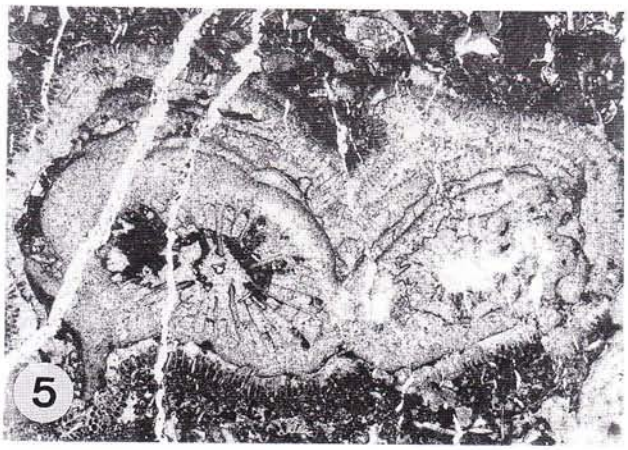
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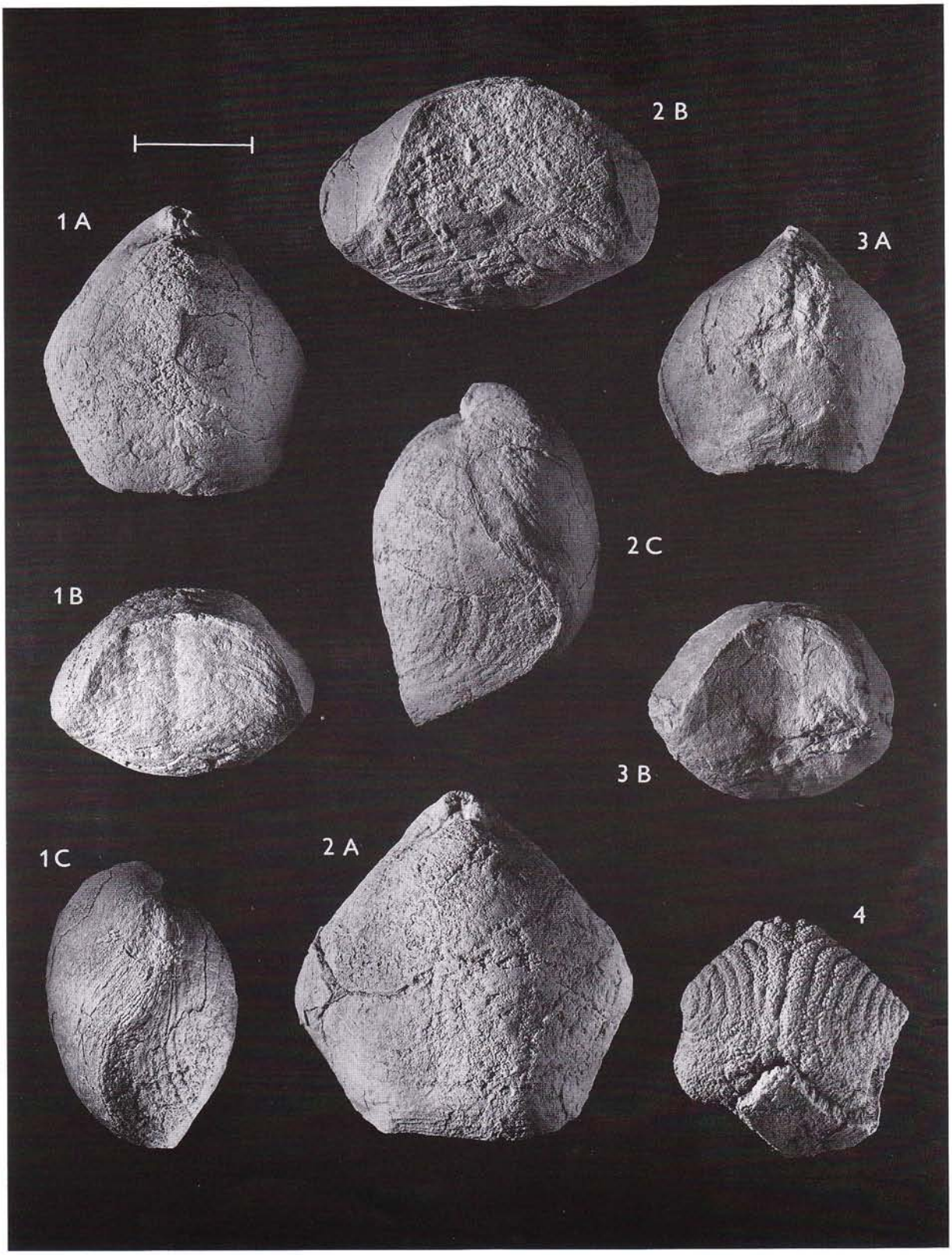

PLATE 4

Brachiopods from the Carnian crinoidal limestones of Al Aqil, Oman (all specimens were coated with ammonium chloride before photographing)

Fig. 1A-1C, 2A-2C - *Oxycolpella arabica* sp. n. (holotype: 2A-C). Bar equals 10 mm.
Fig. 3A-3B - *Oxycolpella* aff. *arabica* sp. n. Sample 92/149.
Fig. 4 - Spiralia of *Oxycolpella arabica* sp. n.

distinct *Oxycolpella*-biofacies. The latter is restricted to the centre of the Kössen basin starting at a depth of around 100 m (Golebiowski, 1991, p. 83). The *Oxycolpella*-biofacies of the Kössen formation includes to a certain extent rhynchonellid and zeilleriid brachiopods of the shallower *Fissirhynchia*-biofacies (> 50 m) and *Zugmayerella*-biofacies (30 - 50 m water depth). Compared with Al Aqil, the abundant and exclusive occurrence of *Oxycolpella* could indicate either a habitat depth below 100 m or the influence of other ecologic factors leading to the monotypical association by high environmental stress. As *Oxycolpella* is a form with a strongly enlarged spire bearing brachidium it might be better adapted for a life habitat with poor nutrient supply. Causes for the latter may be seen in the strongly oxidized sedimentary environment of the crinoidal limestone and a relatively warm bottom water resulting from the low paleolatitude position of the locality. The last factor is, however, difficult to assess since many recent brachiopods tolerate a relatively broad range of water temperature (Lee, 1991).

Acknowledgements.

The authors thank the Ministry of Petroleum and Minerals of the Sultanate of Oman, especially Dr. Hilal Al-Azri (Muscat) for support in Oman. The investigations were carried out within the Priority Project 'Global and Regional Controls on Biogenic Sedimentation' of the German Research Foundation (Project Fl 42/62-1/2). Fieldwork of L. Krystyn was sponsored by the Austrian Committee for IGCP within IGCP project 359. We thank Mrs. L. Neufert (Erlangen) and Mr. J. Brozek (Prague) for photographs.

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